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RESEARCH ARTICLE

Potential User Segmentation Based on Expectations of Social Robots Using Q-Methodology

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ABSTRACT This study explores users' expectations of social robots by employing Q-methodology, a technique that identifies patterns of subjective opinions. By reviewing research papers and conducting interviews, we created 37 statements about social robot issues and users ranked these statements based on perceived importance. This made an individual's subjectivity be measured and analyzed to distinguish between features deemed important by most users and those with high degrees of disagreement. Participants showed low interest in gaming, talking, and bonding with robots. Opinions on additional service charges were neutral while personalization was favored. We identified four types of consumers: those perceiving robots as a burdensome machine, a trusted friend, an emotionally intelligent device, and an energizing gadget. This research suggests a new academic framework to evaluate social robots consists of five dimensions: physical anthropomorphism, psychological anthropomorphism, cognitive intelligence, and user's willingness to comply with robot's suggestions and sacrifice. Our findings offer broad applications for companies developing social robots, providing a methodology that can serve as a basis for market surveys prior to product development and help tailor designs to meet the expectations of specific consumer niches.

INDEX TERMS Anthropomorphism, compliance, intelligence, sacrifice, Q-methodology, social robot, user-experience.

I. INTRODUCTION

Technologies are evolving to provide support to humans in various aspects of their lives, including physical, emotional, mental, cognitive, and decision-making abilities. One specific type of future electronic device that is designed to interact and communicate with humans is the social robot [1], which remains largely in the conceptual development stage and has not seen widespread adoption since the introduction of Sony's AIBO robot dog in 1997, which preceded the introduction of robot vacuum cleaners by four years. ''Researchers have highlighted the potential of robots as effective learning companions that increase learning efficiency [2] and as effective coaches for habit development and performance improvement [3], [4]. Despite the MIT research team's achievement in inventing and mass- producing the JIBO robot with these features, its business activities were later suspended. Research into the potential usefulness and effectiveness of social robots is still ongoing, but their widespread adoption has not accelerated as expected.

To answer this, researchers have found the intention to use through the Technology Acceptance Model perspective, which considers usefulness and ease of use [5], [11], [12], [13]. They have also considered the perspective of Uses & Gratitude and social benefits [14], as well as both benefits and threatening factors. In each study, we found useful variables such as perceived sociability, social influence, social presence, trust [13], perceived enjoyment and need to belong [5], social attractiveness, self- disclosure, relationship quality, empathy, communication skills [15], and mutual goodness [12], [16], which is to overcome asymmetrical relationships and share mutual admiration. But would all

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TABLE 1. Categories of robots and non-robots according to ISO 8373:2021 definitions and their uses.

Robots	Industrial Robots			unmanned production, shipping, work process equipment, semiconductor production equipment
	Service Robots	Professional		medical, military, rescue operations, inspections in underwater, suspension bridge cable, skyscraper wall
		Personal	Public	educational assistance, guidance, entertainment
			Private	(physical) healthcare, security, cleaning, cooking (psychological) education,healthcare, games, older adults care, companionship
Non-robots	1. Not equipped with programmable axes of motion: chatbots, AI, robotic process automation, voice assistant 2. Not designed for multipurpose manipulation but transportation focused: vehicles, drones, unmanned aerial vehicles, unmanned ground vehicles, unmanned underwater vehicles, autonomous cars 3. Not mobile and limited to specific function: ATMs, smart washing machines			

of this be important to everyone, and to the same degree of priority?

In this study, we aimed to innovate the process of designing social robots by drawing a blueprint that fulfills users' priority expectations, identified through meticulous user research involving dozens of variables found in previous research and interviews. In contrast to traditional methods that often focus on a limited set of variables, neglecting others, the Q-methodology involves participants in actively evaluating a wider range of variables and allows them to rank these variables in order of importance. This approach proved invaluable in gaining a holistic understanding of general attitudes towards social robots, as demonstrated by Mettler et al.'s 2017 study on service robots in hospitals [17], [18].

As for the academic significance of this study, first, in order to identify the market for social robots, which is still in the preliminary stage before the market grows, we exploratively summarized the characteristics of social robots based on existing studies and interviews with users and service providers and created 37 statements to segment the initial market through a methodology called the Q-sorting. Second, a framework of five perspectives to identify the characteristics of different is presented. Third, this study classified the social robot market into four patterns and developed a series of processes to draw personas based on the Q-sorting results. Fourth, we suggest that future research should reflect the difference that 4 types of users need and want.

From the practical perspective, first, we proposed Q-sorting as a useful method for analyzing the segmented market when introducing new technologies and suggested to reflect different patterns to perceive and appreciate social robot accordingly. Second, by comparing various characteristics and features of robots at the same time, we summarized the views that have general agreement among users and the views that have a lot of disagreement, which can be used as a reference when designing robots.

II. THEORETICAL BACKGROUND

A. DEFINITION AND SCOPE OF SOCIAL ROBOTS

ISO 8373:2021 defined robot as an automatically controlled, reprogrammable device capable of performing a variety of tasks through programmed motions and functions. Social robots refer to robots that endowed with cognitive and social skills to engage in natural and meaningful social interaction with human. Social robots can be used for a variety of purposes, including education and healthcare, home, care, companionship, and hospitality. Not only personal robots, but also professional or commercial robots can be considered social robots if they are capable of social interaction with humans [19]. In this study, we have defined social robots in the field of personal and private robots as shown in Table 1. As robots are socially intelligent and interactive, they can communicate with like people, making it possible to be friends with human [20]. Researchers have investigated various aspects and dimensions of robots to enhance the interaction and communication between robots and humans, in order to make them more friendly and approachable. These include the robot's appearance, embodiment, surface texture, personality, size, temperature, emotional expression [1], gazing behavior [9], [21], voice [14], [22], language, movement, purchase and maintenance costs, and ethical considerations, and other related factors [23].

Social robots are designed for user-friendly interaction, often resembling humans or animals. They possess human-like mobility, sensory capabilities similar to the five human senses, and can express emotions. This advanced technology offers a significant advantage: it simplifies users' understanding and prediction of the robot's behavior, making the interaction process more intuitive. In addition, they have a physical embodiment designed to improve user's lives, which traditional electronic devices (phones, tablets, and computers) do not have [24]: Social robots can exhibit a diverse range of appearances, such as facial expressions on endearing faces, friendly shapes reminiscent of animals like seals, cats or dogs, materials that are soft and fluffy, and sizes designed for easy hugging. These features are intentionally selected to facilitate the formation of intimate relationships with users. They can also interact with users in a variety of ways using physical language like smiling, gazing, jumping, dancing, turning back etc. [25]. They can cone in different sized and shapes depending on the purpose of use for 24 hours and 7 days, bringing them closer psychologically and physically.

This paper aims to identify the needs and wants that users perceive in social robots, as well as their priorities, and suggest the functions, features, design, and convenience that need to be met for future users.

B. DEFINITION AND SCOPE OF SOCIAL ROBOTS

The Q-methodology was originated by Stephenson [18] and began by suggesting that the study of human personality is not possible with conventional factor analysis methods, and that correlations between people should be used as an alternative. With this methodology, subjective areas that were previously considered impossible to measure scientifically, but communicable, such as feelings, emotions, and attitudes that are related to a particular issue, can now be measured scientifically and the psychological structure inherent in human beings can be explored. Individual subjectivity, which is potential, posteriori, and emotional, can be quantified by forced distribution that scores from -n to +n and adjusts the number of scores fit a frame similar to a standard deviation graph.

Participants' potential, experiential, and emotional individual subjectivity can be quantified and statistically analyzed by asking them to assign a score from -n to +n to a series of statements prepared by the experimenter and sorted to fit the numbers of the scores presented in an array frame similar to a standard deviation graph (force- soring). Therefore, when collecting statements, it is important to ensure that statements are well worded to capture individual subjectivity, and that statements are structed to capture a wide range of opinions. This methodology has been used in studies of marketing, communication, and publics for it allows to understand the psychology of consumers to leading up to consumption, and more recently in psychology, journalism, political science, policy, public administration, sociology, low, public health, nursing, medicine, religious studies.

This study aims to analyze and classify subjective perceptions of personal social robots, which have been in the stage of early technology adoption, since their emergence in 1997, and to identify the requirements that should be regarded to create a sense of closeness between robots and humans. Therefore, by using the Q- methodology, which numerically measures user's subjective perceptions, this study can simultaneously participate in experiments and quantify and analyze various variables covered in the literature and interviews at the same time, as well as subjective variables that were not reflected in the process of existing studies on social robot acceptance, which are mainly conducted in quantitative studies and identify what features of robots are important to people in the social robot market that has not yet been fully commercialized.

The Q-sample is selected set of statements that participants sort during the experiment. Each statement conveys one opinion related to the subject matter and not fact. Therefore, experimenters are interested in how much the participants agrees or disagree, not whether the participants say yes, or no. Q-statements are generally more likely to elicit opinions, or statements from interviews, literature, films, or advertisement rather than newspapers. However, social robots have not been widely used, and researchers have found several features that are not yet built into the robot. Therefore, we extracted many statements form the literature review and asked participants to simulate the situation of interacting with robots.

The participants who participate in the Q-sorting are called P-samples or Q-sorters. This methodology typically involves a small number of participants. Critics often point out this aspect as a limitation for generalization. However, in Q-methodology, the goal is not to statistically infer about the larger population (as in R-methodology) but to understand the spectrum of perspectives within the sampled group, typically 30-50. In Q-methodology, if the number of participants in the experiment is greater than the number of statements being sorted, it can result in a large number of variables and a small amount of data to analyze, known as the 'curse of dimensionality.' This P-sample can be obtained not only from a population, a group of people, but also from a single person by performing multiple experiments at different times, which is called an Extensive Study [26]. The theory of moral development was summarized in 1950 with a few children, and the theory of memory persistence was developed by Ebbinghaus, who used himself as a test subject.

