Effects of robot occupations and user characteristics on perceptions of robots

A Ph.D. Dissertation

Presented to

Graduate School of Comprehensive Human Sciences

Doctoral Program in Design

University of Tsukuba, Tsukuba, Ibaraki, Japan

by

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2024.03

Student ID: 202130491

Keywords: Anthropomorphic robot, robot occupation, NARS, perceived threat, mind perception

Abstract

This thesis focuses on the impact of different robot occupations and user characteristics on people's perceptions of robots. In human-robot interaction research, robot occupational roles and users' characteristics may have a multifaceted impact on users' perceptions of robots, yet research in this area is lacking. Therefore, this study aims to reveal the effects of robot occupations as well as user characteristics on human perceptions of robots, including: negative attitudes towards robots (NARS), mind perception, anthropomorphism preference, perceived anthropomorphism, and perceived threat of robots. This thesis uses robots, security robots and service robots as robot cases. User age, gender and financial anxiety are used as user characteristics. We recruited participants aged 30s and 60s living in Japan to complete our studies.

This dissertation contains four studies that support each of the four main hypotheses: 1. Robot occupation affects people's negative attitudes, mind perceptions, and anthropomorphic preferences towards robots; 2. Robot occupation affects people's perceived robot-human border; 3. Robot occupation affects people's perceived threat toward robots; and 4. there is a positive correlation between users' financial anxiety and negative attitudes toward robots.

Notably, in the results of NARS, mind perception, anthropomorphism preference, robot-human border, and perceived threat of robots, we find that service robots are all significantly different from the other two types of robots (robots and security robots). We point out that people have more positive perceptions of service robots in several dimensions.

Moreover, age and gender of the user were again found to be significant main effects in both Study 2 and Study 3. This study not only reveals the importance of robot occupations for people's perceptions of robots, but also highlights for the first time that users' personal characteristics (especially financial anxiety) may also influence human-robot interactions.

As a study of human-robot interaction, this study attempted to use diverse measures to explore the effects of robot occupation and user characteristics on people's perceptions of robots. The results demonstrate that both robot occupation and user characteristics significantly influence people's perceptions and responses to multiple aspects of robots. In the research about robot design, this study provides a research method based on the social role perspective, which is important for the future development of robot design and robot industry.

Abstract (Long Version)

Background

General robot design research includes the appearance, interaction, behavioral characteristics, and functional development of robots. Design researchers have been focusing on human perception and interaction with robots. In most cases, the purpose of robotics research is related to product development and improving the user experience. People's perceptions of robots are sometimes accompanied by hostility and negativity, which has led researchers from multiple disciplines to investigate the topic of human-robot interaction.

Robotics is becoming an interdisciplinary field of study. Researchers from design, psychology, sociology, and anthropology have studied the relationship between humans and robots. One of the most critical issues is how people perceive robots. Users' perception of robots is a broad and dynamic concept, which mainly includes negative attitudes towards robots (NARS), mind perception of robots, perceived anthropomorphism of robots, perceived threat of robots, and other aspects.

Some researchers argue that advanced social robots with significant autonomy may be seen as possessing a form of consciousness and taking on social roles within human society. Social role theory posits that individuals perceive varying social roles differently. Furthermore, the range of tasks and professions robots undertake has seen remarkable diversification. Robots' social roles are multifaceted and can be influenced by their specific occupations. Consequently, how people view robots may vary based on their respective roles and professions.

Moreover, users' own social characteristics, such as age, gender, occupation, social status and financial status, also make up users' social roles. There may also be some potential relationships between users' social roles and robots' social roles, which may influence people's

perception of robots in different occupations. Some racial and gender characteristics were also discussed. For example, when choosing assistive robots, older people prefer Asian female-looking and white male-looking robots [1]. Highly risk averse users tend to hate the use of mechanized robots [2]. A study has found that people have different naming preferences for robots in different fields of use [3]. However, how robot occupations and users' characteristics affect people's perceptions of robots is a question that remains to be investigated. Perceptions of robots are multifaceted and are rarely discussed dynamically together.

Therefore, in summary, the main objectives of this study are to:

1. Examine the relationship between robot occupations and people's perceptions of robots (including negative attitudes toward robots, mind perception, and anthropomorphic preferences) using robots, security robots, and service robots as examples;

2. Exploring the difference in the border between the robot and human in different robot occupational contexts;

3. Understand the relationship between robot occupations and people's perceived threats in different robot occupational contexts;

4. Explore how people's financial anxiety affects people's negative attitudes toward robots.

Framework

The framework of this study consists of four studies: study 1, study 2, study 3 and study 4.

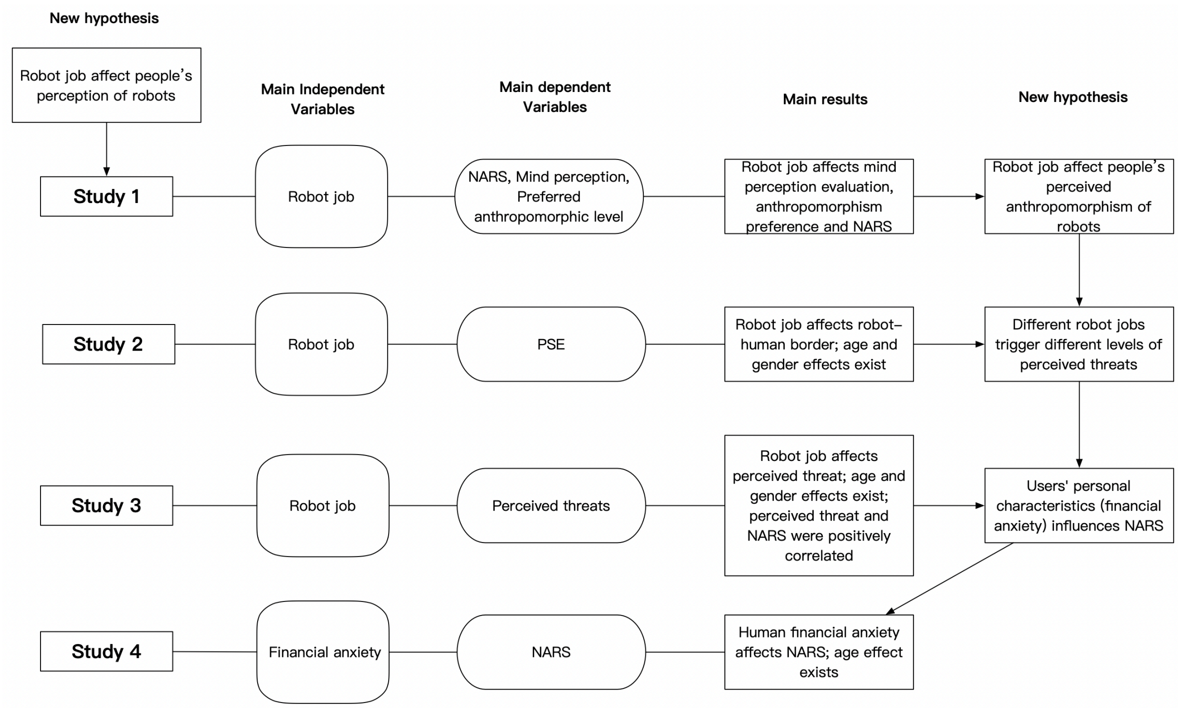

Figure 1 The framework of this thesis

First, it is necessary to choose specific types of robot occupations, people's perceptions of robots, and users' personal characteristics. As presented in the literature review, service robots and security machines have a wide range of applications and research value. Users' age, gender, and financial anxiety may be important influences on perceptions of robots. Aspects of perceptions of robots that are important in human-robot interaction research include: negative attitudes toward robots, mind perception, anthropomorphic preferences, anthropomorphic perceptions, and perceived threat. Four studies were cascaded to address these aspects.

Study 1 consisted of preliminary experiments aimed at investigating the effects of robot occupations on negative attitudes toward robots (NARS), mind perception, and anthropomorphism preferences. We compared the results of perceptions of robots in different occupational contexts.

Study 2 delved into the differences in people's perceptions of the robot-human border in different robot occupational contexts. We used point of subjective equality (PSE) to characterize the proportion of human photographs suggested by the robot-human border. And we discussed the effects of user age and gender on PSE.

Study 3 further revealed that robots in different occupations elicit different levels of perceived threat from users, and discusses the impact of user age and gender on perceived threat.

Study 4 explored the impact of users' financial anxiety on negative attitudes toward robots.

From the results of Study 1, we expected to find an effect of robot occupation on multiple aspects of people's perception of robots, including NARS, mind perception, and anthropomorphic preference. Based on Study 1, we propose the new hypothesis that robot occupations influence people's perceived anthropomorphism of robots. Then, in Study 2, we delved into the effect of robot occupation on PSE thereby revealing that robot occupation influences perceived anthropomorphism towards robots. Subsequently, we propose the new hypothesis that robots with different occupations elicit different levels of perceived threat. We support this hypothesis through Study 3. Perceived threat is directly related to people's financial problems, so we propose the new hypothesis that users' financial anxiety influences NARS. We support this hypothesis through Study 4.

Results and Conclusion

The results suggest that both robot occupations and users' personal characteristics (age, gender, and financial anxiety) have an impact on people's perception about robots. Compared to robots and security robots, people have higher anthropomorphic preferences, higher point of subjective equality (PSE) outcomes as well as lower negative attitudes and lower perceived threat for service robots. Moreover, age and gender have significant effects in people's perception towards robots. We found a significant positive correlation between users' financial anxiety and negative attitudes toward robots.

When we focused on the impact of robot occupations on people's perceptions of robots, we found some commonalities in that people had more positive perceptions of service robots (compared to robots and security robots). And by discussing the anthropomorphic preference and

PSE results from Studies 1 and 2, we found that people had a higher anthropomorphic preference for service robots as well as a more anthropomorphic human-robot border. Together, these two results support the argument that people have higher anthropomorphic expectations for service robots.

When we focus on the impact that users' characteristics have on human-robot interactions, we find that people's age, gender, and financial anxiety are all important influences. Study 2 reveals the main effects and interactions of age and gender on the perceived robot-human border. The PSE results for the older and female groups were significantly higher than the PSE results for the younger and male groups. This suggests that older people and females expects higher levels of anthropomorphism for robots. Study 3 found that females had higher perceived identity threat and realistic threat than males for all the three types of robots. Older people had lower perceived realistic threat for the robots compared to younger people. Study 4 found that people with higher financial anxiety would have higher negative attitudes toward robots. These results suggest that some characteristics of users themselves, including age, gender, and financial anxiety, can influence perceptions of robots.

We attempt to link robot occupations and users' personal identities in an dynamic discussion. We argue that there is some connection between the robot's occupation and the robot's social identity, and that these social identities may affect human identity security to varying degrees. Study 3 supports this view. More interestingly, when financial anxiety was elevated, people's negative attitudes toward robots were also elevated. This suggests that human-robot interaction is not just an issue revolving around robots, but that human factors are also very important and are not limited to some physiological categorizations such as age and gender. The introduction of financial anxiety as an influential factor illustrates that human-robot interaction is a complex sociological phenomenon. Human financial anxiety may have more complex potential effects on human-robot interaction to be explored by researchers.

This study serves as a crucial reference for both designers and the user research domain. It suggests that designers shouldn't solely rely on anthropomorphism when creating robot appearances. Instead, robot designs should be tailored to specific occupations based on diverse user contexts. The question of whether to embrace or resist anthropomorphic expectations for varied robots is still open for debate. Consequently, designers must exercise caution when designing anthropomorphic robots. For user researchers and those shaping robotics market policies, the intended purpose of different robots will significantly influence their production and deployment strategies. Furthermore, this research offers insights to marketers on tailoring robot marketing strategies to users based on age, gender, and financial concerns.

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Acknowledgement

First and foremost, I would like to express my deepest gratitude to my advisor, Dr. Shinichi Koyama, for his invaluable guidance, unwavering support, and mentorship throughout my doctoral journey. His profound insights and encouragement have shaped my academic perspective and instilled in me a lifelong passion for learning.

To my dear friend, Robin, I am profoundly thankful for your companionship, unwavering friendship, and the countless moments of shared laughter and solace. Your presence has been a beacon of light, making the challenges of this journey bearable and the moments of triumph even sweeter.

I owe a debt of gratitude to my parents, who have been my pillars of strength. Their unyielding faith in me, even during the most trying times, has been a source of constant motivation. I am forever grateful for their love, sacrifices, and unwavering belief in my potential.

To my peers and fellow researchers in the lab, thank you for the collaborative spirit, enlightening discussions, and shared experiences. Your camaraderie has been instrumental in making this academic journey both enjoyable and fulfilling.

I would also like to extend my heartfelt thanks to the Japanese government for awarding me the scholarship, which provided not just financial assistance but also a belief in my potential and the importance of the research I undertook.

Lastly, I am deeply appreciative of all the workers who tirelessly ensure we have safe food and a secure living environment. Their often-unseen efforts have created an environment conducive for my studies and for that, I remain eternally grateful.

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Chapter 1: Introduction

1.1 Robot Design Research

Robots are entering our working lives and everyday world [4]. While early robots were mainly industrial robots working in factories, current robots are beginning to take on more diverse roles, thus joining human society more broadly [5]. A robot in this study is a machine, especially one that can be programmed by a computer to automatically perform a complex set of actions. The robots mentioned in this study fall under the category of social robots, i.e. robots that have the ability to interact with humans in some way. People's impression of robots is no longer limited to narratives in science fiction or movies, but may come from real life experiences [6]. Moreover, with the development of AI technology, there are new and constant possibilities for the advancement of robots' functions. These changes mean that the manufacture and use of robots have reached a new stage. Robotics is a growing field today and along with human-robot interaction and psychology has spawned the field of human-robot interaction. Researchers often focus on human-robot interaction and there is a great variety of ways in which human-robot interaction can be used [7].

The appearance, interaction characteristics, and functionality of a robot are the most important aspects for users, and these aspects often differ significantly between different types of robots. It is popular in robotics research to use anthropomorphism to categorize and describe the appearance of robots, although anthropomorphism itself does not yet have a completely universal and accurate standard [8]. From a design perspective, robots with different purposes of use and different user orientations tend to have different appearance characteristics (Figure 2)[9-12]. Robots include electrical-looking, zoomorphic robots, robots with varying degrees of anthropomorphism, and robots that look almost exactly like real people. These robots often have varying degrees of autonomy. With the rapid development of AI technology, some robots have been able to communicate fluently with humans as well as take on some human tasks.

Interestingly, the way a human interacts with a robot can sometimes be described as anthropomorphic, e.g., robots that make line-of-sight communication as well as polite avoidance would be considered anthropomorphic human-robot interaction [13, 14]. When we try to categorize robots in terms of work domains, we are surprised by the diversity of functions that robots perform. Robots are already active and performing impressively in the fields of healthcare, education, socialization, and service [9, 15-17]. Robots are not only working on assembly lines in factories, but are also playing the roles of waiters, guides and cooks in restaurants, hospitals and hotels. The workplace of robots has become very flexible.

Figure 2. Robots with diverse designs [9-12]

Robotics research is increasingly interdisciplinary [18]. Research in Human-Robot Interaction (HRI) is interdisciplinary, encompassing fields such as robotics, engineering, computer science, human-computer interaction, cognitive science, and psychology [7]. Several studies have used interdisciplinary approaches to investigate how people perceive robots and how robots affect users' learning, work and life [19-21].

Cognitive outcomes such as human emotions, feelings, and people's attitudes, trust, and acceptance of robots triggered by robots are being increasingly emphasized by researchers in several fields [22]. Some researchers believe that since people are born to interact with and have faith in humans, the more human-like a robot is, the more we are willing to share our lives with it [23]. Moreover, people can help us deepen our understanding of humans by building a very human-like robot [24]. Social robots have become a hotspot for human-robot interaction research as a new robotics discipline [25]. How robots should be deployed and designed in different contexts provides research support for new scenarios of social robot use [26-28].

1.2 A small discussion on people's perceptions of robots

The study of people's perceptions of robots is a broad field of human-robot interaction, including the study of emotions in human-robot interaction, attitudes toward robots, perceived threats, acceptance and trust, etc [7, 29, 30]. Some believe that robots are a potential threat to humans and could lead to massive human unemployment [31]. And, according to the Uncanny valley theory and related studies [32, 33], people may be fearful of robots with a high degree of anthropomorphism. These resistances to robots have the potential to influence people's deployment and use of robots to the detriment of society's productivity.

In order to reduce negative attitudes towards robots and increase acceptance of robots, several studies have attempted to adapt the appearance of robots by adjusting their anthropomorphism, voice, gesture, personality, and interaction [34-36]. Some researchers have argued that a highly anthropomorphic appearance can make robots more popular with users [37]. However, other studies refute this view and argue that generalizing anthropomorphic robots is a potentially risky design decision [8]. Anthropomorphic robots have become increasingly popular due to multiple cultural and societal influences. People have some stereotypes related to anthropomorphic robots.

In some virtual works, robots often appear as rulers over humans [38]. This may influence some stereotypes about robots. In the real world, robots are still in the position of being dominated by humans. However, the social roles of robots are not static. Due to the diversity of robots' job content, robots of different occupations are considered to assume different social roles [39].

Occupational do as an important social role categorization influences the stereotype of a particular social role [40]. The social roles of robots in different occupations may influence people's perceptions of robots. A study found that people have different levels of acceptance of robots for different occupations, and that the personal characteristics of the users themselves may also affect acceptance of robots [22, 41]. Several human-computer interaction (HCI) studies on users' age, gender, and occupation have suggested that users' personal characteristics may also influence perceptions of multiple aspects of the robot [42-44]. Both the social role of the robot and the personal characteristics of the user may influence the perception of the robot.

While existing research has investigated very broadly around the impact of anthropomorphism on human-robot interaction, no studies have examined in-depth the social roles of robots in relation to occupations and the social characteristics of users. A number of questions about the most basic perceptions of robots remain to be answered. One important question is how the occupation of the robot affects the perception of the robot. This is an important guide to whether and what kind of appearance design as well as interaction design the robot should adopt.

1.3 Motivation of this study

A robot's occupation is an important part of what makes up a robot's social role. And social roles often influence people's stereotypes about an individual as well as a group. People's attitudes and acceptance of robots may be influenced by robot occupations, which in turn affects their willingness to use and preferences for robots. Viewing the outcomes of people's perceptions of robots on various dimensions as important influences on robot careers is an important research perspective. However, existing research still fails to provide an in-depth study of diverse robotic occupations. As a result, the design and deployment of robots for new occupations and purposes will be unguided, leading to homogenization of robot design. Moreover, robot designs that reinforce stereotypes may even have negative impact on the development of the robotics industry and human society. Human-robot interaction research should take into account the identities and roles of both the robot as well as the human. There may be a dynamic relationship between the robot's occupation, and the user's personal attributes. Exploring such relationships is of great value for human-robot interaction.

People's perception of robots is a multidimensional topic, and this study attempts to simultaneously discuss the results of people's multidimensional perceptions of robots in the context of multiple careers. Past research has found that anthropomorphic design does not always have a positive impact on human-robot interaction [8]. However, the factors that influence the differences in anthropomorphic preferences have been unclear. This is a heavy hindrance to the research and development of anthropomorphic robots. Therefore, we need to explore the factors that can potentially influence anthropomorphic preferences. A number of well-established scales and questionnaires on human-robot interaction have been widely used. We are going to explore cognitive investigations of negative attitudes towards robots, perceived threats, and mental awareness related to different occupational contexts. How the anthropomorphic design of robots should be adapted to different occupational contexts remains an open question. We need to investigate whether people have different anthropomorphic expectations for robots with different purposes of use. This is an important addition to anthropomorphization studies of robots and is an important part of the perception of robots.

The main motivation of this study was to assess the results of people's perceptions of robots in different robotics career contexts through robotics-related questionnaires and psychological experiments. On the other hand, the user's own personal characteristics also serve as potential factors that may influence the outcome of people's perceptions of the robot. In this study, perceptions of robots encompassed multiple dimensions: negative attitudes toward robots, heart awareness of robots, anthropomorphic expectations and preferences for robots, perceived threats to robots, and so on.

Chapter 2: Literature Review

2.1 Robot Occupation

2.1.1 Definition of Occupation

Occupation is a word that is widely used in today's society, and occupation is a significant aspect of adult life [45]. Occupation or work refers to a person's role in society, which is the intentional activity people perform to support the needs and wants of themselves, others, or a wider community [46]. However, there are still slight differences between occupations and work. Different occupations carry significantly different responsibilities, yet jobs place more emphasis on being assigned tasks by superiors and following rules for doing things [47]. Moreover, occupation is often considered more as a status characteristic [48].

2.1.2 The Basic Information of Occupation

Career choice significantly influences an individual's self-concept and personal fulfillment [6], and it also offers insights into their skills, earning potential, and social status [49]. Occupations have evolved and changed over time. The categorization of occupations is constantly being updated and improved [50]. The distribution of occupations varies by gender, and the labor force participation rate of women is significantly lower than that of men [51].

Occupation consistently serves vital roles for individuals beyond their economic functions [47]. Occupation is an important way of categorizing social roles and is closely related to an individual's social value and social class [48]. The process of occupational sorting, where individuals choose and are chosen for various occupations, plays a crucial role in social stratification and inequality [52]. Different occupations are considered to have different social status and social classes [53]. Several studies have found that there can also be a strong link between people's health and their own occupation [54, 55]. Occupations, along with specific workplace constraints and resources, independently contribute to psychological distress [56].

Social categorization is the process by which we classify individuals based on social information. Aspects such as gender, race, age, social status and occupation are all categories in which social categorization takes place. This occurs mainly through stereotypical associations and can cause harmful prejudices [57]. Positive, defining values of careers will be used by members to explain people's professional identities and thus create their own personal work identities [58]. Occupations often foster their own unique cultures, distinct from those of the broader organization. Such cultures can inadvertently promote ethnocentrism and a sense of group superiority. Furthermore, these occupational cultures shape the values, norms, and belief systems that members utilize to evaluate both their own actions and those of their peers [59]. In sum, the impact of careers on the construction of society and on the lives of individuals is multifaceted and dynamic.

2.1.3 Robot Occupation in Society

Occupations are fundamentally categorized in society, and each is accompanied by various stereotypes [60]. People often expect service personnel to exhibit high warmth, while security guards are often perceived as solely protecting the assets of the wealthy, thus widening the disparity between the rich and the poor [61, 62]. These occupational classifications shape our perceptions and set varied expectations for others, both in nature and intensity [63]. They have distinct preferences concerning the anthropomorphism, personality, capabilities, and expectations of robots in these roles [64, 65]. With the gradual development of robotics, the work tasks of robots have become more and more diversified. And, some people believe that robots assume certain social roles in society [39, 66]. At this point, we refer to robots undertaking different kinds of work as robots with different occupations. For instance, users might prefer a robot with a warm demeanor for travel services but seek an intelligent robot for financial services [67].

