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Effects of Social Robotics in Promoting Physical Activity in the Shared Workspace

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Abstract: This paper presents a design study exploring the effects of a social robot in facilitating people to participate in light-intensity exercises after a long duration of sitting in a shared workspace. A smart system based on a trolley-like robot, called the Anti-Sedentary Robot, was developed to realize the health intervention as follows. To start, the robot could navigate to the location of a sedentary worker to invite them to participate in a temporal voluntary service of returning items. Upon the invitation being accepted, the robot would then move with the worker to return the item and simultaneously provide guidance for physical exercises. Based on the Anti-Sedentary Robot, a within-subject study (n = 18) was carried out to examine exercise motivations and psychological benefits of our design by making comparisons between a robot-guided intervention and a human-guided intervention. Quantitative results showed that the health intervention based on the Anti-Sedentary Robot increased intrinsic motivations and provided acute mental benefits compared to the human-guided intervention. Qualitative findings suggested that the Anti-sedentary Robot could combat work-related sedentary behaviors due to the pleasant system interactivity and the provision of reciprocal voluntary tasks. We discuss implications for the future development of social robots for office vitality based on our research findings.

Keywords: social robots; sedentary behaviors; health promotion; shared workspace

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1. Introduction

With the rapid penetration of labor-saving technologies, people are increasingly engaged in knowledge-demanding tasks with independent workflow and a flexible work schedule [1]. Accordingly, it has become common practice to adopt shared workspaces as office settings in knowledge-based industries [2], which allow people to have professional working conditions and equipment in different routines and environments [3,4]. Yet, working in a shared environment can contribute to increased sedentary lifestyles, threatening individuals' physiological and psychological wellbeing [5]. Many national surveys have demonstrated that stationary work has become the most critical reason for the prevalence of suboptimal health conditions among knowledge workers and college students [6–9]. There are some barriers that hinder physically active behaviors in the shared workspace. Obviously, the spatial design of most co-working environments primarily focuses on the effective use of the workspace, making it challenging to engage in physical exercises at work [10,11]. Additionally, the presence of colleagues in the same space may demotivate people to leave their desks to improve their health status, due to task efficiency-oriented workplace norms [10–12].

For fitness promotion in a shared workspace, social elements may potentially contribute to this context. In fact, there has been a variety of human–computer interaction (HCI) studies leveraging social features to support individuals to reduce sedentary time and improve personal health status. For instance, Lin et al. [13] developed an interactive game to visualize the physical activity data of a group of office workers on a public display in the office kitchen. Ahtinen and colleagues [14] demonstrated that walking meetings facilitated by a mobile app can encourage physical activity in co-working environments. Ren et al. [15] proposed peer-based cooperative fitness tracking using a pair of wearable devices to establish mutual exercise support between a dyad of co-workers in the same office. Despite these potential persuasions based on social elements, there have also been several challenges in designing HCI systems to socialize physical activity in the shared workspace, e.g., undesired fitness competition between colleagues [16], health-related privacy concerns [17], and blurred work–life boundaries [18].

As a new strand of health promotion, recently, several HCI researchers have paid attention to utilizing robotic technologies for office vitality. Shin and colleagues [19] investigated a robot monitor that can move imperceptibly to correct the seated postures of the occupant. Similarly, Fujita et al. [20] designed TiltChair, which can actively incline its seat to stimulate the user in avoiding prolonged sitting. Moreover, it has been widely demonstrated that social robots can be designed and applied in preventive healthcare, due to their advantages, e.g., simulating social persuasions [21,22], reducing costs when scaling up [23–28], and providing customized user experiences [29,30]. To the best of our knowledge, however, few studies have investigated social robotics as an effective means to combat prolonged sitting while increasing office exercises. Therefore, this paper focuses on understanding whether and how a social robot can create persuasive effects on reducing sedentary behaviors in the shared workspace, as well as what health benefits it can offer to individuals.

