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The Impact of Robots' Nonverbal Expressions on Exercise Motivation and User Experience in Middle-Aged Adults

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서울대학교 대학원
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Abstract

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Middle-aged individuals may experience changes in cognitive and physical abilities, making regular exercise essential for maintaining health and well-being. Access to social support plays a critical role in boosting exercise motivation. However, not everyone can access such resources, and robotic assistance can help bridge these gaps. Studies suggest that humanoid robots hold potential as exercise assistants, particularly in contexts requiring body movement monitoring or personalized feedback. According to the theory of social presence, with the appropriate use of nonverbal expressions, robots can be perceived as social entities capable of providing social support, subsequently promoting exercise motivation.

However, no prior research has explored the effects of robots' nonverbal expressions on exercise motivation and user experience in the context of exercise. Thus, this study aims to examine the effects of robots' nonverbal expressions on middle-aged adults' exercise motivation and user experience, as well as to determine which types of nonverbal expressions are more effective in enhancing exercise motivation and user experience in middle-aged adults.

Study 1 examined the effects of the robot exercise partner's communication methods (verbal vs, verbal and nonverbal) on exercise motivation and user experience. A control condition was included in which participants engaged in physical activity without a robot. Study 2 further categorized the robot's nonverbal interactions into kinesics, haptic, and oculesics, examining which was most effective in increasing exercise motivation.

As a result, in Study 1, exercise motivation significantly improved in the robot condition with verbal and nonverbal expressions, and the change in exercise motivation significantly differed from the control condition. Although the robot condition with both verbal and nonverbal expressions received higher user experience scores, the difference was not statistically significant. In Study 2, exercise motivation significantly increased in the oculesics condition. Additionally, user experience was significantly higher in the oculesics condition compared to the kinesics condition.

This research highlights the importance of nonverbal expressions in exercise partner robots for enhancing exercise motivation and suggests a cost and energy-efficient robot design. Furthermore, findings show that improving exercise motivation helps people stick to exercise routines. Encouraging healthy habits in middle age can continue into old age, making it a useful strategy for successful aging.

Keywords **:** Exercise Motivation, User Experience, Social Presence, Nonverbal Expressions, Oculesics, Robot Exercise Partner, Middle-aged

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Chapter 1. Introduction

Physical activity is crucial for middle-aged adults, a stage often associated with emotional, cognitive, and physical challenges. Midlife crises commonly involve feelings of anxiety, depression, and stress (Jaques, 2018; Levinson et al., 1986). Cognitive abilities, like memory and processing speed, tend to decline as the brain undergoes natural aging (Knopman et al., 2001). Similarly, physical changes like muscle loss and reduced bone density increase the risk of chronic illnesses and disabilities (Tieland et al., 2018; Alcazar et al., 2020). Regular exercise helps manage these challenges by boosting mood, supporting cognitive function, and delaying physical decline (Colcombe et al., 2004; de Oliveira et al., 2019). Building exercise routines during middle age is also crucial for maintaining long-term health and fostering healthy aging.

Despite the well-established benefits of physical activity for middle-aged adults, the World Health Organization (2022) reported a global decline in physical activity across all regions and genders with increasing age among adults aged 18 to 70 and older. This decline is further influenced by reduced exercise motivation, which tends to decrease with age (Scholes & Mindell, 2012). People engage in physical activities for various reasons, such as feeling a sense of achievement, finding joy, or being part of the community (Curry & Weiss, 1989; Vallerand, 2008; Rhodes & Dickau, 2012; Michie et al., 2013; Gavin et al., 2014; Eynon et al., 2019). However, maintaining motivation can be difficult.

Social support is critical in overcoming barriers to exercise and sustaining motivation. Previous studies have consistently shown that encouragement from others significantly increases the likelihood of engaging in regular physical activity (Cohen-Mansfield et al., 2004; Eynon et al., 2019; Scarapicchia et al., 2017; Gjestvang et al., 2021;

Tallis et al., 2022). Social support also enhances long-term participation in exercise routines (Roh & Moon, 2020; Tian & Shi, 2022). Encouragement from friends or fitness coaches enhances *intrinsic motivation*, the inherent satisfaction of an activity (Ryan & Deci, 2000). Intrinsic motivation, rather than external rewards, is a strong predictor of exercise adherence in the long term (Yu, 2012; Vatankhah & Tanbakooei, 2014; Choi, 2018; Lin, 2020; Kim & Seong, 2020; Park & Kim, 2024). In a broader context, social support enhances self-determined motivation, which is crucial for sustained exercise satisfaction and adherence (Roh & Moon, 2020; Choi, 2023). Further details on this relationship will be discussed in the later sections.

However, despite the importance of social support, it decreases with age, and more middle-aged adults live alone due to factors such as divorce, separation, and widowhood (Abell & Steptoe, 2021). Human supporters are in high demand but limited in supply; robotic assistance can help fill this gap. Robots provide support across fields, acting as partners, coaches, and intelligent assistants (Pieskä et al., 2012). In sports, robots have been utilized in dance (Kosuge, 2008), skiing, and gymnastics (Hasegawa et al., 2000), and other areas. However, current applications of robots in sports are limited, focusing mainly on assisting with specific movements, for instance, swing practice or enhancing exercise performance. Additionally, research on exercise-assisting robots has primarily targeted older adults undergoing rehabilitation, presenting another limitation.

Understanding how middle-aged adults experience exercise partner robots is important for promoting physical activity and building active habits. This exploration is also important for reducing public health costs and improving productivity among middle-aged adults. As previously mentioned, social support is important for increasing exercise motivation. According to social presence theory, a non-human object must use nonverbal expressions to be perceived as a social agent. Thus, nonverbal expressions enhance human-robot communication. Urakami and Seaborn (2023) note that nonverbal cues such as body language increase and enhance social presence. Applied to the exercise field, robots that use these communication modes can better be perceived as social entities, thereby increasing exercise motivation in people.

Prior studies have also shown that robots' nonverbal expressions positively impact the user experience by fostering emotional connections, intuitive interactions, clear communication, enhanced social presence, anthropomorphism, emotional transfer, and immersion (Corrales-Paredes et al., 2023; Dautenhahn, 2007; Jeong et al., 2015; Knight et al., 2009; Lee et al., 2006). Despite substantial evidence that robots' nonverbal expressions can enhance exercise motivation and user experience, research in the sports field on this topic remains insufficient. The current study aims to address this gap.

The exercise context relies heavily on body movement, making verbal communication challenging and highlighting the importance of nonverbal body language. Effective nonverbal expressions from robots can facilitate immediate and efficient communication during physical activities, enhancing user experience and motivation. Identifying the most impactful nonverbal expressions is essential to optimize robot design for cost and energy efficiency. For instance, implementing gaze capabilities can be costly due to the motors required for each degree of freedom (Breazeal et al., 2004; Dautenhahn et al., 2009; Kozima et al., 2009). Designers often simplify these systems to balance complexity and cost. Therefore, comparing various nonverbal expressions can help determine which are most effective for improving exercise motivation and user experience.

Chapter 2. Related Work

2.1. Psychological Challenges in Middle-aged Adults

A midlife crisis can arise from major life events, health issues, or career-related concerns, leading to significant psychological distress (Jaques, 2018). Current research emphasizes this period as one of reflection and re-evaluation of the future, often accompanied by anxiety, depression, and stress (Levinson et al., 1986; Weaver, 2009). This phase, known as the midlife transition, involves re-evaluating life structures such as marriage and career, often linked to feelings of disappointment and cynicism. Some individuals may even experience feelings of irreversible loss (Freund & Ritter, 2009; Levinson et al., 1986).

Numerous studies have highlighted the psychological challenges faced during midlife. Roh and Jang (2018) found that middle-aged women experience significant stress due to physiological changes and the pressures of fulfilling essential family roles. This combination increases their risk of feelings of helplessness and depressive states. Similarly, middle-aged men who fulfill roles as fathers, husbands, providers, and professionals often encounter heightened tension and pressure (Song, 2008). This life phase involves re-evaluating marriage, family, past achievements, and future goals, leading to symptoms such as anxiety, depression, reduced concentration, fatigue, sleep disturbances, restlessness, and loss of interest and confidence. Additionally, middle-aged men report economic, social, psychological, and physical difficulties (Lee, 2013).

From a cognitive perspective, aging in the frontal lobe and weakened brain connectivity lead to declines in verbal fluency, processing speed (Knopman et al., 2001), fluid intelligence (Nettelbeck & Burns, 2010), executive functions (such as attention shifting, planning, and problem-solving), and memory (Gunstad et al., 2006).

2.2. Relationship of Physical Activity and Mental Health

Physical activity positively affects mental health and reduces depression (de Oliveira et al., 2019). Studies indicate that sports activities benefit psychological factors and lower the risk of depression (Duman, 2005). Byeon et al. (2011) showed that individuals participating in sports activities had higher levels of ego-resilience than non-participants, suggesting that sports strengthen ego-resilience. Furthermore, Kim and Lee (2011) reported that engaging in activities such as bodyweight exercises and ball sports enhances emotional well-being. Park and Kim (2010) demonstrated that dance activities increase happiness among middle-aged women. Lim (2010) explained that active physical activity induces positive cognitive and emotional states, contributing to happiness through mood improvement and emotional changes. Oh and Shin (2008) proposed that active physical activities improve positive emotions, adaptive self-regulation, and confidence, thus enhancing subjective well-being. Additionally, Kim and Lee (2008) found that regular physical activity promotes psychological happiness by boosting self-esteem, reducing anxiety, and fostering healthy personality development.

Physical activity also plays a key role in preventing and mitigating cognitive decline. Regular exercise helps maintain cognitive function in adults and reduces the risk of diseases like dementia (Sofi et al., 2011). Additionally, interventions combining proper nutrition with exercise improve overall cognitive function in middle-aged adults experiencing cognitive decline (Liu et al., 2021). Colcombe et al. (2004) found that increased cardiovascular fitness positively influences activity in the prefrontal and parietal cortical regions associated with spatial selection and inhibitory control, as well as in the anterior cingulate cortex, which monitors conflicts and signals adjustments within the attentional system. These findings suggest that cardiovascular fitness enhances brain plasticity in aging individuals, potentially slowing both biological and cognitive aging. Northey et al. (2018) supported the positive impact of physical exercise on cognitive health through a meta-analysis of 36 studies, analyzing 333 dependent effect sizes (effect size = 0.29; 95% CI [0.17, 0.41]; $p < 0.01$). The analysis showed that aerobic exercise, resistance training, multicomponent training, and Tai Chi each significantly benefited cognitive function. Notably, for participants over 50, physical exercise improved cognitive function across various cognitive domains. Specifically, resistance training significantly enhanced executive function, memory, and working memory, while Tai Chi demonstrated notable benefits for working memory.

These findings underscore the critical role that various forms of physical exercise play in enhancing cognitive abilities, particularly in older adults (Northey et al., 2018). Moreover, engaging in physical exercise at least three times per week is linked to a reduction in dementia risk of up to 32% (Adams et al., 2023; Marselle et al., 2013; Murray & Cardinale, 2015; Zhao et al., 2014).

2.3. Effects of Exercise on Physical Health in Middle-aged Adults

Muscle degradation starts in both men and women after reaching 40 years of age. (Alcazar et al., 2020; Metter et al., 1997). This decline can lead to limitations in mobility and disabilities (Alcazar et al., 2021; Foldvari et al., 2000), hospitalization (Losa-Reyna et al., 2022), and an increased risk of mortality (Alcazar et al., 2021; Kuo et al., 2006), highlighting the need for preventative measures. Reduced excitability of the motor cortex also causes declines in motor coordination and balance (Kossev et al., 2002). Additionally, cardiopulmonary function gradually declines with age, limiting exercise capacity and daily physical activities. Skeletal density decreases with age, increasing the risk of osteoporosis and fractures (Tieland et al., 2018). The function of the neuromuscular junction, responsible for connecting nerves and muscles, weakens with age, impairing nerve signal transmission, reducing muscle contraction capability, and leading to declines in motor functions (Gonzalez-Freire et al., 2014). Physical activity effectively addresses these issues.

Regular exercise reduces the incidence of cardiovascular diseases, cancer, obesity, and the onset of metabolic syndrome (Kollia et al., 2018; Patel et al., 2019; Xu et al., 2019). Specifically, exercise helps maintain or increase muscle mass and strength, improving neuromuscular junction function (Gonzalez-Freire et al., 2014). Weight-bearing exercises increase bone density, reducing the risk of osteoporosis (Tieland et al., 2018). Additionally, aerobic exercises strengthen cardiopulmonary functions (Seidler et al., 2010), and balance training improves motor coordination and balance, reducing the risk of falls (Kossev et al., 2002). Exercise may also delay mobility limitations and further disability, enabling independent living to continue (Bennett & Winters-Stone, 2011). Thus, physical activity not only helps individual middle-aged adults prevent and address health issues but also serves as a crucial public health concern from a preventative perspective (Adams et al., 2023).

However, despite the benefits of physical activity, many individuals still do not engage in sufficient exercise, highlighting the need to explore ways to enhance their exercise motivation.

2.4. Exercise Motivation and Adherence

Motivation in exercise involves not only enhancing the psychological drive to exercise but also translating it into sustained behavioral outcomes such as participation and adherence. While initial motivation may be a trigger for individuals to start exercising, long-term adherence is critical for reaping the full benefits of physical activity. This involves maintaining consistent routines and integrating exercise into daily life. For instance, even if an individual begins exercising to lose weight or improve physical fitness, maintaining a consistent exercise routine over time is essential for achieving and sustaining the benefits of physical activity. Additionally, sustaining the positive effects of physical activity requires ongoing exercise adherence.

Motivation refers to the inner drive that initiates goal-directed actions and sustains these behaviors over time (Yu, 2006). Exercise motivation specifically encompasses the direct and indirect reasons for engaging in physical activities, serving as the force behind consistent participation and effective performance (Kim & Seong, 2020; Hwang, 2013). It includes various intrinsic and extrinsic factors, such as the desire for improved health, social interaction, or personal achievement.

Exercise motivation extends beyond a mere psychological push; it also predicts the likelihood of engaging in regular exercise and sustaining participation over time. Empirical studies highlight this relationship: Shin (2014) found that exercise motivation positively influences exercise adherence, while Lee et al. (2013) reported that external display, achievement, health, and physical fitness positively affect exercise sustainability in dance sport participants.

Exercise adherence goes beyond participation to include achieving personal outcomes such as health improvement, stress relief, and self-actualization (Yu, 2012). Among the factors influencing adherence, exercise motivation consistently emerges as a key predictor (Kim & Kim, 2021). However, exercise motivation does not always lead to sustained engagement. Negative experiences, loss of interest, or waning determination can cause individuals to discontinue exercise, highlighting the need for additional factors to support adherence.

On such factor is social support, which has been shown to enhance both exercise motivation and long-term participation (George et al., 2013; Tian & Shi, 2022). Social support positively impacts intrinsic motivation – a key predictor of adherence- by providing encouragement, accountability, and connection (Choi, 2018; Kim & Seong, 2020; Park & Kim, 2024; Yu, 2012).