Multiple occupations of robots have been heavily developed and used in real-life human scenarios, such as industrial robots, food delivery robots, nursing robots, and teacher robots, to name a few [9, 17, 68]. However, robots' occupations are not all in positive roles. Some argue that sex robots and military robots challenge ethical and moral standards [69, 70]. There is a risk that people will use robots in things that are detrimental to social and personal safety. However, existing laws are lacking to regulate the use and responsibility of various robots [71].

As an essential social role categorization, occupation is often accompanied by different occupational stereotypes [60]. Specifically, it is widely believed that service workers should have high warmth attributes; security guards are perceived as only protecting the wealth of the rich and contributing to the gap between the rich and the poor [61, 62]. Occupational categorization influences our perceptions and expectations of others in different directions and to different degrees [63]. With the development of robotics and the widespread use of various robots, stereotypes of occupations may have emerged in perceiving robots.

Researchers have identified a number of human stereotypes and prejudices about occupations in robots. These biases are often reflected in preferences for the appearance and performance of robots [72]. And, people tend to have different levels of acceptance for robots in different occupational fields [22]. Due to the proliferation of new occupations for robots, it is worthwhile to consider the validity of previous research findings on robots today. The impact of robot careers on human-robot interaction has yet to be fully investigated.

A robot's role can sway people's anthropomorphic preferences. For instance, users tend to predict a higher food quality when produced by highly anthropomorphic robot chefs as opposed to less anthropomorphic ones [73]. In industrial contexts, a low degree of anthropomorphism is preferred, while in social settings, a high degree is favored. However, in the service sector, there's no distinct preference [3]. The appeal of a robot's anthropomorphic characteristics may vary based on its operational context [74, 75]. People tend to gravitate towards robots whose human-like features align with the expected sociability of their respective occupations [76].

2.2 User Characteristics

2.2.1 Age

Age, as an important way of segmenting groups in user research, is often closely associated with a wide range of user behaviors. In the study of human-robot interaction, researchers have initially revealed that users of different ages are found to have different perceptions and evaluations of the robot's. The age of the user often influences perceptions and preferences for robots. Older people exhibit higher negative emotions towards robots compared to younger groups [41]. Robot designs that align with the anthropomorphic expectations of older individuals might foster more positive attitudes and foster acceptance. Research indicates that three-year-old children are more inclined to attribute biological characteristics to robots than older people [77]. Previous study found that older participants (compared to young participants) strongly disagree with using robots when working and caring for older adults [78, 79]. Each generation in Japan has faced distinct economic and sociocultural challenges [80]. The state of the economy may cause changes in financial anxiety, resulting in a potential evaluation of the robot.

2.2.2 Gender

In human society, the differences between men and women exist not only physically, but also culturally, psychologically, socially, economically, and in many other ways [81]. Differences between the sexes are often found in various user studies. The gender of the user has important implications in human-robot interaction research. In previous design and research related to robotic gender, it has been common to assign human gender characteristics to robots and to socialize robots to be gendered in a variety of ways, despite the fact that the robots themselves. Gendered naming of robots also influences public perceptions. Robots named with male designations are perceived as better suited for security roles, while those with female names fit healthcare roles more aptly. This indicates that beyond physical appearance, ingrained gender characteristics influence people's preferences for robots in various occupations [82]. Previous studies have found females perceived greater anthropomorphism in robotic movements than males [44]. In Japanese society, females often hold a lower status compared to males and possess less social power [83]. These gender differences may cause users to have different perceptions and attitudes towards robots.

2.2.3 Financial Anxiety

Cultural nuances significantly shape our understanding of financial anxiety. In Japan, societal expectations often cast men in the role of primary breadwinners, potentially subjecting them to heightened household financial pressures [84]. However, with the rising participation of women in the workforce [85], it becomes imperative to question if women's financial burdens now parallel those of men. Additionally, financial challenges differ across age groups [86].

Past research indicates that robot integration can decrease human labor costs, thereby posing a threat to human job security. The adoption of robots is believed to bring about various socioeconomic repercussions, such as job scarcity, stringent work conditions, and diminished wages [87-89]. These looming impacts, often perceived as impending realities, could foster resistance towards robots. While an earlier review suggested that attitudes towards workplace robots were predominantly positive, growing concerns about the job landscape being reshaped by robots have emerged. Consequently, this might be shifting the sentiment to a more negative stance towards robots [29]. However, no existing research directly links financial anxiety to NARS, which is the gap we aim to address in our study.

A previous study showed that high-income people have more positive attitudes toward robots [90]. Several researchers have observed that among older adults, the perceived warmth of social robots is inversely related to their financial concerns. Yet, the perceived competence when interacting with robots is linked to their financial standing [91]. Clearly, financial matters stand out as a pivotal element influencing human-robot interaction.

2.3 People's Perceptions of Robots

2.3.1 Mind Perception of Robots

Despite advancements, the relationship between a robot's designated role and users' emotional reactions remains ambiguous. The mind perceptions people hold about robots play a critical role in understanding our emotional interactions with them. A web-based survey discovered that any entity with the capability to feel and act is deemed to possess a mind [92].

Public consensus suggests that robots exhibit some ability for task execution and emotional expression. Earlier studies have affirmed this, indicating that people do ascribe a form of consciousness to robots [93].

Previous research bifurcates robot mind perception into two realms: perceptions of agency (capacity for thinking and planning) and perceptions of experience (ability to feel and respond emotionally) [92, 94]. Some studies indicate that these mind perception dimensions can predict people's evaluations of job suitability [95]. One particular study highlighted an inherent belief that proficiency in social tasks is inversely proportional to proficiency in arithmetic tasks [96]. Intriguingly, participants favored assigning arithmetic tasks to an emotionally deficient robot, even when another emotionally capable robot had equivalent computational skills. This trend aligns with societal biases, like gender biases, in mind perceptions and job compatibility [97].

2.3.2 Negative Attitudes Towards Robots (NARS)

Studying people's negative attitudes towards robots is vital in robot design. In some media and cultural products, robots often appear to be conquering and controlling humans, reflecting hostile and negative attitudes towards robots [98]. Negative attitudes towards robots scale include three dimensions: negative attitudes toward situations of interaction with robots (S1), negative attitudes toward the social influence of robots (S2), and negative attitudes toward emotions in interaction with robots (S3). Negative attitudes towards robots can often influence the willingness to use them, thus limiting their application and development in modern society [29]. Social categorization of robots with different occupations has the potential to bring about different negative attitudes toward robots. Yet, there is still a shortage of research in industry and academia on the perspectives of robots with different occupations, and we do not know what attitudes people would have when confronted with robots with different occupational attributes. The Negative Attitudes Toward Robots Scale has been widely used in research on human-robot interaction [99]. A study finds that people like robots to be able to match personality stereotypes corresponding to human occupations [82]. However, no clear evidence exists that people have different negative attitudes towards robots in various domains. To clarify these questions, I will examine how robot occupations affect people's negative attitudes toward robots when they answer the NARS questionnaire.

Researching human-robot interactions presents myriad challenges given the diverse methods available for evaluating the experience. Scales focusing on negative sentiments toward robots have been crafted, adapted, and integrated across diverse cultural contexts in human-robot interaction studies, with their reliability consistently affirmed [99]. The NARS scale is gaining traction as a pivotal tool in this domain. Pervasive in the literature on human-robot interactions [100, 101], the NARS questionnaire has shed light on intriguing dynamics. For instance, pronounced negative attitudes toward robots correlate with evasive communication patterns [100] and can influence people's willingness to engage with them. As such, NARS stands as a seminal instrument and research focus within the realm of human-robot interaction studies.

Factors influencing NARS have garnered considerable interest. Diverse groups, encompassing different nationalities, educational backgrounds, ages, and genders, have been engaged in NARS-related studies under varying experimental conditions [102, 103]. While some research indicates that participant age can sway negative attitudes toward robots [41], other studies found no such age-related disparities [103-105]. Similarly, the impact of a participant's gender on NARS has yielded inconsistent findings [106, 107]. Given this backdrop, definitive conclusions regarding the influence of age and gender on NARS remain elusive. To mitigate the effects of these potential confounders, our study will explicitly account for and delve into both age and gender as potential variables.

2.3.3 Anthropomorphic Preference of Robots

Anthropomorphic robots are believed to have more abilities related to warmth and emotion than machine-appearing robots, which can cause a preference for anthropomorphic robots [108]. However, recent research has found that people's anthropomorphic preferences for robots may vary depending on the robot's task [109]. People expect higher levels of anthropomorphism from robots in jobs that involve more direct human interaction (e.g., education and hospitality), and lower levels of anthropomorphism from robots that are expected to do jobs that involve less human interaction (e.g., agriculture and construction) [110]. Moreover, researchers found that participants preferred lower anthropomorphic robots to perform boring and dirty jobs rather than jobs requiring extensive human socialization [111]. People have developed expectations of different personalities and abilities for robots in different occupations [65]. This study suggests the importance of focusing on the need for anthropomorphic appearance matched to the robot's occupation in design studies of robots.

Occupational roles affect people's anthropomorphic preferences, and heightened expectations often set the bar higher for satisfaction [112, 113]. This study posits that when there are greater anthropomorphic expectations for robots tied to a particular occupation, discerning the precise degree of anthropomorphism required for them to be perceived as human becomes more challenging. Robots in roles where a high degree of anthropomorphism is anticipated must exhibit more human-like traits to transition from being viewed as mere robots to something akin to humans. The degree of human resemblance, as represented by this robot-human border, is likely to vary depending on the occupation.

Perceptions of anthropomorphism and preferences for robots vary by age. Older individuals tend to favor anthropomorphic robot designs [42] and lean towards either a purely mechanical or human appearance. In contrast, younger individuals appear more open to a hybrid design [114].

2.3.4 Robot-Human Border

The border of human-like appearance distinguishing humans from robots is defined as the robot-human border. Enhanced perceptions of anthropomorphism can arise not only from a robot's appearance but also from its language, movements, and functionalities [8, 115]. Central to perceptual anthropomorphism is a robot's physical appearance [116]. As the human-like elements in a robot's appearance intensify, so does the perceived anthropomorphism. At a particular level of anthropomorphism, observers start to perceive the robot as human-like. The specific proportion of human features that differentiates humans from robots is encapsulated by the term robot-human border.

Morphing image, as a kind of stimulus material commonly used in visual research, are often derived from two different pictures [32]. The researcher can set the proportion of the content of the original picture contained in the generated morphed image by using a number of tools. When faced with visual stimuli, do individuals recognize an entity with human-like features as human? Answering this is pivotal for pinpointing the border between robots and humans. In this research, the point of subjective equality (PSE) is marked as the proportion of human features in a morphed face image where participants are equally likely to categorize the image as robot or human. This PSE acts as the subjective midpoint between the robot and human benchmarks that participants discern during classification tasks.

In psychophysics, the PSE is any of the points along a stimulus dimension at which a variable stimulus (visual, tactile, auditory, and so on) is judged by an observer to be equal to a standard stimulus. In previous studies, the PSE method has been used to measure people's perceptions of hearing and vision [117]. The PSE is the signal duration at which a participant is equally likely to classify the signal as short or long. It represents the subjective midpoint between the short and long anchor values that the participant learned in training.

Historically, researchers have incrementally adjusted the human feature proportion in stimuli and logged participants' reactions and categorizations. Though some studies equate this proportion to human similarity, they aren't precisely the same [118-120]. Employing the idea of human photo proportion, as opposed to human similarity, better aligns with experimental outcomes. Prior research hasn't pinpointed the specific human photo proportion threshold at which observers start perceiving stimuli as more human than robot [8].

The most prevalent theory on this subject is the "Uncanny Valley." This theory posits that as a robot's resemblance to humans increases, its relatability does as well. However, when a robot closely mirrors, but is not quite identical to, a human, it risks provoking intense negative emotions in observers. Once a robot is indistinguishable from a human, it is embraced as one would embrace a fellow human [121]. Nevertheless, Robertson [122] has posited that the Uncanny Valley is tied to the preconceived notion of how a robot should appear. Discomfort arises when robots don't conform to these established stereotypes. If individuals anticipate a robot to possess a rudimentary anthropomorphic appearance and encounter one with a sophisticated anthropomorphic form, it can cause unease. People's expectations for humans and robots differ based on the tasks they associate with each [123]. Thus, if the Uncanny Valley is shaped by our assumptions about a robot's looks, then the border between humans and robots could shift depending on the robot's role.

As the perceived anthropomorphism of a robot incrementally rises, it approaches the threshold between robot and human, eventually crossing it. Existing research indicates that the perception of robot anthropomorphism is shaped by numerous elements. These include attributes of the robot, such as its appearance and behavior, as well as characteristics of the observer, including motivation, social context, age, and gender [124-128]. In varying observational settings, individuals might discern varying levels of anthropomorphism in robots that otherwise look identical. The demarcation between robots and humans could be swayed by elements tied to social attributes. Different domains elicit different preferences in people concerning robot anthropomorphism [3]. A robot's professional role could be a significant factor in determining this robot-human border. The subsequent section delves into how occupation influences perceptions of robot anthropomorphism.

2.3.5 Perceived Threats of Robots

While people have diverse imaginations about robots, these imaginations shape their perceptions. Often, these views are not born from real-life interactions but from fictional narratives [129]. Films, television, and artwork frequently depict conflicts and wars between humans and robots, casting robots as adversaries. Such narratives cultivate stereotypes and set expectations, leading some to fear robots as potential threats, even though incidents of robots intentionally harming humans in reality are scarce [130]. Among various perceptions of robots, the concept of them as a threat is perhaps most paramount. Robots, being distinct from humans, present two primary threats: identity threat and realistic threat [131].

The identity threat pertains to the potential erosion of what is uniquely human. As anthropomorphic robots become more widespread, human-like appearances, voices, and behaviors are not solely human traits anymore but are now seen in robots [132-134]. This blurring line causes concerns about humans losing their unique identity. For instance, a robot exhibiting compassion can challenge our sense of exclusivity, evoking feelings of unease [135].

The realistic threat revolves around concerns related to human resources and safety. Modern robots, sometimes outperforming humans, have assumed various human roles. Media often portrays them as potential dominators of humanity, emphasizing threats to our access to resources and safety [136]. Research suggests that autonomous robots, which limit human control compared to non-autonomous ones, intensify the perceived identity and realistic threats [131, 137]. In HRI context, social power is described as "an asymmetric control over valued resources in a social relationship" [138]. The inherent human drive to seek social power [139] and the desire for control [140] reflects in our interactions with robots. Humans traditionally view robots as subordinate, positioning themselves in a place of power. However, when robots become less controllable, this perceived power diminishes, leading to increased negative sentiments, including perceived threats [131].

Chapter 3: Objectives, Terminology and Framework

3.1 Objectives

The main objectives of this study are to:

1. Examine the relationship between robot occupations and people's perceptions of robots (including negative attitudes toward robots, mind perception, and anthropomorphic preferences) using robots, security robots, and service robots as examples;

2. Exploring the difference in the border between the robot and human in different robot occupational contexts;

3. Understand the relationship between robot occupations (including robots, security robots and service robots) and people's perceived threats in different robot occupational contexts;

4. Explore how people's financial anxiety affects people's negative attitudes toward robots.

3.2 Terminological Definitions

Robots in this study are mainly humanoid robots. Moreover, in part of the study, the robot is compared with service robots and security robots as a robot without a specific occupational description.

Robot occupation in this study refers to the category of robots that corresponds to their work tasks and purpose of use. It mainly includes robots that have specific functions and capabilities in human life.

User characteristic is a way of identifying the target group that helps in market segmentation. User characteristics in this study include categorization based on both demographics (age and gender) and based on economic status (financial anxiety).

People's perception of robots is an interdisciplinary topic that includes multidimensional factors to describe the mix of emotions, attitudes, judgments, and other perceptions of robots.

Perceptions of robots in this study mainly include NARS, heart perception of robots, anthropomorphic preference and anthropomorphic perception.

Financial anxiety is a feeling of worrying about one's financial situation or money situation. This includes a person's income, job security, debt, and ability to buy things.

Negative attitudes towards robots scale (NARS) is a tool that aims to measure the attitudes and emotions of people during the interaction with robot of different kinds. NARS includes three sub-scales: negative attitudes toward situations of interaction with robots (S1), negative attitudes toward the social influence of robots (S2), and negative attitudes toward emotions in interaction with robots (S3). It consists of 17 items, rated from 1=I strongly disagree to 5=I strongly agree.

Mind perception of robots was employed to evaluate the cognitive and emotional capacities of robots. The mind perception scale encompasses two distinct dimensions: Experience and Agency. Specifically, Experience pertains to a character's perceived capacity for sensations and emotions, such as pain, rage, or joy. Conversely, Agency is associated with a character's perceived capability for actions and cognition, including planning, thinking, and communicating. [141].

Point of subjective equality (PSE) refers to the value of a comparison stimulus at which an observer is equally likely to judge it as higher or lower than a given standard stimulus [142]. PSE in this study was used to describe the border of human-like appearance distinguishing humans from robots.

Preferred anthropomorphic level in this study refers to the human photo proportion of one's favorite image in the morphed image selecting tasks. The morphed face pictures contain different levels of human photo proportion, referring to different anthropomorphic level.

3.3 Framework

The structure of this research encompasses four distinct studies: Study 1, Study 2, Study 3, and Study 4.

To commence, there is a necessity to delineate specific robot occupations, delineate people's perceptions of robots, and identify relevant user characteristics. As elucidated in the literature review, service robots and security machines hold significant applicability and research merit. Parameters such as users' age, gender, and financial anxiety might play pivotal roles in shaping perceptions about robots. Central facets in the domain of human-robot interaction research encompass negative attitudes toward robots, mind perception, anthropomorphic preferences and perceptions, and perceived threats. These facets are sequentially addressed across the four studies.

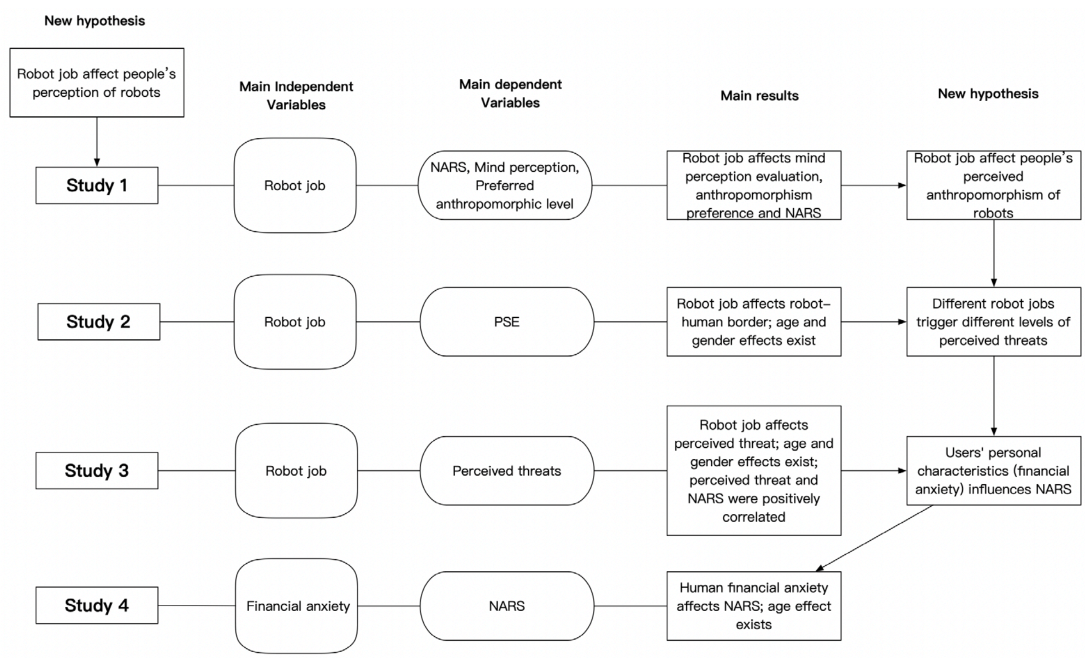


Figure 3. The framework of this thesis

Study 1 entailed preliminary experiments to discern the ramifications of robot occupations on negative attitudes toward robots (NARS), mind perception, and anthropomorphic preferences. We juxtaposed perceptions associated with robots across diverse occupational scenarios.

Study 2 probed into variations in perceptions concerning the robot-human border across differing robot occupational contexts. We employed the point of subjective equality (PSE) as a metric to depict the ratio of human photographs implied by the robot-human demarcation, and elucidated the influences of user age and gender on PSE.

Study 3 unveiled disparate levels of perceived threat elicited by robots in varied occupational capacities and delved into the modulation of this perception by user age and gender.

Study 4 investigated the bearing of users' financial anxieties on their negative dispositions toward robots.

From Study 1's findings, we anticipated discerning the impact of robot occupations on multifarious facets of people's perceptions concerning robots, inclusive of NARS, mind perception, and anthropomorphic preferences. Following the insights from Study 1, we postulated that robot occupations inherently shape perceptions of robot anthropomorphism. Study 2 further elucidated the impact of robot occupation on PSE, signifying that occupational contexts influence perceived anthropomorphism. Building on this, we introduced a hypothesis suggesting that robots from varied occupations evoke differentiated levels of perceived threats, a stance bolstered by Study 3. Given the intrinsic link between perceived threat and financial concerns, we postulated that users' financial anxiety modulates NARS, a hypothesis substantiated by Study 4.

Chapter 4: Study 1 – Exploring The Effect of Robot Occupation on People's Perception of Robots

4.1 Background

In recent years, robots have become increasingly integrated into modern society, leading to a surge in human-robot interaction research. This research spans topics such as user characteristics, robotic roles, and people's mind perceptions of robots. No longer confined to traditional industries, a diverse range of robotic occupations are emerging in daily life and work environments [143].

Robots with human-appearing features are becoming increasingly popular in the robotics market. The transfer of human characteristics to inanimate objects such as machines is known as anthropomorphism and has been widely used in diverse robotic occupations, including service robots, security machines, and chef robot [131, 144, 145]. Some HRI studies have shown that anthropomorphic robot appearance can improve people's attitudes and willingness to use robots in specific usage scenarios [115, 146]. However, this benefit of anthropomorphic design is not stable, and sometimes, highly anthropomorphic robots can trigger user displeasure [8]. These conflicting findings may be influenced by the context of use set out in the study, mainly the purpose of the robot's use and robot occupation [3].

Although anthropomorphic robot designs are widely used in various tasks and work contexts, how the anthropomorphic appearance should be applied to robots in various occupations has become a controversial issue [75]. Whether people have the same negative attitudes and anthropomorphic preferences towards robots for different purposes of use is a question that remains to be investigated. This study will explore and discuss users' anthropomorphism preferences and negative attitudes toward robots in different robot occupational contexts.