In this paper, we present a design case study exploring the use of a social robot system to prompt unhealthy sitting conditions and facilitate the commitment of physical activities in the shared workspace. Specifically, we envisioned a design concept called the Anti-Sedentary Robot, which is a trolley-like robot that could navigate to the location of sedentary workers and invite them to help return items to the original place. Reciprocally, the robot would move with users to find the original place and guide them to perform some light-intensity exercises (e.g., stretch training). Taking a university library as an example of a shared workspace, we conducted a within-subject study of the Anti-Sedentary Robot with 18 college students to examine its resulting exercise motivations and psychological benefits. This paper contributes to HCI and digital health research in the following two aspects:

- Evidence that a social robot-based service system is effective in intervening in sedentary behaviors in the shared workspace with enhanced intrinsic motivations and acute emotional and mental benefits.
- Design implications that leverage social robot systems for promoting physically active behaviors in the shared workspace.

The remainder of this paper is organized as follows. In the next section, we provide a summary of how we developed the Anti-Sedentary Robot. In Sections 3 and 4, we report on the user study and its results, which lead to a discussion on the findings and limitations, with implications for future work, in Section 5. Section 6 contains our conclusions.

2. The Design of Anti-Sedentary Robot

2.1. The Design Concept

In this project, we aimed at developing a social robot that could remind workers of their prolonged sitting period and facilitate physically active behaviors in the shared workspace through establishing a reciprocal relationship with the user [31]. In this light, we envisioned the design concept of the Anti-Sedentary Robot, a voluntary item-returning service system that consisted of a trolley-like robot and a smart co-working environment (Figure 1). In general, the Anti-Sedentary Robot could provide an interactive exercise experience flow to sedentary workers, where the system would facilitate physically active behaviors in combination with the temporal task of returning items. Technically, such a health intervention in the shared workspace can be realized by the Anti-Sedentary Robot in two ways.

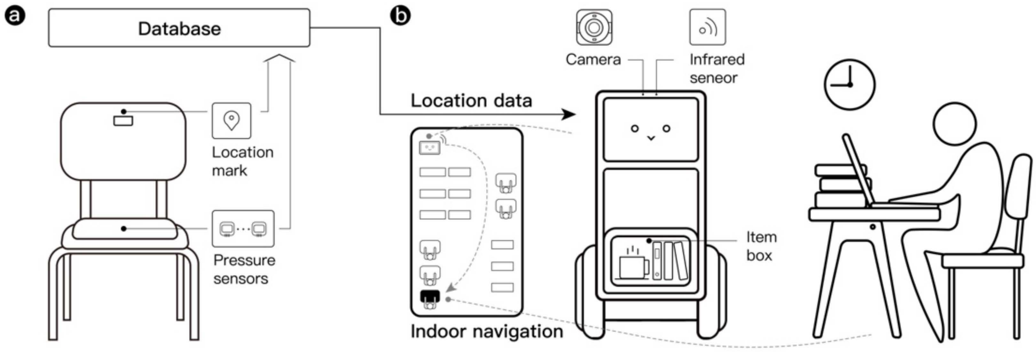

Figure 1. The system design of Anti-Sedentary Robot. (**a**) The real-time vitality database based on smart cushions, equipped with pressure sensors and location marks, distributed in the shared workspace; (**b**) the trolley-like robot with infrared sensors for obstacle avoidance.

Navigating to the target location of a sedentary worker to invite temporal participation in voluntary tasks. As shown in Figure 1a, in this project, we proposed a real-time database based on smart seat cushions distributed in the shared workspace. As in [32,33], each cushion would be embedded with pressure sensors to monitor the postures and sitting duration of the occupant and synchronize the anonymized data to the database, with an indoor location mark. Subsequently, when the system detects that the occupant has been seated too long, the relevant location data would be sent to the trolley-like robot so that it could move to the sedentary person, based on its indoor navigation [34]. As depicted in Figure 1b, the robot would be equipped with infrared sensors for avoiding obstacles while moving in the open workspace.