Self-Determination Theory (SDT) provides a framework for understanding the role of social support. According to SDT, satisfying basic psychological needs for autonomy, relatedness, and competence enhances self-determined motivation, particularly intrinsic motivation. Social support contributes to meeting these needs by fostering a sense of connection, reinforcing personal competence, and supporting autonomous decision-making. Increased self-determined motivation, in turn, predicts greater engagement in and adherence to exercise (Roh & Moon, 2020).

2.5. Social Support and Exercise Motivation

Social support is defined as the assistance and care received within an individual's social network (Cohen & Matthews, 1987). This support includes emotional, instrumental, and informational assistance (Schwarzer & Knoll, 2007). Social support influences attitudes toward physical activity, beliefs about one's ability to engage in specific behaviors, and the mobilization of resources needed to take action (Duncan et al., 2005; Scarapicchia et al., 2017).

According to Lox et al. (2019) social support is the most important form of social influence in exercise and other physical activity environments, playing a crucial role in health behaviors (Cohen et al., 2000; Holt & Hoar, 2006).

Support from social entities such as family, friends, coaches, and peers effectively increase exercise motivation. Engaging in physical activity with others, rather than alone, boosts motivation. For example, support from family and friends (Cousins, 1995, 1996; Kirkby et al., 1999; Newson & Kemps, 2007; Tallis et al., 2022) and support from professionals (Cousins, 1995, 1996; Cohen-Mansfield et al., 2004; Newson & Kemps, 2007) significantly motivate individuals to exercise. The National Sports for All Survey (2018) reported that the most influential factors in promoting exercise participation were 'friends' (32.9%) and 'family/relatives' (22.5%), highlighting social support as a key factor in enhancing exercise motivation to increase participation (Roh & Moon, 2020). Additionally, a meta-analysis found that high social support predicts motivation to participate in physical activity, contributing to well-being and promoting health-enhancing behaviors (Bender et al., 2019; Mendonça et al., 2014; Lindsay Smith et al., 2017).

One study found that the influence of social support on increasing exercise motivation was more significant than other factors, such as self-efficacy and stress reduction (Kirkby et al., 1999). This applies to older adults as well, who often cite social support as a key factor for motivation to engage in physical activity (Cardenas et al., 2009; Costello et al., 2011; Devereux-Fitzgerald et al., 2016). This effect extends to patients in rehabilitation settings. Studies of residents in rehabilitation centers have shown that social support significantly increases exercise motivation, identifying it as a more important predictor of motivation than individual competency (Inui et al., 2022).

Social support is also related to exercise participation. A literature review examining the relationship between social support and physical activity indicates that these two concepts are inseparably linked and predominantly exhibit a positive relationship (George et al., 2013). Peer support interventions, for example, have been effective in increasing physical activity and aerobic capacity among older adults (Neil Thomas et al., 2012). Moreover, researchers have provided additional evidence of this positive relationship across diverse populations, ranging from adolescents to older adults (King et al., 2008; Orsega-Smith et al., 2007; Sharma et al., 2009).

Social support not only increases the quantity of physical activity but also promotes continuous engagement. Participants who received peer support for 16 weeks continued to engage in moderate-intensity physical activity for over a year after the intervention, whereas those who did not receive this support reverted to baseline exercise levels (Buman et al., 2011). In conditions where participants demonstrated unconditional support for each other, they showed marked improvements in physical function and motivation to engage in physical activity compared to the control condition (no robot) (Kamegaya et al., 2014). A study conducted in China during the COVID-19 pandemic surveyed 459 individuals and revealed that social support is an important predictor of exercise adherence and the formation of exercise habits (Tian & Shi, 2022). Ultimately, social support enhances exercise motivation and fosters long-term exercise adherence.

Despite the critical role of social support as a significant predictor of exercise motivation, it tends to decline with increasing age. Koo (2008) reported that family support among middle-aged women was lower than that observed in cancer patients. In light of personnel shortages necessary to support this population, humanoid robots capable of providing social assistance have emerged as a potential alternative for workforce replacement. For robots, rather than humans, to effectively deliver social support, individuals must perceive robots as social entities akin to humans. The theory of social presence offers a framework for enabling this perception.

2.6. Impact of Social Presence and Nonverbal Expressions of Robots on Human Behavior

Social presence is defined differently depending on the researcher and field. For example, Biocca (1997) defined social presence as the subjective experience of being present with a real person and accessing their thoughts and emotions. Others define it as the degree to which an agent is perceived as a real person during interactions (Kumar & Benbasat, 2002; Lee, 2004; Short et al., 1976). In this study, we focus on interactions between robots and humans, adopting a definition that emphasizes the robot's perceived social and emotional engagement.

Initially, social presence theory was used primarily in media and communication research (Nass et al., 1994; Short et al., 1976). It has since been applied to various domains, including education and psychology, to enhance learning outcomes in online environments and understand users' psychological engagement (Kreijns et al., 2022; Tu & McIsaac, 2002; Zhao et al., 2014). More recently, it has been extended to areas involving artificial intelligence, chatbots, and robots (Kang, 2021). Foundational work, such as Nass and Moon (2000), showed that humans often apply social norms and attributions to machines, perceiving them as social entities. Similarly, Reeves and Nass (1996) demonstrated that people treat computers and media as human-like, a phenomenon relevant to understanding how users perceive and engage with social robots.

The increased social presence of robots, achieved through nonverbal expressions, enables people to perceive robots as human-like entities. Consequently, the support provided by robots functioning as social beings can positively influence motivation and user experience, similar to the social support provided by humans (Jeon et al., 2024; Liu et al., 2023).) For example, one study demonstrated that feedback styles in robotic fitness coaching, particularly verbal feedback, directly impact exercise intensity and motivation (Lee, Park et al., 2024). Sackl et al. (2022) found similar effects in sports training sessions, where robots enhanced motivation through verbal and social interactions.

However, earlier research has focused on robots' verbal expressions without detailing the impact of nonverbal expressions from robots on human behavior. Social presence theory emphasizes nonverbal expressions as key factors in enabling robots to achieve social presence. For instance, social robots like Pepper (Softbank Robotics, Japan) or Jibo (Jibo Inc., US) use nonverbal expressions—such as eye contact (oculesics), body language (kinesics), tactile language (haptics), and appearance—to establish a social presence. Urakami and Seaborn (2023) note that these nonverbal expressions breathe "life" into robots, making them perceived as social entities rather than mere machines. Similarly, Serfaty et al. (2023) found that nonverbal cues like eye movements and facial expressions enhance the perceived importance of a robot's social presence. Another study showed that proxemic nonverbal expressions positively impacted perceptions of robots' social presence (Fiore et al., 2013). Winkle et al. (2020) further highlighted that the interactive capabilities of social robots, such as verbal guidance during running exercises, significantly enhance user motivation compared to conditions without robot assistance. These findings suggest that integrating verbal feedback alongside human guidance could improve participants' engagement and adherence to exercise routines.

In a study on long-term interactions, participants' perception of social presence with a robot that used nonverbal expressions during chess games improved over time (Leite et al., 2009). Stacey (2001) found that in e-learning environments, increased social presence through message exchange among learners fosters a sense of belonging and intimacy, thereby strongly motivating learning. Similarly, one study found that in physical rehabilitation coaching, iterative feedback from social robots not only increases adherence but also exercise intensity marked by increased walking speed, suggesting that the motivational effects of robotic coaching extend beyond traditional domains of learning (Lee, Siewiorek et al., 2024).

In summary, nonverbal expressions enhance social presence, and perceiving someone as human-like improves motivation and user experience. However, research focusing on robots' nonverbal expressions has been limited. Furthermore, in the exercise domain, there has been a lack of studies specifically examining robots' nonverbal expressions. The following sections will explore various nonverbal expressions of robots and their respective impacts on motivation and user experience.

2.7. Nonverbal Expressions of Robots and Motivation

Nonverbal expressions refer to communication methods that do not rely on words, including facial expressions, gestures, body language, eye contact, and physical distance. These expressions encompass various types and distinctions, yet no single unified category exists (see Table 1). Nonverbal expressions are considered more important than verbal expressions in communication. Mehrabian (1981) reported that nonverbal elements account for up to 93% of the impact of communication. Specifically, nonverbal bodily expressions that engage visual elements have a greater impact compared to vocal tones and other auditory nonverbal cues, accounting for 55% of communicative influence compared to 7% for verbal content and 38% for vocal tones (Mehrabian, 1981). Supporting this, numerous studies in Human-Robot Interaction (HRI) research have explored the use of nonverbal bodily expressions. Early HRI studies focused primarily on nonverbal signals such as eye contact and nodding (Riek et al., 2010), while more recent research has expanded to include touch, proxemics (Sardar et al., 2012; Nie et al., 2012), and kinesics.

Oculesics refers to eye-related behaviors such as eye contact and gaze (Teel, 2011). Haptics involves communication through touch (Thayer, 1986). Proxemics considers the use of space around us, with interpersonal distance being a primary element (Burgoon et al., 1984). Kinesics encompasses communication through gestures, movements of the head or body, and posture (Andersen, 1999; Birdwhistell, 2010).

Table 1

Classification of Nonverbal Expressions

Name (years)	Classification
Ruesch & Kees (1972)	Sign Language (Gestures)
	Action Language (Body Movement)
	Object Language (Tools, Dress, etc.)
Andersen (1999)	Kinesics (Facial Expressions, Gestures, Interactional Synchrony)
	Physical Appearance
	Oculesics (Eye Contact, Pupil Dilation, Eye Movements)
	Proxemics (Territoriality, Crowding and Density, Personal Space)
	Haptics (Types of Touch, Touch Avoidance)
	Environment (Macro, Micro)
	Chronemics
	Olfactics
	Vocalics
Wrench et al. (2020)	Haptics (Touch)
	Vocalics (Voice)

	Kinesics (Body Movement and Gestures)
	Oculesics / Facial Expressions (Eye and Face Behavior)
	Physical Appearance

Research across various fields has demonstrated that nonverbal expressions by robots can enhance motivation. For example, Nakagawa et al. (2011) studied the impact of a robot's tactile nonverbal cues on motivation during tasks. Participants were instructed to perform the monotonous task of repeatedly dragging a gray circle from the left side of the screen to a square on the right. Under conditions where the robot provided active touch functions, participants showed increased motivation, completed more tasks, and stayed on task longer.

Studies in the education sector have also explored how nonverbal expressions in robots influence learning motivation. For instance, when educational robots displayed nonverbal cues such as nodding, participants increasingly perceived the robot as a socially interactive entity, positively affecting their motivation to learn (Saerbeck et al., 2010). In the communication sector, research has investigated how robots' nonverbal expressions such as nodding, leaning, physical contact (e.g., patting the head or shaking hands), and gaze fixation positively affect participants' perception of robots as conversation partners, fostering interaction motivation (Jeong et al., 2015). There have also been studies in the sports sector examining how nonverbal expressions in robots affect exercise motivation. Süssenbach et al. (2014) found that motivation in cycling groups with a robot present was significantly higher.

However, a limitation of this study was that it did not differentiate between the robot's nonverbal and verbal expressions. Thus, there remains a gap in the sports domain regarding how nonverbal expressions by robots specifically affect exercise motivation.

2.8. Nonverbal Expressions of Robots and User Experience

Many studies on AI products have concluded that nonverbal expressions lead to positive user experiences. This can be attributed to many reasons. In HRI and psychology, nonverbal expressions are believed to enhance user experience through enhancement of social presence, emotional connection, intuitiveness of interaction, clarity of communication, anthropomorphism, emotional contagion, facilitation of immersion, and a sense of trust and safety (Admoni & Scassellati, 2017; Dautenhahn, 2007; Kleinke, 1986; Knight et al., 2009; Lee et al., 2006; Maran et al., 2019; Mutlu et al., 2006; Mutlu et al., 2009; Prochazkova et al., 2018; Shim et al., 2021; Sidner et al., 2005). For example, studies using robots like Paro and AIBO show that haptic nonverbal cues in robots lead to improved human-robot relationships (Fujita, 2004; Wada & Shibata, 2007). Dautenhahn (2007) explains that nonverbal interaction plays a critical role in human-robot interaction. Behaviors like eye contact, facial expressions, and gestures allow interactions between humans and robots to flow more naturally, leading to more positive user experiences. Nonverbal communications are closely linked to how humans naturally interact with each other. The more effective a robot is in employing these strategies, the better the user experience it provides (Cooney et al., 2015; Silvera-Tawil et al., 2014).

Haptic stimulation plays a vital role in human interaction (Field, 2001). Previous studies on robots have shown the positive effects of tactile nonverbal communication on improving how the robot is perceived (Chen & Kemp, 2010; Wada et al., 2004). Haptic nonverbal expressions, such as patting, allow robots that respond to emotional expressions to elicit social reactions, foster a closer relationship in human-robot relationships, and positively impact interactions (Parshall, 2003; Wada et al., 2005; Tanaka et al., 2007; Kanda et al., 2004).

Oculesics is an important nonverbal communication tool as well in human-robot interaction (HRI). For instance, gaze parameters are often used to improve user experience (UX) (Admoni & Scassellati, 2017; Andrist et al., 2014). Generally, oculesics is perceived as a variable that enhances intimacy with the robot and leads to a positive user experience. However, unlike previous studies, Koller et al. (2023) investigated user experience in relation to robot eye contact and found no significant difference in user experience based on oculesics. In fact, prolonged staring may even cause discomfort for users.

Gestures and body movements are another essential component for robots in conveying emotions and intentions as it provides signals that humans can intuitively respond to, fostering a positive user experience. For example, when robots utilize gestures to offer positive feedback or signals understanding of human emotions, users can interact with robots more closely. Marmpena et al. (2018) argued that nonverbal communication, like body language, is an inalienable component of conveying emotions, and integrating such characteristics into HRI can enhance user experience and improve HRI.

In summary, robots' nonverbal expressions are generally considered to lead to positive user experiences. However, there is a need to further disambiguate the mixed results regarding the impact of specific nonverbal cues on user experience. Additionally, although many researchers have emphasized different aspects of nonverbal communication, no study has examined the importance of nonverbal expressions when a robot acts as an exercise partner, and identify which specific nonverbal expressions have a relatively greater impact.

2.9. Present Study

This study aims to investigate the effects of nonverbal communication in robots on exercise motivation and user experience. To achieve this, two studies were conducted.

Study 1 divided participants into three conditions: one exercised with a robot providing only verbal expressions, another with a robot providing both verbal and nonverbal expressions, and a control condition (no robot) that engaged in independent exercise for baseline comparison. The hypotheses for Study 1 are as follows:

$H_{1\text{-}1}$: Both verbal and nonverbal expressions provided by the robot will further enhance exercise motivation in middle-aged adults.

$H_{1\text{-}2}$: Both verbal and nonverbal expressions provided by the robot will further enhance user experience in middle-aged adults

Study 2 aimed to elucidate which nonverbal expressions (kinesics, haptic, oculesics) had a more positive impact on exercise motivation and user experience. The hypotheses for the second study are as follows:

$H_{2\text{-}1}$: The degree to which exercise motivation is enhanced in middle-aged adults will differ based on the type of nonverbal expressions provided by the robot.

$H_{2\text{-}2}$: The degree to which user experience is enhanced in middle-aged adults will differ based on the type of nonverbal expressions provided by the robot.