In this experiment, participants were instructed to read a series of statements and make forced- distribution. For example, they were asked to subjectively assign the highest score to the two statements they deemed most positive and symmetrically the lowest score to the two most negative statements. Next, they assigned a score of one point less than the highest to the three statements they considered the next most positive, and similarly, a score of one point less than the highest to the three statements they considered the next most negative. In such a forced- distribution table, with a total of 33 statements, the number of possible combinations reaches hundreds of millions, ensuring nearly infinite individuality [27].

C. FIVE PERSPECTIVES ON SOCIAL ROBOTS

Research on social robots began in the 2000s and is unique in that these robots were not designed to replace human labor but to engage in emotional interactions with humans.

Studies in this domain underscore the pivotal role of robots in fostering human closeness and intimacy, leading to designs that often mimic familiar animals like seals and dogs, or possess human-like features such as arms and heads. This physical anthropomorphism, complemented by soft, comforting exteriors, enhances the robots' approachability and familiarity [2], [8], [28], [29]. Research on anthropomorphism has shown that anthropomorphism makes people feel immersed, empathetic, and intimate, and makes robots attractive, trustworthy, competent, safe, and preferable [30].

Anthropomorphism, extending beyond physical attributes to psychological dimensions, profoundly influences human perceptions of robots. The incorporation of human- like cues, derived from human-human interactions such as emotional expressiveness [1], error-making [31], and tactile feedback [32], deepens the human-robot connection. Unlike immediate physical anthropomorphism, psychological anthropomorphism's influence emerges over time, playing a crucial role in long-term user satisfaction and future research directions.

Furthermore, studies reveal that a robot's perceived intelligence, often inferred from its physical human- likeness [33], is a cornerstone in establishing trustworthiness and likability [33], [34]. This intelligence, pivotal in defining a robot's autonomy, manifests in both physical actions (movement, identification, speech) and psychological behaviors (emotional expression, personality-driven actions). Attractiveness and intelligence in robotics are not merely aesthetic but functional, significantly influencing user compliance and the adoption of robot-suggested behaviors for well-being [35]. Robotic intelligence can also increase the level of compliance that leads to the selection of robot-suggested behaviors for human well-being.

In this study, we synthesize prior research and insights from user and service provider interviews to formulate statements about Human-Robot Interaction features. These statements, categorized into five groups, will be assessed through a Q-sort process by users. Our aim is to discern the relative importance users attribute to different robot features and to identify unique market segments based on these preferences.

1) PHYSICAL ANTHROPOMORPHISM

In our research, "physical anthropomorphism" encompasses human-like characteristics that are immediately perceptible during initial human-robot interactions. These characteristics include the robot's visual appearance (S1), movement (S2), sound production (S6), language use (S7), vocal tone (S8), and tactile surface (S9). (Note: S# refers to Statement number #.)

The degree of anthropomorphism modulates user perceptions. Interestingly, a robot's enhanced anthropomorphic appearance (S1) or movements, like head motions and blinking (S2), may not necessarily increase compliance [37] or likability [38]. However, these features do elevate user expectations of intelligence [33], thereby creating greater demand to meet user's expectation.

Additionally, the tactile aspect, such as the softness of the robot's surface (S9), plays a significant role in enhancing user interaction satisfaction [8], [28], [40]. The study also underscores the effectiveness of non-verbal communication (S7) in human-robot interaction. For instance, a robot's warm vocal tone (S8) can elicit a more human-like perception, subsequently increasing trust and acceptance [31]. These findings highlight the complexity of anthropomorphism in robotics, where various physical attributes differently influence user perception and experience.

2) PSYCHOLOGICAL ANTHROPOMORPHISM

Unlike physical anthropomorphism in robots, designed to be easily recognizable at once, psychological anthropomorphism is discernable by users through interaction-based psychological cues like social feedback, interaction style [41]. This latter form varies with the user and the context. For instance, akin to human interpretation of facial expressions, a robot's emotional expressions (S3) allow users to intuitively understand its 'inner state,' fostering a deeper connection and affinity [1], [25]. Research indicates that robots exhibiting empathy and emotional responsiveness not only enhance their attractiveness [39] but also improve the efficacy and robustness of human-robot collaboration [42] and boost coaching effectiveness [43]. These features can also serve educational purposes, like fostering empathy in children and aiding individuals with autism [44], [45].

It has been found that for robots to appeal to users, they must exhibit lifelike qualities, such as emotions (S3) and personalities (S4) [39]. Interestingly, a slight degree of disobedience or imperfection (S25) in robots can enhance their realism and liveliness. Similarly, robots making occasional mistakes can paradoxically increase trust and acceptance [31].

Additionally, studies suggest that people may find it easier to communicate with robots than humans (S20) [46]. However, in long-term interactions, predictability in robotic responses can reduce novelty and enjoyment [15]. Just as personal narratives and traits enrich human relationships, equipping robots with their own 'stories' or personalities could sustain engagement, creating interactions akin to human friendships (S5). On the other hand, an experiment conducted by Onnasch [47] showed that the group that was provided with personal information about the robot, such as its personal history and preferences, showed lower compliance than the group that received only mechanical information about the robot, indicating that if the robot is designed for a specific purpose, context and psychological involvement with the robot by participation should also be considered. Meanwhile, a robot with an extroverted personality was more loved than an introverted one (S4) [48].

Interpersonal touch (S21) by robots for friendliness with users has been shown to increase positivity and compliance toward robots [32], and robots approaching users first in a friendly manner, such as with greetings (S18) or hand sanitizing, have had a positive impact on interaction with users [49]. Furthermore, we can suggest not only the one perspective that users empathize with the feelings of robots [39], but also the other perspective that robots detect and respond to users' moods and emotions (S24).

Ethically, the idea of humans forming friendships with robots (S17) raises questions. Some argue, referencing Aristotle's Nicomachean Ethics, that true friendship with digital entities like robots is unattainable due to their inability to genuinely care [50]. While robots might provide utility and pleasure, the human-robot relationship is inherently asymmetrical [51]. Yet, robots can offer physical convenience and emotional comfort, and serve as behavioral models and therapeutic tools [52].

Users may derive pleasure from tormenting robots (S28), but in terms of the relationship between interacting entities, it is far from mutual virtue because as there is no empathy.

Considering that mutual affection and respect between robots and humans is a virtue of relationship, it is necessary to design the social interaction of social robots at a socially acceptable level as a basic ethics of robotics [53].

3) COGNITIVE INTELLIGENCE

Cognitive intelligence encompasses a wide range of mental abilities involved in processes such as learning, reasoning, problem solving, and knowledge representation. Intelligent technologies are computational systems and algorithms that enable and realize the cognitive intelligence of a social robot. These intelligent technologies encompass a wide range of techniques and methods, including mineral detection algorithms, bearing failure diagnosis models, battery life prediction approaches, and image processing tools for object detection, segmentation, face and gesture recognition, environmental feature mapping, and real-time optimization and adaptation [54], [55], [56], [57]. In the area of social robotics, these versatile intelligent technologies can be applied to enable robots to perceive and understand their environment, recognize and respond to human expressions and gestures, navigate and map their operating environment, continuously optimize their behavior based on real-time feedback, and enhance human-robot interaction and assistance in various settings. For instance, robot may have the function to provide valuable and trustworthy information (S10). In specific contexts, such as for users in vulnerable conditions or those seeking to develop good habits, engagement with robots for physical activities (S22) can be appealing [58]. Additionally, users may want to play innovative and regularly updated games with robots (S23) [12], [59]. Moreover, users my want to consult their problems and find better solution through interactions with wise and sophisticated robots (S26) for more positive outcomes. Research indicates that robots using rhetorical expressions can capture greater attention [60] and exhibit enhanced persuasiveness [61], [62]. Conversely, predictable responses from robots may diminish the novelty and enjoyment of the interaction [15], [63], suggesting a user preference for diverse, novel, and unexpected responses from robots (S27). If a robot is equipped with the intelligence to tailor its responses based on the user's words or actions (S29), it can enhance the user's awareness of the robot's presence, creating stronger social engagement [64] and a more pronounced sense of presence [65], though this might also raise concerns about privacy invasion [4].

Fox [66] criticized that treating all users the same is a limitation of Human-Social Robot interaction today. Tailoring robot interactions to individual users (S30) can increase their endearment [39], intimacy, trustworthiness [63], and persuasiveness [67]. However, some argue that hyper-personalization might lead to deceptive practices, such as presenting limited or biased information, underscoring the need for obtaining user consent (S16) as a more intellectually and ethically sound approach [68].

4) USER'S WILLINGNESS TO COMPLY WITH ROBOTS' SUGGESTIONS

In this study, we define compliance as the degree to which users willingly adhere to the recommendations and guidance offered by robots, particularly those aimed at enhancing education and well-being. These recommendations span a variety of areas, including healthcare, exercise, medication adherence, and actions promoting global sustainability like energy conservation [36] and effective food management [69]. It is important to clarify that in our research context, 'compliance' refers specifically to user behavior, and not to the adherence of robot designers or manufacturers to ethical standards, regulations, or laws.

Research demonstrates that robots, through their varied forms and movements, can be instrumental in persuasive technology. Their ability to create a sense of presence, closeness, and intimacy [8], [9], coupled with the intelligent impression they convey, enhances their credibility and persuasiveness. This, in turn, motivates users to follow the robots' suggestions [34]. Context-specific suggestions by robots (S32), such as offering health-care guidance or providing health-related assistance like sanitizer [49], have shown to increase user compliance. Interestingly, the effectiveness of feedback varies depending on the robot's communication style (S31) [36], [58], [70], [71], [72], [73], underlying motivation (S33) [4], [9], [74], and the user's engagement in the interaction. Furthermore, Studies show that robots aid in habit formation (S34) [6], [24], [75], and users expressed a desire for more actively engaging in discussions about personal matters with robots (S35) [11], [76].