The relationship between people's negative attitudes toward robots and their anthropomorphic preferences for robots remains an understudied issue. An implicit association test found that service robots with low human features elicited more positive user attitudes than highly anthropomorphic service robots [147]. Moreover, in the other study, people had lower negative attitudes toward machine-looking than humanoid robots [148]. Of the studies that have been conducted that refer to negative robot attitudes and anthropomorphism preferences, no studies have rationally controlled the anthropomorphism of the experimental stimuli. Researchers have tended to present very different robots without controlling for other potential influences besides anthropomorphism, such as aesthetics, texture, color, and so on. In this study, we sought to reveal whether there is a relationship between negative attitudes toward robots and preferred robot anthropomorphism through a more rigorous experimental approach.

4.2 Objectives

This study aims to explore the relationship between robot occupations and people's perceptions of robots (including negative attitudes toward robots, mind perception, and anthropomorphic preferences) using robots, security robots, and service robots as examples. This study seeks to determine the impact of user age and gender on their mind perceptions of robots in various roles. We will explore how these factors shape perceptions of robots across different occupations, utilizing a mind perception scale tailored for distinct robots. Given the predicted ubiquity of service and security robots—two common anthropomorphic robot types—in the future, this research will focus on these roles. We aim to uncover and discuss the mind perceptions associated with robots, service robots, and security robots across different age and gender populations.

Mind perceptions can have profound effects on both the observer and the observed. It isn't merely a detached process; it can elicit potent emotional responses towards humanoid robots [149]. The question remains: how do robot occupations influence people's mind perceptions [150, 151]?

Such inquiries reveal that perceptions may vary widely among individuals. Factors like a user's gender and age have emerged as significant influencers in perceptions of robots.

4.3 Hypotheses

In this study, we have selected three frequently used and studied types: robots, security robots, and service robots. We propose:

H1.1: People have different anthropomorphic preferences for robots, security robots, and service robots.

H1.2: People have different NARS reports for robots, security robots, and service robots.

H1.3: There is a correlation between negative attitude outcomes toward robots and the preferred anthropomorphism level of robots.

H1.4: People have different mind perceptions for robots, security robots, and service robots.

H1.5: People's age affect the mind perception of robots.

H1.6: People's gender affect the mind perception of robots.

4.4 Method

This study probed how robot occupations influence users' anthropomorphic preferences and their NARS responses. We considered three robot occupations: robots, service robots, and security robots. For each occupation, participants underwent three picture selection tasks and responded to three NARS scales to evaluate the effects of robot occupations on their anthropomorphic preferences and negative attitudes. Furthermore, participants were asked to complete the mind perception scales of each type of robots.

4.5 Experiment

4.5.1 Stimuli

In order to select photographs of Japanese people with similar aesthetic value, we collected a number of photographs of Japanese faces and administered an aesthetic evaluation questionnaire. Twelve master's degree students participated in this aesthetic evaluation, and each participant was asked to score the images aesthetically. Based on the results of the T-test ($p > 0.05$), we selected four photographs with no significant difference in aesthetic scores as the original human face photographs for Study 1 and Study 2.

We utilized five images for this study (Figure 4). These comprised pictures of one robot, one male, and one female. The robot image was of the Telenoid, an android designed with minimal human features [152]. Images of the male and female faces were sourced from the Pakutasso Database [153]. Post-selection, hair was removed from the images, and all were reshaped to a round format, masking their original shapes. To neutralize skin color effects, the images were

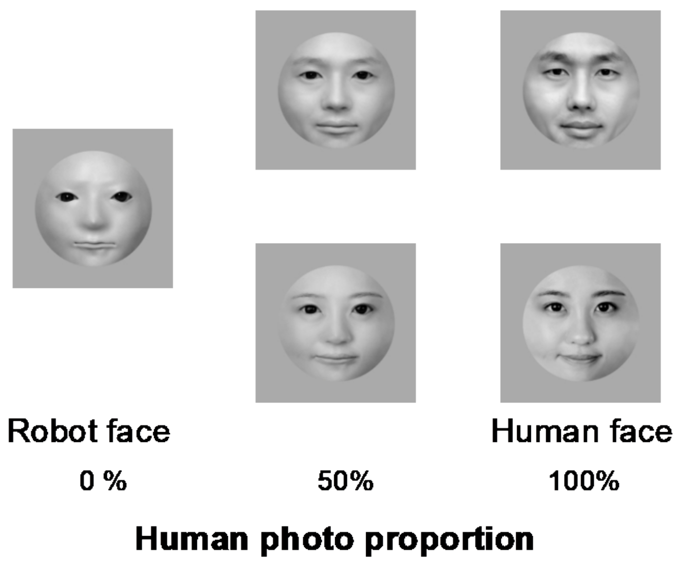


Figure 4. The stimuli used in the experiment

transformed into grayscale and standardized for luminance using Photoshop. We then employed Webmorph [154] to generate three levels of morphed images, incorporating varying degrees of human facial elements. The 0% version was the pure robot image, the 50% version blended robot and human features, and the 100% version was fully human. Each was centrally positioned on a 710px*710px gray backdrop. Display luminance for the MacBook Pro was set at 29.61 cd/m2.

4.5.2 Measurement

This study included two scale: the NARS and mind perception scale. The NARS questionnaire was selected as the primary measurement instrument [99]. Three robot occupations, robots, service robots, and security robots were selected. We made changes based on the Japanese version of the NARS ($\alpha = 0.803$) to adapt the new questionnaire to the two occupations: service and security robots. Two Japanese scales were produced: the NARS-service robots scale ($\alpha = 0.847$) and the NARS-security robots scale ($\alpha = 0.889$). Moreover, the NARS includes three aspects, and reliability tests were conducted for S1 (negative attitudes towards interactions with robots), S2 (negative attitudes towards the social influence of robots), and S3 (negative attitudes towards emotional interactions with robots) of the three NARS questionnaires, all of which measuring a high degree of reliability ($\alpha > 0.7$).

The second evaluation tool employed was the mind perception questionnaire [94]. This questionnaire was tailored to address the specific contexts of service robots and security robots. An existing English version of the mind perception questionnaire was initially revised by a panel of three experts. Subsequently, it was back-translated and meticulously reviewed by two bilingual professionals fluent in both English and Japanese. For evaluating mind perception, we implemented a 7-point Likert scale, with endpoints defined as 1 (not at all) and 7 (very).

4.5.3 Participants

The Research Ethics Committee of the Art and Design Faculty at the University of Tsukuba approved our human participant studies, under the code No. G22-12. All methods adhered to the Declaration of Helsinki, and we ensured informed consent from every participant before data collection. We initially recruited 240 participants from Japan via Freeasy, an online survey platform. In lieu of cash, participants were compensated with points redeemable at specific stores. We did not recruit the adolescent and intermediate groups for this study because the number of subjects required for uniform sampling exceeded our budget. After excluding those with experience in robot design, construction, or use, and those who answered screening questions incorrectly, we had 114 valid participant datasets ($M = 46.29$, $SD = 19.93$). This included two age and gender distributions: females aged 20-30 (26 participants, $M = 25.38$, $SD = 2.51$) and 60-70

(28 participants, M = 64.32, SD = 3.19), and males aged 20-30 (27 participants, M = 24.96, SD = 2.82) and 60-70 (33 participants, M = 64.91, SD = 3.52).

4.5.4 Procedure

We employed the web-based questionnaire platform, Freeasy, for participant recruitment and data collection. All participants were briefed on the general terms and conditions. At the outset of the experiment, they were advised to ensure they possessed either normal vision or vision corrected to normal standards. It was imperative that the test be conducted in a well-lit, quiet environment. Participants were instructed to adjust their screen brightness to a comfortable level. Once these conditions were met, they proceeded with the online survey.

The survey was divided into three parts: 1) NARS, 2) picture selection tasks, and 3) mind perception scale. The NARS section presented three distinct scales tailored for robots, service robots, and security robots. In the picture selection section, participants were prompted with three questions, each asking them to choose an image that best represented their ideal version of the three robot types. For each question, participants were provided with five stimulus images, displayed in a randomized sequence. Robot occupations appeared in the questionnaire only as text and there was no description of the different occupations of the robots.

Upon concluding the three sections, participants shared personal details, including gender, age, occupation, and their frequency of robot usage. The survey culminated in a screening question designed to identify attentive participants. It read: "Which of the following is mentioned in this survey: (i) robot, (ii) service robot, (iii) industry robot, (iv) education robot, (v) security robot, (vi) toy robot." Those selecting options (iii), (iv), or (vi) were subsequently excluded. Finally, we excluded 60 males and 66 females.

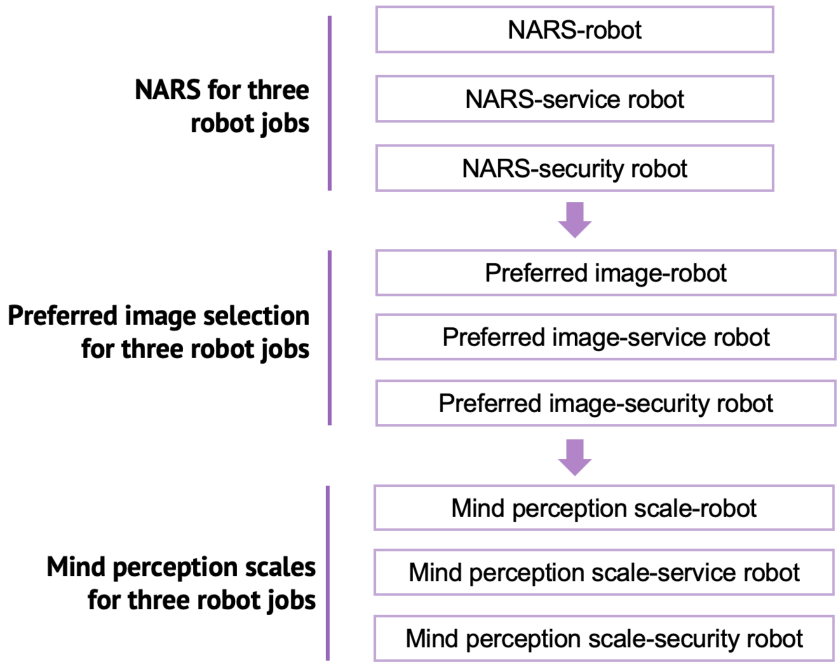


Figure 5 Procedure of study 1

4.6 Results

4.6.1 Preferred Anthropomorphic Level

We conducted a one-way ANOVA to investigate whether the occupation of the robot influenced the proportion of human photos selected in the preferred face picture across three picture-selection tasks. As illustrated in Figure 5, there were significant differences in the proportion of human photos selected for service robots compared to robots and security robots, $F(2, 226) = 10.32$, $p < 0.001$, with an effect size of $\eta^2 = 0.084$. Error bars denote 95% CI of mean. $^*p < 0.05$, $^{**}p < 0.01$.

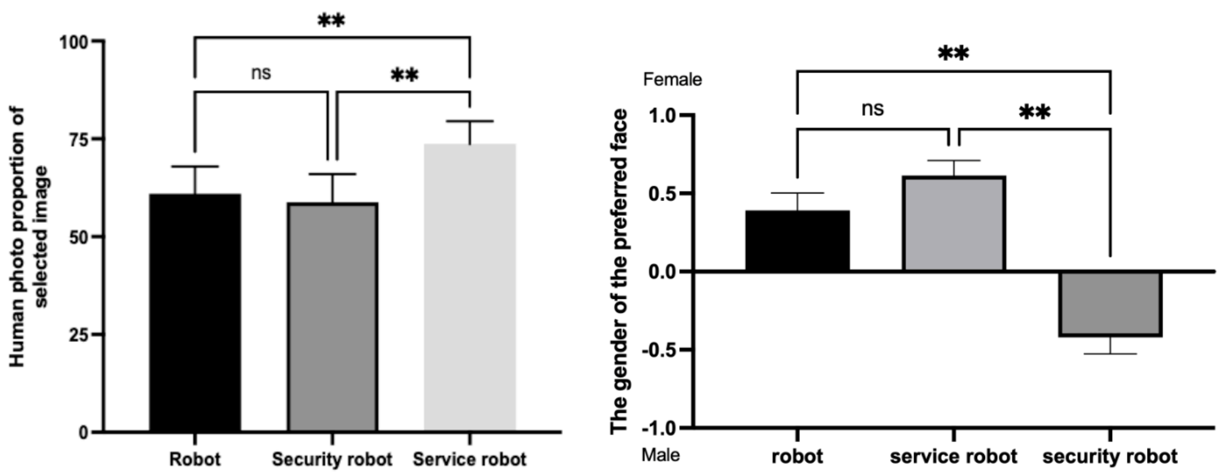


Figure 6. The human photo proportion and preferred gender of selected robot, security robot and service robot

Following the ANOVA, Tukey's multiple comparison test was conducted. It demonstrated that the mean human photo proportion for service robots (M = 60.96, SE = 3.511, 95%CI = [54.01, 67.92]) was significantly greater than for both regular robots (mean difference between service robots and robots = 12.72, SE = 2.842, p < 0.001) and security robots (mean difference between service robots and security robots = 14.91, SE = 3.682, p < 0.001). This finding indicates that robot occupation can influence anthropomorphic preferences towards robots, thereby supporting hypothesis H1.1. Moreover, using the Friedman test, we found that participants also had different gender preferences for robots with different occupations (p < 0.0001). Participants tended to favor males when choosing security robots and preferred female pictures when choosing service robots (Figure 5）. The error bars denote 95% CI of the mean.

4.6.2 Negative Attitudes of Robots

We conducted an ANOVA to examine if the robot occupation influenced the NARS scores of individuals. Reliability tests for NARS-robot, NARS-service robot, and NARS-security robot all showed a high degree of reliability (α > 0.8). Subsequently, results from the RM one-way ANOVA indicated a significant difference among NARS-robot, NARS-service robots, and NARS-security robots ($F(2, 226) = 6.466$, $p < 0.001$, $\eta^2 = 0.613$), as depicted in Figure 6.

Results from Tukey's multiple comparison test indicated that the mean NARS score for service robots (M = 35.87, SE = 0.696, 95%CI = [34.49, 37.25]) was significantly lower compared

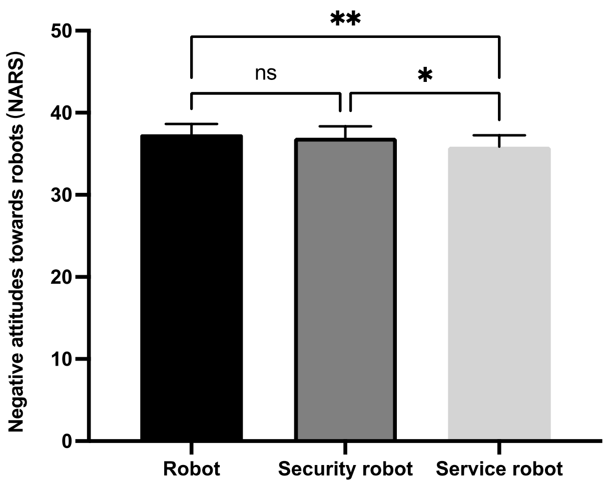


Figure 7. NARS of robots, security robots and service robots

to both NARS-robot (mean difference between service robot and robot = -1.482, SE = 0.429, p = 0.002) and NARS-security robots (mean difference between service robot and security robot = -1.105, SE = 0.429, p = 0.028). However, no significant difference was noted in participants' negative attitudes between robots and security robots (p > 0.05).

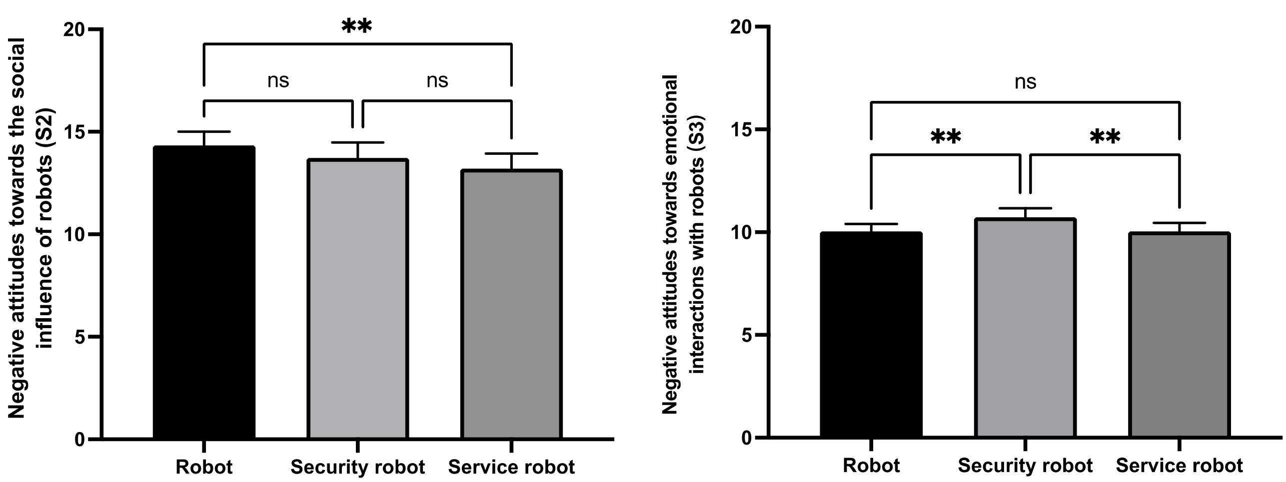


Figure 8. S2 of robots, security robots and service robots

The NARS comprises three dimensions: S1, S2, and S3. Each of these dimensions was individually analyzed. For the S1 (negative attitudes towards interactions with robots) component, Tukey's multiple comparison test found no significant differences in scores across the three robot occupations ($p > 0.05$). However, in the S2 component, Tukey's test identified a significant disparity between the S2 scores of service robots (M = 13.21, SE = 0.367, 95%CI = [12.48, 13.94]) and the S2 scores of robots, with a mean difference of 1.132 (SE = 0.245; $F(2, 226) = 9.4$, $p < 0.001$, $\eta^2 = 0.077$) as displayed in Figure 7.

Furthermore, in the S3 component, the scores for security robots (M = 10.73, SE = 0.218, 95%CI = [10.30, 11.16]) were significantly elevated compared to both robots (mean difference between security robot and robot = 0.684, SE = 0.195, p = 0.002) and service robots (mean difference between security robot and service robot = 0.684, SE = 0.192, p = 0.002). This difference was further supported by $F(2, 226) = 10.35$, $p < 0.001$, and $\eta^2 = 0.084$, as presented in Figure 8. These findings indicate varying negative perceptions towards robots based on their specific occupations, thus corroborating hypothesis H1.2.

Figure 9. S3 of robots, security robot and service robots

4.6.3 NARS and Preferred Anthropomorphic Level

We conducted a regression analysis for each dimension of the NARS in relation to anthropomorphism preferences, analyzing data from all three types of robots. A significant correlation was observed between the proportion of selected images and NARS scores. Among the dimensions, only the negative attitudes towards interaction with robots (S1) emerged as a significant and positive predictor of the proportion of chosen images ($r = 0.18$, $R^2 = 0.03$) as outlined in Table 1. This finding suggests a link between users' S1 scores and their anthropomorphic preferences for robots, thereby substantiating hypothesis H1.3.

Table 1. Regression analysis results of three dimensions of NARS and preferred robot image

	Human photo proportion of selected images			
	B	t	P value	95% CI

S1	1.528	3.397	<0.001	0.643	2.413
S2	0.628	1.234	0.218	-0.373	1.629
S3	-1.201	-1.324	0.186	-2.986	0.584

4.6.4 Mind Perception

We assessed the reliability of all three mind perception questionnaires, finding consistently high reliability ($\alpha > 0.8$). Using a two-tailed unpaired T-test, we discovered a significant age-related effect on participants' evaluation of the experience ability for both the robot and security robot. Participants aged 20 to 30 years rated significantly higher on the experience dimensions for robots (M = 3.53, SD = 1.03) and security robots (M = 3.41, SD = 1.13) compared to those aged 60 to 70 years (M = 3.03, SD = 0.89, $t(112) = 2.75$, $p = 0.007$; M = 3.00, SD = 1.02, $t(112) = 2.05$, $p = 0.04$)(Fig.9(a)). This result supported H1.4.

However, there was no significant difference between the 20-30 (M = 3.44, SD = 1.18) and 60-70 (M = 3.12, SD = 0.95, $t(112) = 1.591$, $p = 0.11$) age groups regarding their evaluations of the service robot's experience ability ($p = 0.11$).

Employing the two-tailed Mann-Whitney test, a gender effect emerged in participants' assessment of the robot's agency ability. Female participants (M = 4.28, SD = 1.07) ranked the robot's agency ability higher than male participants did (M = 3.96, SD = 1.01, $p = 0.03$)(Fig. 9(b)). This result supported H1.5. However, no gender effect was found when evaluating the agency ability of security robots ($p = 0.22$) or service robots ($p = 0.18$).

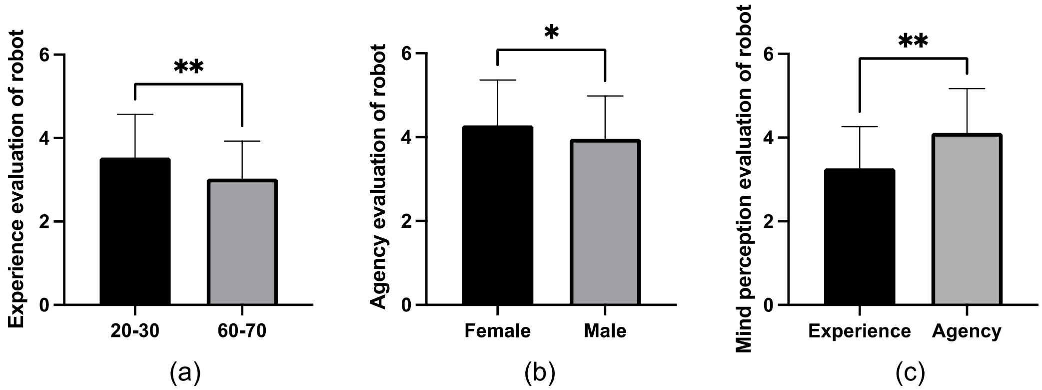


Figure 10. Mind perception of robots (including experience and agency evaluation)

To discern differences between agency and experience evaluations, we applied the Wilcoxon test. As shown in Fig. 9(c), participants significantly favored agency evaluations (M = 4.11, SD = 1.05) over experience expectations (M = 3.26, SD = 0.99) for robots ($p < 0.01$). Similar trends were evident for service and security robots ($p < 0.01$), with higher agency ratings for service robots (M = 4.04, SD = 1.14) than experience expectations (M = 3.26, SD = 1.07, $p < 0.01$) and for security robots, agency evaluations (M = 3.97, SD = 1.20) surpassed experience expectations (M = 3.19, SD = 1.11, $p < 0.01$).