Chapter 3. Study 1

3.1. Method

3.1.1. Participants

A total of 67 individuals participated in this study. Participants were recruited through online community boards and campus bulletin board posters, targeting healthy middle-aged adults capable of engaging in physical activity. Participation in the study was fully voluntary, and all data were securely managed by the principal investigator in accordance with ethical guidelines.

The participants spent a total of 30 minutes on exercise and survey completion. The experiment was halted if the robot stopped functioning or participants encountered movement difficulties. Consequently, out of the 67 initial participants, three were excluded from the final analysis, resulting in a final sample of 64 participants (Nmale = 33, Mage = 51.62). Descriptive statistics for each condition are presented in Table 2. After the experiment, participants received a 5,000 KRW gift voucher or an equivalent e-coupon as a token of appreciation.

Table 2

Descriptive Statistics for Study1

Condition	*n*	Age (Mean)	Min	Max
Verbal Expressions	22	53	41	63
Verbal and Nonverbal Expressions	21	51	41	59
Control Condition	21	50	40	63

3.1.2. Experimental Design

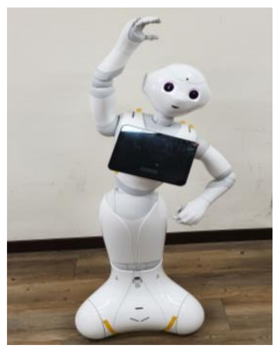
The first study was conducted using a between-subjects design. The first condition, labeled as the “verbal expression” condition, received only verbal instructions from the robot. Participants engaged in physical activities with a robot that provided verbal exercise guidance while remaining stationary without any movements.

The second condition, labeled as the “verbal & non-verbal expression” condition, received both verbal and non-verbal expressions from the robot. Participants engaged in physical activities with a robot that communicated through both speech and non-verbal cues.

The third condition, labeled as the “no robot” condition, served as a control condition, where participants exercised without the presence of a robot. Participants were randomly assigned to one of the three conditions. Refer to Table 3 for examples of robots with Verbal expression condition and Verbal and Non-verbal expression condition.

Table 3

Verbal and Non-verbal Condition Example in Study 1

		No motion	
Verbal Expression			
	Kinesics (Waving)	Kinesics (Stretching)	Haptic (Patting)
			
Non-Verbal Expression	Kinesics (Clapping)	Kinesics (Squatting)	Oculesics (Gaze)
			

3.1.3. Development of Exercise Partner Robot

The scenarios consisted of movement guidance, encouragement, and posture feedback. The exercise routine followed the Korea Disease Control and Prevention Agency's guidelines (Korean Disease Control and Prevention Agency [KDCA], 2023) for safe physical activity, incorporating warm-up, aerobic, strength, and stretching exercises.

An example of movement guidance includes statements such as, "Next is a lower body strength exercise. We will do the movement of sitting down and standing up from a chair 10 times, twice. Position your feet slightly wider than shoulder-width apart. Slowly repeat the action of sitting back down and standing up 10 times. Ready, start!". Examples of encouragement include phrases such as, "Looking good!", "Great job, keep it up!" accompanied by gestures like clapping or showing a thumbs-up for motivation. Examples of posture feedback include, "Make sure your feet are parallel," "Gently tuck your chin as if pushing your head back," and "Engage your core!"

For a warm-up, participants were given time to stretch freely. The aerobic exercise consisted of walking, and the strength exercise was a modified squat where participants sat down and stood up from a chair to ensure safety. Finally, stretching included arm rotations and movements to relax the sides, neck, and arm muscles. The designed scenario was implemented as an application on the humanoid robot "Pepper."

Upon opening the app, a screen appeared, allowing participants to select a condition. Once a condition was selected, a start button appeared on the screen, initiating the physical activity scenario when pressed. An Android phone was used to monitor Pepper's progress in real time, and an option was provided to advance to the next exercise in case of any errors with the robot.

3.1.4. Measures

We used the Sport Motivation Scale-II (SMS-II) to assess sports participation motivation. The SMS is one of sports research's most frequently cited motivation measurement questionnaires (Clancy et al., 2017). The SMS-II is a revised scale designed to address the limitations of the original SMS. It aligns with Self-Determination Theory (SDT), measuring various types of motivation, including intrinsic motivation, extrinsic motivation, and amotivation (Pelletier et al., 2013). The calculation method for this scale can be adapted based on research objectives. In this study, we adopted an approach suitable for calculating overall motivation, which is commonly used. Therefore, amotivation was excluded from the calculation.

The SMS-II comprises 18 items, each rated on a 7-point Likert scale (Pelletier et al., 2013). Compared to the original SMS, the SMS-II has fewer items and includes an integrated regulation factor, with validity and reliability verified through factor analysis, internal consistency testing, and correlation analysis among sub-factors. We translated SMS-II items to Korean following standard translation and back-translation procedures to ensure linguistic and conceptual equivalence. The reliability analysis yielded a Cronbach's alpha of 0.84, indicating good internal consistency for the motivation scale.

To measure user experience with the robot, we used the System Usability Scale (SUS). The SUS, developed by John Brooke in 1996, is a quick and straightforward tool for evaluating user experience (Brooke, 1996). It consists of 10 items rated on a scale from 1 (*strongly disagree*) to 5 (*strongly agree*). The individual items in the SUS cover aspects such as ease of use, learnability, and satisfaction, allowing for a comprehensive evaluation of usability. The SUS provides a subjective assessment of usability with a single score out of 100. Calculation involves separating the 10 items into five positive (odd-numbered) and five negative (even-numbered) items, each scored on a 1–5 scale and then adjusted by multiplying by 2.5 to align with a 100-point scale.

The SUS has been widely regarded for its high reliability and validity in usability assessments (Lewis, 2018). Bangor et al. (2009) analyzed 2,324 SUS evaluations from 206 usability assessments conducted over a decade and found that the SUS had a reliability coefficient of 0.91, indicating higher reliability than other subjective usability measures. The SUS is also commonly used in psychological research; for instance, it has been applied to evaluate the usability of internet-based cognitive behavioral therapy (iCBT) (Mol et al., 2020), and a simplified version has been used with participants with cognitive impairments (Hastings et al., 2021). These examples demonstrate the versatility of the SUS across diverse populations and research settings. Given the middle-aged participant group in this study, who may be less familiar with technical terminology or lengthy surveys, the SUS's simplicity and reliability are expected to facilitate participant understanding and response. This study used a version of the SUS modified for domestic use (Kim et al., 2018) and adapted for the study's objectives. The internal consistency of the SUS was evaluated, resulting in a Cronbach's alpha of 0.73, which indicates acceptable reliability for the user experience scale. We also collected demographic information such as age and gender.

3.1.5. Procedure

Participants received an explanation from the researcher regarding the study's purpose and procedures and then completed a consent form. Additionally, to ensure safe participation, they completed the Physical Activity Readiness Questionnaire (PAR-Q) on the day of the experiment to confirm they were fit for physical activity. The humanoid robot "Pepper" used in this experiment provided participants with movement instructions, encouragement, and real-time posture feedback during physical activity.

Participants were then randomly assigned to one of the three primary conditions: verbal expression, verbal and non-verbal expression, or the control condition of exercising without the robot. Before starting the exercise, all participants completed the Sport Motivation Scale-II (SMS-II) questionnaire to assess their exercise motivation. The same questionnaires were administered across all six conditions.

Each condition involved the following procedures. In the condition providing verbal expressions of the robot, participants engaged in a sequence of physical activities. They began with a warm-up, followed by walking around the lab. Next, they performed a sit-to-stand exercise and concluded with arm stretching. During this sequence, the robot coach remained stationary and provided verbal instructions and encouragement. For example, the robot would say, “Make sure your feet are parallel,” and “Great job!” to guide participants through the exercises.

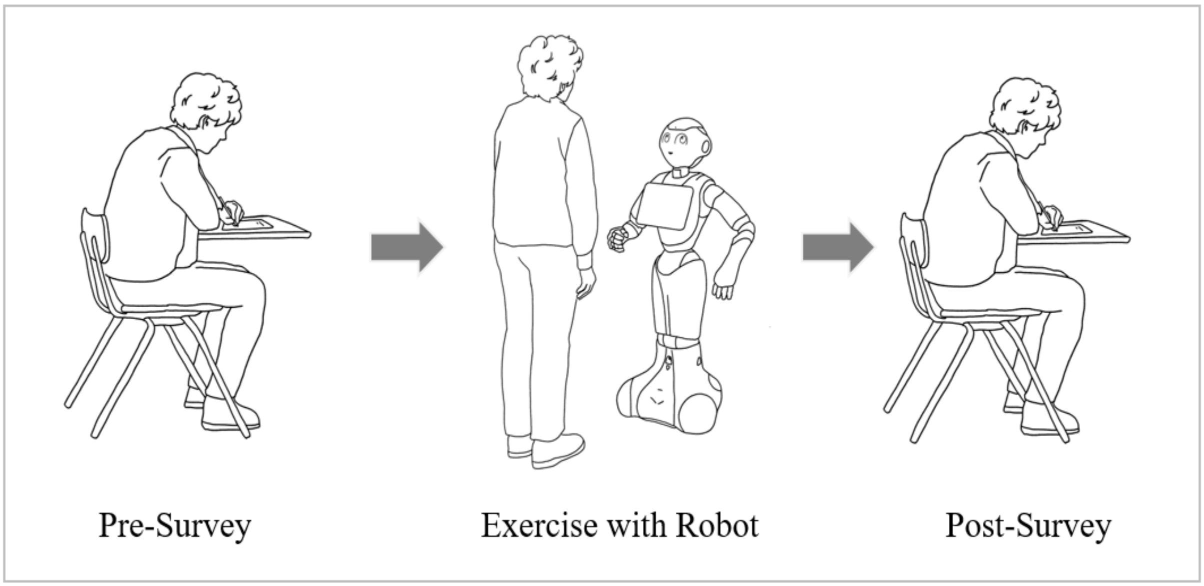
In the condition providing verbal and nonverbal expressions of the robot, participants engaged in the same exercise sequence. They started with a warm-up, then walked around the lab, performed a sit-to-stand exercise, and finished with arm stretching. In this condition, the robot coach actively participated in the exercises by demonstrating movements alongside the participants. The robot used both verbal and non-verbal expressions for guidance and encouragement. For instance, Pepper would say, “Keep it up!” while making a supportive arm gesture. The experimental procedure is illustrated in Figure 1.

In the no robot condition, participants engaged in the same sequence of exercises: warm-up, walking around the lab, sit-to-stand exercise, and arm stretching, but without the robot. Following the physical activity, participants completed two self-report questionnaires. The Sport Motivation Scale-II (SMS-II) assessed their sports participation motivation, and the

System Usability Scale (SUS) evaluated their user experience with the robot. The experiment concluded upon completion of the questionnaires. The entire experimental process took approximately 30 minutes.

Figure 1

Experimental Procedure



3.2. Results

3.2.1. Normality Test

Before performing statistical tests, Shapiro-Wilk tests were conducted to evaluate the normality of the data distributions for each condition. The results revealed that some conditions violated the assumption of normality (e.g., p = 0.01 for control condition). Therefore, non-parametric tests (e.g., Wilcoxon signed-rank tests, Mann-Whitney U test, and Kruskal-Wallis tests) were employed to analyze differences in exercise motivation and user experience across conditions due to their robustness against violations of normality.

3.2.2. Exercise Motivation Change: Between-Group Differences

A Kruskal-Wallis test was performed to determine whether the change in exercise motivation (post_total_motivation minus pre_total_motivation) differed across groups. The results indicated a significant change in exercise motivation between conditions ($\chi^2(2) = 6.34$, $p = .041$, $\eta^2 = .10$).

Subsequent Dunn's post hoc tests revealed a significant difference between the control condition and the robot with both verbal and nonverbal expression condition (p = .029). However, the differences between the robot with verbal expressions and the robot with both verbal and nonverbal expressions condition (p = .066) and between the robot with verbal expressions and the control condition (p = 1.000) were not statistically significant.

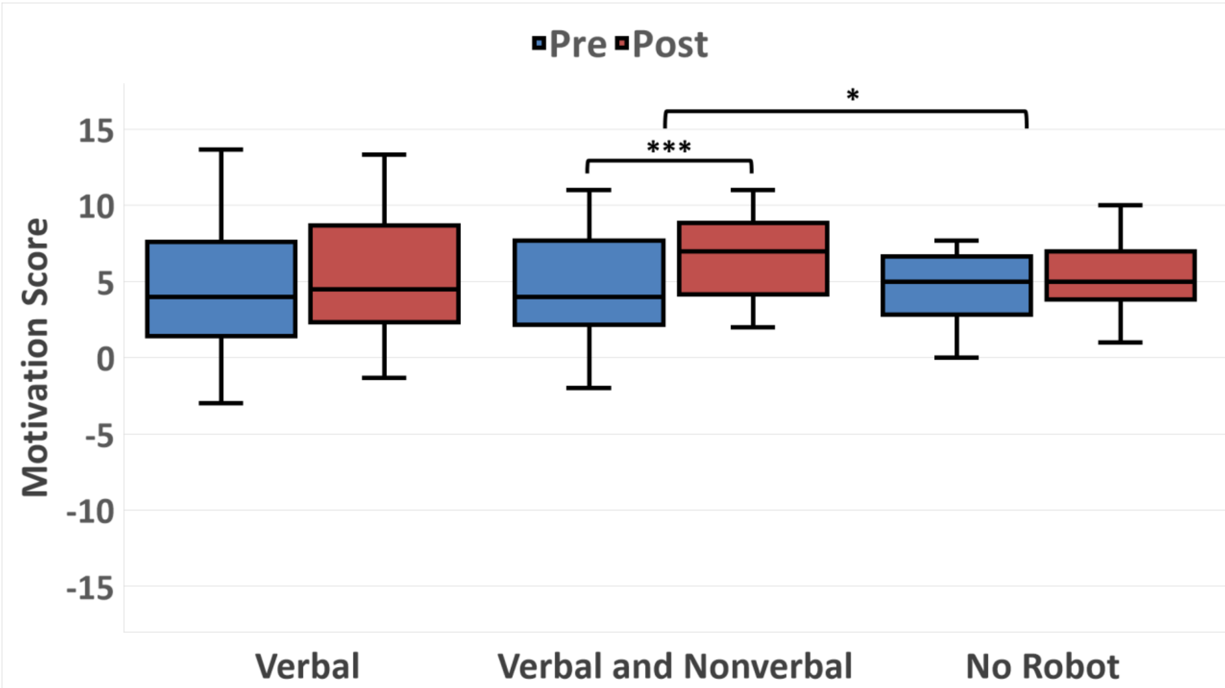
3.2.3. Exercise Motivation: Pre- and Post-Intervention Differences

Wilcoxon signed-rank tests were conducted to examine significant changes in exercise motivation scores before and after the intervention across the three conditions (robot with only verbal expressions, robot with verbal and nonverbal expressions, and control condition).