5) SACRIFICE

Acceptance of new technologies such as robots, computers, and new software entails sacrifices on the part of users. Users need to collect and understand comprehending details about the technology's specifications, functionality, and capabilities, as well as evaluating whether these align with their needs and circumstances. Additionally, users must weight their initial price (S14) and ongoing expenses, such as data or content usage fees (S15).

Learning how to operate the technology (S19), ensuring regular charging (S37), and managing maintenance in the event of errors or malfunctions are also essential considerations (S36) [62], [77]. Furthermore, there are privacy concerns, such as the risk of personal information leakage through the built-in microphone (S12) or camera (S13), and the handling of personal or interaction data (S11) [4], [78]. Our research delves into the sacrifices consumers make when using science and technology, aiming to understand the subjective significance users place on these sacrifices compared to the benefits of technology usage. We aim to categorize and analyze the varying degrees of sacrifice sensitivity among different users. Our objective is to gather common and differing perspectives from participants by quantitatively assessing their views on anticipated functions and benefits of robot interaction, along with the associated sacrifices.

By segmenting these opinions based on unique characteristics, we aim to identify niche groups and personas, thereby enhancing our understanding of user experiences with technology.

III. RESEARCH DESIGN AND METHODOLOGY

A. RESEARCH DESIGN AND PARTICIPANTS

1) DEVELOPING THE Q-STATEMENTS

This research aimed to elucidate the essential criteria for social robots, particularly those designed for emulating and reciprocating human emotions to foster deeper human-robot connections. To achieve this objective, the study employed Q methodology, a qualitative research tool ideal for exploring latent needs of users in relation to social robots. The focus of this methodology lies in extracting specific, contextual insights rather than generalizing findings across a broad population. To capture a broad perspective on social robots, the study included a comprehensive review of existing literature and conducted interviews with a diverse range of stakeholders. These stakeholders comprised users, product researchers, customer experience designers, customer satisfaction experts, and software developers. Details of this process are illustrated below.

From 2020 to 2022, our team of researchers, equipped with extensive knowledge from literature reviews, participated in workshops hosted by manufacturers. These workshops focused on innovating products and enhancing customer service to align with customer needs and played a crucial role in designing subsequent products based on customer feedback. The details of the interviewees involved are provided in Table 2.

The Q-set consisting of 37 statements was systematically developed to comprehensively represent the key domains and considerations surrounding social robots designed for emulating and reciprocating human emotions. Initially, a pool of 110 candidate statements was constructed by triangulating insights from three primary sources: 1) A literature review covering theoretical and empirical research from 2010-2022 in the domains of social robotics, human-robot interaction, and affiliated areas, sourced from IEEE Xplore, ACM Digital Library, and Google Scholar (yielding 60 statements); 2) Analysis of real-world artifacts including product advertisements, reviews, and user interviews for commercial social robots like EMO, Aibo, and Loomo (20 statements); and 3) Semi-structured interviews with 12 industry professionals spanning product research, customer experience design, user satisfaction, and software engineering roles at leading social robotics companies (30 statements). This iterative process ensured that the final 37 statements were clearly expressed, represented different perspectives, and were appropriately categorized into the five key domains: Physical Anthropomorphism, Psychological Anthropomorphism, Cognitive Intelligence, Compliance to Robot's Suggestions, and Sacrifice.

TABLE 2. Interviewees for design of initial Q-statements.

No.	Occupation	Specialty	Relevant Experiences (at least n years)	No. of Interviewees
1	Researcher	Social Robot, Human Computer Interaction	2	3
2	Robotics Developers	IT Developer	4	4
3	Robot Service Providers	CEOs & Customer Satisfaction	4	6
4	Coaches	Life Coach	6	2
5	Various	Users	2	12

To ensure the validity of the Q-set, which is crucial in Q-methodology, the initial statement pool underwent a rigorous multi-stage refinement and validation process involving pilot testing overseen by a panel of 5 experts with extensive experience in Q-methodology and the social robotics domain. The pilot process rigorously evaluated the statement wordings for clarity, lack of ambiguity, and representation of diverse perspectives. Based on pilot feedback, statements were iteratively refined, with 28 statements being modified for clarity and 45 statements removed due to redundancy or lack of relevance. The final Q-set comprised positively and negatively worded statements to minimize potential response biases.

The framework of five dimensions presented here is intended to serve as a structured lens through which researchers can view and categorize the various factors that shape users' perceptions of and experiences with social robots. Our focus on practical categorization allows for a thorough exploration of robot characteristics from multiple perspectives, providing valuable insights without tilting toward a particular theoretical foundation. Specifically, we have defined each dimension as follows, and specific statements with relevant references can be found in Table 3.

- Physical Anthropomorphism: This dimension refers to the extent to which social robots embody human-like physical characteristics. It encompasses aspects such as appearance, movement, voice quality, language proficiency, and tactile properties. The goal is to create robots that closely mimic human physical attributes to enhance natural interaction and user comfort.
- Psychological Anthropomorphism: This dimension focuses on the robot's ability to exhibit human-like psychological traits and behaviors. It includes emotional expression, personality development, backstory creation, social initiation, emotional intelligence, and humor. This dimension aims to create robots that can engage in more human-like social and emotional interactions.

TABLE 3. **37 Statements by five attributes.**

Attributes	Q-Statements	Reference
Physical Anthropomorphism (PHY)	1. Social robots require human-like appearance.	36
	2. Biomimetic social robots must move like the realorganism.	37, 38
	6. Human-like voices are crucial for social robots to sound natural, not machine-generated.	31
	7. Human language proficiency is essential for social robots to communicate effectively.	39
	8. Social robots need to speak friendly and kindly.	31
	9. Smooth, warm surfaces are preferred for social robots.	8, 28, 40
Psychological Anthropomorphism (PSY)	3. The ability to express emotions is crucial.	1, 25, 42 ,43
	4. Social robots should display distinct personalities and reactions in similar situations.	15, 39, 48
	5. Compelling stories about social robots' history, origin, and everyday life are necessary for user interest.	39, 47
	17*. We need to re-evaluate the ethics of befriending social robots.	50, 51, 52
	18*. Designing social robots to initiate greetings first is not good idea.	32
	20*. Social robots should surpass humans in communication with personal and satisfactory responses.	46
	21. Social robots initiating touch with users can enhance feelings of closeness.	32
	24. Social robots' ability to detect and respond to user emotions is desirable.	39
	25*. Social robots should not make mistakes.	31, 39
	28*. Social robots should respond humorously to teasing.	53
Cognitive Intelligence (INT)	10. Meaningful information from reliable, objective data is desirable in social robots.	34
	16. Personalizing social robots with clear user consent is necessary not to violate users' privacy and autonomy.	64
	22. Incorporating physical exercise into human-robot interactions can increase user engagement and motivation.	54
	23. Frequent updates to fun game content can enhance emotional bonding and engagement with social robots.	12, 55
	26. Social need to command adaptive and nuanced communication styles.	56, 57, 58
	27. Social robots require diverse and innovative communication styles.	15, 59
	29. Social robots respond to user behavior and words for effective engagement.	4, 60, 61
	30. Social robots remember the past conversations and respond.	39, 59, 61
Compliance (COM)	31. Social robots provide positive feedback that makes users feel uplifted.	36, 58, 66, 67, 68, 69
	32. Social robots provide proactive and mood- adaptive suggestions.	49
	33. Providing motivational feedback is essential.	4, 9, 70
	34. Social robots can assist users in forming and maintaining good habits based on users' preferences and goals.	6, 24, 71
	35. Social robots support users by providing thoughtful and helpful advice on challenging decision-making issues.	11, 72
Sacrifice (SAC)	11. Ensure no personal information is leaked from conversations and activities with social robots.	4, 74
	12. The microphones installed in social robots must not pose a privacy threat to users.	4
	13. Social robots must ensure that the cameras installed do not inadvertently disclose users' appearances.	4
	14. The price of social robots must be competitive with other comparable technology products.	73
	15. There should be no additional fees for their use beyond the initial purchase price.	73
	16. Social robots' usage should be intuitive and user- friendly.	73
	17. Simple and user-friendly maintenance procedures are a critical requirement.	73
	18. The ability to self-charge is a necessary feature.	62, 73

* =Reserved Negative Question

- Cognitive Intelligence: This dimension relates to the robot's capacity for information processing, learning, and adaptive behavior. It includes the ability to provide meaningful information, personalize interactions, adapt communication styles, remember past conversations, and engage in diverse and innovative ways. The focus is on creating robots that can think, learn, and respond intelligently to user needs and environmental changes.
- Compliance to Robot's Suggestions: This dimension refers to the robot's ability to provide guidance, feedback, and support that users are likely to follow. It includes offering positive and motivational feedback, proactive suggestions, assistance in habit formation, and support in decision-making. The goal is to create robots that can effectively influence and assist users in beneficial ways.
- Sacrifice: This dimension encompasses the trade-offs or concessions users must make to interact with social robots. It includes considerations of privacy (ensuring personal information, conversations, and appearances are protected), cost-effectiveness (competitive pricing and no hidden fees), and ease of use (intuitive operation and simple maintenance). This dimension acknowledges that adopting social robot technology may require users to sacrifice certain aspects of privacy, finances, or convenience, and aims to minimize these sacrifices.

2) P-SAMPLE (Q-SORTER) SELECTION

The study involved a diverse group of 31 participants with varying levels of familiarity and experience with social robots. The participant pool consisted of 16 males and 15 females, with a wide age range represented, including one teenager, 20 individuals in their 20s, 4 in their 30s, 2 in their 40s, and 4 in their 50s. For the involvement of the teenager participant, we obtained proper parental consent.

To account for the potential influence of prior exposure and knowledge about social robots, we categorized the participants into three levels of indirect experience:

Level 1: Individuals with more than 2 years of research experience related to social robots or human-robot interaction.