Facilitating light intensity exercises with user-system interactions on the way to returning items. After arriving at the target location, Figure 2a shows that the robot would stop and invite the sedentary worker to commit a voluntary task of returning a shared item to the original place (e.g., sending books back to the shelf, returning cups to the office kitchen, etc.). The invitation would be presented on the screen of the robot, where the user could accept or reject the request through interacting with its user interfaces. Once the invitation is accepted, the user would be assigned an item from the trolley and accompanied by the robot to find the return location. While following the robot to return the item, the user would be presented with some fitness tutorials (e.g., stretching, squat, etc.) as guidance to facilitate office exercises (see Figure 2b).

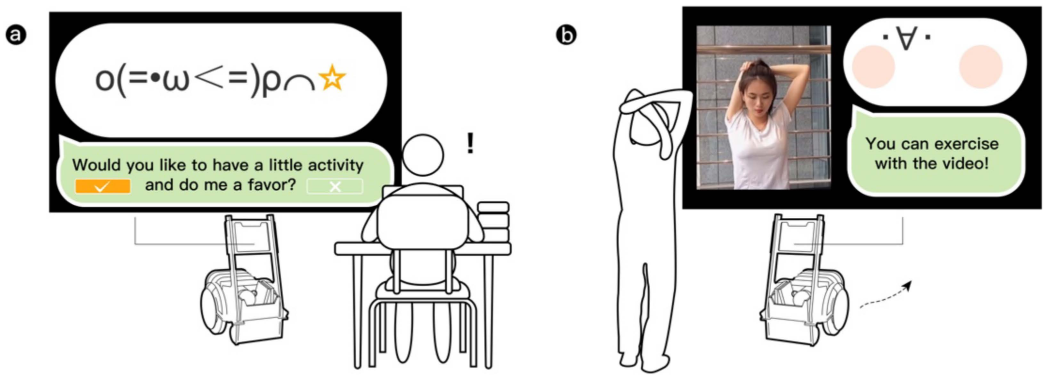

Figure 2. User system interactions of the Anti-Sedentary Robot. (**a**) The invitation from the robot for the performance of a voluntary task; (**b**) the robot would present some office exercise guidance to the user on the way to return the items.

2.2. Development of the Wizard-of-Oz Prototype

At this stage, we aimed at efficiently verifying our design concept in reducing sedentary behaviors and motivating physical activities in the shared workspace. Therefore, we applied the rapid prototyping approach [35] that allowed the demonstration and user experience of our design concept without fully implementing all the technical components and data infrastructures.

Through an iterative design process (see Figure 3a), we eventually developed the prototype of the Anti-Sedentary Robot, based on a radio control vehicle, a laser-cut frame using medium-density fiberboard, and an iPad with the keynote app. Based on the Wizard-of-OZ method [36,37], our final prototype (Figure 3b) facilitates the user experience flow of the Anti-Sedentary Robot in two aspects. First, the trolley-like robot could be controlled at a distance to approach a user who had been sitting for a long time. Second, we developed an interactive mockup using the Keynote application to achieve interactive effects and utilized the screen-sharing function of a remote meeting application called Tencent meeting [38] to enable remote monitoring of the user–system interactions.

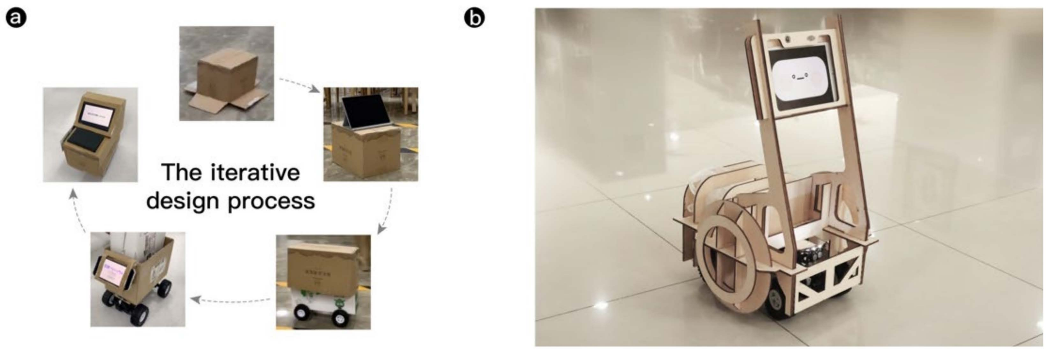

Figure 3. (**a**) Prototypes of previous iterations; (**b**) the final prototype of Anti-Sedentary Robot based on a radio control vehicle.