In the robot with only verbal expressions condition, there was no significant increase in exercise motivation from pre-intervention (median = 4.00) to post-intervention (median = 4.50; $Z = -0.33$, $p = .398$, $r = .07$). Conversely, the robot with both verbal and nonverbal expressions condition exhibited a significant increase in exercise motivation pre-intervention (median = 4.00) compared to post-intervention (median = 7.00; $Z = 3.37$, $p < .001$, $r = .74$). In the control condition, no significant difference was observed between pre-intervention (median = 5.00) and post-intervention (median = 5.00) exercise motivation scores ($Z = .45$, $p = .664$).

Figure 2

Between-Group Differences in Sport Motivation Change and Pre-Post Differences in Sport Motivation by Condition in Study 1



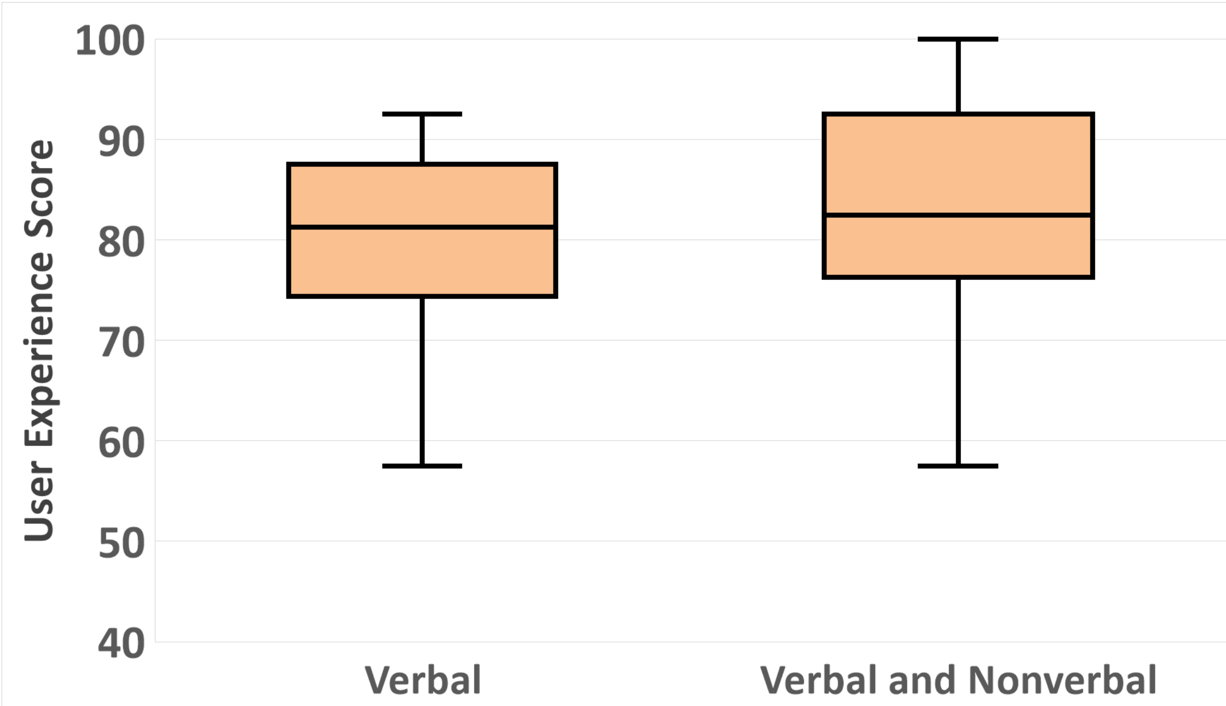
Note. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

3.2.4. User Experience: Between-Group Differences

To assess whether user experience differed between the robot with only verbal expressions and robot with both verbal and nonverbal expression conditions, a Mann-Whitney U test was conducted. Although the user experience scores in the robot with both verbal and nonverbal expressions condition (median = 82.5) were higher than those in the robot with only verbal expressions condition (median = 81.3, the analysis showed no significant difference in user experience between the two groups ($W = 189$, $p = .311$, $r = .13$). This could be due to both conditions having sufficiently high scores, with both exceeding 68, which is regarded as the average user experience score, thereby preventing significant differences from emerging.

Figure 3

User Experience Differences Between Conditions in Study 1



3.3. Discussion

We examined the effects of the robot exercise partner's communication methods on exercise motivation. The results indicated that our manipulation of the importance of the robot's nonverbal expressions was successful.

The motivation change in the verbal and nonverbal robot condition was significantly higher compared to the condition where participants exercised alone without a robot. This suggests that utilizing various physical nonverbal expressions, such as the robot's movements, tactile communication, and gaze, to engage participants in exercise activities and provide feedback and encouragement effectively enhances individuals' exercise motivation.

Additionally, When the robot provided nonverbal expressions, participants showed an improvement in exercise motivation scores (H_{1-1}). However, there were no significant changes in exercise motivation when the robot only provided verbal expression. This indicates that even when providing exercise guidance and encouragement, relying solely on verbal communication without utilizing nonverbal expressions is insufficient to significantly impact exercise motivation. These findings align with the studies by Nakagawa et al. (2011) and Süssenbach et al. (2014). Nakagawa et al. found that nonverbal cues provided by robots increased participants' motivation and task persistence during monotonous tasks. Similarly, Süssenbach et al. (2014) reported that the presence of a robot in cycling groups significantly enhanced participants' motivation levels.

However, a limitation of these studies was the lack of distinction between the provision of verbal and nonverbal expressions, making it difficult to isolate the specific effects of nonverbal cues. Unlike prior research, the present study explicitly separated these conditions in its experimental design, providing significant results that address this gap and advance the academic understanding of the role of nonverbal expressions. Moreover, some studies have noted potential limitations in the effects of nonverbal expressions, and this study contributes to extending this discussion. By specifically focusing on the nonverbal expressions of robots within the physical exercise domain, this research is the first to confirm their positive effects on exercise motivation, thereby expanding the scope of applied psychology and emphasizing the importance of integrating nonverbal communication in human-robot interaction.

Next, we investigated the effects of the robot exercise partner's communication methods (verbal, verbal and nonverbal) on user experience ($H_{1\text{-}2}$). When the robot provided nonverbal expressions, participants' user experience was enhanced compared to conditions where only verbal expressions were provided. However, this improvement was not statistically significant.

This non-significant yet positive trend suggests that the integration of nonverbal cues such as movements, tactile feedback, and gaze could enhance the overall user experience by fostering a more engaging and supportive interaction. The lack of statistical significance in these findings could be attributed to The absence of a significant difference between the conditions can be interpreted as resulting from the relatively high scores observed in both conditions. According to established SUS norms, a score of 68 represents the threshold for average usability, while a score above 80 indicates an above-average user experience (Lewis & Sauro, 2018; Sauro & Lewis, 2016). Specifically, SUS scores exceeding 80 fall within the 85th to 100th percentile range, corresponding to an A grade (Sauro, 2011; Lewis & Sauro, 2016). In this context, both Condition 1 and Condition 2 can be interpreted as providing highly positive user experiences.

Given that SUS scores exceeded 80 in both conditions, participants appeared to find the interactions, whether through verbal expressions alone or through both verbal and nonverbal expressions, to be highly usable and satisfying. This aligns with industry benchmarks, where achieving an SUS score above 80 is considered evidence of an above-average user experience (Lewis & Sauro, 2018). The minimal difference in median scores suggests that when a system achieves a high level of usability, further improvements in user experience may not produce statistically significant differences. Lewis and Sauro (2018) pointed out that when SUS scores are in the A range, they reflect an experience with few usability issues, making additional differentiation challenging. These findings indicate that the high SUS scores observed in both conditions suggest that both verbal and nonverbal communication strategies employed by the robot were effective in enhancing the user experience.

Another reason could be the insufficient sample size, which may have limited the study's power to detect meaningful differences. Future research with larger participant pools is necessary to confirm whether the addition of nonverbal expressions consistently leads to improved user experiences. Additionally, increasing the sample size could help in achieving the required statistical power to validate the hypothesized benefits of combined verbal and nonverbal communication in robotic exercise partners.

Chapter 4. Study 2

4.1. Method

In Study 2, this study followed the procedure of Study 1, with modifications to Conditions 1, 2, and 3.

4.1.1. Participants

A total of 67 people participated in this study. They were recruited through postings on online community boards and campus bulletin boards, targeting healthy middle-aged adults capable of physical activity to allow voluntary participation. All data was managed by the main researcher.

The entire process, including exercise and survey completion, took approximately 30 minutes per participant. If the robot stopped functioning or participants had trouble with the movements, the experiment was halted. As a result, of the initial 67 participants, 3 were excluded from analysis, leaving a final sample of 64 participants ($N_{male} = 40$, $M_{age} = 51.54$). Descriptive statistics for each condition are presented in Table 4. After the experiment, participants received a 5,000 KRW gift voucher or an equivalent e-coupon as a token of appreciation.

Table 4

Descriptive Statistics for Study 2

Condition	*n*	Age (Mean)	Min	Max
Kinesics	21	54	48	62
Haptic	21	51	40	59
Oculesics	22	49	40	60

4.1.2. Experiment Design

Study 2 followed the procedure of Study 1, with modifications to Conditions 1, 2, and 3. The first study was conducted using a between-subjects design.

The first condition, labeled as the "Kinesics" condition, involved a robot that provided movement-based non-verbal expressions through kinesics communication. Participants engaged in physical activities with a robot that utilized non-verbal gestures such as arm movements and knee bending, excluding haptic and gaze-based non-verbal cues. The second condition, labeled as the "Haptic" condition, involved a robot that provided haptic non-verbal expressions. Participants engaged in physical activities with a robot that offered non-verbal expressions, such as allowing participants to pat their heads. The third condition, labeled as the "Oculesics" condition, involved a robot that provided gaze-based non-verbal expressions. Participants engaged in physical activities with a robot that adjusted its gaze according to the participant's movements.

Participants were randomly assigned to the three conditions. Examples by condition in Study 2 are presented in Table 4.

Table 5

Examples of Robots by Condition for Study 2

Kinesics	Haptic	Oculesics
		

4.2. Result

4.2.1. Normality Test

Before performing statistical tests, Shapiro-Wilk tests were conducted to evaluate the normality of the data distributions for each condition. The results revealed that some conditions violated the assumption of normality (e.g., p = 0.01 for Oculesics condition). Therefore, non-parametric tests (e.g., Wilcoxon signed-rank tests, Mann-Whitney U test, Kruskal-Wallis tests) were employed to analyze differences in exercise motivation and user experience across conditions. Non-parametric methods were chosen due to their robustness against violations of normality.

4.2.2. Between-Group Differences in Exercise Motivation Change

A Kruskal-Wallis test was conducted to examine differences in exercise motivation change across the Kinesics, Haptic, and Oculesics conditions. The results indicated no significant differences between groups ($\chi 2(2) = 1.863$, $p = .394$).

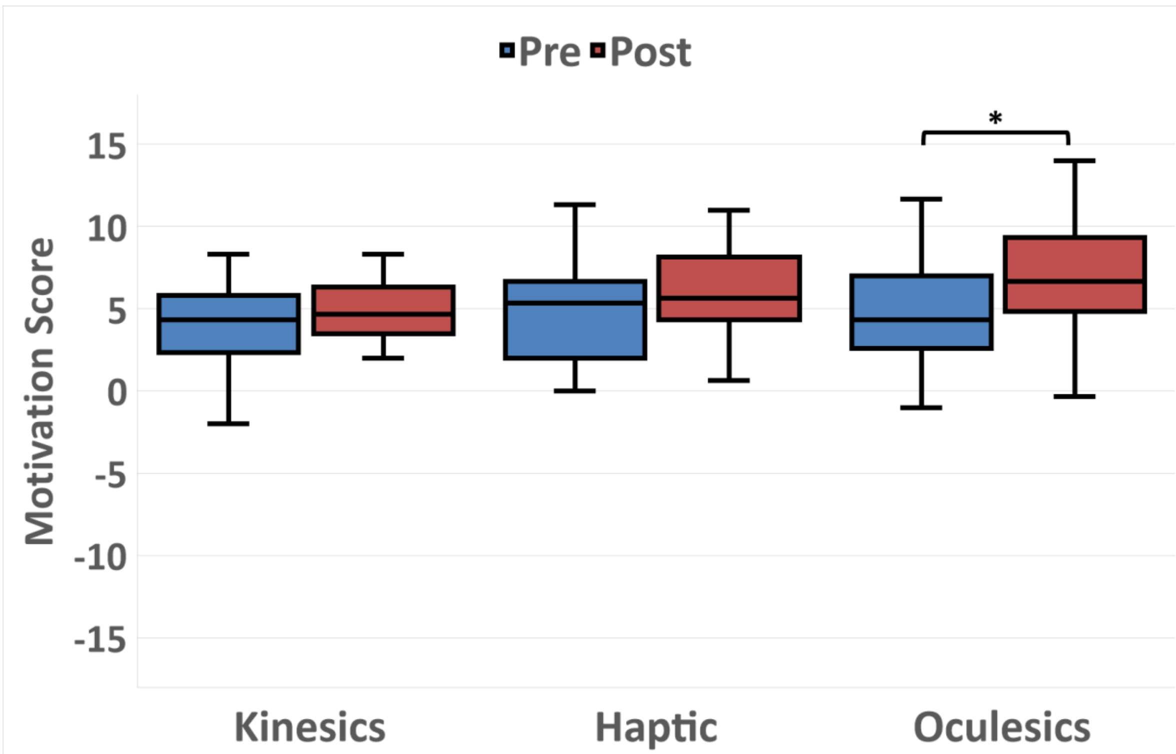
4.2.3. Exercise Motivation Pre- and Post-Intervention Differences

Wilcoxon signed-rank tests were performed to evaluate changes in exercise motivation scores before and after the intervention for the Kinesics, Haptic, and Oculesics conditions. In the Kinesics condition, there was no significant change in exercise motivation from pre-intervention (median = 4.33) to post-intervention (median = 4.67; Z=0.90, p=.375, r=.20). Similarly, the Haptic condition did not show a significant difference between pre-intervention (median = 5.33) and post-intervention (median = 5.67) scores (Z = 0.78, p = .225, r = .17). In the Oculesics condition, the increase in exercise motivation was statistically significant from pre-intervention (median = 4.33) to post-intervention (median =

6.67; $Z = 2.14$, $p = .033$, $r = .47$).