Following an RM one-way ANOVA, we found no significant differences in participants' expectations regarding the experience or agency abilities across the three robot types ($p > 0.05$). In this study, our result did not support H1.6.

4.7 Discussion

4.7.1 Robot Occupation Affects NARS

Our study found that people rated negative attitudes toward service robots significantly lower than robots and security robots. In the S1 (negative attitudes towards interactions with robots) dimension, these three robots do not reflect significant differences. Moreover, the occupational differences in the S2 (negative attitudes towards the social influence of robots) and S3 (negative attitudes towards emotional interactions with robots) dimensions were inconsistent. Negative attitudes towards robots were significantly higher in the S2 (negative attitudes toward the social influence of robots) dimension than security and service robots. Negative attitudes towards security robots were significantly higher than the other two robots in the S3 dimension.

Regarding S2, both service and security robots have predictable work content and behavioral predictions. However, for robots with no specifically stated purpose of use, people might expect a broader range of work, thus leading to higher expectations of the social influence of robots. Regarding S3, service workers have more robust emotional interaction attributes in their occupational stereotypes than security workers. Assuming that service robots are perceived to be aligned with the occupational stereotypes of service workers in human society, it is easy to explain the significantly lower S3 of service robots compared to security robots. The impact of occupations on negative attitudes varies in different ways. This shows the complexity of the stereotypes about robot careers.

4.7.2 Robot Occupation Affects Preferred Anthropomorphic Level

Our study found that people have higher anthropomorphic expectations of service robots (compared to robots and security robots), and this result supports H1. The service robot interacts more directly with people than the other two robots. This result supports previous research that people have higher anthropomorphic expectations for robots interacting more directly with people [110]. Compared to previous studies with diverse robot occupations and anthropomorphic preferences, the present study used strictly controlled pictures of different anthropomorphic degrees as stimuli [109-111]. To reduce potential factors such as gender, skin color, and face shape, we used both male and female photographs as source material and adjusted all images to grayscale with the same brightness. These experimental designs allowed our study to more directly and rationally validate the effect of robot occupation on anthropomorphic preferences.

Moreover, we found no significant difference between people's preferred anthropomorphism for security robots and robots. Thus, we cannot simply infer that changing the robot's occupation leads to significantly different anthropomorphism preferences. The stereotypes associated with robot careers are complex, so researchers need further studies to explore more direct influences on anthropomorphic preferences. Changes in anthropomorphic preferences induced by robot occupations may increase the complexity and difficulty of robotics research. However, this finding is necessary for the long-term development of the robotics industry and research.

4.7.3 Correlation Between NARS and Preferred Anthropomorphic Level

This study reveals for the first time a correlation between S1 and anthropomorphic preference for robots. The results show that when people have higher negative attitudes towards emotional interactions with robots, they are more inclined to choose a highly anthropomorphic robot appearance. Previous research has found that people have higher positive evaluations of highly anthropomorphic robots [37]. People with more negative attitudes toward robotic interaction have a greater need for highly anthropomorphic robots to compensate for this psychological discomfort. Interestingly, in the results of the NARS, only S1 did not produce a significant change due to occupational change. However, in the results of the correlation analysis between NARS and anthropomorphic preference, only S1 and anthropomorphic preference were significantly correlated. Past research has not found a relationship between negative attitudes toward robots and anthropomorphic preferences for robots. The present study bridges the gap in this research question, which has important implications for robotics research and design.

Some researchers have proposed that the gender and personality of social robots interact with the corresponding role stereotypes that influence users' feelings about social robots [82]. Because this experiment included people of different ages and genders, the number of participants was insufficient to support our analysis of age and gender as potential influencing factors. In subsequent studies, we need to recruit more participants to control for possible effects on the results due to the age and gender of the participants. Some researchers have also found that personality dimensions affect how individuals perceive the robots they interact with. Participants' personalities may also affect the results of NARS, especially S1 and S3 [155]. Therefore, repeated trials, as well as screening of participants, should be emphasized in NARS-related research. Since how people perceive different robotic careers is a complex issue that encompasses sociology, psychology, and ethics, in the future, we need more in-depth research to explore and reveal the results of this study.

4.7.4 Gender and Age Differences in Mind Perception of Robots

This study sought to explore how users' age and gender influence their mind perceptions of robots across different occupational contexts. We used three distinct robot mind perception questionnaires to assess users' views on the agency and experience abilities of robots, service robots, and security robots. Our findings revealed that across all robot types, agency was consistently rated higher than experience. Additionally, female participants assessed the robot's agency capabilities more positively than males did. The younger participants, in contrast to older participants, rated the experience dimension higher for both robots and security robots.

Our study has illuminated pronounced variances in how different genders and age brackets perceive robots. By adhering to the established mind perception scale from previous research, we verified its reliability [94]. Intriguingly, our results suggest that people anticipate robots to have certain experiential capacities despite robots lacking sensory faculties or emotions. This aligns with the notion that humans can perceive robots as having minds [93].

A notable age disparity emerged in participants' assessment of the robot's experience capabilities. The younger group assigned higher scores to the experience dimensions of robots and security robots when compared to the older group. Yet, the younger and older groups did not show significant differences in their evaluation of service robots' experience abilities. This trend may suggest that older individuals, potentially having greater service needs, harbor elevated expectations for service robots relative to the other robot types. Such insights can guide the design of service robots tailored to senior users, emphasizing experience features that cater to their needs.

It was unexpected to note the absence of significant differences in the agency or experience evaluations across the three distinct robot roles, despite their divergent social functions and tasks. Previous research posited that perceived robot-task fit governed collaboration, assigning emotive robots to social roles [97]. Despite presuming varying social levels for the three robot types in our study, we did not identify differences in agency or experience ratings across them.

For this study, we engaged participants without prior familiarity with robots. This might have limited their ability to differentiate between the tasks associated with unfamiliar security and service robots. Consequently, their differentiation might not be precise. Alternatively, it's possible that the mind perceptions of these robot roles were intrinsically similar. Exploring how individuals comprehend and distinguish between varied robot roles necessitates broader research methodologies than just the mind perception scale. We intend to delve deeper into these mechanisms in forthcoming studies.

In every robotic occupational context studied, participants ascribed higher agency and lower experience abilities. We posit that people universally hold high agency and low experience expectations for robots across different roles. Future research could further investigate this by examining perceptions for robots in an even broader range of occupations.

4.8 Summary

We found that people's negative attitudes towards robots and preferred anthropomorphic level change along with robot occupation. People’s NARS reports of service robots are significantly lower than those of robots and security robots. Moreover, people preferred service robots with highly anthropomorphic designs over robots and security robots. This study reveals for the first time a significant positive correlation exists between negative attitudes towards interactions with robots and preferred anthropomorphic levels.

Moreover, we discovered that across all three robot categories, participants consistently rated agency higher than experience. Women, in particular, evaluated the agency abilities of robots greater than men did. Younger individuals, compared to older participants, gave notably higher ratings for the experience capabilities of robots and security robots. However, our data didn’t indicate significant variances in the mind perceptions based on different robot occupations. This study marks a pioneering effort in highlighting how participants' age and gender can distinctly influence people's mind perceptions of robots. It also hints at the potential role of robot occupations in shaping these perceptions. These insights are crucial for future human-robot interaction studies and have significant ramifications for the development and design of robotic technologies.

Chapter 5: Study 2 - Robot Occupation Affects The Robot-Human Border

5.1 Background

In recent years, advances in robotics and artificial intelligence have led to a proliferation of robots in diverse occupational roles, such as industrial, social, service, security, and culinary [156]. The prevailing trend in the robotics industry emphasizes the importance of integrating anthropomorphic features into robots. Such features enhance users' perceptions of anthropomorphism, fostering increased trust and favorability towards robots [37, 146, 157]. As a result, to cater to user preferences, humanoid robots are gaining prominence across various sectors. This trend has also popularized designs that make robots resemble humans [158]. Nonetheless, the move towards anthropomorphic designs isn't universally applauded, and the degree of anthropomorphism in robots remains a topic of debate [115]. Both service and security robots have become prevalent and are subjects of considerable study [23, 159]. Society holds distinct stereotypes for service personnel and security guards [61, 62].

The question of whether gender influences the perception of robot anthropomorphism is intriguing. One study focused on robots for children revealed that girls exhibited a stronger preference for humanoid robots compared to boys [43]. Another study highlighted that males, in comparison to females, derived greater enjoyment from interactions with highly anthropomorphic robots. This suggests that gender might play a role in defining the robot-human border.

5.2 Objectives

This study categorizes robots into three occupational groups: robots, service robots, and security robots. It aims to examine the influence of robot occupation (robot vs. service robot vs.

security robot) on the proportion of human features, as defined by the robot-human border, using a classification task with morphed face images.

To delve deeper, this study harnessed a psychophysical approach to gauge the robot-human border. Participants classified images with varying human face proportions as either human or robot, facilitating the estimation of the point of subjective equality (PSE). This experiment contributes to the ongoing exploration of the extent of human likeness that signifies the robot-human demarcation. The study's objectives were twofold: to probe the impact of robot roles (whether robots, service robots, or security robots) on human resemblance at this border using a morphed face image classification task, and to assess how participants' gender and age shape their perceptions of robot anthropomorphism.

Different occupations influence people's preferences for anthropomorphism, and higher expectations may lead to higher satisfaction standards [112]. This study hypothesizes that when people have higher anthropomorphism expectations for robots engaged in a specific occupation, it would be more challenging to perceive precise anthropomorphism to recognize them as human. Robots in occupations with high expectations of anthropomorphism would need to have more human-like features to cross the border from robot to human. The human similarity represented by the robot–human border will vary by occupation.

5.3 Hypotheses

H2.1: Robot occupation influences the human photo proportion at the robot-human border.

H2.2: Participant age influences the human photo proportion at the robot-human border.

H2.3: Participant gender influences the human photo proportion at the robot-human border.

5.4 Method

This study explored how different robot roles impact users' perceptions concerning the robot-human border. Specifically, we analyzed three distinct robot occupations: robots, service robots, and security robots. In line with these categories, three classification tasks using morphed face images were conducted to assess the influence of these roles on the robot-human border. Additionally, the study considered participants' age and gender as potential contributing factors.

5.5 Experiment

5.5.1 Stimuli

A set of 25 images were utilized for this study (refer to Figure 10). We selected facial photographs of one robot, two male individuals, and two female individuals. The robotic facial image was derived from the Telenoid, an android designed with a minimalistic human appearance, capturing only the essential human features [152]. The male and female human facial photographs were sourced from the freely accessible Pakutasso database [153].

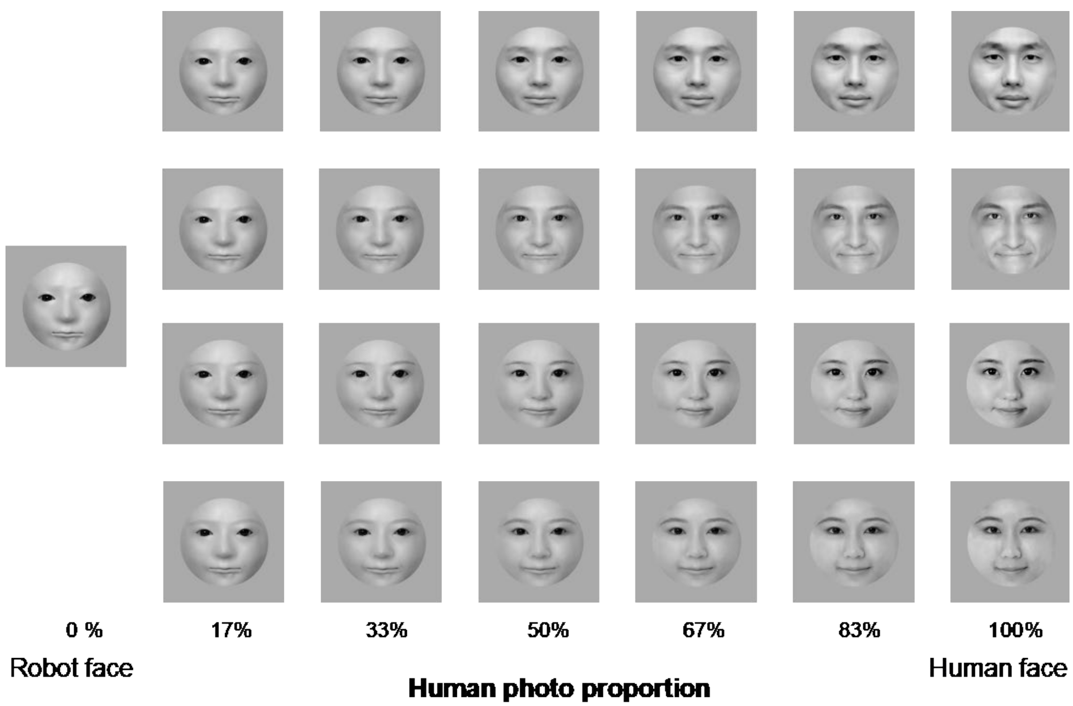


Figure 11. Morphed images used in the experiment

Once the images were chosen, any hair was digitally removed, and each of the five images was adapted to a round shape, masking their original face structures. To eliminate the potential influence of skin tone, all photographs were transformed into grayscale images, standardized for luminance using Photoshop. The online tool Webmorph [154] facilitated the creation of a 7-level equally stepped morphed images, with human facial feature proportions ranging from 0% to 100%.

The image labeled with 0% human feature proportion displayed the pure robotic face, while the 100% variant showcased an unaltered human face. Every image was centrally positioned against a 710px by 710px squared gray backdrop. When viewed on a MacBook Pro display, the luminance of this gray background measured 29.61 cd/m^2.

5.5.2 Measurement

Participants were tasked with deciding whether each image represented a human or a specific type of robot—selected randomly from the three categories: robot, service robot, or security robot. There were no time constraints. Participants sequentially progressed through the three blocks. Both the sequence of the three blocks and the arrangement of the 25 images within each block were randomized.

5.5.3 Participants

The experiments with human participants underwent review and received approval from the Research Ethics Committee of the Art and Design Faculty at the University of Tsukuba, under the reference No. G22-12. All methods adhered to the Declaration of Helsinki standards. Before data collection began, informed consent was secured from every participant.

In January 2023, 1159 participants were enlisted from Japan via Yahoo! Crowdsourcing, a premier online survey platform in the country. In appreciation of their participation, individuals were awarded points that could be redeemed in lieu of cash at select stores. The smallest effect size of interest of $\eta 2 = 0.03$ was used in sample size planning [160]. Based on an a priori power analysis using G*Power with a power $(1 - \beta)$ set to 0. 95 and $\alpha = 0.05$, the targeted sample size was 600.

To ensure the quality of responses, a verification code and a screening question were utilized as evaluation criteria. The screening query was: “Which of the following has not been discussed in this survey: (i) service robot, (ii) medical robot, (iii) security robot.” Responses choosing either option (i) or (iii) were discarded. Out of the initial 1159 participants, 1024 successfully finished the survey, correctly answering both the screening question and the verification code. The age bracket of 30-39 years comprised 259 males (M = 35.59, SD = 2.72) and 251 females (M = 35.26, SD = 2.94). The 60-69 years category had 286 males (M = 63.70, SD = 2.88) and 228 females (M = 63.36, SD = 2.84). When queried about their occupation, the sample revealed individuals from robot-related (n = 3), service (n = 16), and security (n = 17) sectors, with the majority from other fields (n = 988)

5.5.4 Procedure

The survey was distributed via SurveyMonkey, with participants sourced from the online platform, Yahoo! Crowdsourcing. Each participant accessed the survey through a provided link and followed the accompanying instructions. Participation was restricted to those using desktop computers. Before commencing, they were briefed on the general terms and conditions. At the survey's outset, participants confirmed they possessed either normal or corrected-to-normal vision. It was emphasized that the testing environment should remain quiet and well-lit, and distractions, such as other multimedia devices like music or TV, should be avoided. Participants were advised to use a display size of at least 10.5 inches for optimal image presentation. They were also guided to adjust their screen's brightness to a comfortable level and ensure a seating position approximately 60 cm from the screen. Once these preparations were confirmed, the online survey proceeded.

The questionnaire was crafted to investigate participants' ability to discern morphed faces in varying robot occupational contexts. The survey was organized into three blocks, each corresponding to a distinct robot occupation. Participants were provided with one of the following noun pairs as multiple-choice options for each image: “human/robot,” “human/service robot,” and “human/security robot.” Each of the 25 images was displayed on individual pages within the questionnaire. Directly below each image, participants encountered a binary query: “Which of the following options most closely resembles this image?” They were then presented with a randomly chosen pair from the aforementioned noun pairs.

After navigating through 75 categorization tasks, participants provided personal details such as gender, age, and occupation. At the survey's conclusion, a screening question was introduced to identify participants who had diligently read through the questions. Rewards were only granted to those who correctly answered both the screening question and the verification code. Data collected was subsequently analyzed using IBM SPSS Statistics 29.0.

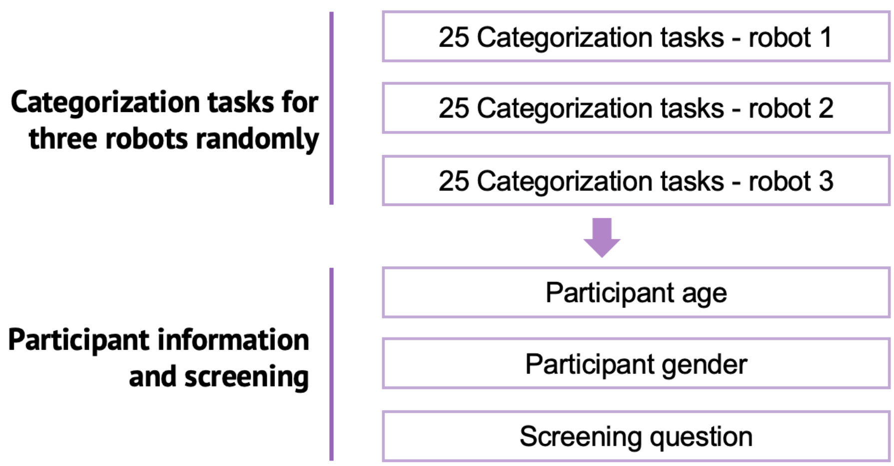


Figure 12 Procedure of study 2

5.6 Results

A three-way Analysis of Variance (ANOVA) was conducted to discern the impact of robot occupation (robots, security robots, service robots), participant gender (female and male), and participant age (individuals in their 30s vs. those in their 60s) on point of subjective equality (PSE) outcomes using factor composites. The results are displayed in Table 1. Preliminary checks ensured the error variance of the dependent variables was consistent across groups. The data indicated that each dataset adhered to a normal distribution ($p > 0.05$). Mauchly's test of sphericity confirmed that the error covariance matrix of the orthonormalized transformed dependent variables aligned proportionally with an identity matrix ($p > 0.05$). If statistical differences were detected, post hoc tests with a Bonferroni correction for multiple comparisons were employed. In the three-way ANOVA, all primary effects were found to be significant. The only noteworthy interaction was between participant age and gender.

5.6.1 Point of subjective equality (PSE)

The data from the image differentiation process can be quantified by determining the proportion of human responses participants gave for each image based on the robot occupation. In these differentiation tasks, responses labeled as “human” were coded as “1”, while all other responses were coded as “0”. Morphed images were scored according to their human photo proportion, specifically 0, 0.17, 0.5, 0.67, 0.83, and 1. These scores, together with the responses, were then used to compute the PSE for each task using R Studio. As depicted in Figure 11(a), the PSE for each task represents the human photo proportion where the likelihood of a "human" designation is 0.5. This PSE value denotes the human photo proportion of the image where a participant is equally inclined to categorize the image as either human or a specific robot type. Essentially, the PSE signifies the subjective balance between robot and human perceptions that participants experienced during the task. A rise in the PSE (or a shift of the curve to the right) indicates participants frequently selected “human”. Conversely, a dip in the PSE (or a leftward shift in the curve) demonstrates a bias towards designations like “robot”, “service robot”, or “security robot”.

5.6.2 Interaction Between Age and Gender on PSE

As illustrated in Figure 11(b), a significant interaction was observed between participant age and gender regarding point of subjective equality (PSE), with $F(1, 3060) = 8.746$, $p = 0.003$, and $\eta = 0.055$. No other two-way or three-way interactions reached statistical significance. Post-hoc analyses, adjusted using Bonferroni correction, revealed significant mean differences in PSE between females in their 30s compared to their male counterparts (mean difference = 0.015, $p = 0.015$, 95% CI = [0.003, 0.028]). Similarly, the PSE of females in their 60s was notably higher than that of males in the same age bracket (mean difference = 0.042, $p < 0.001$, 95% CI = [0.030, 0.054]).

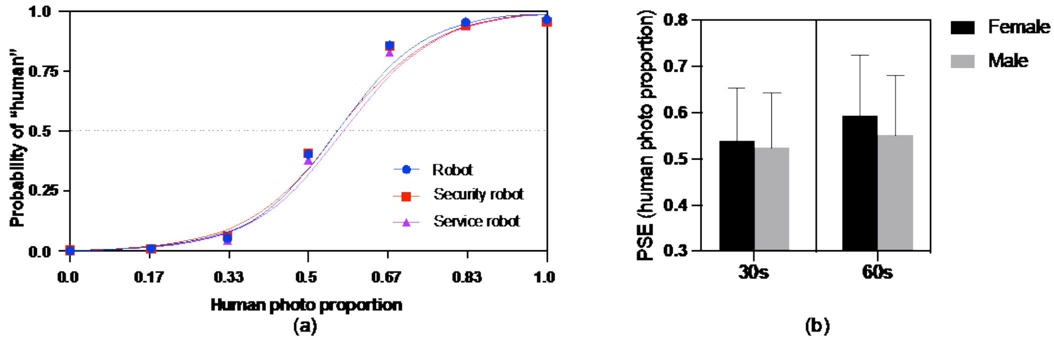


Figure 13. PSE results of the experiment

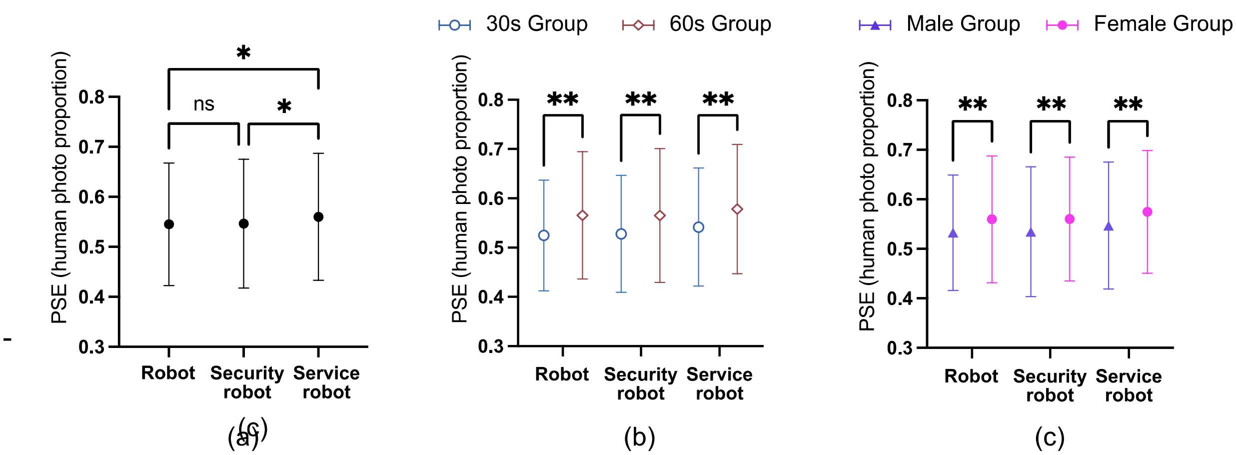
Table 2. Results of a three-way analysis of PSE

Effects	SS	*df*	MS	*F*	*p*	*η*
Robot occupation	0.135	2	0.067	4.390	0.012*	0.055
Participant age	1.250	1	1.250	81.521	<0.001**	0.161
Participant gender	0.628	1	0.628	40.966	<0.001**	0.114
Robot occupation × Participant age	0.004	2	0.002	0.119	0.888	<0.001
Robot occupation × Participant gender	0.001	2	0.0000	0.021	0.979	<0.001
Participant age × Participant gender	0.134	1	0.134	8.746	0.003**	0.055
Robot occupation × Participant age × Participant gender	0.012	2	0.006	0.384	0.681	<0.001
Error	46.911	3060	0.015			

A closer examination by gender highlighted distinct differences. Among females, the PSE between those in their 30s and those in their 60s varied significantly, with a mean difference of -0.054, p < 0.001, 95% CI = [-0.067, -0.041]. In contrast, among males, the difference in PSE between the two age groups was -0.027, p < 0.001, 95% CI = [-0.039, -0.015]. For a comprehensive breakdown of these findings, refer to Table 2.