3. The Study

3.1. Study Design and Hypothses

To examine the effectiveness of the Anti-Sedentary Robot, we selected the public workspace in a library as the study context. In this case, the voluntary task was defined as returning books to the shelf. We applied a within-subject design to compare two types of health interventions that were developed as follows:

- **The robot-guided intervention (RGI):** The Anti-Sedentary Robot reminds users of their sedentary period duration by inviting them to return books and facilitates upper body stretching while performing the voluntary task.
- **The human-guided intervention (HGI):** A colleague reminds users of their sedentary time by inviting them to return books and offering guidance to complete upper body stretching exercises afterward.

The overarching goal of this study was to investigate whether our design could create positive impacts in combating sedentary behaviors in a shared workspace, such as in a library. We compared the RGI and HGI conditions related to participants' motivations and psychological benefits, with the following two hypotheses.

Hypothesis 1 (H1). *The RGI will enhance intrinsic motivation in adhering to physically active behaviors in the shared workspace of a library more than the HGI.*

Hypothesis 2 (H2). *Exercising in the RGI will increase participants' emotional and mental states more than in the HGI.*

3.2. Setup

The study was carried out in the library at the Beijing Institute of Technology. To ensure a unified study setup, all the experiments were conducted in a public lobby with bookshelves. In the RGI condition, we adopted the Wizard-of-Oz method that allowed us to carry out a user study before the technical infrastructure of the system is completely implemented. The movement of the robot was controlled through manual manipulation, and a screen-sharing technique was used through which we were able to monitor the user–system interactions. Before the test, we had practiced the experiment several times to ensure smooth control of the robot. During the test, the interaction process of the participant was passively observed on a computer from the researcher's side, and the movement of the robot was controlled remotely. In the HGI condition, one of the authors was responsible for guiding the participants to complete physical activities.

3.3. Participants

A total of 18 participants (9 males, 9 females) aged 19 to 22 (M = 21.00 SE = 0.13) were recruited for the study. We recruited participants by spreading information via social media. All the participants were university students who performed sedentary work for more than six hours every day and had a habit of frequently staying seated for more than an hour. They had varied study backgrounds, ranging from science and engineering to humanities, design, and arts, which enriched the diversity of the user feedback. They could all read English materials independently. Before the test, they were fully informed of the study procedure without discussing its hypotheses and were given the opportunity to withdraw at any point. Each participant was compensated with a gift worth 1 dollar upon completion of the study.

3.4. Procedure

Prior to the study, each participant was briefed with the details of the experiment and signed an informed consent form, and was then asked to select a mental task of their choice that required sitting, including reading books, writing emails, handling administrative tasks, etc. During the experiment, we simulated an independent working status wherein the participant stayed seated and concentrated on their pre-selected task. After approximately an hour, the participant was reminded to fill out the Self-Assessment Manikin (SAM) scale [39] and to complete an arithmetic task with five questions. The participant then entered one of the two conditions unobtrusively. After the intervention, the participant was required to fill out the SAM scale again, as well as complete another similar arithmetic task, after which the participant was asked to fill out the Intrinsic Motivation Inventory (IMI) scale [40]. After this, the participant resumed the seated task to repeat the experiment with another condition. In this study, the exposure to two conditions was fully counterbalanced. When the participant had experienced both conditions, an exit interview was conducted in person.

3.5. Measurements

We collected both quantitative and qualitative data from the participants to evaluate the effects of our design, in terms of intrinsic motivations and psychological benefits. First, we mainly used an IMI 7-point Likert scale to compare the user experience between the two conditions. IMI was mainly used to evaluate the intrinsic motivation of participants, which contained 7 dimensions and 45 questions in total [40]. In this study, we selected the first five dimensions that related to our study focus, including interest/enjoyment, perceived competence, effort/importance, pressure/tension, and perceived choice.