Figure 4

Pre-Post Differences in Sport Motivation by Condition in Study 2



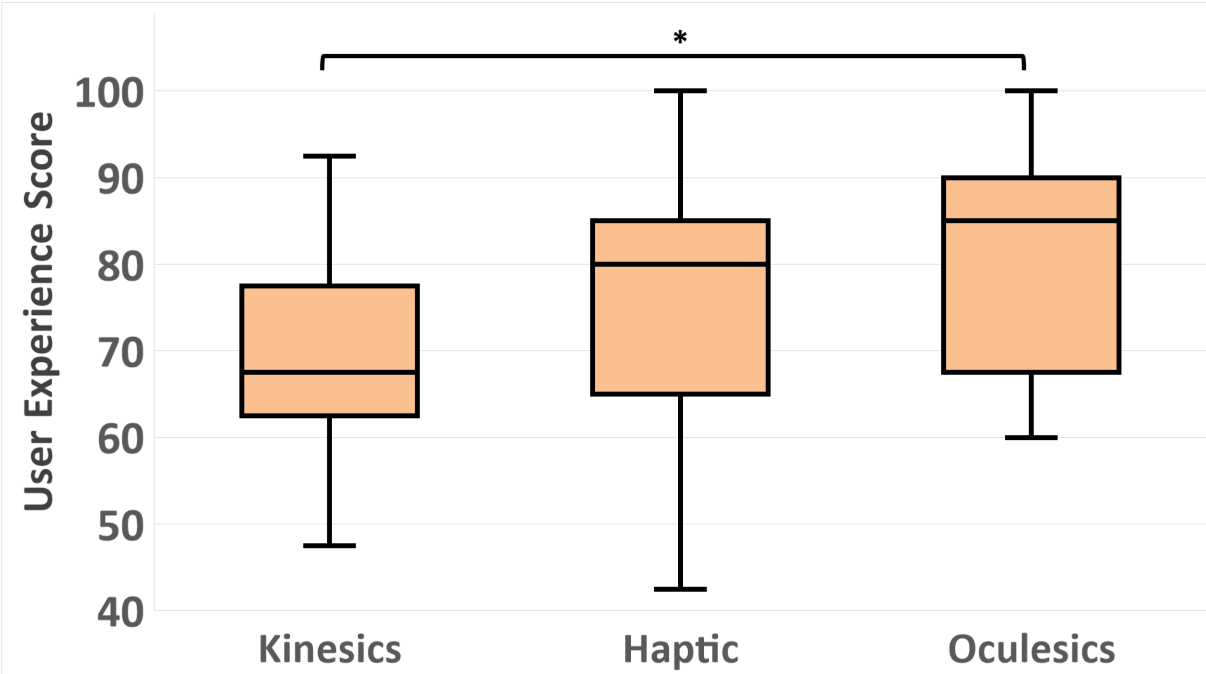
Note. *$p < .05$, **$p < .01$, ***$p < .001$

4.2.4. User Experience: Between-Group Differences

To investigate differences in user experience among the Kinesics, Haptic, and Oculesics conditions, a Kruskal-Wallis test was conducted. The results revealed a statistically significant difference in user experience across the three conditions ($\chi 2(2) = 9.98$, $p = .006$, $\eta 2 = 0.158$). Subsequent Dunn's post hoc tests with Bonferroni correction indicated a significant difference between the Kinesics and Oculesics ($p = .003$; $\delta = 0.487$). However, no significant difference was found between the Kinesics and Haptic ($p = .099$) or between the Haptic and Oculesics ($p = .298$).

Figure 5

User Experience Differences Between Conditions in Study 2



Note. *$p < .05$, **$p < .01$, ***$p < .001$

4.3. Discussion

In Study 2, we categorized the robot's nonverbal interactions into kinesics, haptics, and oculesics to identify which was most effective in increasing exercise motivation (H_{2-1}). Specifically, the oculesics condition—which included eye contact and gaze adjustment—led to a significant increase in exercise motivation scores from pre- to post-intervention. In contrast, the kinesics and haptics conditions showed no significant changes. This suggests that gaze-based nonverbal expressions, such as eye contact and gaze modulation, effectively enhance exercise motivation by increasing perceived social support and social presence. These findings align with Jeong et al. (2015), who found that a robot's gaze fixation made participants view the robot as a conversational partner, thereby boosting interaction motivation.

Additionally, we examined which nonverbal interaction most effectively enhanced user experience (H_{2-2}). The results showed a significant difference between the oculesics and kinesics conditions, with the oculesics condition leading to higher user experience scores than the kinesics condition. However, there was no significant difference between the haptics and oculesics conditions. This indicates that while gaze-based interactions may improve user experience more than kinesics interactions, haptics did not show a significant advantage over oculesics. This result aligns with Admoni and Scassellati (2017) and Andrist et al. (2014), who reported that gaze parameters enhance user experience. However, our findings contrast with Koller et al. (2023), who found no significant differences in user experience based on a robot's eye contact.

Oculesics play a critical role in both user experience and exercise motivation by fostering emotional connections, enhancing interaction intuitiveness, and strengthening social presence. Gaze cues are essential social signals (Admoni & Scassellati, 2017). For example, humans use gaze direction to convey intentions and mental states in social situations (Emery, 2000). This principle also applies to robots, as gaze cues can indicate location and timing during handovers (Moon et al., 2014) and signal task completion (Terzioğlu et al., 2020). Therefore, oculesics serve as fundamental signals for conveying social presence (Khambhaita et al., 2016; Wiltshire et al., 2013), which may have enhanced perceived social presence. This increased perception of the robot as a human-like entity offering social support likely boosted exercise motivation and improved user experience.

From a developmental psychology perspective, humans begin to understand the world, form social relationships, and learn communication through observing others' gaze from infancy (Flom et al., 2017). For instance, the perception of eye gaze is known to play a crucial role in mother-infant interactions and provides an essential foundation for social development (e.g., Jaffe, Stern, & Peery, 1973). Based on this developmental process, the gaze serves as a fundamental mechanism in human social cognition and emotional connection. Therefore, gaze alignment in robots likely evokes a natural perception in individuals that the robot is focused on them, fostering a sense of interaction akin to human social bonding, thereby leading to positive effects.

This study contributes to the literature by demonstrating that specific nonverbal interactions, particularly oculesics, are effective in enhancing exercise motivation and user experience in sports-related robotic interventions.

Chapter 5. General Discussion

5.1. Summary of Results

This study conducted two experiments to investigate how a robot's nonverbal communication affects exercise motivation and user experience among middle-aged adults.

Study 1 evaluated the impact of the robot's communication style, verbal expression versus both verbal and nonverbal expressions, on exercise motivation and user experience. The condition that received both verbal and nonverbal expressions showed significantly higher exercise motivation compared to the no robot control condition, which exercised alone. And also exhibited a significant increase in exercise motivation.

Study 2 further categorized the robot's nonverbal interactions into kinesics, haptics, and oculesics. The robot partner using oculesics significantly increased exercise motivation and reported higher user experience scores compared to the kinesics condition.

Combined, the findings from both studies highlight the essential role of a robot's nonverbal expressions, specifically certain nonverbal expressions, such as oculesics, in enhancing exercise motivation and user experience among middle-aged adults.

5.2. Theoretical Implications

This study underscores the crucial role of a robot's nonverbal expressions in user interactions, grounded in Social Presence Theory.

Study 1 found that when robots used both verbal and nonverbal expressions, exercise motivation increased. This suggests that nonverbal expressions enhance social presence, making the robot feel more human-like and thereby boosting exercise motivation. However, since social presence was not directly measured in this study, future research should explicitly examine and verify this factor.

Study 2 confirmed that oculesics, such as eye contact and gaze modulation, had the most positive impact on exercise motivation and user experience. Specifically, gaze behaviors significantly increased exercise motivation. Additionally, user experience scores were higher when the robot used gaze behaviors compared to nonverbal body movements.

These findings emphasize the need to thoughtfully design and integrate nonverbal communication elements in robots for effective Human-Robot Interaction (HRI). Furthermore, this study is the first to demonstrate that specific types of nonverbal communication positively influence exercise motivation and user experience, contributing new knowledge to the field of exercise research. The comparison between gaze behaviors and body movements in enhancing user experience also provides valuable insights for future robot designs.

5.3. Practical Implications

The findings of this study have practical implications for designing and developing exercise-support robots. The results demonstrate that nonverbal expressions, especially oculesics, effectively enhance user experience and exercise motivation. Therefore, prioritizing these elements in robot design is recommended. For example, when creating exercise-support robots for middle-aged adults, improving gaze modulation can increase the robot's perceived social presence. This allows users to feel greater social support, effectively boosting their exercise motivation. Additionally, fostering emotional connections and increasing anthropomorphism can enhance user satisfaction, perceived usefulness, and intention to use, thereby enriching the overall user experience.

Optimizing the robot's nonverbal expressions also offers opportunities to improve cost and energy efficiency by reducing design complexity, minimizing errors, and lowering development and maintenance costs. This optimization makes these technologies more accessible to a broader user base. By focusing on practicality, this study moves beyond theoretical applications to highlight real-world relevance, providing insights that could inform public health policy development.

As AI technologies continue to expand across various domains, it is increasingly important to identify which types of AI products should be prioritized to meet user needs and achieve desired outcomes effectively. This study addresses this question by demonstrating the potential benefits of humanoid robots equipped with physical and nonverbal expressions. Specifically, the findings highlight the effectiveness of such robots in enhancing exercise motivation and user experience. These insights are valuable for designing and developing AI systems that align with user expectations and foster positive interactions.

The findings of this study can also be extended and applied to the field of multimodal interactions. In human-robot interaction, the appropriate use of multiple modalities, rather than a single modality, has been shown to enhance positive effects, as demonstrated in various studies. For example, Iio et al. (2011) conducted a study measuring participants' levels of "entrainment"—the tendency to mimic or synchronize with the robot’s actions—when a robot used gaze and pointing either in combination or independently. The results revealed that the highest level of entrainment occurred when the robot utilized both gaze and pointing together. Similarly, in a study by Zecca et al. (2009), the humanoid robot KOBIAN expressed various emotions through body gestures and facial expressions, allowing participants to recognize these emotions. While individual modalities yielded lower recognition rates, the combination of the two achieved an average recognition rate of 70%.

These studies underscore the importance of understanding which combinations of multimodal approaches are most effective in human-robot interaction. The current study clearly demonstrates the impact of nonverbal gaze. Based on these findings, it can be inferred that combining the nonverbal gaze with other modalities in a multimodal framework is likely to be more effective.

5.4. Limitations and Future Research

This study has several limitations and future research directions are proposed to address them. First, this study employed a single-session, short-term intervention, which limits its ability to evaluate the long-term effects of the robot's nonverbal expressions on changes in exercise motivation and user experience. Although the potential for exercise continuity (sustained engagement in physical activity) was inferred, this was not empirically validated in the current study. As previously mentioned, exercise continuity is important. It is necessary to examine whether the effects of the robot observed in this study are merely short-term positive outcomes, for example, driven by curiosity and novelty from encountering the robot for the first time, or if these effects persist in the long term even after the robot becomes familiar. Future research should investigate whether repeated interventions with the robot's nonverbal expressions can lead to sustained exercise participation over time.

Second, the study faced physical limitations of the robot used (e.g., inability to implement certain movements, such as foot gestures), which constrained the range of nonverbal communication that could be evaluated. This limitation may have restricted a comprehensive assessment of the effects of nonverbal expressions on exercise motivation and user experience. Future studies should employ robots capable of a broader range of nonverbal expressions or focus on improving the robot's design. Additionally, identifying optimal combinations of nonverbal expressions that have the most significant impact on exercise motivation and user experience would provide valuable insights.

Third, the lack of significant differences in user experience observed in Study 1 may be attributable to the small sample size, potentially reducing the statistical power of the findings. Future studies should recruit larger participant samples to enhance statistical power and improve the reliability of the results. Furthermore, while the current study focused on middle-aged adults, future research could expand the target population to include older adults, enabling a comparative analysis of how nonverbal expressions affect different age groups. This approach would provide a deeper understanding of the age-specific impacts of robot nonverbal communication.

Fourth, the study did not measure objective physical effects or physiological factors resulting from exercising with the robot. Future research should incorporate objective physical indicators—such as increases in muscle mass, changes in body fat percentage, and improvements in exercise performance metrics—alongside physiological factors like heart rate (HR), heart rate variability (HRV), oxygen saturation, respiratory rate, caloric expenditure, blood pressure, muscle activation, sweat rate, and fatigue-related data (e.g., perceived fatigue and lactate levels). Including these measures can be useful in evaluating whether the benefits extend beyond psychological factors to influence physical and physiological outcomes and tangible improvements.

Based on these limitations, future research should consider several key directions. First, longitudinal studies with repeated interventions are needed to assess the long-term effects of robots' nonverbal expressions on sustained exercise participation, moving beyond initial curiosity and novelty to determine whether these effects persist over time. Second, enhanced robot capabilities should be pursued; employing robots capable of a wider range of nonverbal expressions—such as foot gestures—or improving existing designs would allow for a more comprehensive assessment of how various nonverbal cues impact exercise motivation and user experience, as well as identify optimal combinations of these expressions. Third, future studies should recruit larger and more diverse participant samples, including older adults, to increase statistical power, improve reliability, and compare the effects of nonverbal expressions across different age groups. Fourth, research should incorporate comprehensive outcome measures by including both objective physical indicators (such as increases in muscle mass, changes in body fat percentage, and improvements in exercise performance metrics) and physiological factors (including heart rate, heart rate variability, oxygen saturation, respiratory rate, caloric expenditure, blood pressure, muscle activation, sweat rate, and fatigue-related data like perceived fatigue and lactate levels). This comprehensive approach will help determine whether the observed benefits extend beyond psychological factors to produce tangible physical and physiological improvements.

Chapter 6. Conclusion

This study examined the impact of exercise partner robots' nonverbal expressions on exercise motivation and user experience among middle-aged adults.

Study 1 revealed that when the robot provided nonverbal and verbal expressions, participants experienced enhanced exercise motivation. Moreover, the motivation change was significant between the control condition and the robot providing verbal and nonverbal expressions. The change in exercise motivation in the robot condition that provided verbal and nonverbal expressions was greater than that in the control condition.

Study 2 categorized nonverbal expressions into kinesics, haptics, and oculesics, identifying that oculesics, such as eye contact and gaze modulation, had the most significant positive effects on both exercise motivation and user experience.

These results demonstrate that robots' nonverbal expressions can enhance users' perception of social presence, fostering a sense of social support that positively influences exercise motivation and user experience. This suggests that incorporating nonverbal expressions, particularly oculesics, into the design of exercise-support robots can effectively improve their interaction quality and utility for middle-aged adults.

The findings have important implications for developing and utilizing humanoid robots. By leveraging nonverbal expressions to enhance social presence, exercise partner robots can serve as practical tools for promoting exercise motivation, which is crucial for maintaining physical and mental health in middle-aged adults. Additionally, the study emphasizes the need for thoughtful design and integration of nonverbal communication in robots to maximize their effectiveness in fostering emotional connections, increasing user satisfaction, and encouraging sustained exercise participation.

Future research should expand on this study by conducting repeated interventions to evaluate the long-term effects of robots' nonverbal expressions, addressing current technological limitations, and exploring the integration of diverse nonverbal expressions. Moreover, including larger participant samples and objective physical performance metrics will enhance the reliability and applicability of future findings. This study lays a foundation for advancing human-robot interaction research and underscores the potential of humanoid robots to contribute to public health initiatives, particularly in aging societies.

References

Abell, J. G., & Steptoe, A. (2021). Why is living alone in older age related to increased mortality risk? A longitudinal cohort study. *Age and Ageing, 50*(6), 2019–2024.

Adams, J., Stirling, A. E., Heron, A. L., MacPherson, E. A., & Banwell, J. M. (2023). The importance of touch in sport: Athletes' and coaches' reflections. *International Journal of Social Science Studies, 3*, 56.

Admoni, H., & Scassellati, B. (2017). Social eye gaze in human-robot interaction: A review. *Journal of Human-Robot Interaction*, *6*(1), 25-63.