5.6.3 Robot Occupation and PSE

There was a pronounced main effect related to robot occupation. As depicted in Figure 12(a), the point of subjective equality (PSE) associated with the service robot differed significantly from that of the robot, with F(2, 3060) = 4.39, p = 0.012, and η = 0.055. Subsequent post-hoc analyses, adjusted using the Bonferroni method, revealed that the PSE for service robots was notably higher than both the robots (mean difference = 0.015, SE = 0.005, p = 0.024, 95% CI = [0.001, 0.028]) and the security robots (mean difference = 0.014, SE = 0.005, p = 0.041, 95% CI



= [0.000, 0.027]). Essentially, the PSE offers insights into whether participants' perceptions of anthropomorphism veered towards underestimating or overestimating the human-like attributes of different occupational robots.

5.6.4 Participant Age and PSE

Participant age exerted a significant main effect on PSE, with F(1, 3060) = 81.521, p < 0.001, and η = 0.161. As indicated in Table 1, there was no significant interaction effect between robot occupation and participant age on PSE: F(2, 3060) = 0.119, p = 0.888, and η < 0.001. Figure 12(b) highlights the differences in PSE between the two age groups. Notably, the average PSE for participants in their 60s was significantly elevated compared to those in their 30s, presenting a mean difference of (60s-30s) = 0.040, SE = 0.004, p < 0.001, and a 95% confidence interval of [0.032, 0.049].

Figure 14. The PSE results of robots, security robots and service robots

5.6.5 Participant Gender and PSE

Gender had a discernible main effect on point of subjective equality (PSE), as shown by F(1, 3060) = 40.966, p < 0.001, and η = 0.114. Table 1 reveals no significant interaction between robot occupation and gender with respect to PSE: $F(2, 3060) = 0.021$, $p = 0.979$, and $\eta < 0.001$. As illustrated in Figure 12(c), there's a clear difference in PSE between genders. Notably, the average PSE for females was higher than for males, characterized by a mean difference of 0.029, SE = 0.004, $p < 0.001$, and 95% CI = [0.020, 0.037].

The results from the three-way ANOVA indicate that people display varying PSEs of human photo proportion when evaluating morphed images set against different occupational contexts. Specifically, to be perceived as human in the "human/service robot" task, the morphed face image necessitated a more pronounced human photo proportion compared to the "human/robot" and "human/security robot" tasks. There were observable differences among participants based on age and gender, accompanied by a significant interaction between the two. Table 2 provides an in-depth breakdown and aggregate overview of the aforementioned findings, shedding light on the influence of robot occupation, participant age, and gender on PSE. Consequently, hypotheses H2.1, H2.2, and H2.3 found empirical support.

5.7 Discussion

This study explored the influence of robot occupation, alongside participants' gender and age, on the human photo proportion as delineated by the robot-human border. We assessed the classification outcomes of morphed face images across varied levels of human photo proportion using the PSE method.

5.7.1 Robot Occupation Affects Robot-Human Border

Our research strongly supports the idea that robot occupation significantly influences perceptions of human likeness, as reflected by the robot-human border. Consistent with the hypotheses outlined in H2.1, participants indicated the greatest human photo proportion for the service robot-human interface compared to robots and security robots.

People exhibit varied anthropomorphic preferences when choosing robots associated with different occupations [67]. While the point of subjective equality (PSE) was notably higher for service robots compared to both robots and security robots, the human photo proportion, as indicated by the robot-human border, did not show significant variations between robots and security robots. This suggests that individuals anticipate service robots to bear a closer resemblance to humans than security robots do. Such observations highlight the multifaceted influences on the robot-human demarcation driven by distinct robot professions. These findings align with Robertson's perspective that individuals' expectations about human appearances in specific roles get mirrored in the design of robots for those same roles. This, in turn, can further reinforce their anticipations regarding appearances in those particular professions [122].

In this research, we morphed images of both males and females to mitigate the influence of gender stereotypes associated with different professions. Given the significant role skin color plays in shaping human perceptions [94], we used grayscale images, minimizing potential biases in gauging human likeness. Consequently, this study's approach—by not using direct robot images but rather controlling for several variables—enhances the reliability and validity of our findings.

5.7.2 Age Effect on Robot-Human Border

The findings of our study align with H2.2: Older participants registered higher PSE scores than their younger counterparts. In comparison to younger participants, older adults discerned less anthropomorphism in identical morphed facial images. Previous research indicates a preference among older adults for highly anthropomorphic robots, in contrast to younger individuals [42]. This study posited that as preferences and expectations for human-like proportions in robots amplify, the morphed facial images need to exhibit heightened human proportions to straddle the robot-human border. Consequently, this might reduce the perceived anthropomorphism of the image. The underlying reasons for this age disparity remain ambiguous, potentially stemming from variances in educational backgrounds or sociocultural influences, which might sway perceptions of the robot-human demarcation. This insight is invaluable for the tailored design of robots intended for older demographics. Notably, even though older individuals exhibit a more pronounced skepticism towards robots compared to younger groups [41], robot designs that align with the anthropomorphic expectations of older individuals might foster more positive attitudes and foster acceptance. Research indicates that three-year-old children are more inclined to attribute biological characteristics to robots than older individuals [77]. Robots exhibiting high anthropomorphism levels can be perceived as possessing 'mind-like' or 'conscious' attributes, reminiscent of Animistic beliefs. Such perceptions can potentially mold human-robot interactions, making them more instinctive and immersive.

5.7.3 Gender Effect on Robot-Human Border

The results revealed significant gender disparities in PSE scores, reinforcing H2.3. Females exhibited a higher PSE than their male counterparts. These findings suggest that for females to recognize robots as human, the robots would require more human-like features compared to the requirements for males. It can be inferred that females, relative to males, harbor elevated expectations and a stronger preference for a pronounced human element in the facial design of robots, leading to the observed higher PSE values. This research addresses a notable gap in the literature by investigating gender's influence on the perceived anthropomorphism of robot faces. Prior studies have documented females perceiving greater anthropomorphism in robotic movements than males [44]. Even though the current study aligns with the notion that females discern lower anthropomorphic attributes in robotic faces compared to males, this seeming discrepancy suggests that the static appearance and dynamic movements of robots might elicit distinct gender-based responses in terms of perceived anthropomorphism.

5.7.4 Interaction Between Age and Gender on Robot-Human Border

A notable interaction effect between participant age and gender emerged in relation to PSE. Such an interaction could be attributed to a combination of cultural and physiological factors. While females consistently exhibited higher PSE scores than males across both age brackets, this gender disparity was more accentuated among participants in their 60s compared to those in their 30s. Within the domain of anthropomorphic robot research, interactions between age and gender are relatively rare. This finding underscores the significance of accounting for both age and gender when investigating robot anthropomorphism in studies. This result may be affected by factors such as culture and participants' physiology. Since the participants invited in our study were all Japanese residents, our results have some limitations. The health information of the participants we recruited is unknown, and we did not recruit participants of every age, so physiologic differences due to age may also affect the results of this study.

5.8 Summary

This study elucidated that the nature of a robot's occupation significantly shapes the robot-human border. Specifically, service robots necessitate a greater human photo proportion to be identified as human, compared to their robot and security robot counterparts. Notably, older participants gravitated towards images with a higher human photo proportion as being human across all occupational contexts, in contrast to their younger counterparts. Additionally, females registered a higher point of subjective equality (PSE) compared to males. This underscores the notion that individuals harbor varying anthropomorphic expectations for robots based on their respective occupations, as mirrored in the human photo proportions characterizing the robot-human border. It's imperative to meticulously study and design robots tailored to fit diverse occupational contexts. This research underscores the salience of considering robot occupation, participant age, and gender, laying the foundation for future inquiries into robot anthropomorphism.

Chapter 6: Study 3 - Robot Occupation And Perceived Threats Of Robots

6.1 Background

With the advancement of artificial intelligence technology, robots have become increasingly prevalent in society. Enhancing user experience when interacting with robots has turned into a pivotal topic in robot design. Studies show that users' perceptions and attitudes towards robots directly influence their satisfaction levels with robots [161]. Hence, understanding human perceptions of robots has become a significant area of research in human-robot interaction (HRI).

The ability of a robot to complete a job is described as working performance. The research thus far suggests that the working performance of a robot influences its perceived threat. However, the significance of occupation, a crucial factor for distinguishing robot work performance, has yet to be explored in relation to perceived threats from robots. Additionally, numerous studies have indicated that robot occupations profoundly influence Human-Robot Interaction (HRI). Human occupations are frequently accompanied by stereotypes and perceived social statuses. For instance, service staff are often seen as individuals of lower status, taking orders, while security guards, though also of lower social status, primarily protect the property of the affluent [61, 62]. With robots taking on a broader range of roles such as service robots, chef robots, and social robots [73, 156, 162], recent findings suggest that people are forming stereotypes about robots based on their occupations. These stereotypes encompass beliefs about robots' appropriate gender, anthropomorphic appearance, and personality [3, 64, 67]. We postulate that these occupation-based stereotypes could shape the perceived threats from robots.

6.2 Objectives

Drawing from social power and professional stereotype theories, service staff are typically directed and follow user instructions, whereas security personnel are less commonly commanded by users. Consequently, individuals feel a heightened sense of control over service staff compared to security personnel. We posit that this dynamic is also true for service robots versus security robots, leading to varying levels of perceived identity and realistic threats. In the modern context, both service and security robots are becoming increasingly prevalent and researched [159, 163]. For this study, we've chosen these two robot occupations and included robots without a defined occupation as a control group.

The potential age and gender differences concerning identity and realistic threats posed by robots have yet to be explored. As such, we aim to delve into possible age and gender effects in our study by engaging participants from diverse age and gender groups. Previous research has shown that age and gender significantly influence attitudes towards robot usage. Women and older individuals are less open to AI assuming roles of peers or leaders [78], while men and higher earners generally hold a more positive outlook on the introduction of robots in the workplace [90]. Age and gender can also influence perceived social status and power dynamics. Historically, women have had a lower social standing than men, and younger individuals face a greater risk of unemployment compared to their older people. Based on these insights, we hypothesize that both women and older individuals will perceive higher identity and realistic threats from robots.

The perceived threat of robots include two dimension: identity threat and realistic threat. This study aims to explore whether robot occupation could affect people's perceived threats of robots. Three occupation contexts were applied: robots, security robots and service robots. Participant age and gender was considered as potential factors on perceived threats. Furthermore, the potential interaction between robot occupation, participant age and gender will be explored.

6.3 Hypotheses

Given the discussions on robot occupation and perceived threat, we put forth the following hypotheses for exploration in this paper:

H3.1: Service robots pose a lesser identity threat compared to robots and security robots.

H3.2: Younger participants perceive a greater identity threat from robots than older participants.

H3.3: Female participants perceive a greater identity threat from robots than male participants.

H3.4: Service robots pose a lesser realistic threat compared to robots and security robots.

H3.5: Younger participants perceive a greater realistic threat from robots than older participants.

H3.6: Female participants perceive a greater realistic threat from robots than male participants.

6.4 Method

We translated and applied the perceived threat questionnaire of three robot occupations: robots, security robots and service robots. We used an online survey platform to recruit participants to collect their responses of perceived threats of robots in different occupational contexts. The perceived threat scale includes two dimension: identity threat and realistic threat. We analyzed the result to explore if our hypotheses could be supported by the study.

6.5 Experiment

6.5.1 Measurement

The questionnaire used in this study was developed to explore people's perceived identity threat and realistic threat toward robots of different occupations. We selected two questions for the identity threat and two questions for the realistic threat to measure participants' perceived threat of different robots. These questions were adapted from previous research [144, 164] and used in the HRI research [131, 165]. The identity threat included: "Recent advances in robot technology are challenging the very essence of what it means to be human.", "Technological advancements in the area of robotics are threatening human uniqueness." These questions focused on the human identification and uniqueness threatened by robots. The realistic threat scale included: "The increased use of robots in our everyday life is causing more job loss for humans" and "In the long run, robots pose a direct threat to human safety and wellbeing." The questions of realistic threat concentrated on the unemployment and personal security threatened by robots. These four questions were measured on a 7-point scale, from strongly disagree (0) to strongly agree (6).

This study focused on three specific robot occupations: the robot, security robot, and service robot. We adapted the new questionnaire to cater to these three robot occupations. The original English versions of both the identity threat scale and the realistic threat scale were reviewed and revised by three experts. Subsequently, they were back-translated and meticulously proofread by two experts fluent in both English and Japanese.

6.5.2 Participants

The study was conducted online through Yahoo! Crowdsourcing in Japan. Of all 1159 participants who finished the study, 135 answered the trap question incorrectly. Totally, 1024 people participated in this study, and we paid 80 JPY to each. The 30s group aged 30 to 39 included 259 males (M = 35.59, SD = 2.72) and 251 females (M = 35.26, SD = 2.94). The 60s group aged from 60 to 69 years old included 286 males (M = 63.70, SD = 2.88) and 228 females (M = 63.36, SD = 2.84). The sample included people with backgrounds in the robot-related domain (n = 3), in the service domain (n = 16), in the security domain (n = 17), and other fields (n = 988).

6.5.3 Procedure

We applied the questionnaire survey via the online survey platform Yahoo! Crowdsourcing. Each participant could use a link to complete the online survey by following a series of guidance. The survey has three blocks corresponding to three types of robot occupations. Within each block, participants answered the identity and realistic threats scales. Participants completed the three blocks one by one. The order of the three blocks is randomized. After completing the identity threat and realistic threat scales for three robot occupational contexts, participants answered the questions about their personal information, including gender, age, and occupation. At the end of the questionnaire, there are two trap questions to select the people who read the question carefully. Only the people who answered the trap questions correctly could get the reward.

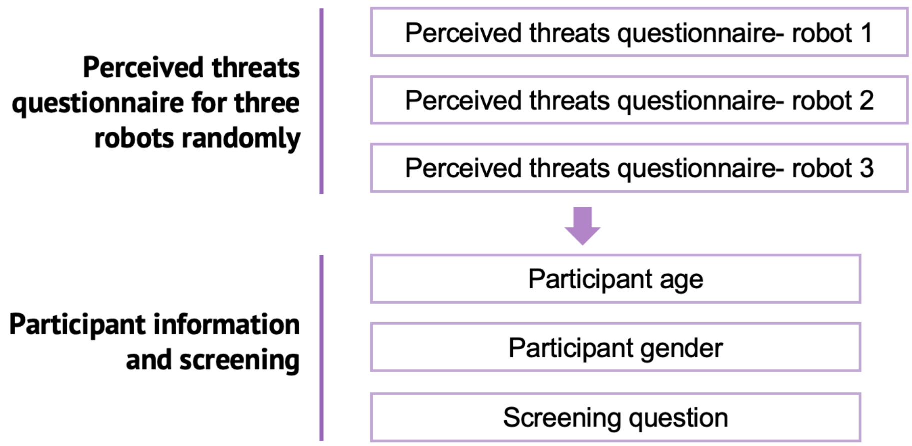


Figure 15 Procedure of study 3

6.6 Results

6.6.1 Identity Threats

We used ANOVA to test whether the robot's occupation and participant age affect perceived identity threat differently. The results were statistically analysed using IBM SPSS Statistics 29.0. A composite measure of identity threat was created by adding all two items on the questionnaire after ensuring that it had enough consistency ($\alpha > 0.85$) for all three occupation contexts. We checked the data and confirmed that the error variance of the dependent variables is equal across both the 30s and 60s groups. The inspection results showed that each data group conforms to the normal distribution ($p > 0.05$). Based on Mauchly's test of sphericity, the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix ($p > 0.05$).

We applied three-way-ANOVA to explore if there were any interaction effects among gender, age and occupation and found there was no interaction effect on the perceived identity threat (p = 0.971). Therefore, we performed a two-way mixed analysis of variance (ANOVA, within-subject factor: robot vs. security robot vs. service robot; between-subject factor: 30s vs. 60s) on the identity threat.

It was found that robot occupation had a significant main effect on identity threat, $F(2, 1018) = 8.359$, $p < 0.001$, and $\eta^2 = 0.016$. However, participant age did not significantly affect identity threat, $F(1, 509) = 0.7$, $p = 0.403$, and $\eta^2 = 0.001$. In addition, the robot occupation and participant age did not have significant interaction effects on identity threat, $F(2, 1018) = 2.629$, $p = 0.073$, and $\eta^2 = 0.005$.

As illustrated by Figure 13(a), the mean value of identity threat of the service robot was significantly lower than the robot (mean difference (service robot-robot) = -0.122., *SE* = 0.041, $p = 0.01$, 95%CI = [-0.221, -0.023]) and security robot (mean difference (service robot-security robot) = -0.155, *SE* = 0.042, $p < 0.001$, 95%CI = [-0.255, -0.055]). In comparison, no significant differences were observed between the robot and the security robot ($p > 0.05$).

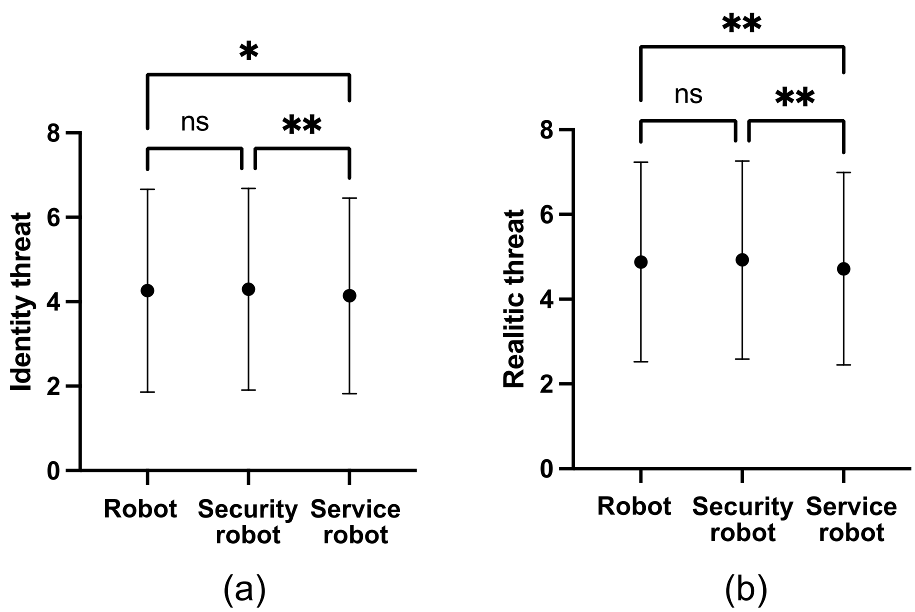


Figure 16. Identity threat and realistic threat for the robot, security robot and service robot.

The detailed description and comprehensive summary of the above experimental results are shown in Table 3, showing the effects of robot occupation and participant age on identity threat. Therefore, the results showed that H3.1 was supported.

Table 3. Effects of robot occupation and participant age on identity threat

Effects	Statistical significance	Compare the identity threat	Hypothesis results
A. Robot occupation	Significant	Service robot (M = 4.14, SD = 2.32) < Robot (M = 4.26, SD = 2.40), Service robot (M = 4.14, SD = 2.32) < Security robot (M = 4.29, SD = 2.39)	Support H1
B. Participant age	No significant	N/A	N/A
A×B			
at Robot	No significant	N/A	N/A
at Security robot	No significant	N/A	N/A
at Service robot	No significant	N/A	N/A
at the 30s	Significant	Service robot (M = 4.15, SD = 2.62) < Robot (M = 4.35, SD = 2.69), Service robot (M = 4.15, SD = 2.62) < Security robot (M = 4.38, SD = 2.67)	Support H1
at the 60s	No significant	N/A	N/A

We used ANOVA to test whether the robot's occupation and participant gender affect identity threat. Similar to the previous procedure, we performed the two-way mixed analysis of variance (ANOVA, within-subject factor: robot vs. security robot vs. service robot; between-subject factor: males vs. females) on the identity threat. Robot occupation and participant gender have significant interaction effects on identity threat, $F(2, 956) = 16.145$, $p < 0.001$, and $\eta^2 < 0.033$. Then, we explored the simple effect of robot occupation and participant gender.

As shown in Figure 14(a), females and males showed significant differences in the identity threat of robots (mean difference (female-male) = 0.564., SE = 0.159, $p < 0.001$, 95%CI = [0.252, 0.876]), security robots (mean difference (female-male) = 0.495., SE = 0.158, p = 0.002, 95%CI = [0.185, 0.805]) and service robots (female-male) = 0.351., SE = 0.154, p = 0.023, 95%CI = [0.049, 0.653]).