Second, to evaluate psychological benefits, we mainly used SAM and mental arithmetic questions. SAM was used before and after each intervention to measure the emotional state of participants. SAM [39] is a simple pictorial assessment technique that directly measures the pleasure, arousal, and dominance (from 1-negative to 9-positive) associated with a person's affective reaction to a wide variety of stimuli. We also assessed the mental focus of participants by comparing their mental arithmetic performance before and after each test condition. We used mental arithmetic test software [41] to ensure that all arithmetic tests were equivalent levels of difficulty. Each test contained five arithmetic questions regarding multiplication and division involving 2-and 3-digit numbers and decimals. We measured the correction rate and time spent for each participant.

After the experiment, a semi-structured interview was conducted for about 15 min per person. During the interview, we asked participants a series of three questions: *"Do you prefer human-guided exercises or robot-guided exercise?"*, *"Please describe the reason for your choice."*, and *"Do you have any suggestions concerning the Anti-sedentary Robot system?"*. There was enough space for participants to freely provide feedback on their experience. All interviews were audio-recorded and transcribed later for analysis.

3.6. Data Analysis

The questionnaire responses and arithmetic test results were analyzed using SPSS software. We initiated the quantitative analysis with the descriptive statistics, in which we checked the distribution of all data using the Shapiro–Wilk test. For data with normality in both RGI and HGI conditions, we conducted paired-sample *t*-tests. For data that were not normally distributed, we conducted non-parametric paired Wilcoxon tests.

All the interview transcripts were analyzed qualitatively based on a thematic analysis [42]. To begin with, the transcripts were segmented into quote statements and labeled using affinity diagrams [43] to identify clusters and themes. Next, all the identified themes and clusters were reviewed, discussed, and revised through several iterations to validate the findings. The objectives of the qualitative analysis were to support the interpretation of our quantitative results and to gain insight into future developments of relevant HCIs.

4. Results

4.1. Quantitative Analysis

4.1.1. Intrinsic Motivation

As shown in Figure 4, our participants were positively motivated to engage in the provided health interventions, with reasonably high scores on the subscales of interest/enjoyment, perceived competence, and perceived choice. Additionally, ratings of all conditions for effort/importance and pressure/tension were moderate, which indicated that the interventions were not very demanding for our participants. Paired-sample *t*-tests showed that there were significant differences in enjoyment, perceived choice, and effort between the two conditions.

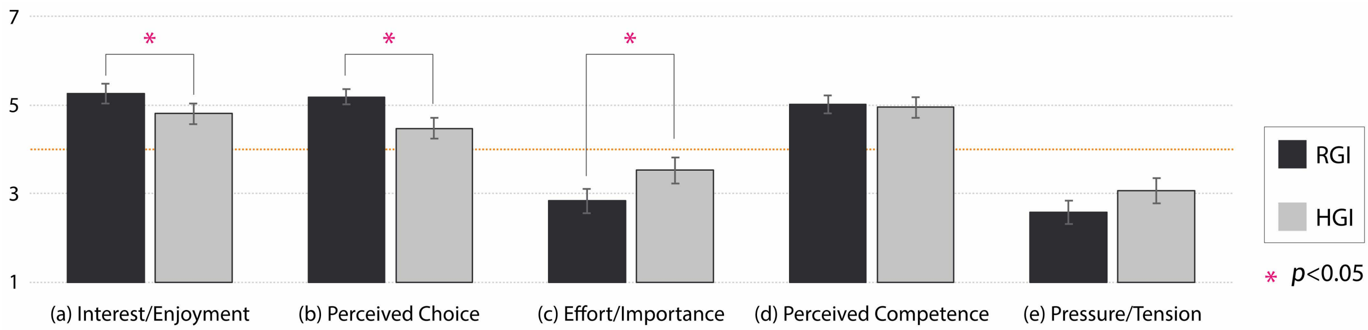

Figure 4. Mean and SE of IMI.