Level 2: Individuals with at least one semester of coursework related to social robots or human-robot interaction.

Level 3: Individuals with less than one day of exposure or coursework related to social robots or human-robot interaction.

This categorization allowed us to capture perspectives from participants with varying levels of familiarity and expertise, ranging from those with extensive research experience to those with minimal prior exposure. Furthermore, to ensure a common baseline understanding, we provided all participants with a comprehensive overview of social robots' various uses, functions, and typical human-robot interaction dynamics in different environments such as healthcare, education, and personal assistance. This overview included visual aids such as images and videos to facilitate a shared context before the participants engaged in the subjective categorization task.

Detailed information about each participant such as age, gender and indirect experience level is provided in Table 6 in the 4. Data Analysis Result chapter later.

B. EXPERIMENTAL PROCEDURES (Q-SORTING)

This experiment was designed to measure subjective opinions about a new technology in an online environment. In places with multiple computers, participants took part in the experiment simultaneously in groups. Conversely, in locations where only a single computer was available, this experiment was conducted sequentially with individual participants.

The experimental procedures are as follows: Participants find a set of 37 statements and a Q-sorting frame on a collaborative online whiteboard application among the various experiment sets, which are copied as many times as there are participants. Then they were asked to approach the area with their name on it, read the statements on the poster, and force-distribute them into the Q-sorting frame according to their subjective perceived importance. The Q-scale array frame is in the form of a normal distribution with nine scales ranging from −4 (strongly disagree) to +4 (strongly agree), and the forced-distribution is in an inverted pyramid grid as shown in the Figure 1. The 37 statements were assigned two to −4 and +4, three to −3 and +3, four to -2 and +2, six to −1 and +1, and seven to zero. After the participants completed their assignments, the researcher looked at the assigned statements and asked them questions about the importance of the statements to ensure their understanding of the statements and to check their assignments. Participants who completed the experiment were rewarded with a $10 gift.

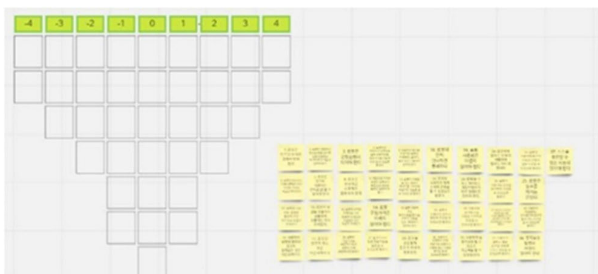


FIGURE 1. Fixed quasi-normal distribution and 27 statements in this study on the collaborative online whiteboard platform.

C. DATA ANALYSIS METHOD

This study was analyzed using Ken-Q Analysis, an open-source program dedicated to Q-methodology analysis. Using Principal Component Factor analysis and Varimax rotation, we calculated four factors that explain 70% of the total users based on an Eigenvalue of 1.00 or higher, communality of factors and specificity of each type. Before describing the four Niches, we found statements that participants commonly agreed as requirements for social robots to become more friendly to users base on Z-score values. Z-score is a statistical measurement that explains the relationship between a value and the mean of a group of values. A Z-score of 1.0 indicate that it is one standard deviation from the mean and negative score indicates that it is below the mean. Based on the Z-score, we examined the statements with low variance, indicating little difference in opinions, and high variance, indicating significant differences in opinions. Next, we examined the characteristics of each of the four niches, compared the Z- scores to see which statements are distinguished from the others, and which statements are important to each niche.

To help understand the distinction among the four niches, five features (physical / psychological anthropomorphism, cognitive intelligence, user's compliance, and sacrifice) by inserting graphs, illustrations, and persona techniques to help compare the characteristics.

IV. DATA ANALYSIS RESULTS

As a result of analyzing according to the Q-methodology guidelines, we extracted seven factors from 31 P-samples, each with an eigenvalue exceeding 1. The four most distinctly differing factors, ordered by descending eigenvalues, accounted for 64% of the overall variance. Each factor was named N1, N2, N3 and N4, respectively, and "N" is an abbreviation for "Niche". In each niche, 8, 8, 10, and 5 people are placed and 8, 6, 10, and 3 are selected. The total number of P-sample, Average Relative Coefficient, Composite Reliability, Standard Errors of Niche Z-scores, Eigenvalues, Variance, Explained Cumulative variance can be found in Table 4. Table 5 presents the correlations between the niches, showing that N1, N3, and N4 have correlations around 0.5, while N2 shows a clearer difference with correlations below 0.39. Table 6 displays the factor loading values of each participant in each niche. It also shows participants' prior experience with social robots, gender, age and indirect experience level. The asterisks (*) in the table indicate defining sorts that were flagged based on their significant loading on a particular factor. However we only found age to be different between the groups: N2 had a significantly higher average age. The higher the factor loading value, the more it represents the

TABLE 4. Q-sort cumulative communalities matrix.

	Factor 1	Factor 2	Factor 3	Factor 4
No. of P-sample	8	6	10	3
Avg. Rel. Coef.	0.8	0.8	0.8	0.8
Composite Reliability	0.970	0.960	0.976	0.923
S.E. of Factor Z-scores	0.173	0.2	0.155	0.277
Eigenvalues	6.080	5.732	4.666	3.478
Variance (%)	41	12	6	5
Cumulative Variance (%)	41	53	59	64

TABLE 5. Factor score correlations.

	Factor 1	Factor 2	Factor 3	Factor 4
Factor 1	1			
Factor 2	0.1152	1		
Factor 3	0.6477	0.3871	1	
Factor 4	0.5644	0.1328	0.5962	1

TABLE 6. Participant demographics and factor loadings.

No.	P No.	Age	Gender	Experience Level	N1	N2	N3	N4
1	P19	30	M	2	0.8396*	0.0427	0.1682	0.024
2	P26	24	F	2	0.7655*	0.0025	0.2316	0.2537
3	P9	26	F	2	0.7021*	0.1529	0.378	0.218
4	P11	23	F	2	0.6624*	-0.1494	0.0798	0.3189
5	P14	23	M	2	0.6267*	0.0282	0.5445	0.2115
6	P5	25	F	2	0.6135*	0.2592	0.1378	0.3688
7	P2	29	M	1	0.5637*	-0.0709	0.4761	0.1752
8	P27	42	F	3	0.4964*	0.088	0.0015	0.3989
9	P22	41	F	1	-0.2332	0.8357*	0.0669	0.032
10	P32	26	F	3	-0.0612	0.7318*	0.3042	0.2662
11	P7	24	M	2	0.2058	0.7305*	-0.1996	-0.0684
12	P23	52	M	2	-0.1488	0.7071*	0.2424	0.0227
13	P24	50	M	2	0.3408	0.6938*	0.3298	-0.2878
14	P21	25	M	1	0.3837	0.5686	0.242	0.4186
15	P16	21	M	2	0.4985	0.5067	0.3059	0.1548
16	P29	52	F	3	0.1272	0.4442*	0.1701	0.2301
17	P13	20	F	2	0.103	0.1129	0.7527*	0.3694
18	P10	21	F	2	0.3585	0.2743	0.7176*	0.1996
19	P3	25	M	1	0.3037	0.294	0.7139*	0.0217
20	P6	23	M	2	-0.1424	0.2593	0.6799*	0.2202
21	P25	21	F	2	0.2359	0.2779	0.6770*	0.2257
22	P17	20	F	2	0.4505	0.3913	0.6188*	0.109
23	P20	30	M	2	0.5139	0.2687	0.6054*	0.0239
24	P15	20	F	2	0.4848	-0.2611	0.5992*	0.0146
25	P12	22	M	2	0.2009	0.0447	0.5877*	0.4732
26	P28	55	M	3	0.2386	0.101	0.5530*	0.262
27	P4	25	M	2	0.2764	0.0007	0.2012	0.7714*
28	P18	39	F	2	0.2807	0.379	0.2516	0.6407*
29	P30	14	M	3	0.1639	-0.2116	0.4115	0.5869*
30	P8	23	M	2	0.3965	0.2637	0.3504	0.5325
31	P31	31	F	3	0.2817	0.359	0.3944	0.5154

* = defining sorts flagged

characteristics of that niche. Finally, VI displays each participant's demographics and factor loadings.

A. CONSENT AND DISSENT STATEMENTS

The purpose of this experiment is to identify user expectations for social robots in the early stages of commercialization. First, we examined the statements that participants generally agreed or disagreed with in order to identify the characteristics that robots should have as a basic requirement and those that require further research. Table 7 consists of statements with a z-score variance of 0.1 or less, indicating that they are statements on which participants mostly agree.

First, many participants rated the importance of playing frequently updated games with social robots and physical exercise as low or negative, as evidenced by a score of 0 or −1 (S23, S22) for emotional bonding and engagement. They paid little attention to the robot's communication style (S26) and expressed the belief that social robots should surpass humans in communication with personal and satisfying responses (S20). They also disagreed that it is important for robots to speak in a natural human voice (S6) and were not interested in the idea that personalization could potentially violate users' privacy and autonomy (S16). In terms of sacrifice, they expressed neutrality towards paying additional fees for data transmission and content (S15), but favored the idea that low maintenance effort is desirable (S15, Z-score variance 0.088).

On the other hand, Table 8 contains highly controversial statements, all of which belong to the sacrifice group. While participants in N4 are willing to pay as little as possible, participants in N1 think that price is not the main issue (S14). The other three highly controversial statements relate to privacy issues: the risks of illegal filming (S13), illegal wiretapping (S12), and personal information (S11) are more of a concern for participants in Niches 1, 3, and 4 than for those in Niche 2.