Alcazar, J., Aagaard, P., Haddock, B., Kamper, R. S., Hansen, S. K., Prescott, E., Alegre, L. M., Frandsen, U., & Suetta, C. (2020). Age-and sex-specific changes in lower-limb muscle power throughout the lifespan. *The Journals of Gerontology: Series A, 75*(7), 1369-1378.

Alcazar, J., Aagaard, P., Haddock, B., Kamper, R. S., Hansen, S. K., Prescott, E., Ara, I., Alegre, L. M., Frandsen, U., & Suetta, C. (2021). Assessment of functional sit-to-stand muscle power: Cross-sectional trajectories across the lifespan. *Experimental gerontology, 152*, 111448.

Andersen, P. A. (1999). *Nonverbal communication: Forms and functions*. Mayfield Publishing Co.

Andrist, S., Tan, X. Z., Gleicher, M., & Mutlu, B. (2014, March). Conversational gaze aversion for humanlike robots. In *Proceedings of the 2014 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 25–32).

Bangor, A., Kortum, P., & Miller, J. (2009). Determining what individual SUS scores mean: Adding an adjective rating scale. *Journal of Usability Studies, 4*(3), 114–123.

Bender, T. A., Cook, P., & Schiller, S. (2019). The importance of social support in adherence to exercise: A review. *Scandinavian Journal of Medicine & Science in Sports, 29*(3), 640–648.

Bennett, J. A., & Winters-Stone, K. (2011). Motivating older adults to exercise: What works? *Age and Ageing, 40*(2), 148–149.

Biocca, F. (1997). The cyborg's dilemma: Progressive embodiment in virtual environments. *Journal of Computer-Mediated Communication, 3*(2), JCMC324.

Birdwhistell, R. L. (2010). *Kinesics and context: Essays on body motion communication*. University of Pennsylvania Press.

Breazeal, C., Hoffman, G., & Lockerd, A. (2004). Teaching and working with robots as a collaboration. In *Proceedings of the 3rd International Joint Conference on Autonomous Agents and Multiagent Systems, 3*, 1030-1037.

Brooke, J. (1996). SUS-A quick and dirty usability scale. *Usability evaluation in industry*, *189*(194), 4-7.

Buman, M. P., Giacobbi, P. R., Dzierzewski, J. M., Morgan, A. A., McCrae, C. S., Roberts, B. L., & Marsiske, M. (2011). Peer volunteers improve long-term maintenance of physical activity with older adults: A randomized controlled trial. *Journal of Physical Activity and Health, 8*(S2), S257–S266.

Burgoon, J. K., Buller, D. B., Hale, J. L., & Turck, M. A. (1984). Relational messages associated with nonverbal behaviors. *Human Communication Research, 10*(3), 351–378.

Byeon, H.-S., & Noh, J.-H. (2011). *Chodeunghaksaeng-ui banggwahu hakgyo yeogasupocheu chamga-wa simnijeok welbing-ui gwangyeso jaatanryeokseong-ui maegye hyogwa* [The mediating effect of ego-resilience on the relationship between elementary school students' after-school leisure sports participation and psychological well-being]. *Hanguk Sahoe Cheyukhak Hoiji*, 44(1), 479–492.

Cardenas, D., Henderson, K. A., & Wilson, B. E. (2009). Physical activity and senior games participation: Benefits, constraints, and behaviors. *Journal of Aging and Physical Activity, 17*(2), 135–153.

Chen, T. L., & Kemp, C. C. (2010, March). Lead me by the hand: Evaluation of a direct physical interface for nursing assistant robots. In *2010 5th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (pp. 367–374).

Choi, J. (2023). The effect of social support on exercise motivation and adherence among middle-aged adults. *Journal of Sport and Exercise Psychology, 45*(2), 142–157.

Choi, J. H. (2018). *Daehak baedeuminteon dongari chamyeoja-ui chamyeo donggi-ga undong mollip mit undong jisok-e michineun yeonghyang* [The effect of participation motivation on exercise flow and exercise continuation of university badminton club participants] [Master's thesis, Yongin University]. Yongin University Repository.

Clancy, R. B., Herring, M. P., & Campbell, M. J. (2017). Motivation measures in sport: A critical review and bibliometric analysis. *Frontiers in Psychology, 8*, 348.

Cohen, S., & Matthews, K. A. (1987). Social support, type A behavior, and coronary artery disease. *Psychosomatic Medicine, 49*(4), 325-330.

Cohen, S., Gottlieb, B. H., & Underwood, L. G. (2000). Social relationships and health: Challenges. *Advances in Mind-Body Medicine,* 17, 129-141.

Cohen-Mansfield, J., Marx, M. S., Biddison, J. R., & Guralnik, J. M. (2004). Socio-environmental exercise preferences among older adults. *Preventive Medicine, 38*(6), 804-811.

Colcombe, S. J., Kramer, A. F., Erickson, K. I., Scalf, P., McAuley, E., Cohen, N. J., ... & Elavsky, S. (2004). Cardiovascular fitness, cortical plasticity, and aging. *Proceedings of the National Academy of Sciences, 101*(9), 3316–3321.

Cooney, M. D., Nishio, S., & Ishiguro, H. (2015). Recognizing affection for a touch-based interaction with a humanoid robot. *International Journal of Humanoid Robotics, 12*(1), 143–154.

Corrales-Paredes, A., Sanz, D. O., Terrón-López, M. J., & Egido-García, V. (2023). User experience design for social robots: A case study in integrating embodiment. *Sensors, 23*(11), 5274.

Costello, E., Kafchinski, M., Vrazel, J., & Sullivan, P. (2011). Motivators, barriers, and beliefs regarding physical activity in an older adult population. *Journal of Geriatric Physical Therapy, 34*(3), 138–147.

Cousins, S. O. (1995). Social support for exercise among elderly women. *Journal of Aging and Physical Activity, 3*(2), 287–303.

Cousins, S. O. (1996). Support for physical activity: Social network, social support, and motivation to exercise. *Journal of Aging and Health, 8*(3), 262–285.

Curry, T. J., & Weiss, O. (1989). Sport identity and motivation for sport participation: A comparison between American college athletes and Austrian student sport club members. *Sociology of Sport Journal, 6*(3), 257–268.

Dautenhahn, K. (2007). Socially intelligent robots: Dimensions of human-robot interaction. *Philosophical Transactions of the Royal Society B: Biological Sciences, 362*(1480), 679–704.

Dautenhahn, K., Nehaniv, C. L., Walters, M., Robins, B., Kose-Bagci, H., Mirza, N. A., & Blow, M. (2009). KASPAR–a minimally expressive humanoid robot for human-robot interaction research. *Applied Bionics and Biomechanics, 6*(3-4), 369–397.

de Oliveira, L. D. S. S. C. B., Souza, E. C., Rodrigues, R. A. S., Fett, C. A., & Piva, A. B. (2019). The effects of physical activity on anxiety, depression, and quality of life in elderly people living in the community. *Trends in Psychiatry and Psychotherapy, 41*, 36–42.

Devereux-Fitzgerald, A., Powell, R., Dewhurst, A., & French, D. P. (2016). The acceptability of physical activity interventions to older adults: A systematic review and meta-synthesis. *Social Science & Medicine, 158*, 14–23.

Duman, R. S. (2005). Neurotrophic factors and regulation of mood: role of exercise, diet and metabolism. *Neurobiology of aging*, *26*(1), 88-93.

Duncan, S. C., Duncan, T. E., & Strycker, L. A. (2005). Sources and types of social support in youth physical activity. *Health psychology*, *24*(1), 3.

Emery N. J. (2000). The eyes have it: the neuroethology, function and evolution of social gaze. *Neuroscience and biobehavioral reviews, 24*(6), 581–604.

Eynon, M., Foad, J., Downey, J., Bowmer, Y., & Mills, H. (2019). Assessing the psychosocial factors associated with adherence to exercise referral schemes: A systematic review. *Scandinavian Journal of Medicine & Science in Sports*, *29*(5), 638-650.

Field, T. (2001). Massage therapy facilitates weight gain in preterm infants. *Current Directions in Psychological Science, 10*(2), 51-54.

Fiore, S. M., Wiltshire, T. J., Lobato, E. J., Jentsch, F., Huang, W., & Axelrod, B. (2013). Toward understanding social cues and social influences in human–robot interaction: Effects of robot gaze and proxemics. *Frontiers in Psychology, 4*, 859.

Flom, R., Lee, K., & Muir, D. (Eds.). (2017). *Gaze-following: Its development and* *significance*. Psychology Press.

Foldvari, M., Clark, M., Laviolette, L. C., Bernstein, M. A., Kaliton, D., Castaneda, C., & Singh, M. A. F. (2000). Association of muscle power with functional status in community-dwelling elderly women. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 55*(4), M192–M199.

Freund, A. M., & Ritter, J. O. (2009). Midlife crisis: A debate. *Annual Review of Psychology, 60*, 145-171.

Fujita, M. (2004). On activating human communications with pet-type robot AIBO. *Proceedings of the IEEE, 92*(11), 1804-1813.

Gavin, J., Keough, M., Abravanel, M., Moudrakovski, T., & Mcbrearty, M. (2014). Motivations for participation in physical activity across the lifespan. *International Journal of Wellbeing, 4*(1).

George, M., Eys, M. A., Oddson, B., Roy-Charland, A., Schinke, R. J., & Bruner, M. W. (2013). The role of self-determination in the relationship between social support and physical activity intentions. *Journal of Applied Social Psychology, 43*(6), 1333–1341.

Gjestvang, C., Abrahamsen, F., & Stensrud, T. (2021). Social support as a predictor of exercise adherence among novice exercisers in fitness clubs. *Frontiers in Physiology, 12*, 638928.

Gonzalez-Freire, M., de Cabo, R., Studenski, S. A., & Ferrucci, L. (2014). The neuromuscular junction: Aging at the crossroad between nerves and muscle. *Frontiers in Aging Neuroscience, 6*, 208.

Gunstad, J., Paul, R. H., Brickman, A. M., Cohen, R. A., Arns, M., Roe, D., & Gordon, E. (2006). Patterns of cognitive performance in middle-aged and older adults: A cluster analytic examination. *Journal of Geriatric Psychiatry and Neurology, 19*(2), 59-64.

Hasegawa, Y., Hoshino, Y., & Takahashi, S. (2000). Teaching basic skills for skiing and gymnastics with a humanoid robot. In *Proceedings of the 9th IEEE International Workshop on Robot and Human Interactive Communication* (pp. 127–132).

Hastings, S. N., Mahanna, E. P., Berkowitz, T. S. Z., Smith, V. A., Choate, A. L., Hughes, J. M., Pavon, J., Robinson, K., Hendrix, C., Van Houtven, C., Gentry, P., Rose, C., Plassman, B. L., Potter, G., & Oddone, E. (2021). Video-enhanced care management for medically complex older adults with cognitive impairment. *Journal of the American Geriatrics Society*, *69*(1), 77-84.

Holt, N. L., & Hoar, S. D. (2006). The multidimensional construct of social support. *Literature reviews in sport psychology*, 199-225.

Inui, Y., Ogawa, T., Tanaka, Y., Hayashida, K., & Morioka, S. (2022). Relationship between exercise motivation and social support in a support facility for persons with disabilities in Japan. *Annals of Medicine, 54*(1), 820-829.

Iio, T., Shiomi, M., Shinozawa, K., Akimoto, T., Shimohara, K., & Hagita, N. (2011). Investigating entrainment of people's pointing gestures by robot's gestures using a WOz method. *International Journal of Social Robotics*, *3*, 405-414.

Jaffe, J., Stern, D. N., & Peery, J. C. (1973). "Conversational" coupling of gaze behavior in prelinguistic human development. *Journal of Psycholinguistic Research*, *2*(4), 321-329.

Jaques, E. (2018). The midlife crisis. In *International Encyclopedia of the Social & Behavioral Sciences* (2nd ed., pp. 351-356). Elsevier.

Jeon, Gyu-Ri, Lee, Chae-Hyeon, Jeong, Seong-Mi, & Choi, Jeong-Il. (2024). *Sosyeol jineung robos-ui teukseong-i manjok-gwa sayong-uido-e michineun yeonghyang: Il-*

in gagu sosyeol jineung robos sayongjareul jungsimeuro [The effect of characteristics of social intelligence robots on satisfaction and intention to use: Focused on users of single person households]. *Pumjilgyeongyeonghakhoeji*, *52*(1), 95−113.

Jeong, S., Shin, D. H., & Gu, J. (2015). A case study on the nonverbal immediacy of the robot. *The Journal of the Korea Contents Association*, *15*(7), 181–192.

Kamegaya, T., Araki, Y., Koike, K., & Suzuki, T. (2014). Long-term effects of a peer-support program for community-dwelling older adults. *Geriatrics & Gerontology International, 14*(1), 112-118.

Kanda, T., Hirano, T., Eaton, D., & Ishiguro, H. (2004). Interactive robots as social partners and peer tutors for children: A field trial. *Human–Computer Interaction, 19*(1-2), 61-84.

Kang, M. (2021). Non-verbal emotional expressions for social presence of chatbot interface. *The Journal of the Korea Contents Association*, 21(1), 1–11.

Khambhaita H, Rios-Martinez J, Alami R (2016) Head-body motion coordination for human aware robot navigation. In: Proceedings of the international workshop HFR, pp 1–8. https://hal.laas.fr/hal-01568838

Kim, H., & Seong, M. J. (2020). The Relationship between Participation Motivation, Fun factor, Leisure satisfaction and continued exercise of elderly sports. *The Korean Society of Applied Science and Technology, 37*(4), 807–819.

Kim, J. H., & Lee, H. Y. (2008). *Jikjangin-ui yeoga seupeocheu chamyeo donggi-ga molip gyeongheom-e michineun yeonghyang* [The effect of leisure sports participation motivation on flow experience in office workers]. *Hanguk Yeoga Rekrieisyeon*

Hakhoeji, *32*(3), 165–175.

Kim, Ji-Hae, Gwon, O-Seong, & Jeon, Su-Jin. (2018). *Jiche jang-aein-ui hwilcheeo dijein-eul wihan jeongseongjeok sayongja josa bangbeop yeongu* [A study on qualitative user research methods for wheelchair design for people with physical disabilities]. *Hanguk Dijein Munhwahakhoeji*, *24*(1), 141–153.

Kim, Y. G., & Lee, K. S. (2011). *Noin-ui seupocheu hwaldong chamyeo-wa jeongseojeok haengboggam-ui gwan-gye* [The relationship between participation in sports activities and emotional happiness among the elderly]. *Hanguk Yeoga Rekrieisyeon Hakhoeji*, *35*(3), 7–15.

Kim, Y. H., & Kim, J. H. (2021). *Baedeuminteon keulleop membeo-ui chamyeo donggi-wa undong mollip-i undong jisok-e michineun yeonghyang* [The effect of participation motivation and exercise flow on exercise continuation of badminton club members]. *Yunghap-gwa Tongseop*, *4*(2), 17–34.

King, K. A., Tergerson, J. L., & Wilson, B. R. (2008). Effect of social support on adolescents' perceptions of and engagement in physical activity. *Journal of Physical Activity and Health*, *5*(3), 374-384.