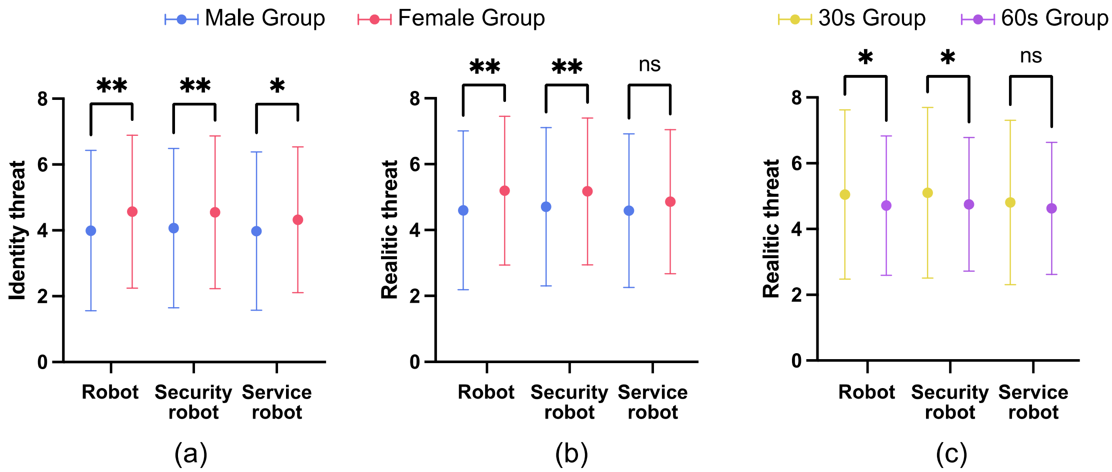


Figure 17. Perceived threat for three types of robot occupational contexts.

For males, there was no significant difference among the identity threat of robots, security robots, and service robots ($p > 0.05$). However, for females, the identity threat of service robots showed significant differences with the identity threat of robot mean difference (service robot-robot) = -0.244, *SE* = 0.067, $p < 0.001$, 95%CI = [-0.406, -0.082]) and security robot mean difference (service robot-security robot) = -0.228, *SE* = 0.065, $p = 0.001$, 95%CI = [-0.383, -0.072]).

The detailed description and comprehensive summary of the above experimental results are shown in Table 4, showing the effects of robot occupation and the participant gender on identity threats. Therefore, the results showed that H3.1 and H3.3 were supported.

Table 4. Effects of robot occupation and participant gender on identity threat

Effects	Statistical significance	Compare the identity threat	Hypothesis results
A. Robot occupation	Significant	Service robot (*M* = 4.14, *SD* = 2.32) < Robot (*M* = 4.26, *SD* = 2.40), Service robot (*M* = 4.14, *SD* = 2.32) < Security robot (*M* = 4.29, *SD* = 2.39)	Support H1
B. Participant gender	Significant	Male (*M* = 4.01, *SD* = 2.42) < Female (*M* = 4.48, *SD* = 2.29)	Support H3
A×B			
at Robot	Significant	Robot × Male (*M* = 4.00, *SD* = 2.47) < Robot × Female (*M* = 4.57, *SD* = 2.32)	Support H3
at Security robot	Significant	Security robot × Male (*M* = 4.06, *SD* = 2.43) < Security robot × Female (*M* = 4.55, *SD* = 2.32)	Support H3

at Service robot	Significant	Service robot × Male (*M* = 3.97, *SD* = 2.43) < Service robot × Female (*M* = 4.32, *SD* = 2.21)	Support H3
at male	No significant	N/A	N/A
at female	Significant	Service robot (*M* = 4.32, *SD* = 2.21) < Robot (*M* = 4.57, *SD* = 2.32), Service robot (*M* = 4.32, *SD* = 2.21) < Security robot (*M* = 4.55, *SD* = 2.31)	Support H1

6.6.2 Realistic Threats

We applied three-way-ANOVA to explore if there were any interaction effects among gender, age and occupation and found there was no interaction effect on the perceived realistic threat (p = 0.956). Then, we applied ANOVA to test whether the robot's occupation and participant age influenced the realistic threat. Robot occupation significantly affected identity threat, $F(2, 1018) = 12.482$, $p < 0.001$, and $\eta^2 = 0.024$. Furthermore, as shown in Figure 14(c), participant age significantly affected identity threat, $F(1, 509) = 4.165$, $p = 0.042$, and $\eta^2 = 0.008$. No significant interaction was observed in identity threat between robot occupation and participant age ($p > 0.05$).

As illustrated by Figure 13(b), the mean value of the realistic threat of service robots was significantly lower than robots (mean difference (service robot-robot) = -0.161., $SE = 0.043$, $p < 0.001$, 95%CI = [-0.264, -0.058]) and security robots (mean difference (service robot-security robot) = -0.208, $SE = 0.047$, $p < 0.001$, 95%CI = [-0.322, -0.094]). While no significant differences existed between the robot and the security robot ($p > 0.05$). The 60s realistic identity was significantly lower than that of 30s (mean difference (60s-30s) = -0.282, $SE = 0.138$, $p = 0.042$, 95%CI = [-0.553, -0.011]).

The detailed description and comprehensive summary of the above experimental results are shown in Table 5, showing the effects of robot occupation and participant age on identity threat. Therefore, the results showed that H3.4 and H3.5 were supported.

Table 5. Effects of robot occupation and participant age on realistic threat

Effects	**Statistical significance**	**Compare the realistic threat**	**Hypothesis results**
A. Robot occupation	Significant	Service robot (*M* = 4.72, *SD* = 2.27) < Robot (*M* = 4.88, *SD* = 2.36), Service robot (*M* = 4.72, *SD* = 2.27) < Security robot (*M* = 4.93, *SD* = 2.33)	Support H4
B. Participant age	Significant	60s (*M* = 4.70, *SD* = 2.05) < 30s (*M* = 4.99, *SD* = 2.56)	Support H5
A×B			

at Robot	Significant	Robot × 60s (*M* = 4.72, *SD* = 2.12) < Robot × 30s (*M* = 5.05, *SD* = 2.57)	Support H5
at Security robot	Significant	Security robot × 60s (*M* = 4.76, *SD* = 2.04) < Security robot × 30s (*M* = 5.10, *SD* = 2.59)	Support H5
at Service robot	No significant	N/A	N/A
at the 30s	Significant	Service robot (*M* = 4.81, *SD* = 2.50) < Robot (*M* = 5.05, *SD* = 2.57), Service robot (*M* = 4.81, *SD* = 2.50) < Security robot (*M* = 5.10, *SD* = 2.59)	Support H4
at the 60s	No significant	N/A	N/A

We performed two-way ANOVA to test whether the robot's occupation and participant gender affect the realistic threat. Robot occupation and participant gender have significant interaction effects on identity threat, $F(2, 956) = 6.711$, $p < 0.001$, and $\eta^2 < 0.033$. Then, we explored the simple effect of robot occupation and participant gender on the realistic threat.

As shown in Figure 14(b), females and males showed significant differences in the identity threat of robots (mean difference (female-male) = 0.543., *SE* = 0.151, $p < 0.001$, 95%CI = [0.247, 0.839]) and security robot (mean difference (female-male) = 0.436., *SE* = 0.149, $p = 0.004$, 95%CI = [0.143, 0.73]). However, no significant differences were observed between males and females on the realistic threat of service robots ($p > 0.05$).

For males, there were no significant differences among the realistic threat of robots, security robots, and service robots ($p > 0.05$). However, for females, the identity threat of service robot show significant differences with the identity threat of robot mean difference (service robot-robot) = -0.334, *SE* = 0.066, $p < 0.001$, 95%CI = [-0.464, -0.204]) and security robot mean difference (service robot-security robot) = -0.311, *SE* = 0.069, $p < 0.001$, 95%CI = [-0.448, -0.175]).

Table 6. Effects of robot occupation and participant gender on realistic threat

Effects	Statistical significance	Compare the realistic threat	Hypothesis results
A. Robot occupation	Significant	Service robot (*M* = 4.72, *SD* = 2.27) < Robot (*M* = 4.88, *SD* = 2.36), Service robot (*M* = 4.72, *SD* = 2.27) < Security robot (*M* = 4.93, *SD* = 2.33)	Support H4
B. Participant gender	Significant	Male (*M* = 4.63, *SD* = 2.38) < Female (*M* = 5.08, *SD* = 2.23)	Support H6
A×B			

at Robot	Significant	Robot × Male (M = 4.66, SD = 2.43) < Robot × Female (M = 5.20, SD = 2.26)	Support H6
at Security robot	Significant	Security robot × Male (M = 4.74, SD = 2.44) < Security robot × Female (M = 5.18, SD = 2.23)	Support H6
at Service robot	No significant	N/A	N/A
at male	No significant	N/A	N/A
at female	Significant	Service robot (M = 4.86, SD = 2.18) < Robot (M = 5.20, SD = 2.26), Service robot (M = 4.86, SD = 2.18) < Security robot (M = 5.18, SD = 2.27)	Support H4

The detailed description and comprehensive summary of the above experimental results are shown in Table 6, showing the effects of robot occupation and the participant gender on PSE. Therefore, the results showed that H3.4 and H3.6 were supported.

6.7 Discussion

6.7.1 Robot Occupation Affect Identity Threat of Robots

In this study, we investigated the impact of robot occupations on people's perceived identity threat and realistic threat. In particular, we hypothesized that service robots would be perceived as less threatening than security robots or robots. Furthermore, we hypothesized that females and younger participants perceived higher threats to robots.

The results supported our H3.1-participant's perceived service robots as posing more identity threats than security robots and robots. There were no significant identity threat differences between robots and security robots. The service robot was perceived as blurring the borderline between humans and robots less than robots and security robots. Identity threat is related to people's uniqueness and distinctiveness. Service robots are seen to express less human uniqueness regarding autonomy by conveying higher obedience and less autonomy.

Furthermore, we explicitly stated that people perceived similar threats of security robots and robots. This result suggests that robots without any occupational description are perceived to have social power and autonomy, similar to that of security robots. Some other studies also proposed that people think robots have high power and robots can rule humans [166, 167].

6.7.2 Participant Age Affect Identity Threat of Robots

We observed some interesting findings when we looked into the age effect of perceived threats. There were no significant differences in the identity threat between the 30s and 60s groups, which did not support H3.2. However, the 30s group perceived more realistic threats of robots and security robots than the 60s group and supported H3.5. In this study, the young and old groups shared similar degrees of perceived identity threats from all three types of robots. Some studies on negative attitudes towards robots (NARS) did not observe age differences, either [168]. While the previous study found that older participants (compared to young participants) strongly disagree with using robots when working and caring for older adults [78, 79].

6.7.3 Participant Gender Affect Identity Threat of Robots

The mass use of robots diminishes the social and economic value that females represent as mothers. In this case, the identity value of females was negatively affected by robots. Females perceived higher identity threats; the female's potentially affected identity was the mother. We proposed that the differences in social power and social role between female and male participants contributed to the gender effect of perceived threats of robots. Moreover, a previous study showed that high-income people have more positive attitudes toward robots [90]. Other potential factors, such as self-confidence and educational background, may influence the realistic threat and identity threats of robots.

6.7.4 Robot Occupation Affect Realistic Threat of Robots

The results supported the H3.4: service robots will be perceived as posing more realistic threats than security robots and robots. Since this measure relates to material threats, service robots (compared to robots and security robots) could be perceived as posing lower risks when taking over human jobs. Service robots present a high ability to obey orders which decreases people's realistic threats. Moreover, the realistic threat also indicates that people are concerned about their safety. In our study, the security robot and robot were perceived as more dangerous to human safety than the service robot. Based on the theory of social power, service robots are easier to control than security robots and robots. Since people have less sense of power in the robot and security robot contexts, people feel more insecurity from them.

These results indicate that service robots are less threatening to people than robots and security robots. These results supported the previous research on autonomous robots, which suggested that the high-power (autonomous) robot was perceived as more threatening than the low-power (non-autonomous) robot [131]. We did not present the information on social power directly in our experiment. According to the stereotype study of occupations, the service robot is easy to control, representing low power. In contrast, the security robot is hard to be controlled by humans, which represents high power [62, 169]. Our results suggest that a lower-power robot occupation will evoke fewer identity and realistic threats than high-power robots. In fact, robots of different occupations were perceived with varying levels of social power and autonomy. It is difficult to define the absolute autonomous robot or non-autonomous robot. This study provides more practical values for robot design than the previous research, which divided robots into autonomous and non-autonomous [131].

6.7.5 Participant Age Affect Realistic Threat of Robots

In this study, no age difference was observed in the identity threats. However, the younger group reported higher realistic threats of robots and security robots than the older group. In this study, participants aged 60-69 are going to or have already retired, so they face less unemployment anxiety than younger participants [170]. Robots are more likely to replace the younger participants' job positions. However, this assumption cannot explain why there were no age differences in realistic threats observed for the service robots. Whether and how participant age influences people's perception of robots is still controversial.

6.7.6 Participant Gender Affect Realistic Threat of Robots

The results also support H3.3 and H3.6. Both identity and realistic threats were perceived as higher by female participants than male participants. In Japanese society, females have lower status than males, and females have less social power than males [83]. If robots begin to take over human jobs, females will face a higher risk of unemployment related to realistic threats. On the other hand, robots can act as laborers in modern society, but no need for the reproductive process by females.

6.8 Summary

Robots' occupations and roles in modern society are becoming show diverse. People's perception of robots with complex occupations may affect their acceptance and user experience of robots. Therefore, it is essential to understand how people perceive robots in different occupations. In this study, we investigated that people have lower perceived identity and realistic threats of service robots than robots and security robots. Furthermore, the younger group and female participants showed higher perceived threats of robots and security robots.

The present study showed an essential factor in HRI, robot occupation. The finding suggested that robot designers and managers need to consider the occupation when designing and applying robots with different occupations. Future research needs to investigate why service robots are perceived as less threatening. In particular, we proposed that different occupations were perceived with different levels of social power, which may contribute to the differences in perceived threats. Exploring users' perception of robots in different occupations can benefit the high satisfaction in HRI and improve the diversity of the robot industry.

Chapter 7: Study 4 - The Relationship Between People's Financial Anxiety and Negative Attitudes Toward Robots

7.1 Background

A pivotal inquiry in the realm of human-robot interaction centers on the potential linkage between users' financial anxiety and their negative predispositions towards robots. In this paper, we postulate that individuals exhibiting elevated personal financial anxiety may harbor intensified aversions to robots. Supporting evidence for this linkage emerges from a study addressing unemployment [171]. Conducted in the United States, this research discerned that robots and artificial intelligence played a role in modulating individuals' anxiety related to financial vulnerabilities.

The Negative Attitudes Toward Robots Scale (NARS) is a widely recognized and extensively discussed tool in research. This questionnaire delineates specific robot-related scenarios, capturing a range of negative sentiments. Consequently, we selected the Negative Attitudes Towards Robots Scale as our primary metric for assessing human-robot relations. In this paper, we investigate the hypothesis that individuals with heightened financial anxiety possess more pronounced negative perceptions of robots. Additionally, given that both age and gender appear to influence financial anxiety [172], we also delve into their potential effects on financial anxiety and consequent perceptions of robots.

7.2 Objectives

In previous studies, we have revealed that robot occupations influence users' perceptions of robots, including negative attitudes toward robots. Robots frequently invoke concerns of competing with human employment, and factors such as unemployment and financial instability significantly contribute to financial anxiety [173]. Given this context, we have elected to prioritize people's financial anxiety as a pivotal area of investigation within human-robot interaction studies.

This study aims to explore if there is a correlation between people's financial anxiety and negative attitudes towards robots. Moreover, this study seeks to discern variations in financial anxieties across different genders and age groups.

7.3 Hypotheses

In the present study, we aim to evaluate the following hypotheses through a comprehensive questionnaire that incorporates the NARS scale and measures self-reported financial anxiety:

H4.1: Younger people have higher financial anxiety than older people.

H4.2: Males have higher financial anxiety than females.

H4.3: People with higher financial anxiety have higher negative attitudes toward robots.

7.4 Method

7.5 Experiment

7.5.1 Measurement

In our survey, we utilized the Japanese adaptation of the Negative Attitudes Towards Robots Scale (NARS) [4]. Subsequent to the NARS, participants were prompted with a question gauging financial anxiety. We employed two 11-point scales to measure this anxiety, ranging from 0 (indicating "no anxiety at all") to 10 (indicating "extreme anxiety"). To conclude the questionnaire, participants were asked two demographic questions regarding their age and gender.

7.5.2 Participants

Given the uncertainty regarding the anticipated effect size, we based our sample size planning on the smallest effect size of interest, $\eta^2 = 0.03$ [160]. An a priori power analysis, with an alpha level set at 0.05, revealed that a total sample size of 798 participants would provide sufficient power (95%) to detect the primary effect of participants' financial anxiety on their negative attitudes towards robots. This power analysis was performed using the G*Power Software in advance of the study.

After excluding participants who failed to answer the check questions accurately, we engaged 1024 Japanese participants via the Yahoo online platform, compensating each with 80 JPY. The younger cohort, ranging from 30 to 39 years, comprised 259 males (M = 35.59, SD = 2.72) and 251 females (M = 35.26, SD = 2.94). The elderly group aged from 60 to 69 years old included 286 males (M = 63.70, SD = 2.88) and 228 females (M = 63.36, SD = 2.84).

7.5.3 Procedure

We conducted the survey online using Yahoo. Prior to participating, individuals were informed that the study had received Institutional Review Board (IRB) approval. We assured participants of the proper handling and confidentiality of their data, emphasizing their right to withdraw at any point. Participants were then instructed to complete the questionnaire in a distraction-free setting. The survey consisted of the NARS, followed by the financial anxiety questions. To conclude, participants were presented with three check items to ensure the integrity and sincerity of their responses.

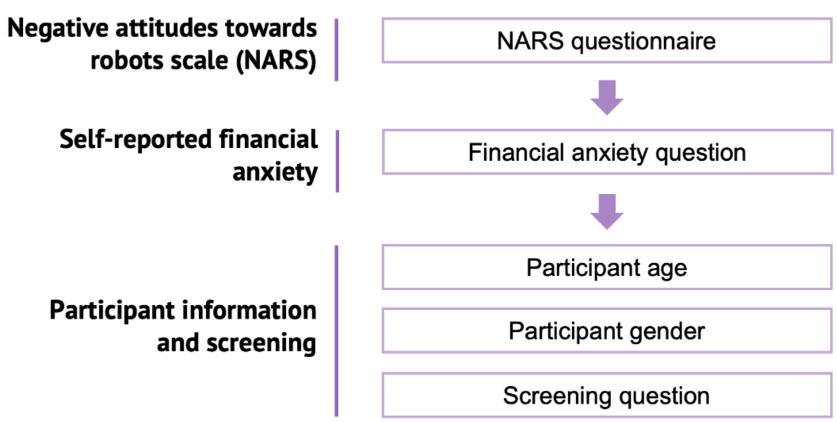


Figure 18 Procedure of study 4

7.6 Results

7.6.1 Financial Anxiety

We analyzed the data using IBM SPSS Statistics 29.0. We applied the two-way ANOVA to explore the potential interaction effect between participant age and gender on the financial anxiety, and found there was no significant interaction between them (p = 0.617).

An unpaired two-tailed T-test was conducted to compare financial anxiety between the younger (30s) and older (60s) participants. Significant differences were observed: younger participants reported higher financial anxiety (M = 6.68, SD = 2.48) than older participants (M = 5.25, SD = 2.66; t(1022) = 8.90, p < 0.0001) as illustrated in Figure 15. This finding supported our first hypothesis (H4.1) regarding the age-related difference in financial anxiety.

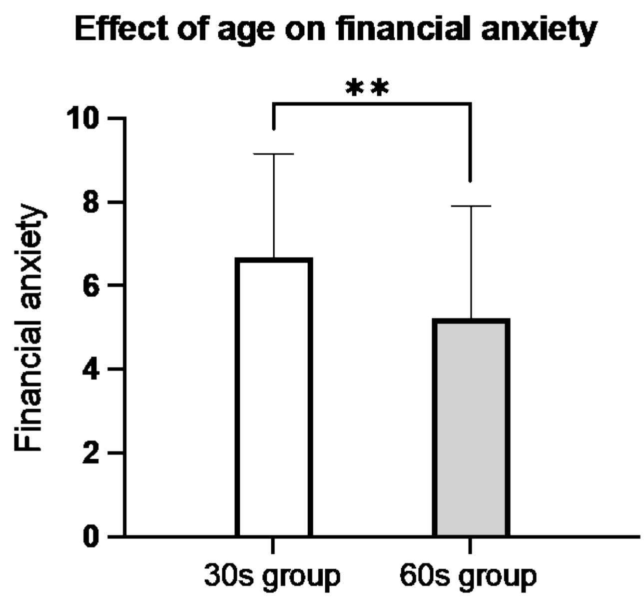


Figure 19. Perceived financial anxiety by 30s groups and 60s groups

Nevertheless, no significant differences emerged between the financial anxiety of young males (M = 6.59, SD = 2.41) and females (M = 6.77, SD = 2.55, t(508) = 0.81, p = 0.42). A parallel observation was made within the group aged in their 60s. Among them, there was no significant distinction in financial anxiety between elderly males (M = 5.24, SD = 2.53) and females (M = 5.25, SD = 2.78, t(512) = 0.07, p = 0.94). Consequently, these findings did not align with H4.2.

7.6.2 Negative Attitudes Towards Robots

We subsequently evaluated the reliability of NARS, S1, S2, and S3 individually using Cronbach's coefficient alpha, finding high reliability (α >0.8) for each. The NARS encompasses three distinct sections: S1, which assesses negative attitudes toward situations of interaction with robots; S2 (negative attitudes toward the social influence of robots), which delves into negative attitudes toward the social influence of robots; and S3, focusing on negative attitudes toward emotions in robot interactions. Our objective was to discern potential age or gender influences on NARS. However, upon executing a series of two-tailed unpaired T-tests, we discerned no significant effects of either age or gender on NARS, S1, S2, or S3 ($p > 0.05$) as depicted in Table 7. We applied a series of two-way ANOVA and found there was no significant interaction between participant gender and age on NARS, S1, S2 and S3 ($p > 0.05$).

Table 7. Two-tailed unpaired t-test results of NARS (p value)

	S1	S2	S3	NARS
Participant gender	0.83	0.10	0.91	0.29
Participant age	0.87	0.07	0.08	0.12

7.6.3 Financial Anxiety and NARS Results

In our concluding analysis, we explored the correlation between financial anxiety and negative sentiments towards robots. As illustrated in Figure 16, a positive correlation emerged between financial anxiety and NARS ($r = 0.19$, $p < 0.0001$), S1 ($r = 0.16$, $p = 0.0004$), and S2 (negative attitudes toward the social influence of robots) ($r = 0.18$, $p < 0.0001$). The error bars present 95% CI. Contrarily, no significant association was detected between financial anxiety and S3 ($r = 0.04$, $p = 0.35$). These findings validate our H4.3 hypothesis, indicating that individuals with elevated financial anxiety exhibit more pronounced negative perceptions of robots.