B. FORMATION OF NICHES

To identify the characteristics of each statement, the Z- score values of each statement were summed by group, and reverse coding was applied to statements 16, 17, 18, 20, 25, and 27 to ensure that high values flowed in the same direction. The Q-sort experiment we designed allowed scores ranging from −4 to +4 for each statement, with 2 statements receiving scores of −4 and 4, 3 statements receiving scores of −3 and 3, 4 statements receiving scores of −2 and 2, 6 statements receiving scores of −1 and 1, and 7 statements receiving a score of 0. Each group consisted of 5 to 10 questions. The average values of the statements in each group for each niche ranged from −0.46 to 1.176 in this experiment, and these values were converted to positive values by taking the absolute value. The group scores obtained for each niche were then calculated as percentages and presented in Table 9 and Figure 2.

Our in-depth analysis of user expectations for social robots, categorized into distinct niches, reveals varied preferences based on five key constructs: Physical Anthropomorphism, Psychological Anthropomorphism, Cognitive Intelligence, Compliance, and Sacrifice.

Physical Anthropomorphism: Across the board, this factor is deemed least important, with its significance occupying under 16% in overall importance. This is particularly evident in Niche 2 (N2), where it is overshadowed by psychological aspects.

TABLE 7. Consent statements and factor scores (Z-score variance below 0.1).

Q-Statements	Group	Factor 1	Factor 2	Factor 3	Factor 4	Z-score variance
23. Frequent updates to fun game content can enhance emotional bonding and engagement with social robots. *	INT	0	-1	-1	-1	0.013
26. Social robots need to command adaptive and nuanced communication styles. **	INT	0	-1	0	0	0.022
20. Social robots should surpass humans in communication with personal and satisfactory responses. *	PSY	1	0	1	2	0.035
6. Human-like voices are crucial for social robots to sound natural, not machine-generated. *	PHY	0	-1	-1	-2	0.049
15. There should be noadditional fees for their use beyond the initial purchase price.	SAC	-1	0	0	0	0.077
22. Incorporating physical exercise into human-robot interactions can increase user engagement and motivation. *	INT	0	1	0	0	0.086
36. Simple and user-friendly maintenance procedures are a critical requirement.	SAC	1	1	3	2	0.088
16^{R}. Personalizing social robots with clear user consent is necessary not to violate users' privacy and autonomy.	INT	-3	-2	-4	-4	0.098

*$p < 0.01$, **$p < 0.05$

TABLE 8. Dissent statements and factor scores (Z-score variance above 1.0).

Q-Statements	Group	Factor 1	Factor 2	Factor 3	Factor 4	Z-score variance
14. The price of social robots must be competitive with other comparable technology products.	SAC	-3	-1	0	4	1.13
13. Social robots must ensurethat the cameras installed do not inadvertently disclose users' appearances.	SAC	3	-2	2	3	1.276
12. The microphones installedin social robots must not pose a privacy threat to users.	SAC	3	-3	2	1	1.398
11. Ensure no personal information is leaked from conversations and activities with social robots.	SAC	4	-3	2	1	1.473

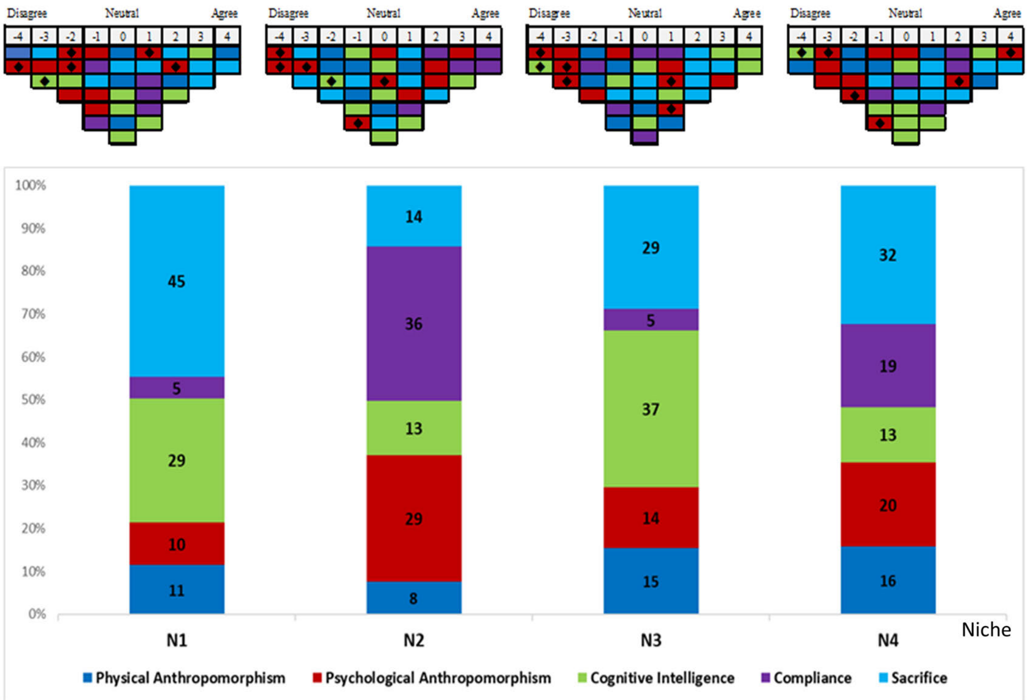


FIGURE 2. Participant's perceived proportions by 5 constructs within each niche.

TABLE 9. The absolute and proportion value of Z-score means by group and niche.

	Mean |Z-score|				Proportion (%)			
	N1	N2	N3	N4	N1	N2	N3	N4
Physical Anthropomorphism	0.15	0.25	0.36	0.32	11	8	15	16
Psychological Anthropomorphism	0.13	0.96	0.33	0.39	10	29	14	20
Intelligence	0.38	0.41	0.84	0.26	29	13	37	13
Compliance	0.06	1.18	0.12	0.39	5	36	5	19
Sacrifice	0.58	0.46	0.67	0.65	45	14	29	32
Sum	1.30	3.26	2.30	2.00	100	100	100	100

Psychological Anthropomorphism: N2 distinctively prioritizes this aspect, aligning robots closely with human- like characteristics. Conversely, Niches 1 (N1) and 3 (N3) demonstrate a moderate interest in this area, with N3 placing slightly higher emphasis compared to N1.

Cognitive Intelligence: N3 and N1 stand out for its high valuation of a robot's cognitive intelligence, differentiating it from N2 and N4, which place least importance on this attribute within this construct.

Compliance: This is a predominant concern in N2, which sets it apart from other niches. N4 also, in comparison to other constructs, attributes relatively high importance to compliance. N1 and N3 exhibit the lowest emphasis on compliance.

Sacrifice: N3 and N4 exhibit a stronger inclination towards sacrifice, with N1 experiencing the highest burden in this regard. Niche 2, in contrast, places minimal emphasis on this construct, reflecting its unique stance within the spectrum of user expectations.

Overall, N2 stands out from its counterparts in its strong emphasis on compliance and viewing robots as similar to humans. At the other end of the spectrum, N1 shows a greater readiness to embrace monetary sacrifice, while being highly concerned with privacy and less concerned with compliance. N3 reflects lower compliance but with an expectation of robot's high cognitive intelligence and emotional intelligence. Participants in Niche 4 demonstrate receptiveness to robot suggestions, although robots are still regarded as a machine and have interests in other constructs around. Further comparative analysis can be found in Table 10.

The niches are aptly named to reflect these traits: Niche 1 as "Robot as a Burdensome Machine for Information," Niche 2 as "Robot as a Trusted Friend," Niche 3 as "Robot as a Smart Device for Social Engagement," and Niche 4 as "Robot as an Energizing Gadget." More detailed preferences of each niche will be elaborated in the subsequent sections (4.2.1 to 4.2.4).

Additionally, Appendix contains persona representations of the four types of personas derived these results. Each persona is directly derived from the four consumer types identified through Q-sorting analysis, embodying each type's key characteristics, preferences, and attitudes. These personas offer a more tangible and relatable representation of Q-methodology's statistical insights, helping readers envision

TABLE 10. Comparative analysis of user perception across N1 to N4.

Comparative Analysis of User Perception Across N1 to N4Characteristic	Niche 1: "Robot as a Burdensome Machine"	Niche 2: "Robot as a Trusted Friend"	Niche 3: "Robot as an Emotionally Intelligent Device"	Niche 4: "Robot as an Energizing Gadget"
Primary Perception	Complex and overwhelming	Reliable companions providing emotional support	Advanced interactive technology with emotion-sensing technology	Efficient and practical system to boost user's performance.
Expectation of Humanness	Low	High	Low	Low
Expectation of Intelligence	High	Low	High	Low
Compliance	Low	High	Low	Moderate
Sacrifice	High	Low	Moderate	High
Usage Pattern	Limited, mostly for necessity	Frequent, integrated into daily life	When needed for emotional support	Regularly to maintain efficiency
Emotional Response	Anxiety or reserved	Trust and comfort	Indifferent	Detached.
Attitude towards payment	Price-tolerant	Payment-ready	Cost-benefit focused	Cost-averse
Technological Aptitude	Low to moderate	Moderate to high	High	Very high
Privacy Concerns	High	Low	Moderate	Moderate
Representative Quote	"These devices are too complicated for me."	"My robot is like a reliable friend."	"My robot has to care about my feelings."	"I love exploring all the new features, if is not expensive!"

how the identified consumer types might manifest in real-world scenarios. Lastly, by translating statistical data into narrative personas, we provide a valuable tool for researchers, designers, and marketers to better understand and apply the research findings in practical contexts.

1) NICHE 1: ROBOTS AS A BURDENSOMEMACHINE FOR INFORMATION(N1)

Participants in Niche 1 (N1) exhibit a distinct perspective on the role of robots in facilitating a more effortless lifestyle, underscored by a marked willingness to embrace sacrifice. This group anticipates that robots will streamline their daily routines with minimal exertion in terms of learning, interaction or protection. For example, they express a preference for robots proficient in human language (S7), capable of fulfilling personalized demands (S16), and user-friendly (S19), all while maintaining stringent privacy controls (S11, S12, and S13).