Kirkby, R. J., Kolt, G. S., Habel, K., & Adams, J. (1999). Exercise in older women: Motives for participation. *Australian Psychologist, 34*(2), 122-127.

Kleinke, C. L. (1986). Gaze and eye contact: A research review. *Psychological Bulletin, 100*(1), 78.

Knight, H., Toscano, R., Stiehl, W. D., Chang, A., Wang, Y., & Breazeal, C. (2009, October). Real-time social touch gesture recognition for sensate robots. In *2009 IEEE/RSJ International Conference on Intelligent Robots and Systems* (pp. 3715-3720). IEEE.

Knopman, D., Boland, L. L., Mosley, T., Howard, G., Liao, D., Szklo, M., & Folsom, A. R. (2001). Cardiovascular risk factors and cognitive decline in middle-aged adults. *Neurology, 56*(1), 42-48.

Koller, M., Weiss, A., Hirschmanner, M., & Vincze, M. (2023). Robotic gaze and human views: A systematic exploration of robotic gaze aversion and its effects on human behaviors and attitudes. *Frontiers in Robotics and AI, 10*, Article 1062714.

Kollia, N., Panagiotakos, D. B., Chrysohoou, C., Georgousopoulou, E., Tousoulis, D., Stefanadis, C., ... & Pitsavos, C. (2018). Determinants of healthy ageing and its relation to 10-year cardiovascular disease incidence: the ATTICA study. *Central European journal of public health*, *26*(1).

Koo, B. J. (2008). The influence of resilience, hope, marital intimacy, and family support on quality of life for middle-aged women. *Journal of Korean Academy of Psychiatric and Mental Health Nursing*, *17*(4), 421-430.

Kossev, A. R., Schrader, C., Däuper, J., Dengler, R., & Rollnik, J. D. (2002). Increased intracortical inhibition in middle-aged humans: A study using paired-pulse transcranial magnetic stimulation. *Neuroscience Letters, 333*(2), 83-86.

Kosuge, K. (2008). Dancing with robots: Toward a new discipline of robotic arts. *Advanced Robotics, 22*(6-7), 655-671.

Kozima, H., Michalowski, M. P., & Nakagawa, C. (2009). Keepon: A playful robot for research, therapy, and entertainment. *International Journal of Social Robotics, 1*, 3–18.

Kreijns, K., Xu, K., & Weidlich, J. (2022). Social presence: Conceptualization and measurement. *Educational Psychology Review*, *34*(1), 139-170.

Kumar, N., & Benbasat, I. (2002). Para-social presence: A re-conceptualization of 'social presence' to capture the relationship between a website and her visitors. In *Proceedings of the 35th Annual Hawaii International Conference on System Sciences* (pp. 106–112).

Kuo, H. K., Leveille, S. G., Yen, C. J., Chaiwanichsiri, D., & Yeh, S. C. (2006). Exploring the association between handgrip strength and functional limitation in older adults. *American Journal of Preventive Medicine, 31*(5), 451-457.

Lee, E.-J. (2013). *Jungnyeon jeoneopjubu-ui sahoejeok gwangye wa haengbokgam-e gwanhan yeongu* [A study on social relationships and happiness of middle-aged full-time housewives] [Doctoral dissertation, Seoul National University]. Seoul National University Repository.

Lee, H. S., Ahn, J. D., & Han, N. I. (2013). *Daenseu seupeocheu chamyeo donggi-ga yeoga manjok mit undong jisok-e michineun yeonghyang* [The effect of dance sport participation motivation on leisure satisfaction and exercise continuance]. *Hanguk Bal-yuk Bal-dal Hakhoeji*, *21*(2), 117–125.

Lee, M. H., Siewiorek, D. P., Smailagic, A., Bernardino, A., & Badia, S. B. I. (2024). Enabling AI and robotic coaches for physical rehabilitation therapy: Iterative design and evaluation with therapists and post-stroke survivors. *International Journal of Social Robotics, 16*(1), 1-22.

Lee, K. M. (2004). Presence, explicated. *Communication Theory, 14*(1), 27-50.

Lee, K., Jung, Y., Kim, J., & Kim, S. R. (2006). Are physically embodied social agents better than disembodied social agents? The effects of physical embodiment, tactile interaction, and people's loneliness in human-robot interaction. *International Journal of Human-Computer Studies, 64*(10), 962–973.

Lee, Y. K., Park, Y., Shin, M., & Hahn, S. (2024). Effect of feedback styles in robotic fitness coaching on exercise intensity. *Journal of HCI Korea, 19*(2), 35-45.

Leite, I., Martinho, C., Pereira, A., & Paiva, A. (2009). As time goes by: Long-term evaluation of social presence in robotic companions. In *Proceedings of the IEEE International Workshop on Robot and Human Interactive Communication* (pp. 669–674).

Levinson, D. J. (1986). *The Seasons of a Man's Life: The Groundbreaking 10-Year Study That Was the Basis for Passages!*. Ballantine Books.

Lewis, J. R. (2018). The system usability scale: past, present, and future. *International Journal of Human–Computer Interaction, 34*(7), 577-590.

Lewis, J. R., & Sauro, J. (2018). Item benchmarks for the System Usability Scale. *Journal of Usability Studies, 13*(3), 158-167.

Lim, I. (2010). The effects of yoga participation on body image and physical self-concept in adult women. *Korean Journal of Sport Psychology, 21*(1), 127-141.

Lin, Y. Y. (2020). Support matters: Predictors of intrinsic motivation in older learners in Taiwan. *Australian journal of adult learning*, *60*(2), 190-212.

Lindsay Smith, G., Banting, L., Eime, R., O'Sullivan, G., & Van Uffelen, J. G. (2017). The association between social support and physical activity in older adults: A systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 14*, Article 56.

Liu, T. et al. (2021). Nutrition and exercise interventions could ameliorate age-related cognitive decline: a meta-analysis of randomized controlled trials. *Aging Clinical and Experimental Research, 33*, 1799-1809.

Liu, X., Dong, J., & Jeon, M. (2023). Robots'"Woohoo" and "Argh" Can Enhance Users'

Emotional and Social Perceptions: An Exploratory Study on Non-lexical Vocalizations and Non-linguistic Sounds. *ACM Transactions on Human-Robot Interaction*, *12*(4), 1-20.

Losa-Reyna, J., Alcazar, J., Carnicero, J., Alfaro-Acha, A., Castillo-Gallego, C., Rosado-Artalejo, C., & García-García, F. J. (2022). Impact of relative muscle power on hospitalization and all-cause mortality in older adults. *The Journals of Gerontology: Series A, 77*(4), 781-789.

Lox, C. L., Ginis, K. A. M., Gainforth, H. L., & Petruzzello, S. J. (2019). *The psychology of exercise: Integrating theory and practice*. Routledge.

Maran, T., Furtner, M., Liegl, S., Kraus, S., & Sachse, P. (2019). In the eye of a leader: Eye-directed gazing shapes perceptions of leaders' charisma. *The Leadership Quarterly, 30*(6), 101337.

Marmpena, M., Lim, A., & Dahl, T. S. (2018). How does the robot feel? Perception of valence and arousal in emotional body language. *Paladyn, Journal of Behavioral Robotics, 9*(1), 168-182.

Marselle, M. R., Irvine, K. N., & Warber, S. L. (2013). Walking for well-being: are group walks in certain types of natural environments better for well-being than group walks in urban environments?. *International journal of environmental research and public health*, *10*(11), 5603-5628.

Mehrabian, A. (1981). *Silent messages: Implicit communication of emotions and attitudes*. Wadsworth.

Mendonça, G., Cheng, L. A., Mélo, E. N., & de Farias Júnior, J. C. (2014). Physical activity and social support in adolescents: A systematic review. *Health Education Research, 29*(5), 822-839.

Metter, E. J., Conwit, R., Tobin, J., & Fozard, J. L. (1997). Age-associated loss of power and strength in the upper extremities in women and men. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *52*(5), B267-B276.

Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., & Wood, C. E. (2013). The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: Building an international consensus for the reporting of behavior change interventions. *Annals of Behavioral Medicine, 46*(1), 81-95.

Mol, M., van Schaik, A., Dozeman, E., Ruwaard, J., Vis, C., Ebert, D. D., ... & Smit, J. H. (2020). Dimensionality of the system usability scale among professionals using internet-based interventions for depression: a confirmatory factor analysis. *BMC psychiatry*, *20*, 1-10.

Moon, A., Troniak, D. M., Gleeson, B., Pan, M. K., Zheng, M., Blumer, B. A., ... & Croft, E. A. (2014, March). Meet me where I’m gazing: How shared attention gaze affects human-robot handover timing. *Proceedings of the 2014 ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, 334–341. ACM.

Murray, A., & Cardinale, M. (2015). Cold applications for recovery in adolescent athletes: A systematic review and meta-analysis. *Extreme Physiology & Medicine, 4*, 17.

Mutlu, B., Forlizzi, J., & Hodgins, J. (2006). A storytelling robot: Modeling and evaluation of human-like gaze behavior. *Proceedings of the 6th IEEE-RAS International Conference on Humanoid Robots*, 518-523. IEEE.

Mutlu, B., Shiwa, T., Kanda, T., Ishiguro, H., & Hagita, N. (2009). Footing in human-robot conversations: How robots might shape participant roles using gaze cues.

Proceedings of the 4th ACM/IEEE International Conference on Human-Robot Interaction, 61-68. ACM.

Nakagawa, K., Shiomi, M., Shinozawa, K., Matsumura, R., Ishiguro, H., & Hagita, N. (2011). Effect of robot's active touch on people's motivation. *Proceedings of the 6th International Conference on Human-Robot Interaction*, 465–472. ACM.

Nass, C., & Moon, Y. (2000). Machines and mindlessness: Social responses to computers. *Journal of Social Issues, 56*(1), 81-103.

Nass, C., Steuer, J., & Tauber, E. R. (1994). Computers are social actors. In *Proceedings of CHI'94 Human Factors in Computing Systems* (pp. 72–78). Boston, MA: ACM.

Neil Thomas, G., Macfarlane, D. J., Guo, B., Cheung, B. M., McGhee, S. M., Chou, K. L., & Tomlinson, B. (2012). Health promotion in older Chinese: A 12-month cluster randomized controlled trial of pedometry and peer support. *Medicine and Science in Sports and Exercise, 44*(6), 1159-1166.

Nettelbeck, T., & Burns, N. R. (2010). Processing speed, working memory and reasoning ability from childhood to old age. *Personality and Individual Differences, 48*(4), 379-384.

Newson, R. S., & Kemps, E. B. (2007). Factors that promote and prevent exercise engagement in older adults. *Journal of Aging and Health, 19*(3), 470–481.

Nie, J., Park, M., Marin, A. L., & Sundar, S. S. (2012). Can you hold my hand? Physical warmth in human-robot interaction. *Proceedings of the Seventh Annual ACM/IEEE International Conference on Human-Robot Interaction*, 201-202. ACM.

Roh, M. Y., & Mun, H. S. (2020). *Undong chamyeo yeodaesaeng-ui sahoejeok jiji, gibon simni yoggu, chamyeo donggi-wa undong mollip mit undong jisok-ui-ui gujogeok gwangye* [The structural relationship between social support, basic psychological needs, participation motivation, exercise flow, and exercise continuation intention of female college students participating in exercise]. *Hanguk Yeo-seong Cheyukhakhoeji*, 34(1), 1–15.

Northey, J. M., Cherbuin, N., Pumpa, K. L., Smee, D. J., & Rattray, B. (2018). Exercise interventions for cognitive function in adults older than 50: A systematic review with meta-analysis. *British Journal of Sports Medicine, 52*(3), 154-160.

Oh, S. I., & Shin, H. S. (2008). *Muyong hwaldong-e chamyeohan noin yeoseong-deul-ui simrijeok haengboggam, jaa jonjunggwa molip gyeongheom-gwa-ui gwan-gye* [The relationship among psychological happiness, self-esteem, and flow experience in elderly women participating in dance activities]. *Hanguk Sahoe Cheyuk Hakhoeji*, 34(1), 725–732.

Orsega-Smith, E. M., Payne, L. L., Mowen, A. J., Ho, C. H., & Godbey, G. C. (2007). The role of social support and self-efficacy in shaping the leisure time physical activity of older adults. *Journal of Leisure research*, *39*(4), 705-727.

Park, I., & Kim, Y. (2010). The impact of line dance club members' participation on behaviors to Improve health and psychological happiness: Targeting middle-aged women. *Journal of Korean Physical Education Association for Girls and Women*, *24*(5), 57-70.

Park, J. Y., & Kim, H. R. (2024). *Daenseu chamyeo jungnyeon yeoseong-deul-ui laipeu-seutail-gwa chamyeo donggi mit undong jisok gan-ui gwan-gye* [The relationship between lifestyle, participation motivation, and exercise adherence of middle-aged women participating in dance]. *Hanguk Wellness Hakhoeji*, 19(1), 183–191.

Parshall, D. P. (2003). Research and reflection: Animal-assisted therapy in mental health settings. *Counseling and Values, 48*(1), 47-56.

Patel, A. V., Friedenreich, C. M., Moore, S. C., Hayes, S. C., Silver, J. K., Campbell, K. L., & Schmitz, K. H. (2019). American college of sports medicine roundtable report on physical activity, sedentary behavior, and cancer prevention and control. *Medicine and Science in Sports and Exercise, 51*, 2391–2402.

Pelletier, L. G., Rocchi, M. A., Vallerand, R. J., Deci, E. L., & Ryan, R. M. (2013). Validation of the revised sport motivation scale (SMS-II). *Psychology of Sport and Exercise, 14*(3), 329-341.

Pieskä, S., Mäkelä, M., & Salmi, S. (2012). Robots in social care and sports. *International Journal of Healthcare Technology and Management, 13*(1–2), 111–123.

Prochazkova, E., Prochazkova, L., Giffin, M. R., Scholte, H. S., De Dreu, C. K., & Kret, M. E. (2018). Pupil mimicry promotes trust through the theory-of-mind network. *Proceedings of the National Academy of Sciences, 115*(31), E7265-E7274.

Rhodes, R. E., & Dickau, L. (2012). Experimental evidence for the intention–behavior relationship in the physical activity domain: A meta-analysis. *Health Psychology, 31*(6), 724-727.

Reeves, B., & Nass, C. (1996). *The media equation: How people treat computers, television, and new media like real people and places.* Cambridge, UK: Center for the Study of Language and Information.

Riek, L. D., Paul, P. C., & Robinson, P. (2010). When my robot smiles at me: Enabling human-robot rapport via real-time head gesture mimicry. *Journal on Multimodal User Interfaces, 3*(1-2), 99–108.

Roh, S. & Jang, S. (2018). A Study on Depression, Powerlessness, Family Support and Problem Drinking of Middle-Aged Women. *The Korean Journal of Growth and Development, 26*(2), 143-151.

Ruesch, J., Kees, W. (1972). *Nonverbal Communication: Notes on the Visual Perception of Human Relations*. University of California Press.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology, 25*(1), 54-67.

Sackl, A., Pretolesi, D., Burger, S., Ganglbauer, M., & Tscheligi, M. (2022). Social robots as coaches: How human-robot interaction positively impacts motivation in sports training sessions. In *Proceedings of the 31st IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)* (pp. 141–148). Naples, Italy: IEEE.