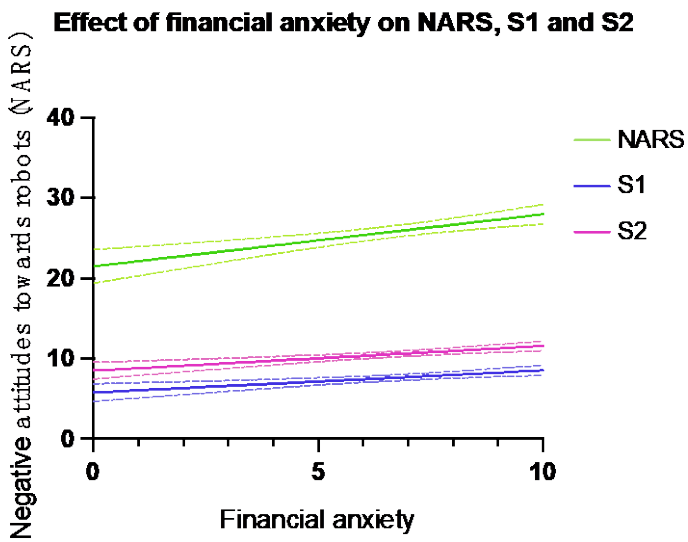


Figure 20. Pearson's correlation examining the relationship between NARS, S1, S2 and financial anxiety

7.7 Discussion

7.7.1 Effect of Age on Financial Anxiety

This study delved into the relationship between individuals' financial anxiety levels and their negative perceptions of robots. As hypothesized, we found that heightened financial anxiety correlated with more pronounced negative attitudes towards robots. Intriguingly, older adults exhibited lower financial anxiety compared to their younger counterparts. Additionally, our findings indicated negligible influence of age and gender on NARS. Our research echoes and extends the findings of previous investigations [171], which suggested that individuals apprehensive about job loss tend to harbor greater fears about robots. By utilizing the broader notion of financial anxiety, our study captures concerns not just limited to unemployment but also spanning other facets of financial instability. Our study reveals that people have stronger negative attitudes toward robots when they feel higher anxiety about their financial situation, specifically negative attitude toward situations of interaction with robots (S1) and negative attitudes toward the social influence of robots (S2).

Interestingly, while participants' financial anxiety levels influenced S1 and S2, they had no bearing on S3 (negative attitudes toward emotions in interaction with robots). This suggests that as financial anxiety intensifies, people's negative attitudes toward scenarios of robot interactions and their social influence become more pronounced. However, this heightened financial anxiety doesn't amplify their negative perceptions regarding the idea that robots possess emotions. It seems that participants might be more receptive to the emotional or affective actions of robots when facing elevated financial anxiety. This outcome underscores the nuanced characteristics of robots in human-robot interactions. The implications of endowing robots with emotions in such interactions merits deeper exploration. Moreover, our findings emphasize the importance of considering S1, S2, and S3 distinctly when employing NARS as a research instrument.

In analyzing participants across various age brackets, we observed that older individuals exhibited lower levels of financial anxiety compared to their younger counterparts, a finding that is noteworthy. Generally, older individuals face greater challenges in workforce participation and in securing stable employment [174]. However, they express lesser concerns regarding financial matters compared to the younger cohort. This indicates the presence of other variables that modulate financial anxiety. As previously highlighted, anxiety is often spurred by an aversion to anticipated, yet unrealized events [175]. Grounded in this theoretical framework, we postulate that the heightened uncertainty younger individuals harbor regarding their future financial prospects might fuel their anxiety, accounting for the age-related discrepancies in financial anxiety levels observed in our study. It's also essential to recognize that participants in this study hail from diverse generational backgrounds. Each generation encountered unique economic and sociocultural conditions in Japan [80]. Consequently, variations in lifestyle choices and consumption patterns across generations might play a role in shaping the observed patterns of financial anxiety.

Our study serves as a pivotal reference for subsequent research focused on human-robot interaction. In this investigation, we ensured a robust participant pool representing both genders and two distinct age groups. Notably, our findings did not identify any significant gender or age disparities linked to NARS, corroborating outcomes from previous studies [103-105]. Given that attitudes toward robots can vary based on regional and geographic factors [102], we advocate for a judicious consideration of gender and age as potential confounders in studies employing the NARS. The results of our research can offer guidance to fellow scholars examining gender and age-associated patterns.

Drawing from our empirical findings, we underscore observed variances in financial anxiety across populations and identify a notable positive association between financial anxiety and NARS. A significant number of prior studies in human-robot interaction overlooked the dimension of users' financial anxiety, a potential oversight that might introduce unforeseen experimental inaccuracies. We therefore propose that professionals and scholars in robotics give due consideration to the role of users' financial anxiety in shaping human-robot interactions.

This study employed the NARS scale to elucidate individuals' negative perceptions of robots. Our approach offered a broad conceptualization of robots, refraining from delving into robots with varied roles or appearances. While extant literature has yet to confirm varied NARS outcomes contingent on robot types, prior investigations have posited that a robot's role and appearance might influence human emotional responses and perceptions [176]. As such, it remains a pertinent research inquiry to discern whether the relationship between users' financial anxiety and NARS, as primarily highlighted in this study, persists irrespective of specific robot attributes.

Our study underscores the significance of the human element in human-robot interaction. Negative perceptions of robots among users are intrinsically tied to their financial anxieties, offering vital insights for both scholarly research and practical implementation of robots. From the outcomes of this experiment, we postulate that individuals might harbor pronounced negative sentiments towards robots when they grapple with acute financial concerns, irrespective of the robot's design and functionality. While this poses challenges for robot designers, it also presents a valuable opportunity. Entities responsible for shaping robot deployment strategies, including governmental bodies, can investigate and address this issue comprehensively. Perhaps, in an environment where individuals aren't perpetually anxious about their financial state, robots will find a more accepting user base.

7.7.2 The Correlation Between Financial Anxiety and NARS

This research is pioneering in its exploration and analysis of the correlation between people’s financial anxiety and their negative predispositions towards robots. We underscore the pivotal influence of financial anxiety in the domain of human-robot interaction. The findings from our investigation hold profound consequences for the political, economic, and cultural trajectories associated with the robotics sector. Scholars in the field of human-robot interaction have historically emphasized tailoring robots to facilitate easier acceptance in daily life and professional settings. However, the ramifications of robot utilization on human economic well-being subtly shape public perceptions of these machines. Such insights urge a reevaluation of a pertinent question: Might addressing human-centric issues be a more potent catalyst for fostering robot acceptance than mere design enhancements? While alleviating users' financial concerns might pose greater challenges than robot design, addressing these concerns is a long-term investment towards cultivating a harmonious coexistence between humans and robots.

7.8 Summary

This study examined the relation between people’s financial anxiety and negative attitudes toward robots (NARS) through a survey of Japanese residents. This study indicated a significant positive association between participants’ financial anxiety and negative attitudes toward robots. Higher financial anxiety of the participants elicited stronger negative attitudes toward robots. We observed that the S1 and S2 were influenced by changes in financial anxiety. Financial anxiety was higher in younger adults than in older adults. No gender differences or age differences related to NARS were found in this study. Our findings underscore the significance of considering users' financial anxiety profiles in human-robot interaction studies. These insights carry substantial implications for the formulation of economic and cultural policies pertaining to the field of robotics.

Chapter 8: General Discussion

8.1 Effect of Robot Occupation on User's Perception of Robots

This thesis used four studies to explore the impact of robot occupation on with users' perceptions of robots. Overall, robot occupations can influence perceptions of robots in a number of ways, including negative attitudes toward robots, anthropomorphism preferences, human-robot categorization demarcation lines, and perceived threats. We used three occupational descriptions of robots: robots, service robots, and security robots. Using these four studies, we found that people have lower negative attitudes toward service robots, higher anthropomorphic preferences, higher PSE outcomes, and lower perceived threat. These findings support the idea that the robot's occupation has a wide-ranging effect on people's perceptions of robots.

8.1.1 Effect of Robot Occupation on NARS

Our research indicates that negative attitudes toward service robots were notably less prevalent than those toward both robots and security robots. Within the S1 dimension (negative attitudes towards interactions with robots), no significant disparities were evident among these three categories of robots. However, the differences based on occupation in the S2 (negative attitudes towards the social influence of robots) and S3 (negative attitudes towards emotional interactions with robots) dimensions were not uniform. Within the S2 dimension, negative attitudes towards general robots significantly exceeded those towards both security and service robots. For the S3 dimension, negative sentiments directed at security robots were considerably more pronounced than those toward the other two categories.

In the dimension of S2, both service and security robots display predictable functionalities and behaviors. In contrast, for robots without a clearly defined operational purpose, people might anticipate a more extensive scope of functions, thereby fostering greater expectations regarding the robot's societal influence. Pertaining to S3, service-oriented roles inherently embody stronger emotional interaction traits compared to security roles. If we posit that service robots align with the occupational stereotypes of service professionals in human society, the notably reduced S3 scores for service robots vis-à-vis security robots become comprehensible. The influence of occupational roles on negative predispositions manifests in diverse manners, underscoring the intricate nature of stereotypes associated with robotic professions.

The robots' occupations in this study have highly distinguishable occupational characteristics and task categories. The occupational attributes of the robots and people's occupational stereotypes are also what we believe may influence the NARS results. The effects of gender stereotypes and negative attitudes toward robots on gender appearance preferences have been discussed [151]. This study's groundbreaking finding that negative attitudes toward robots change along with robot occupations has essential value for research related to robot occupations. Researchers may be unable to use the original NARS to address robotics research in various domains and usage scenarios.

8.1.2 Effect of Robot Occupation on Preferred Anthropomorphic Level

Our research indicates that people have greater anthropomorphic expectations for service robots compared to both robots and security robots. To mitigate potential biases arising from gender, skin tone, or facial structure, we utilized photographs of both male and female subjects as the basis and standardized all images to grayscale, ensuring consistent brightness levels. These methodological decisions enhanced the precision and validity of our examination into the influence of robot occupations on anthropomorphic predilections.

Furthermore, we discerned no statistically significant disparities in the anthropomorphic preferences between security robots and generic robots. Consequently, it's untenable to merely deduce that a shift in a robot's occupational role will yield significant alterations in anthropomorphic preferences. Stereotypes linked to robotic occupations are multifaceted, necessitating comprehensive research to uncover the primary drivers of anthropomorphic expectations. The variability in anthropomorphic inclinations due to robot occupations might elevate the challenges inherent in robotics research. Nevertheless, understanding this dynamic is paramount for the sustained progression of both the robotics sector and associated research endeavors.

Delving into the anthropomorphic preference and PSE findings from Studies 1 and 2, we ascertained that there is a marked preference for the anthropomorphic characteristics of service robots, with a notable inclination toward a more human-like border between robots and humans. Examining the influence of robot occupations on individuals' perceptions, we identified a trend: people generally have a more favorable view of service robots than of general or security robots. Prior research indicates that people tend to view highly anthropomorphic robots more positively [37]. This study refines the previous view that people have different anthropomorphic preferences for robots with different occupations, which may affect the user experience resulting from anthropomorphic design. Additionally, people's anthropomorphic preferences vary when selecting robots for different occupations [67]. Our study reveals for the first time that people's perceived anthropomorphism with respect to robots is influenced by the robot's occupation, which provides an explanatory perspective. Collectively, these findings underscore the notion that individuals harbor heightened anthropomorphic expectations for service robots.

8.1.3 Effect of Robot Occupation on PSE

Our findings largely substantiate the notion that the type of robot occupation shapes perceptions of human photo proportion as indicated by the robot-human border. Participants exhibited the highest human photo proportion for the service robot-human border when contrasted with robots and security robots. Such an outcome aligns with research suggesting that people have varied anticipations concerning the anthropomorphism of robots partaking in distinct roles [64]. Specifically, participants expect heightened anthropomorphism in vocations that entail more intimate human engagements, like education and hospitality [110]. In comparison to security robots and robots, service robots have more direct interaction with humans. Furthermore, previous research has illuminated that there's a prevailing inclination among people for service robots to address and resonate with the emotional requisites of both users and service personnel. This emphasizes a distinct aspiration for the human-like traits of service robots, a sentiment deeply embedded in the intrinsic character of the service domain [177]. Drawing from this, it can be inferred that participants likely hold amplified humanization anticipations for service robots as opposed to security robots, manifesting in augmented PSE results.

8.1.4 Effect of Robot Occupation on Perceived Threats

Our findings indicated that participants perceived service robots as presenting more significant identity threats compared to both security robots and general robots. Notably, there was no discernible difference in the identity threat perception between the latter two categories. Service robots were perceived as creating a less distinct border between humans and robots compared to their counterparts. The concept of identity threat is intrinsically linked to an individual's sense of uniqueness and distinctiveness. In terms of autonomy, service robots were perceived to embody less of the human characteristic of individuality, as they exhibited greater compliance and lesser autonomy. Moreover, our analysis explicitly revealed that participants perceive security robots and robots as posing similar threats. Such an outcome implies that when robots lack a specific occupational designation, they are perceived to wield social influence and autonomy akin to security robots.

Furthermore, the findings from our study suggested that service robots are perceived as posing a greater realistic threat compared to both security robots and general robots. Given that this metric is associated with tangible threats, service robots, when contrasted with robots and security robots, may be seen as less risky in terms of replacing human employment. This could be attributed to the inherent characteristic of service robots to efficiently follow commands, subsequently reducing people's perceived realistic threats. The concept of a realistic threat also encapsulates concerns regarding human safety. Within our study's context, both the robots and security robots were seen as posing a greater risk to human safety compared to service robots.

Drawing from the social power theory, service robots are perceived as more controllable than their security and robot counterparts [178]. This heightened perception of control reduces associated feelings of insecurity among humans when dealing with service robots, whereas robots and security robots, in contexts that diminish human sense of power, elevate feelings of vulnerability.

8.2 Effect of User Characteristics on User's Perception of Robots

G15This thesis investigates several characteristics common to users: age and gender, as well as a financial anxiety that has received little attention in the field of robotics research. We were pleasantly surprised to find that both age and gender of users had a significant impact in diversifying perceptions of robots. And, for the first time, we found a positive correlation between users' financial anxiety and negative attitudes towards robots. These findings provide important guidance for robot-related research and design and emphasize the importance of focusing on different user characteristics.

8.2.1 Effect of Age and Gender on Mind Perception

This research aimed to investigate the impact of users' age and gender on their perceptions of robots' minds within various occupational settings. We employed three unique robot mind perception questionnaires to evaluate users' opinions on the agency and experience capacities of robots, service robots, and security robots. Our results indicated that, regardless of robot type, agency was consistently rated more prominently than experience. Furthermore, female respondents evaluated the agency capabilities of the robot more favorably than their male counterparts. On the other hand, younger participants, compared to their older peers, assigned higher scores to the experience aspects of both robots and security robots.

The analysis revealed a distinct age-related variation in participants' evaluation of the robots' experience capabilities. Younger participants perceived higher experience ability to both robots and security robots in comparison to their older counterparts. However, there were no substantial differences between younger and older groups when assessing the experience abilities of service robots. This pattern could imply that older individuals, possibly due to heightened service needs, have more pronounced expectations for service robots compared to other robot categories. These findings offer valuable insights for customizing the design of service robots specifically for older users, focusing on experience ability that resonate with their requirements.

8.2.2 Effect of Age and Gender on PSE

The results of our research suggested that older participants recorded higher point of subjective equality (PSE) scores compared to younger individuals. When faced with the same morphed facial images, older adults perceived less anthropomorphism than younger participants. Our study suggested that as the preference and expectation for human-like features in robots increase, the morphed facial images must present a greater proportion of human-like characteristics to bridge the border between robots and humans. As a result, this could diminish the perceived anthropomorphism of the image. The exact causes behind this age-related difference remain elusive and might be influenced by factors such as differences in educational backgrounds or sociocultural contexts, which can shape perceptions of where the border between robots and humans lies. Different upbringings, economic and cultural environments are likely to be associated with such an age effect. These findings are crucial for designing robots specifically targeting older populations.

The findings underscored pronounced gender differences in PSE score. Female participants registered higher PSE scores compared to males. This suggests that for females to perceive robots as bearing human resemblance, these robots would necessitate more pronounced human features than what might be required for males. Such results indicate that females, in comparison to males, might have heightened expectations and a more pronounced inclination for human-like characteristics in the facial design of robots, culminating in the observed elevated PSE values.

8.2.3 Effect of Age and Gender on Perceived Threats

When examining the influence of age on perceived threats, we noted interesting results. There wasn't a significant difference in identity threats between participants in their 30s and those in their 60s. Yet, participants in their 30s perceived a heightened sense of realistic threats from both robots and security robots compared to their counterparts in their 60s. We conjecture that young people face more uncertainty about future unemployment, while older people have retired or will retire soon and therefore do not worry about losing their jobs. The perceived realistic threat is higher among the young than among the old because of the potential for robots to replace people's jobs. In our research, both the younger and older cohorts displayed comparable levels of perceived identity threats across all three robot categories. Young people have felt a higher level of identity threat when confronted with robots from different professions. This makes the age difference between the young and the old even more compelling. We hypothesize that young people perceive more identity threat because they are more confused and uncertain about their place and role in society compared to older people.

In this study, no age difference was observed in the identity threats. However, the younger group reported higher realistic threats of robots and security robots than the older group. Both identity and realistic threats were perceived as higher by female participants than male participants.

The widespread adoption of robots appears to erode the social and economic significance traditionally associated with females in their roles as mothers. Consequently, this impacts the identity value of females adversely in the context of robots. Females were found to perceive heightened identity threats, with the identity most notably at risk being that of a mother. We theorized that discrepancies in social power and roles between female and male participants underpin the observed gender-specific effects in perceived robot threats.

8.2.4 Effect of Financial Anxiety on NARS

This research stands at the forefront of delving into and analyzing the relationship between individuals' financial anxiety and their negative attitudes towards robots. We highlight the critical role of financial anxiety in shaping dynamics within human-robot interaction. The insights drawn from our study have significant implications for the political, economic, and socio-cultural dimensions surrounding the robotics arena.

Historically, researchers specializing in human-robot interaction have prioritized adapting robots to ensure their seamless integration into daily routines and occupational spheres. However, the underlying impacts of robot integration on human economic stability play a subtle yet influential role in determining public perceptions of these entities. This newfound understanding prompts a reconsideration of an essential question: Could addressing human-centric concerns potentially be more effective in advancing robot acceptance than mere design modifications? Although mitigating financial apprehensions might prove more challenging than refining robot designs, targeting these human-centric issues represents a pivotal stride towards fostering a symbiotic relationship between humans and robots.

Chapter 9: Conclusion, Limitation and Future Study

9.1 Conclusion

Many researchers have focused on the question of what expectations and preferences users have for the appearance of robots. Related studies present very complex and diverse results. It is often difficult to truly understand users' expectations of the robot's appearance. Users expect the robot's appearance to match the task in interviews, yet do not show the same results in subjective evaluations [179]. This illustrates how directly asking users about their expectations of the robot is not always effective. User-perceived in-group membership of the robot led to greater anthropomorphic inferences and more positive evaluations of the robot [180]. The role that a robot's anthropomorphism can play may vary depending on the conditions of use.

The results indicate that both the occupations of robots and users' personal attributes, including age, gender, and financial anxiety, significantly influence perceptions about robots. When juxtaposed with general and security robots, individuals demonstrate a pronounced anthropomorphic preference and higher point of subjective equality (PSE) outcomes for service robots, accompanied by reduced negative attitudes and a diminished perceived threat. Furthermore, age and gender play critical roles in shaping perceptions about robots. A notable positive correlation between users' financial anxiety and their adverse attitudes toward robots was observed.

Turning our attention to the effects of user characteristics on human-robot interactions, we discerned that attributes such as age, gender, and financial anxiety wield substantial influence. Previous research suggests that older adults tend to prefer highly anthropomorphic robots, unlike their younger counterparts [42]. Additionally, previous studies have shown that females tend to perceive robotic movements as more anthropomorphic than males do [44]. Study 2 unveiled pronounced impacts and interplays of age and gender on the perceived border between robots and humans. Specifically, the PSE scores were notably higher for older and female participants compared to their younger and male counterparts, suggesting that the former group expects a greater degree of anthropomorphism in robots.

Both Study 1 and Study 2 support the result that people have higher anthropomorphic preferences and anthropomorphic expectations for service robots (compared to robots and security robots). Study 1 took a broader view to explore the outcomes of perceptions of robots that can be influenced by robotics careers. And study1 found that participants had different gender preferences for robots in different occupations. Compared to Study 1, Study 2 analyzed in more depth the boundaries of people's human-robot categorization of robots with different occupations.

Study 3 highlighted that, across all robot types, females perceived a higher identity and realistic threat than males did. Furthermore, older individuals tended to perceive a diminished realistic threat from robots in comparison to younger ones. A prior study indicated that individuals with higher incomes tend to have more favorable views on robots [90]. We posited that disparities in social power and roles among participants led to the gender-specific perceptions of robot threats.

Study 4 corroborated that individuals grappling with pronounced financial anxiety are inclined to harbor more negative attitudes toward robots. These insights underscore that intrinsic user characteristics, encompassing age, gender, and financial anxiety, significantly mold perceptions about robots. Our study reinforces and builds upon previous research [171], indicating that individuals concerned about job displacement are more likely to have heightened fears regarding robots. Moreover, this study is groundbreaking in its examination of the link between individuals' financial anxieties and their adverse perceptions of robots.

Both Study 1 and Study 4 looked at NARS outcomes for participants. Study 1 revealed that robot careers influence people's negative attitudes toward robots. Study 4 revealed a positive correlation between people's financial anxiety and NARS. This demonstrates that not only the occupational characteristics of the robot, but also the personal characteristics of the user may influence people's attitudes toward the robot and other related perceptions of the robot.

Interestingly, in Study 1, robot occupation influenced the results of NARS, S2, and S3. However, in Study 4, it was NARS, S1, and S2 that were associated with financial anxiety. This illustrates the need to examine S1,S2, and S3 separately.

Venturing to draw connections between robot occupations and users' personal identities, we posit a tangible link between a robot's professional role and its societal identity. Moreover, these societal identities might modulate human identity security to diverse extents, a stance buttressed by the findings from Study 3. Intriguingly, an upsurge in financial anxiety corresponded to intensified negative perceptions of robots. This pattern intimates that human-robot interactions transcend mere robotic considerations; human elements are paramount and transcend mere physiological classifications, such as age and gender. Highlighting financial anxiety as a pivotal determinant underscores the intricate sociocultural nature of human-robot interactions. The intricate ramifications of human financial anxiety on such interactions warrant further exploration by scholars.

As design and robotics practitioners, utilizing previous research results and limited manufacturing resources to design robots that satisfy users is an important goal. Existing research suggests that the context in which a robot is used significantly affects the user's evaluation of the robot. In a prisoner's dilemma game, the more human-like the robot looks, the more people can attribute human qualities to the robot [181]. And, a moderate anthropomorphic appearance combined with appropriate social cues can increase children's preference and acceptance of robots [146]. The higher the consumer demand for human interaction, the stronger the relationship between anthropomorphization and adoption [182]. If there can be reliable evidence that higher anthropomorphism improves users' evaluation of robots, then I recommend designers to try high anthropomorphism design solutions and find target users to test them.