Perceiving robots as an evolution of stationary computing technology, N1 users demonstrate a readiness to incur higher costs, if necessary (S14), prioritizing the delivery of reliable and valuable data (S10). They deem error-free performance (S25) as crucial, whereas the enjoyment of pragmatic interactions with robots (S27) is deemed superfluous.

N1 users' focus on simplifying life through robotic assistance correlates with a lack of interest in forming meaningful relationships with robots. They harbor no expectations of human-like interactions (S1) or intimate gestures such as soft touches (S21). Instead, they prefer interactions where robots are treated respectfully, free from teasing or aggression (S28).

Given that N1 represents 42% of the study participants, their pronounced concerns regarding privacy emerge as a critical factor. There is apprehension about the recording of data via microphones or cameras and the potential exposure of personal information, including interaction logs. Tables 11 and 12 provide further insight, with Table 11 outlining statements that confirm N1's position and Table 12 outlining statements that differentiate this niche from others.

2) NICHE 2: ROBOTS AS A TRUSTED FRIEND (N2)

Participants in Niche 2 (N2) favored having friendships with robots (S17). They display a pronounced willingness to collaborate with robots in areas of decision-making and emotional connection. They exhibit a preference for robots that provide insightful advice on complex decisions (S35), proactive and mood-responsive suggestions (S32), and emotionally attuned responses (S24). This preference stems from their interest in a shared mental and emotional experience with robots. Consequently, they place less emphasis on receiving cognitively valuable or unbiased information from robots (S10). Concerns regarding the infringement of privacy and autonomy due to personalized interactions (S16)

TABLE 11. Statements that support niche 1 most and least.

Q-Statements	Z-score	N1	N2	N3	N4
7. Human language proficiency is essential for social robots to communicate effectively. [d]	1.847	4	1	1	1
11. Ensure no personal information is leaked from conversations and activities with social robots. [d]	1.701	4	-3	2	1
10. Meaningful information from reliable,objective data is desirable in social robots.	1.612	3	0	4	3
12. The microphones installed in social robots must not pose a privacy threat to users.	1.422	3	-3	2	1
13. Social robots must ensure that thecameras installed do not inadvertently disclose users' appearances.	1.284	3	-2	2	3
19. Social robots' usage should be intuitiveand user-friendly.	1.098	2	2	2	-1
25. Social robots should not make mistakes. [d]	1.068	2	-1	1	4
14. The price of social robots must becompetitive with other comparable technology products. [d]	-1.025	-3	-1	0	4
21. Social robots initiating touch with userscan enhance feelings of closeness.	-1.071	-3	1	-2	-3
16. Personalizing social robots with clear user consent is necessary not to violate users' privacy and autonomy.	-1.697	-3	-2	-4	-4
1. Social robots require human-likeappearance.	-1.884	-4	-2	-2	-4
28. Social robots respond humorously toteasing.	-2.332	-4	-4	-3	-1

[d] denotes distinguishing statement

TABLE 12. Other distinguishing statements for niche 1 and its Q-SV.

Q-Statements	Z-score	N1	N2	N3	N4
2. Biomimetic social robots must move likethe real organism. *	0.943	2	0	-2	-2
5. Compelling stories about social robots'history, origin, and everyday life are necessary for user interest. *	-0.352	-1	0	-3	-3
4. Social robots should display distinct personalities and reactions in similar situations.	-0.516	-1	2	1	0
17. Re-evaluate the ethics of befriendingsocial robots.	-0.709	-2	-4	-4	-3

* $p < 0.01$

are notably minimal within this group. Moreover, they do not anticipate risks associated with personal data breaches, including interaction history (S11) or unintended information leaks from robot-mounted cameras (S13) and microphones (S12). This niche is characterized by a factor score correlation below 0.387, indicating distinct preferences and perceptions.

Participants in Niche 2 (N2) also show a lack of preference for the physical attributes of robots, such as soft or warm surfaces that convey friendliness (S9), but rather prefer robots that initiate greetings (S18). This may be due to an already established positive relationship with robots.

Other distinguishing features of N2 include a high valuation of robot's emotional expressions (S3), a positive view of initial robot-initiated touch for intimacy (S21), and an openness to learning about the robot's story like individual history, background, and daily experiences (S5). Tables 13 and 14 present statements that corroborate and differentiate N2's distinct profile, respectively.

3) NICHE 3: ROBOTS AS AN EMOTIONALLY INTELLIGENT DEVICES (N3)

Participants in Niche 3 see robots primarily as intelligent devices, with a focus on enhanced interaction through social engagement features. Their expectations focus on user's convenience, rather than on forming an intimate relationship with robots to or being positively influenced by the robots.

One of the key capabilities that N3 participants expect robots to have is the ability to provide unbiased, reliable, and valuable information (S10). Robots' ability to utilize past conversation data (S30) to tailor information more accurately to the user and minimize redundancy is crucial. As a function to enhance user's emotional satisfaction, they favor if robots initiate greetings (S18) and expect robots to competently detect and respond to their words, actions (S29), and emotions (S24).

In contrast, N3 participants show a marked indifference towards robot's own life story (S5), emotional expressions (S3), and physical appearance (S1). This extends to physical contact, as there is no significant desire to use touch as a means of establishing closeness with the robot (S21). Additionally, N3 participants are notably less concerned about the potential influence of robots on their decisions or lifestyle compared to other niches. Meanwhile, N3 values the concept of sacrifice, expecting reasonable pricing (S14), straightforward maintenance (S36), and private issues like camera designs that safeguard against unintentional exposure of user images (S13). Despite these utilitarian views, they maintain a positive stance towards the robot, deeming

TABLE 13. Statements that support niche 2 most and least.

Q-Statements	Z-score	N1	N2	N3	N4
35. Social robots support users by providing thoughtful and helpful advice on challenging decision-making issues. [d]	1.784	1	4	0	1
32. Social robots provide proactive and mood-adaptive suggestions. [d]	1.776	-1	4	0	0
24. Social robots' ability to detect and respond to user emotions is desirable.	1.602	-1	3	3	-1
16. Personalizing social robots with clear user consent is necessary not to violate users' privacy and autonomy.	-1.26	-3	-2	-4	-4
13. Social robots must ensure that thecameras installed do not inadvertently disclose users' appearances. [d]	-1.413	3	-2	2	3
11. Ensure no personal information is leaked from conversations and activities with social robots. [d]	-1.556	4	-3	2	1
18. Designing social robots to initiategreetings first is not good idea.	-1.6	-2	-3	-3	-2
12. The microphones installed in social robots must not pose a privacy threat to users	-1.643	3	-3	2	1
28. Social robots respond humorously toteasing.	-1.843	-4	-4	-3	-1
17. Re-evaluate the ethics of befriendingsocial robots.	-1.961	-2	-4	-4	-3
28. Social robots respond humorously toteasing.	-2.332	-4	-4	-3	-1

[d] denotes distinguishing statement

that robots can be a friend (S17). They advocate respectful treatment of the robot, opposing any enjoyment derived from tormenting it (S28), and perceive personalization as non-intrusive to privacy and autonomy (S16). For a comprehensive understanding, Table 15 presents statements reinforcing N3's viewpoints, while Table 16 highlights the distinguishing features of this niche.

4) NICHE 4: ROBOTS AS AN ENERGIZING GADGET (N4)

Participants in Niche 4 (N4) view robots as efficient systems designed to keep them motivated (S33) by providing valuable information (S10) in human language (S7) at a reasonable cost (S14), with an emphasis on error- free performance (S25). A notable distinction of Niche 4, in contrast to Niche 2, is their desire for emotional and motivational support from robots without anthropomorphizing them. This group even had the most doubts about the ethics of being friends with robots (S17) and preferred robots with machine-like voices (S6) to human-like ones. Therefore, they do not expect robots to look like humans (S1), initiate intimate physical contact, such as light touches (S21), have robots' personal stories (S5). However, they are opened to greetings initiated by robots (S18) and tailored interactions to user's preferences (S16). Additionally, this group preferred for robots with soft, warm surfaces (S9) and the capability for self- charging (S37).

Tables 17 and 18 provide further details, with Table 17 highlighting statements supporting the characteristics of Niche 4, and Table 18 focusing on statements that differentiate this group.

TABLE 14. Other distinguishing statements for niche 2 and its Q-SV.

Q-Statements	Z-score	N1	N2	N3	N4
2. Biomimetic social robots must move likethe real organism. *	0.943	2	0	-2	-2
5. Compelling stories about social robots'history, origin, and everyday life are necessary for user interest. *	-0.352	-1	0	-3	-3
4. Social robots should display distinctpersonalities and reactions in similar situations.	-0.516	-1	2	1	0
17. Re-evaluate the ethics of befriendingsocial robots.	-0.709	-2	-4	-4	-3

* $p < 0.01$

V. DISCUSSION

This study has taken a novel approach to understanding user expectations of social robots, which are anticipated for imminent commercialization. Current research primarily focuses on features, design aesthetics, the degree of anthropomorphism, and user concerns to enhance end-user adoption. However, as suggested by Mettler [17], employing diverse methodologies is crucial for introducing new technologies. In response, we utilized Q-Methodology to compile and analyze 37 statements that reflect user satisfaction and the discrepancies related to social robots, gathered through literature reviews and interviews. Our findings reveal four distinct expectation patterns, showcasing a diverse range of user priorities and challenging the traditional view of companion robots as mere friends.

In addition to Q-methodology, other methods such as Conjoint Analysis, Multidimensional Scaling (MDS), and Structured Qualitative Analysis can be used to segment markets based on the numerical measurement and

TABLE 15. Statements that support niche 3 most and least.