Saerbeck, M., Schut, T., Bartneck, C., & Janse, M. D. (2010). Expressive robots in education: Varying the degree of social supportive behavior of a robotic tutor. *Proceedings of the 28th international conference on Human factors in computing systems*, 1613–1622. ACM.

Sardar, A., Joosse, M., Weiss, A., & Evers, V. (2012). Don't stand so close to me: Users' attitudinal and behavioral responses to personal space invasion by robots. *Proceedings of the Seventh Annual ACM/IEEE International Conference on Human-Robot Interaction*, 229-230. ACM.

Sauro, J. (2011). *A practical guide to the System Usability Scale*. Denver, CO: Measuring Usability LLC.

Sauro, J., & Lewis, J. R. (2016). *Quantifying the user experience: Practical statistics for user research* (2nd ed.). Cambridge, MA: Morgan-Kaufmann.

Scarapicchia, T. M. F., Amireault, S., Faulkner, G., & Sabiston, C. M. (2017). Social support and physical activity participation among healthy adults: A systematic review of prospective studies. *International Review of Sport and Exercise*

Psychology, 10, 50–83.

Scholes, S., & Mindell, J. (2012). Physical activity in adults. *Health survey for England*, *1*(2), 1-49.

Schwarzer, R., & Knoll, N. (2007). Functional roles of social support within the stress and coping process: A theoretical and empirical overview. *International Journal of Psychology, 42*(4), 243–252.

Seidler, R. D., Bernard, J. A., Burutolu, T. B., Fling, B. W., Gordon, M. T., Gwin, J. T., & Lipps, D. B. (2010). Motor control and aging: Links to age-related brain structural, functional, and biochemical effects. *Neuroscience & Biobehavioral Reviews, 34*(5), 721–733.

Serfaty, G. J., Barnard, V. O., & Salisbury, J. P. (2023). Generative facial expressions and eye gaze behavior from prompts for multi-human-robot interaction. *Adjunct Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology*, 1-3. ACM.

Sharma, S. V., Hoelscher, D. M., Kelder, S. H., Diamond, P. M., Day, R. S., & Hergenroeder, A. C. (2009). A path analysis to identify the psychosocial factors influencing physical activity and bone health in middle-school girls. *Journal of physical activity and health*, *6*(5), 606-616.

Shim, S. H., Livingston, R. W., Phillips, K. W., & Lam, S. S. (2021). The impact of leader eye gaze on disparity in member influence: Implications for process and performance in diverse groups. *Academy of Management Journal, 64*(6), 1873-1900.

Shin, C. H. (2014). The effects of participation motivation on exercise adherence and leisure satisfaction in senior welfare center sports programs. *The Korea Journal of*

Sport, 12(1), 291–302.

Short, J., Williams, E., & Christie, B. (1976). *The social psychology of telecommunications*. Wiley.

Sidner, C., Lee, C., Kidd, C., Lesh, N., & Rich, C. (2005). Explorations in engagement for humans and robots. *Artificial Intelligence, 166*(1–2), 140–164.

Silvera-Tawil, D., Rye, D., & Velonaki, M. (2014). Interpretation of social touch on an artificial arm covered with an EIT-based sensitive skin. *International Journal of Social Robotics, 6*(4), 489-505.

Sofi, F., Valecchi, D., Bacci, D., Abbate, R., Gensini, G. F., Casini, A., & Macchi, C. (2011). Physical activity and risk of cognitive decline: A meta-analysis of prospective studies. *Journal of Internal Medicine, 269*(1), 107–117.

Song, H. (2008). An Analysis of the Research Trends and Tasks on Senior Citizens and Later Life in the Aging Society-Focused on the Field of Home Economics. *Journal of Families and Better Life*, *26*(3), 79-99.

Stacey, E. (2001, July). Social presence online: Networking learners at a distance. In *IFIP World Conference on Computers in Education* (pp. 39–48). Boston, MA: Springer US.

Süssenbach, L., Riether, N., Schneider, S., Berger, I., Kummert, F., Lütkebohle, I., & Pitsch, K. (2014). A robot as fitness companion: towards an interactive action-based motivation model. *The 23rd IEEE international symposium on robot and human interactive communication*, 286-293. IEEE.

Tallis, J., Richardson, D. L., & Eyre, E. L. J. (2022). The influence of easing COVID-19 restrictions on the physical activity intentions and perceived barriers to physical activity in UK older adults. *International Journal of Environmental Research and*

Public Health, 19(21), 12521.

Tanaka, F., Cicourel, A., & Movellan, J. R. (2007). Socialization between toddlers and robots at an early childhood education center. *Proceedings of the National Academy of Sciences of the United States of America, 104*(46), 17954-17958.

Teel, J. B. (2011). *An examination of the relationship between cognitive learning style preference and nonverbal immediacy behaviors in undergraduate students* (Publication No. 3480654) [Doctoral dissertation, Auburn University]. ProQuest Dissertations and Theses Global.

Terzioğlu, Y., Mutlu, B., & Şahin, E. (2020). Designing social cues for collaborative robots: the role of gaze and breathing in human-robot collaboration. *Proceedings of the 2020 ACM/IEEE international conference on human-robot interaction*, 343-357. ACM.

Thayer, S. (1986). History and Strategies of Research on Social Touch. *Journal of Nonverbal Behavior, 10*(1), 12-28.

Tian, Y., & Shi, Z. (2022). The relationship between social support and exercise adherence among Chinese college students during the COVID-19 pandemic: The mediating effects of subjective exercise experience and commitment. *International Journal of Environmental Research and Public Health*, 19(18), 11827.

Tieland, M., Trouwborst, I., & Clark, B. C. (2018). Skeletal muscle performance and ageing. *Journal of Cachexia, Sarcopenia and Muscle, 9*(1), 3–19.

Tu, C. H., & McIsaac, M. S. (2002). An examination of social presence to increase interaction in online classes. *American Journal of Distance Education, 16*(2), 131–150.

Urakami, J., & Seaborn, K. (2023). Nonverbal cues in human–robot interaction: A communication studies perspective. *ACM Transactions on Human-Robot Interaction*, *12*(2), 1-21.

Vallerand, R. J. (2008). On the psychology of passion: In search of what makes people's lives most worth living. *Canadian Psychology, 49*(1), 1-13.

Vatankhah, M., & Tanbakooei, N. (2014). The role of social support on intrinsic and extrinsic motivation among Iranian EFL learners. *Procedia-Social and Behavioral Sciences*, *98*, 1912-1918.

Wada, K., & Shibata, T. (2007). Living with seal robots—Its sociopsychological and physiological influences on the elderly at a care house. *IEEE Transactions on Robotics, 23*(5), 972-980.

Wada, K., Shibata, T., Saito, T., & Tanie, K. (2004). Effects of robot-assisted activity for elderly people and nurses at a day service center. *Proceedings of the IEEE, 92*(11), 1780-1788. IEEE.

Wada, K., Shibata, T., Sakamoto, K., & Tanie, K. (2005). Quantitative analysis of utterance of elderly people in long-term robot assisted activity. *ROMAN 2005. IEEE International Workshop on Robot and Human Interactive Communication, 2005*, 267-272. IEEE.

Weaver, A. J. (2009). Midlife crisis reconsidered: A psychosocial perspective. *Psychology and Aging, 24*(1), 132–139.

Winkle, K., Lemaignan, S., Caleb-Solly, P., Leonards, U., Turton, A., & Bremner, P. (2020). Couch to 5km robot coach: An autonomous, human-trained socially assistive robot. In *Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 520–522). New York, NY: ACM.

Wiltshire, T. J., Lobato, E. J., Wedell, A. V., Huang, W., Axelrod, B., & Fiore, S. M. (2013).

Effects of robot gaze and proxemic behavior on perceived social presence during a hallway navigation scenario. *Proceedings of the human factors and ergonomics society annual meeting*, *57*(1), 1273-1277. SAGE Publications.

World Health Organization. (2022). *Global status report on physical activity 2022*. https://www.who.int/teams/health-promotion/physical-activity/global-status-report-on-physical-activity-2022

Wrench, J. S., Punyanunt-Carter, N. M., Thweatt, K. S. (2020). *Interpersonal Communication: A Mindful Approach to Relationships*. Milne Library Publishing.

Xu, F., Liu, Y., & Zhang, W. (2019). The association between physical activity and metabolic syndrome in older adults with obesity. *Journal of Frailty & Aging, 8*(1), 27-32.

Yu, J. (2012). *The effect of badminton club members' participation level and motivation on leisure satisfaction and exercise continuation.* [Master's thesis, Chonnam National University]. Chonnam National University Repository.

Yu, Yang-Seop. (2006). *Juni-eo golpeu seonsu-ui chamga donggi-ga mollip gyeongheom-e michineun yeonghyang* [The effect of participation motivation on flow experience of junior golf players]. *Hanguk Cheyuk Gwahakhoeji*, 15(1), 223–232.

Zecca, M., Mizoguchi, Y., Endo, K., Iida, F., Kawabata, Y., Endo, N., ... & Takanishi, A. (2009, September). Whole body emotion expressions for KOBIAN humanoid robot—preliminary experiments with different Emotional patterns—. In *RO-MAN 2009-The 18th IEEE International Symposium on Robot and Human Interactive Communication* (pp. 381-386). IEEE.

Zhao, E., Tranovich, M. J., & Wright, V. J. (2014). The role of mobility as a protective factor of cognitive functioning in aging adults: A review. *Sports Health, 6*, 63-69.\

Appendix

Appendix A. System Usability Scale(SUS) (Brooke, 1996)

전혀 동의하지 않는다				매우 동의한다
1	2	3	4	5

1. 나는 이 로봇을 자주 사용할 것 같다

2. 나는 이 로봇의 사용법이 쓸데없이 복잡하다고 생각한다

3. 나는 이 로봇을 사용하는 것이 쉽다고 생각했다

4. 나는 이 로봇을 사용하기 위해 전문가의 도움이 필요하다고 생각한다

5. 나는 이 로봇의 다양한 기능들이 잘 통합되어 있다고 생각한다

6. 나는 이 로봇에 너무 많은 모순이 있다고 생각했다

7. 나는 대부분의 사람들이 이 로봇 사용법을 매우 빨리 익힐 것이라고 생각한다

8. 나는 이 로봇을 사용하는 게 매우 불편하다고 느꼈다

9. 나는 이 로봇을 사용하는 게 매우 편했다

10. 나는 많은 것을 배워야 이 로봇을 사용할 수 있었다

Appendix B. Sport Motivation Scale-II(SMS-II) (Pelletier et al., 2013)

전혀 동의하지 않는다			보통이다	동의한다		
1	2	3	4	5	6	7

1. 이 운동을 성공할 수 없을 거 같다는 느낌이 든다

2. 운동을 배우는 것이 즐겁기 때문에

3. 운동을 하지 않으면 기분이 나쁘기 때문에

4. 운동을 하는 것은 진정 내가 누구인가를 반영하기 때문에

5. 스포츠를 통해, 나의 깊은 원칙에 따라 살기 때문에

6. 운동을 하지 않으면 주변 사람들이 나를 탐탁하지 않을 것이라 생각하기 때문에

7. 운동을 하면 어떻게 개선시킬 수 있는지 배우는 것은 매우 흥미로운 일이기 때문에

8. 주변 사람들이 내가 하는 일에 대해 나를 칭찬할 것이기 때문에

9. 자기 개발의 방법으로 이 스포츠를 선택했기 때문에

10. 운동하는 것은 나와는 관계가 없는 일인 것 같다

11. 나의 다른 면을 발전시키기 위해 내가 선택한 가장 좋은 방법 중 하나이기 때문에

12. 운동을 하면 내가 나 자신에 대해 더 좋게 느끼기 때문에

13. 새로운 훈련 전략을 발견하는 것이 즐겁기 때문에

14. 운동을 하지 않았다면 나는 보람을 느끼지 못했을 것이기 때문에

15. 운동에 참여하는 것은 내 인생에서 필수적인 부분이기 때문에

16. 내가 아끼는 사람들이 내가 운동을 하지 않는다면 속상할 것이기 때문에

17. 스스로 나의 가치를 개발하는 좋은 방법을 발견했기 때문에

18. 스포츠를 하는데 좋은 이유가 있었지만, 지금은 계속해야 하는지에 대해 고민한다

국문 초록

중년층은 인지 및 신체 능력에 변화가 발생하기 때문에, 건강과 웰빙 유지를 위해 규칙적인 운동이 필수적이다. 사회적 지지는 운동 동기를 높이는 데 중요한 역할을 하지만, 모든 사람이 이러한 자원을 활용할 수 있는 것은 아니다. 이에 로봇 보조는 이러한 격차를 해소하는 데 도움이 될 수 있다. 연구에 따르면, 휴머노이드 로봇은 신체 움직임 모니터링이나 맞춤형 피드백이 필요한 상황에서 운동 보조자로서 잠재력을 갖고 있다. 사회적 현존감 이론에 따르면, 적절한 비언어적 표현을 사용할 경우 로봇은 사회적 지원을 제공하는 사회적 실체로 인식될 수 있으며, 이는 운동 동기를 촉진한다.

그러나 운동 맥락에서 로봇의 비언어적 표현이 운동 동기와 사용자 경험에 미치는 영향을 탐구한 선행 연구는 부족하다. 따라서 본 연구는 로봇의 비언어적 표현이 중년층의 운동 동기와 사용자 경험에 미치는 효과를 검증하고, 어떤 비언어적 표현이 운동 동기 및 사용자 경험 향상에 더 효과적인지 확인하고자 한다.

연구 1에서는 로봇 운동 파트너의 의사소통 방식(언어적 표현 vs. 언어 및 비언어적 표현)이 운동 동기와 사용자 경험에 미치는 영향을 검증하였다. 또한, 로봇 없이 자유롭게 운동하는 통제 조건을 포함하였다. 연구 2에서는 로봇의 비언어적 상호작용을 동작, 촉각, 시선으로 세분화하여 어느 표현이 운동 동기 향상에 가장 효과적인지 분석하였다.

그 결과, 연구 1에서는 로봇이 언어와 비언어적 표현을 함께 사용할 때 운동 동기가 유의미하게 향상되었으며, 이러한 변화는 통제 조건과 유의미한 차이를 보였다. 사용자 경험 점수는 로봇의 언어 및 비언어적 표현 조건에서

더 높았으나 통계적으로 유의미하지는 않았다. 연구 2에서는 시선 조건에서 운동 동기가 유의미하게 증가하였고, 사용자 경험 또한 시선 조건이 동작 조건보다 유의미하게 높았다.

본 연구는 운동 파트너 로봇에서 비언어적 표현이 운동 동기 향상에 중요하다는 점을 강조하며, 비용과 에너지 효율적인 로봇 설계를 제안한다. 또한, 운동 동기를 높이는 것이 운동 습관을 지속하는 데 도움이 되며, 중년기에 형성된 건강한 습관은 노년기까지 이어져 성공적 노화 전략으로 활용될 수 있음을 시사한다.

주요어: 운동 동기, 사용자 경험, 사회적 현존감, 비언어적 표현, 비언어적 표현, 시선 비언어, 로봇 운동 파트너, 중장년층

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