Moreover, some studies have found that high anthropomorphism is not appropriate for robots in some specific use contexts, e.g., the human appearance of a companion robot did not increase consumer acceptance [183]; robots with a human appearance were rated as more disturbing when they were moving naturally [184]; and too much resemblance between a social robot and a human raises concerns about the negative impacts of the technology on humans, as a group. concerns about the negative impact of this technology on humans, who as a group are more universally identified because similarities blur the boundaries of categories and undermine the uniqueness of humans [185]. Designers should be sensitive to relevant research and try to utilize the findings to guide their designs.

The appearance and features of a product can often influence our stereotypes of things. It has been found that participants perceive anthropomorphic robots as having more social presence than functional ones [186]. The design of a robot can influence people's perceptions and attitudes towards robots, thus shaping the role of robots in society and the relationship between people and robots. A number of studies with preteens have found that despite having little knowledge about robots, some attitudes and perceptions about robots already exist in the next generation. Children have strong stereotypes about mechanical anthropomorphic systems [187]. Having robots as educators is sometimes thought to stimulate creativity in students. However, some researchers argue that creativity is a product of social construction and that the main reason for students' interest in robots is the fascination with the illusion of life [188]. It is difficult to estimate the impact of blindly using robots in various fields. In particular, what kind of robotic information will cognitively immature pre-teens be faced with that is more conducive to their development? Our current trends in robot design will shape and influence the stereotypes of robots in the future. Avoiding exacerbating stereotypes or appealing to them is not yet a settled issue in the robotics industry. Sociological researchers need to work with robotics researchers to explore this question.

This study is an important guide for designers as well as for the field of user research. Based on the results found in this study, designers should not blindly pursue anthropomorphism when designing the appearance of robots, but should design robots for different occupations separately according to different user contexts. Moreover, whether to cater to or reject people's anthropomorphic expectations for different robots remains a debatable issue. Therefore, designers need to be more cautious about the design of anthropomorphic robots. For user researchers and those who formulate robotics market policies, the purpose for which different robots are used will be an important factor influencing robot production and deployment strategies. This study will also guide marketers in customizing robot marketing programs for users of different ages, genders, and financial anxieties.

9.2 Limitation and Future Study

In the study 1, though no gender differences emerged in experience dimension of mind perception, it was intriguing to find that females rated general robots' agency capacities higher than males did. However, this distinction did not extend to security or service robots. This finding lays foundational insights for the intersection of gender studies and robotics [151]. For the first time, we've identified age and gender as significant determinants of mind perception of robots, underscoring the need for future research to consider these demographic factors, reducing potential experimental variance.

While our current findings did not supported that a robot's occupation influences human perceptions, we discerned higher experience evaluations for robots and security robots among younger participants compared to older people. The absence of age-related differences for service robots hints at the occupation potentially moderating mind perceptions, even if our data didn't provide a direct statistical affirmation. Future endeavors should involve a more extensive participant base and refined experimental methodologies to probe these nuances further. It's paramount to recognize the multifaceted and varied nature of occupational roles within human society when assessing robot perceptions. Ensuring efficient and informed selection of robot roles will be pivotal in future research endeavors.

In the study 2, while we endeavored to interpret the experimental outcomes in the context of occupational stereotypes, individual perceptions and expectations of robots in distinct occupations can differ widely [189]. Given the multifaceted differences in occupational stereotypes for service personnel and security guards in human societies [61, 62], pinpointing the specific stereotypical variations that influence anthropomorphic expectations proves challenging. It's ambiguous whether human occupational stereotypes align with those assigned to robots with equivalent roles. Since individual preferences for robot appearances might not strictly adhere to these occupational stereotypes, it would be an oversimplification to assert that anthropomorphic preferences for robots are occupation-dependent. Consequently, the exact impact of robot stereotyping on human societies remains elusive. Addressing this requires thorough categorization and quantitative scrutiny of particular occupational stereotypes in forthcoming research. There's an imperative to delve into how occupation affects other facets of robot anthropomorphism and understand the interplay between context, professional stereotypes, and preferences for anthropomorphic robots. While this study conveyed anthropomorphism using images of anthropomorphic faces, robot anthropomorphism can extend beyond mere aesthetics, encompassing communication, contextual interactions, and a spectrum of behaviors [190, 191]. Although occupation, as a delineator for social roles, serves as this study's foundational categorization method, alternative social role classifications might be of relevance in subsequent robot research, such as robot skin color, gender, and hierarchical standing. Additionally, the interaction between participant age and gender in relation to PSE merits deeper inquiry. In studies 1 and 2, we reused certain images. However we do not guarantee that there was no overlap in participants between the two studies. And different images may lead to different results.

In the study 4, participants' financial anxiety was gauged using a singular question, making it challenging to ascertain the root causes of their financial anxiety or their income levels. This limitation curtails our ability to delve deeper into the mechanisms through which financial anxiety influences negative attitudes towards robots. Future research endeavors will encompass more detailed and comprehensive experiments to further investigate this relationship. Additionally, given the brief interval between responses to the NARS and financial anxiety questions, we cannot entirely discount the potential influence of the NARS on participants' perceptions of financial anxiety. As a result, the reported levels of financial anxiety might not be wholly accurate, highlighting an avenue for refinement in subsequent studies.

In our study, we only changed the robot occupation without claiming any behaviors or appearances of robots. Then, people imagine robots' features based on their stereotypes which could show high diversity. Because we did not provide specific descriptions of robots in different occupations before we began the survey, it was difficult to be sure that participants understood the questions in the questionnaire as we had anticipated. We did not measure participants' stereotypes of different occupations of robots. Therefore, the relationship between occupational stereotypes and perceived threats still needs adequate study. Furthermore, although females (compared to males) often have lower power in society, we did not measure the perceived social power of each participant. Future research could incorporate elements of more individual differences to explore the potential effect of the perceived threats of robots. In this thesis, we consider only two particular robotic occupations. We need to introduce more diverse robot occupations to make the findings more convincing.

Due to the diversity and complexity of human societies, regions and populations from various cultures also have different preferences for robots. When the social nature of a robot's task is reduced, the participation of participants from low-context cultures decreases significantly [179]. Japanese people are less likely to prefer highly anthropomorphic robots compared to Americans [192]. Girls are more accepting of anthropomorphic robots than boys, especially female robots [43]. Different forms of social disengagement (structural and trait-based) may produce different types of social motivation, thus affecting different aspects of anthropomorphic thinking [193]. There is a clear positive correlation between extraversion and the tendency of robots to be anthropomorphic, with personality dimensions influencing how individuals perceive the robots they interact with [155]. Even the way robots are perceived by people varies depending on the robot's country of origin [194]. It is due to the diversity and complexity of human societies and cultures that the study of robots is challenging and novel. Researchers and designers can choose very diverse perspectives on the relationship between humans and robots and on robot design.

In this thesis, all participants were Japan-based. The unbalanced social status between males and females in this study was more significant than in the United States [195]. Therefore, our results, especially the gender effect, could be culture-specific. Furthermore, in different cultural contexts, different occupations were perceived with various stereotypes. In the United States, waitresses sometimes were sexually objectified [196]. Therefore, in other countries, the difference between the perception of service and security robots may differ from this study. Due to the different social status and stereotypes of different occupations in different cultures, perhaps Americans (compared to Japanese), users will have a higher level of negative attitudes towards service robots. This study is a cross-sectional study, so differences between different age groups do not necessarily indicate an effect of age. In order to understand the effect of age, we need to follow a group over time. Although we collected data from users of different age groups, however, we lacked responses and data from children, adolescents, and middle-aged adults. The relationship between robot careers and users' careers remains unknown. We cannot be sure whether the same occupation will cause good or bad feelings in users. Therefore, we removed some of the participants who overlapped with the robot occupation.

How do robots of the future look like? The relationship between the user's imagination and knowledge can be confusing because the human-like characteristics of fictional robots are more advanced than what factual robots can achieve [197]. In previous studies, researchers have tended to use fictional robot characters as stimuli for experiments, yet real-world robots are different from hypothetical ones. Highly anthropomorphic-looking real robots exist only in some specific laboratory conditions and are not widely used in human life scenarios. A number of technical difficulties and cost issues may continue to be a gap between people's ideal and real robots. Ethical research on robots has also become an important topic. Should the social needs of robots be taken seriously by humans when they have human-like ways of speaking and expressing emotions? One study found that while anthropomorphizing a robot may lead us to save it from imminent extinction, it does not lead us to consider its social needs more in everyday situations [198]. Exactly what kind of role robots should assume remains a challenging question.

Note

This dissertation interpolates materials from 3 papers by the author [199-201]. Chapter 4 uses material from reference [199], coauthored with Shinichi Koyama. Meanwhile, chapter 4 uses material from reference [200], coauthored with Shinichi Koyama and Guyue Tang. Meanwhile, chapter 5 uses material from reference [201], coauthored with Shinichi Koyama and Guyue Tang.

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Appendix A: Mind Perception Scale

Japanese version of mind perception scale:

ロボットは、どの程度、身体的・精神的な痛みを感じることができると思いますか?

ロボットは、どの程度、恐怖を感じることができると思いますか?

ロボットは、激しい怒りや制御不能な怒りをどの程度経験することができると思いますか?

ロボットは、どの程度、他のロボットとは違う個性を持つことが可能だと思いますか?

ロボットは、欲望や感情、衝動に対してどの程度自制することができると思いますか?

ロボットは、どの程度、経験や認識をすることができると思いますか?

ロボットがどの程度、相手に思いや感情を伝えることができると思いますか?

ロボットは、どの程度、憧れや希望を抱くことができると思いますか?

ロボットには、計画を立てたり、目標に向かって努力したりする能力がどの程度あると思いますか?

ロボットは、善悪を判断し、正しいことを行おうとする能力がどの程度あると思いますか?

ロボットには、相手の気持ちを理解する能力がどの程度あるとお考えでしょうか?

ロボットには、どの程度の記憶力があると思いますか?

English version of mind perception scale:

To what extent do you think robots can feel physical and mental pain?

To what extent do you think robots can feel fear?

To what extent do you think robots can experience rage and uncontrollable anger?

To what extent do you think a robot can have a unique personality?

To what extent do you think robots are capable of self-controlling over their desires, emotions, and impulses?

To what extent do you think robots are capable of experiencing and recognizing?

To what extent do you think robots can convey thoughts and feelings?

To what extent do you think robots can have longing and hope?

To what extent do you think robots can make plans and work towards the goals?

To what extent do you think robots can judge right from wrong and try to do the right thing?

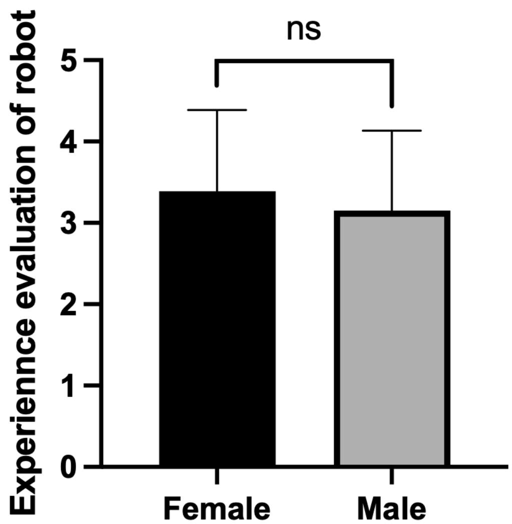
To what extent do you think robots can understand others' feelings?

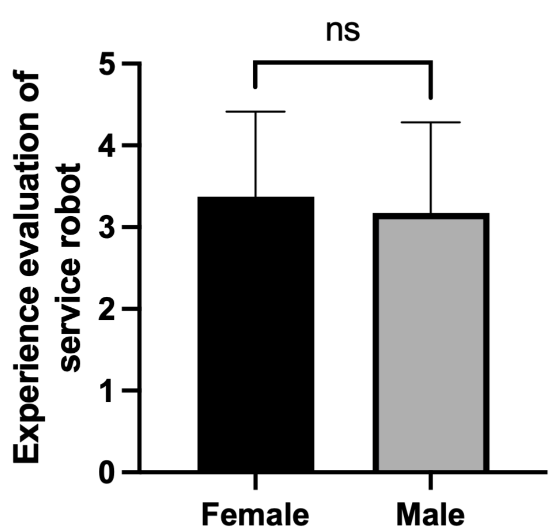
To what extent do you think robots have memory?

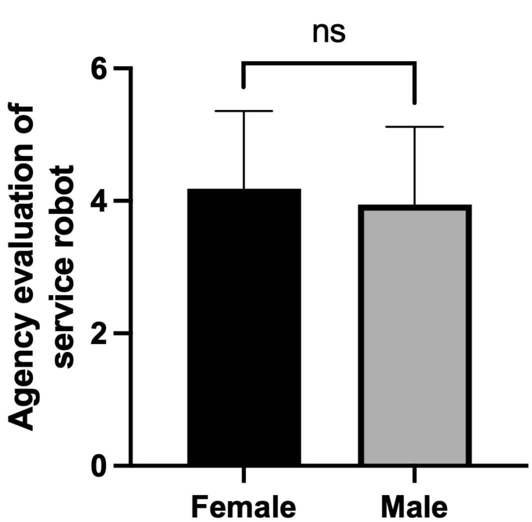
Appendix B: Raw Data of the thesis

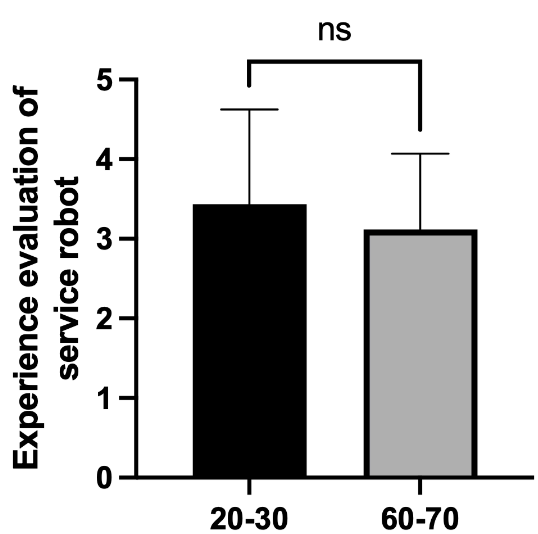
All raw data has been uploaded to the cloud disease can be accessed via the link below.
https://drive.google.com/drive/folders/1It8f5l-hxF6VFuqZ8AgLm11DypNTtGeC?usp=drive_link

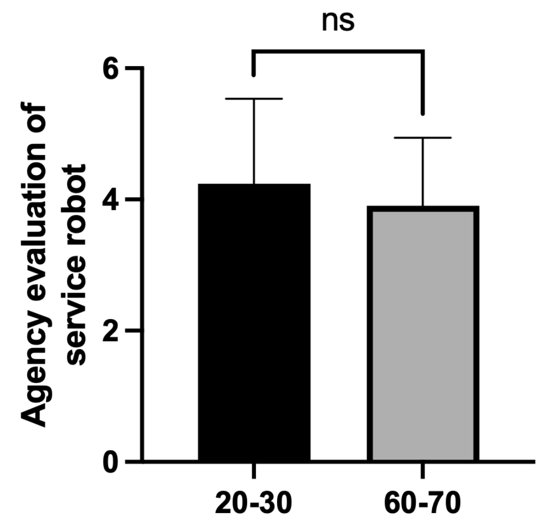
Error bars denote standard errors of the mean. *p < 0.05, **p < 0.01

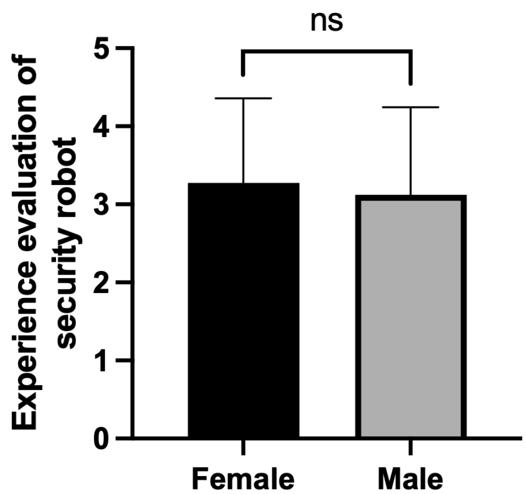


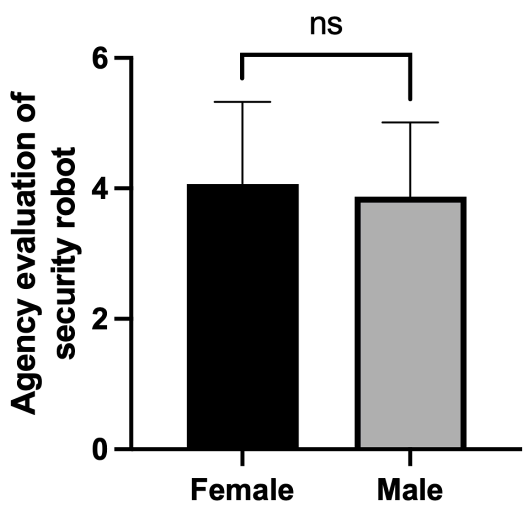


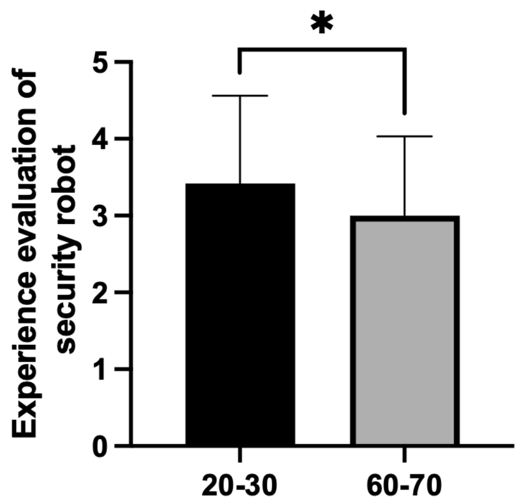





ns
Agency evaluation of service robot
0
2
4
6
20-30
60-70


ns
Experience evaluation of security robot
0
1
2
3
4
5
Female
Male


ns
Agency evaluation of security robot
0
2
4
6
Female
Male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Experience evaluation of security robot
0
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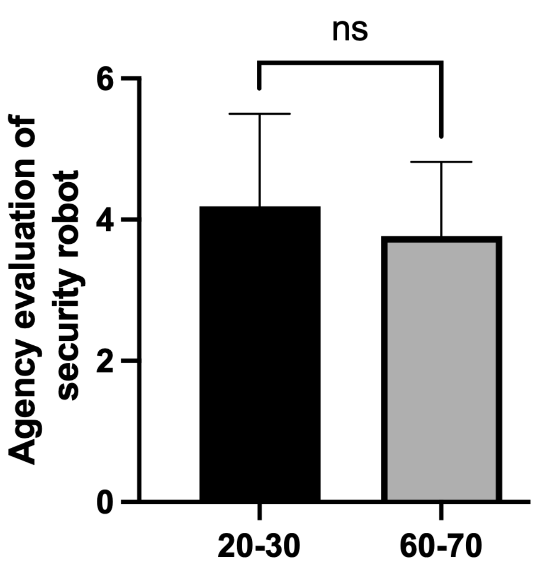
20-30
60-70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Agency evaluation of security robot
0
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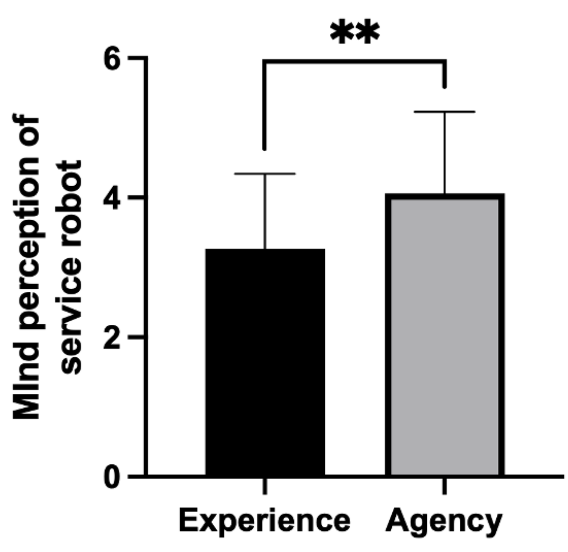
60-70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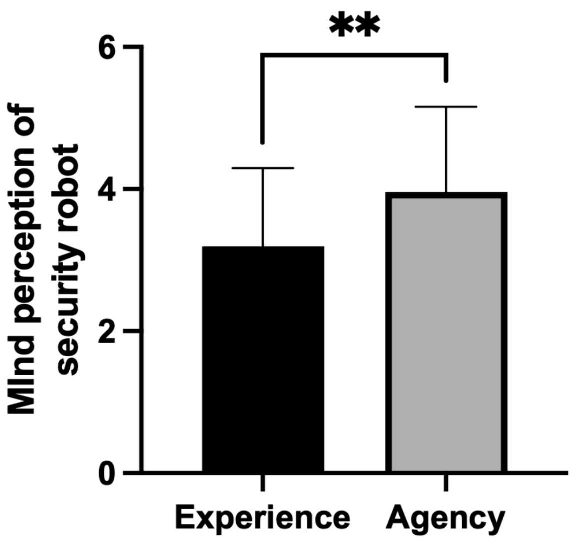
MInd perception of service robot
0
2
4
6
Experience
Agency


**
6
4
2
0
MInd perception of
security robot
Experience
Agency

Appendix C: English and Japanese version of scale of perceived threats

Japanese version of perceived threats scale:

1. 日常生活におけるロボットの利用拡大が、人間の雇用喪失をより多く引き起こしている。
2. 長い目で見れば、ロボットは人間の安全と幸福を直接的に脅かすものです。
3. 最近のロボット技術の進歩は、人間の本質を脅かしている。
4. ロボット工学の分野における技術の進歩は、人間の独自性を脅かすものです。

English version of perceived threats scale:

1. The increased use of robots in our everyday life is causing more job loss for humans
2. In the long run, robots pose a direct threat to human safety and well-being.
3. Recent advances in robot technology are challenging the very essence of what it means to be.
4. Technological advancements in the area of robotics is threatening to human uniqueness.

Appendix D: English and Japanese version of scale of financial anxiety

Japanese version of perceived threats scale:

現在のあなたの経済状況について、どの程度不安を感じていますか? (0:全く不安はない 10: 非常に不安である)

English version of perceived threats scale:

How anxious are you about your current financial situation? (0: not at all anxious 10: extreme anxious)