Q-Statements	Z-score	N1	N2	N3	N4
30. Social robots remember the pastconversations and respond. [d]	1.448	1	0	4	0
10. Meaningful information from reliable,objective data is desirable in social robots.	1.434	3	0	4	3
29. Social robots respond to user behavior and words for effective engagement.	1.288	2	3	3	0
36. Simple and user-friendly maintenance procedures are a critical requirement.	1.267	1	1	3	2
24. Social robots' ability to detect and respond to user emotions is desirable.	1.208	-1	3	3	-1
13. Social robots must ensure that thecameras installed do not inadvertently disclose users' appearances.	1.059	3	-2	2	3
1. Social robots require human-likeappearance.	-1.136	-4	-2	-2	-4
21. Social robots initiating touch with users can enhance feelings of closeness.	-1.233	-3	1	-2	-3
5. Compelling stories about social robots'history, origin, and everyday life are necessary for user interest.	-1.357	-1	0	-3	-3
28. Social robots respond humorously toteasing.	-1.533	-4	-4	-3	-1
18. Designing social robots to initiategreetings first is not good idea.	-1.617	-2	-3	-3	-2
17. Re-evaluate the ethics of befriendingsocial robots.	-2.032	-2	-4	-4	-3
16. Personalizing social robots with clear user consent is necessary not to violate users' privacy and autonomy.	-2.127	-3	-2	-4	-4

[d] denotes distinguishing statement

analysis of subjective trends across multiple variables. However, Q-methodology can be used to quantitatively measure respondents' subjective views on 30-50 variables, as each of the 30-50 selected statements can cover a new variable, allowing researchers to understand which variables are relatively important to users across a range of variables without burdening participants with processing the information. Based on these measurements, researchers can cluster opinions and segment markets. Additionally, this method reveals which opinions are widely shared across a market and which are more likely to provoke disagreement.

TABLE 16. Other distinguishing statements for niche 3 and its Q-SV.

Q-Statements	Z-score	N1	N2	N3	N4
25. Social robots should not make mistakes.	0.570	2	-1	1	4
14. The price of social robots must be competitive with other comparable technology products.	0.301	-3	-1	0	4
3. The ability to express emotions is crucial.	-0.106	-2	2	-1	-2
34. Social robots can assist users in forming and maintaining good habits based on users' preferences and goals. *	-0.681	1	1	-1	2

* $p < 0.01$

Participants scored each statement based on its perceived importance, and we conducted the Q-sorting analysis software KADE. This facilitated a robust quantitative analysis, allowing us to identify crucial features and distinguish four distinct consumer types: a burdensome machine, a trusted friend, an emotionally intelligent device, and an energizing gadget. Each group's specific preferences for various characteristics of social robots were also detailed.

Furthermore, we introduced a comprehensive methodological framework for analyzing social robots from five perspectives: physical and psychological anthropomorphism, cognitive intelligence, user compliance willingness, and sacrifice. In this framework, 'cognitive intelligence' is redefined from its general biological context—typically associated with the ability to process information and perform tasks—to the artificial capacity of robots to emulate human-like cognitive abilities for more satisfying user interactions. Similarly, 'compliance' here does not relate to the robot's adherence to regulations but to the user's willingness to follow the robot's recommendations [79].

This study confirmed the diverse needs and perspectives that users have toward social robots. While the majority, as seen in types 1, 3, and 4, desire the practical functions and services of robots, there are also users who value emotional bonding and rapport, as observed in type 2, 'Trusted Friend.' Furthermore, just as in the field of chatbots, where the initial focus was on practical conversational capabilities, but emotion recognition and empathy became major tasks in the later stages of development, we can anticipate that more people will expect to engage in emotional dialogues with robots in the future.

The participants that expected practical abilities from robots (type 1, 3, and 4) viewed sacrifices as the most significant concern. To mitigate these sacrifices mentioned in the study, we propose customization, pricing, and educational strategies.

Our finding allows for customizing the social robot's interaction mode to cater to different user types and individual

TABLE 17. Other distinguishing statements for niche 4 and its Q-SV.

Q-Statements	Z-score	N1	N2	N3	N4
25. Social robots should not make mistakes. [d]	2.115	2	-1	1	4
14. The price of social robots must be competitive with other comparable technology products. [d]	1.856	-3	-1	0	4
10. Meaningful information from reliable, objective data is desirable in social robots.	1.397	3	0	4	3
13. Social robots must ensure that the cameras installed do not inadvertently disclose users' appearances.	1.223	3	-2	2	3
9. Smooth, warm surfaces are preferred for social robots.[d]	1.212	0	-1	0	3
33. Providing motivational feedback is essential.	1.138	-1	3	-2	2
18. Designing social robots to initiate greetings first is not good idea.	-1.332	-2	-3	-3	0
17. Re-evaluate the ethics of befriending social robots.	-1.332	-2	-4	-4	-1
21. Social Robots initiating touch with users can enhance feelings of closeness	-1.428	-3	-1	-2	-2
5. Compelling stories about social robots' history, origin, and everyday life are necessary for user interest.	-1.439	-1	0	-3	-3
16. Personalizing social robots with clear user consent is necessary not to violate users' privacy and autonomy.	-1.534	-3	-2	-4	-2
1. Social robots require human-like appearance.	-2.046	-4	-2	-2	-4

[d] = distinguishing statement

preferences through various approaches. Firstly, users can directly set their preferences. Among the four user types presented in this study (the burdensome machine, friend, new technology, and wellbeing toy), users can select the type that best suits them, and the robot's interaction mode will be customized accordingly. Secondly, the system can automatically optimize based on monitoring user responses and employing algorithms. For instance, if a user gradually expresses more emotions, the robot can recognize this and transition to a more emotionally-focused dialogue style. Conversely, if the user demands factual information, the robot can shift to a more information-based interaction mode. Furthermore, for more granular customization, specific aspects of the robot's personality, conversational style, and other attributes can be adjusted

TABLE 18. Other distinguishing statements for niche 4 and its Q-SV.

Q-Statements	Z-score	N1	N2	N3	N4
29. Social robots respond to user behavior and words for effective engagement.	0	2	3	3	0
31. Social robots provide positive feedback that makes users feel uplifted.	-0.376	1	2	1	-1
19. Social robots' usage should be intuitive and user-friendly. *	-0.376	2	2	2	-1
28. Social robots respond humorously to teasing. *	-0.454	-4	-4	-3	-1

* $p < 0.01$

within each user type. For users oriented toward interpersonal relationships, the robot could exhibit a friendly, cheerful personality akin to a friend. For more introverted users, the robot could adopt a calm yet positive demeanor. By leveraging these various customization approaches – direct user settings, automatic optimization, and fine-tuned adjustments – the system can provide an optimal user experience tailored to individual needs.

Our survey revealed that most users have an open attitude toward paying additional service fees for social robots. Therefore, an effective strategy would be to launch the device itself at a relatively affordable price to lower the barrier to purchase, while introducing a subscription service model. This would enable companies to secure a stable revenue stream, allowing for continuous service provision and updates, gradually offering users an increasingly advanced intelligent robot experience and satisfaction. Additionally, we could adopt an approach similar to smartphones, where the robot's base design is kept simple, but users can personalize its appearance through various accessories such as clothing, hats, and headbands. This would reduce costs associated with exterior design, enabling a lower price point for the robot itself, while satisfying users' diverse preferences and fostering the growth of a related ecosystem.

User education and training may play a vital role not only in enhancing experiences with social robots but also in reducing the sacrifices mentioned in this study due to the learning process. For participants aged 20-40 like in this experiment, much of this education and training can be delivered via video-sharing platform, and sharing user reviews and experiences through such platform will be highly encouraged. Involving users from the product development stage may greatly improve customer experience, and creating local communities for robot users, similar to those for dog owners, can foster social bonds and shared experiences. User education and training for robots are particularly effective for vulnerable groups. In South Korea, the elderly care robot Hyodol, which holds the highest market share, provides continuous education and support through regular visits by social workers to support to ensure continuous usage [80]. In addition to education, social events also play a crucial role. When the robots are delivered, an 80-year-old elderly user living alone is given a special experience by standing on a stage and receiving big applause from a large audience. This ceremony aims to enhance the user's engagement, satisfaction, and compliance with using the robot. These the special moments increase user's interaction between users and robots, satisfaction and compliance. In addition, to increase user satisfaction and extend the product life cycle, it is essential not to simply stop at launching the product, but to continually improve and update it. To this end, robot maker's willingness to listen to user feedback and closely monitor market trends in order to respond quickly. In light of our findings, we propose several design recommendations and market strategies tailored to each identified niche. These practical implications aim to bridge the gap between our research outcomes and real-world applications in the social robotics industry.

For Niche 1, characterized as "Burdensome Machine," we recommend focusing on simplifying user interfaces and minimalize physical design to reduce perceived complexity. This could involve implementing intuitive controls and clear, step-by-step guidance features. Implementing camera designs and robust data encryption that prioritize user privacy is essential. From a marketing perspective, busy users seeking to optimize their daily routines would be the target users. Positioning the robot as highly efficient tool for simplifying daily life and timesaving, emphasizing ease of use and low maintenance requirements could appeal to those hesitant about technology adoption. Collaborations with cybersecurity firms could be beneficial in certifying and promoting the robot's data protection capabilities. Implementing advanced error checking and self-correcting mechanisms to ensure near-perfect performance and context-aware information filtering to deliver only relevant information is necessary because Niche 1 is less tolerant of imperfection than any other group. This Niche is willing to pay premium prices for high functionality.

Niche 2, the "Trusted Friend" segment, calls for robust conversational abilities coupled with empathetic responses. This niche requires the development of features that provide helpful advice, proactive suggestions, and emotionally intelligent interactions. To cater to this segment, robots should be designed with enhanced empathy abilities, enabling them to offer personalized support that contributes to users' well-being and happiness. Implementing features that facilitate intimate, initiative-taking interactions and customized responses could be particularly effective in creating a sense of companionship. The goal is to develop a robot that not only assists in daily tasks but also enriches the user's life through wise counsel and empathetic engagement, ultimately fostering a trusted, friend-like relationship between the user and the robot. Marketing strategies for this niche should highlight the robot's companionship aspects and its ability to provide emotional support, potentially focusing on applications in eldercare, single-person households, and mental health support.

For Niche 3, "Emotionally Intelligent Devices," we suggest prioritizing intelligent interaction and practical functionality over emotional companion, as users first want an intelligent robot that provides unbiased, reliable, accurate, and valuable information. Although it is an important function to recognize and respond to users' verbal and non-verbal cues, users in Niche 3 do not allow for deep emotional attachment. Physical appearance is not a concern for this group, while camera designs and robust data encryption that prioritize user privacy and a user-friendly interface that facilitates easy maintenance and operation must be helpful. For effective penetration, pricing strategies such as flexible payment options to improve accessibility are promising, as value for money is very important to users in N3.

Finally, for Niche 4, the "Energizing Gadget" segment, we suggest creating sleek, modern designs with customizable features. Since, like the other group, the robot's ability to provide valuable data and near-perfect performance are considered important, this group prefers motivational AI. Therefore, the implementation of goal setting and progress-tracking features must be helpful. An intuitive and user-friendly interface that requires minimal learning is important, but without being overly personal and crossing into friendship territory. The primary target users for Niche 4 are productivity-driven professionals, goal-oriented individuals, and busy executives. These users value efficiency, seek data-driven support for personal and professional growth, and require consistent motivation and valuable information to improve their performance and achieve their goals.

Across all niches, we recommend implementing robust privacy and data protection features and developing modular designs that allow for customization to better meet the specific needs of each niche.

While current commercially available robots often emphasize enjoyable activities like playing and dancing, along with other social interaction capabilities in their marketing, our results suggest that this "emotional" domain is preferred only by customers in Niche 2, comprising approximately 12-20% of all customers across our various experiments. Users in Niches 1, 3, and 4 perceive these elements as secondary to the robot's primary functions, viewing robots primarily as tools to improve productivity, increase efficiency, or solve specific problems, rather than as social companions. This preference for functionality over emotional engagement likely stems from users' perception of robots as more sophisticated than mere computers or productivity applications, leading to higher expectations for their practical utility. It's important to note that the statements regarding talking and bonding with robots in our study are derived from academically verified findings demonstrating positive effects on user experience. Therefore, the observed "low interest" should be interpreted as a lower priority compared to other features, rather than an absolute lack of interest. This relative ranking is significantly meaningful as it reflects users' current preferences and priorities when interacting with robots. Such findings highlight a significant divide between current marketing approaches and the preferences of most potential robot users, suggesting a need for more function-oriented product development and marketing strategies. These insights are valuable for researchers' designing experiments, robot planners developing feature models, and marketers highlighting key functions to potential customers.

Additionally, our interviews with Korean university students revealed that despite being surrounded by the latest mobile applications and various Internet of Things devices, approximately 80% of them still exhibit a degree of apprehension towards robots. These students prefer human-to-human contact for their social and emotional needs, viewing robot interactions as supplementary rather than primary sources of social engagement. This finding aligns with our earlier results, which showed that only 15-20% of users belong to Niche 2, the group that regards robots as potential friends. This insight underscores the persistence of traditional social preferences even among tech-savvy younger generations, highlighting the challenges that robot developers and marketers face in promoting social and emotional engagement features to a broader audience.

However, limited exposure to socially capable robots in everyday life may contribute to uncertainty about their potential benefits, influencing users' current interest levels. As users gain more experience with these technologies, their perceptions and priorities may evolve. Notably, during our experiments, we observed instances where participants' perspectives shifted after witnessing the release of GPT-4.o and its capacity for emotionally nuanced conversations. This demonstrates the potential for rapid changes in user attitudes as AI capabilities advance. Future research could explore how increased exposure to and familiarity with socially interactive robots might change user preferences over time.

VI. CONCLUSION

This research benefits both academia and industry by providing a structured approach to understanding user expectations, potentially reducing development costs and improving user acceptance. In addition, this study bridges the gap between theoretical concepts and practical applications in social robotics. The proposed framework and consumer segmentation can guide future research and development in social robotics, contributing to more user-centric robot designs.

The academic contribution of this research primarily resides in its methodological innovation and the development of a comprehensive framework for analyzing social robots from five key perspectives: physical and psychological anthropomorphism, cognitive intelligence, user compliance willingness, and sacrifice. We employed Q-methodology to effectively segment the emerging market, analyzing 37 different perspectives gathered from literature, stakeholders, and users, providing a robust foundation for future research.

Our findings challenge the conventional perception of social robots merely as companions by revealing that viewing robots as friends represents just one of four identified user types. This suggests a need for a broader, more comprehensive approach to user research and targeted robot development, aimed at expanding the user base.

The practical implications of this study are significant, particularly in the areas of market segmentation and product customization. By demonstrating that Q-methodology can manage 30-50 variables effectively without overburdening participants, our study offers a scalable model for researchers and practitioners in the field of emerging technologies. The identification of four consumer types with distinct preferences offers critical insights for robot designers and manufacturers, enabling tailored designs to meet diverse user needs. Our attempt to transform statistical data into narrative personas provides a framework to translate our findings into practical applications. This approach bridges quantitative results and user-centered design, facilitating more effective strategies for robot development and marketing.

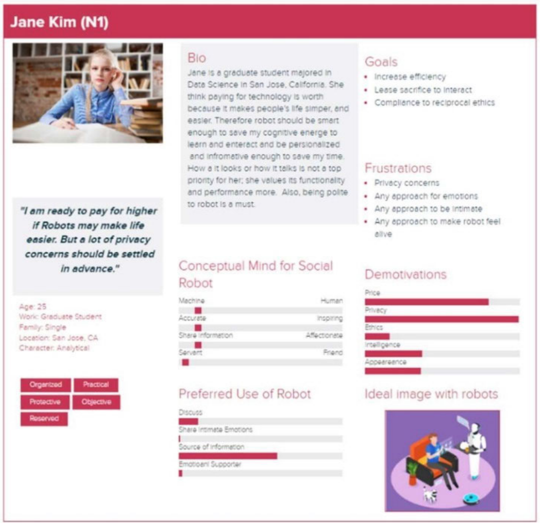
Additionally, we addressed ethical and privacy concerns. Generally, participants expressed a strong ethical stance towards robots, with only one of the four niches showing tolerance towards potential privacy issues such as data leakage or inadvertent disclosure of personal information. Consequently, it is essential for robot designers to prioritize consumer reassurance by implementing simple but effective modifications, such as covering robots' cameras with hats or eyelids and microphones with earmuffs or headphones. These modifications are intended to make users feel more comfortable and secure about their privacy.

Lastly, this study acknowledges potential limitations arising from subtle semantic nuances in the translation process from Korean to English, which may impact the interpretation of results from an empiricist perspective [81]. To further enhance our understanding, future research could include multicultural participants and focus on cross-cultural comparative analyses. Additionally, conducting experiments involving direct interaction experiences with robots and comparing groups with varying levels of scientific and technological literacy would provide valuable insights. These approaches will allow for a more nuanced refinement of our findings and contribute to the ongoing advancement of user-centered social robot technologies.

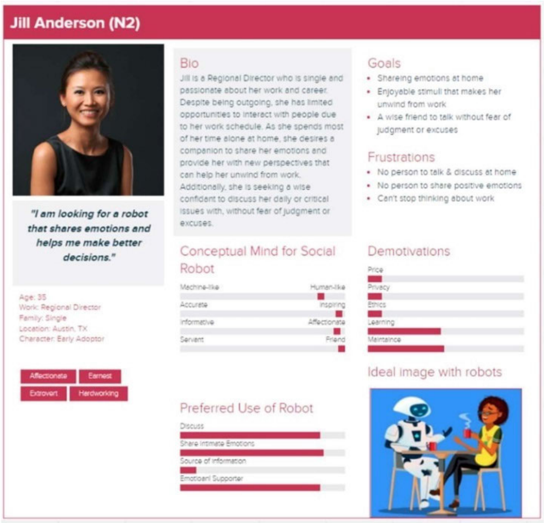
APPENDIX

- The personas are systematically constructed from the four consumer types identified through Q-methodology analysis, quantitatively representing the key characteristics, preferences, and attitudes of each typology.
- These data-driven narrative models transform abstract statistical insights into tangible representations, providing researchers, designers, and marketers with a practical framework to visualize consumer types in real-world scenarios and to operationalize the study's findings in applied contexts.

A. PERSONA FOR N1

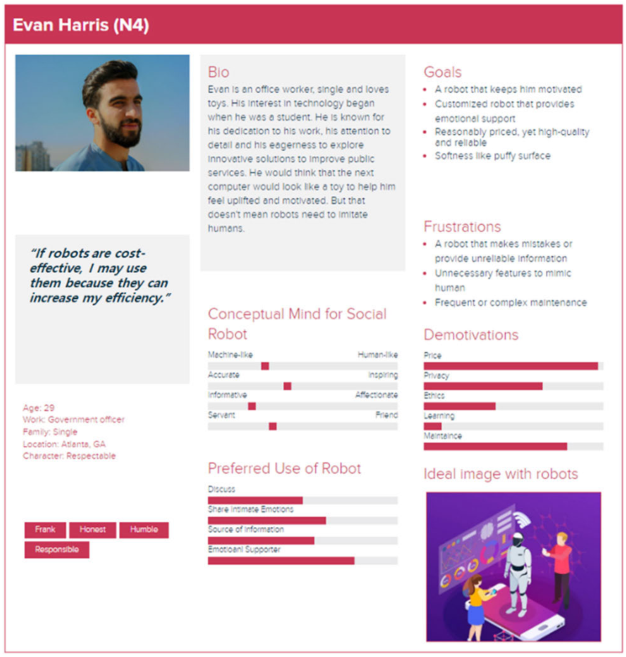


B. PERSONA FOR N2



C. PERSONA FOR N3

D. PERSONA FOR N4



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