Specifically, Figure 4a shows that interest/enjoyment was rated significantly higher for the RGI (M = 5.25, *SE* = 0.22) than for the HGI (M = 4.80, *SE* = 0.24), with $t = 2.60$, $p < 0.05$. As shown in Figure 4b, the participants perceived having significantly more choice in the RGI (M = 5.18, *SE* = 0.17) than in the HGI (M = 4.47, *SE* = 0.23), with $t = 2.53$, $p < 0.05$. In contrast, Figure 4c shows that the intervention was considered significantly more demanding in the HGI (M = 3.52, *SE* = 0.30) than in the RGI (M = 2.83, *SE* = 0.27), with $t = 2.36$, $p < 0.05$.

Regarding the perceived competence subscale (see Figure 4d), the participants felt slightly more competent in the RGI (M = 5.01, *SE* = 0.20) than in the HGI (M = 4.94, *SE* = 0.23). Yet, no statistical difference was found ($p = 0.658$). Although Figure 4e shows that participants rated the RGI (M = 2.57, *SE* = 0.26) to be less pressured than in the HGI (M = 3.06, *SE* = 0.29), there was no significant difference ($p = 0.222$).

Based on the results of IMI, we find that the Anti-Sedentary Robot enhances users' intrinsic motivation to avoid sedentary behaviors and perform fitness activities in the shared workspace of a library, with increased enjoyment, perceived choice, and reduced effort. These elements can be crucial to sustaining the effectiveness of the Anti-Sedentary Robot in stimulating physical activity in a shared workspace [44].

4.1.2. Acute Benefits

Affective State. As can be seen in Table 1, participants' pleasure increased significantly after the health intervention in both RGI ($p < 0.01$) and HGI ($p < 0.01$), as well as showing greater arousal for the RGI ($p < 0.05$). No significant differences were shown in the improvement in participants' pleasure, arousal, and dominance states between the RGI and the HGI.

Table 1. Mean, SE, and Wilcoxon tests for SAM.

Conditions	Pleasure				Arousal				Dominance			
	Pre	Post	Z, p	Improv. *	Pre	Post	Z, p	Improv. *	Pre	Post	Z, p	Improv. *
RGI	5.83	7.11	2.61	1.28	4.39	5.39	2.20	1.00	5.83	6.33	1.06	0.50
	0.31	0.21	0.009	0.37	0.36	0.39	0.028	0.40	0.44	0.43	0.288	0.44
HGI	5.39	7.22	3.01	1.83	4.17	4.89	1.32	0.72	6.39	6.50	0.16	0.11
	0.33	0.39	0.003	0.44	0.39	0.43	0.186	0.54	0.47	0.41	0.877	0.46
Z, p	1.15			1.56	0.60			0.46	1.49			0.20
	0.249			0.118	0.551			0.645	0.136			0.842

* Represents Mean and SE for the difference between pre and post.

Arithmetic Tests. Table 2 shows that the correction rate of arithmetic tests was enhanced after the health intervention with the social robot while dropping slightly after exercising with a peer. Yet, none of the differences occurred at a significant level. Additionally, the completion time of the tests was reduced after the health intervention in both conditions. However, the improvement was only significant after the social robot-based health intervention ($Z = 2.22$, $p < 0.05$). The improvement in the test completion time was not significantly different between the two conditions.

Table 2. Mean, SE, and Wilcoxon tests for math tests.

Conditions	Correction Rate				Completion Time (by Second)			
	Pre	Post	Z, p	Improv. *	Pre	Post	Z, p	Improv. *
RGI	87%	92%	1.16	5%	66.4	47.2	2.22	19.2
	0.03	0.03	0.248	0.04	9.91	6.26	0.026	7.86
HGI	87%	85%	0.51	2%	53.2	51.5	0.04	1.7
	0.02	0.02	.608	0.04	7.15	5.57	0.965	5.39
Z, p	0.11			0.94	0.52			1.49
	0.916			0.347	0.601			0.136

* Represents Mean and SE for the difference between pre and post.

To summarize, the results suggest that a work break containing a voluntary task of returning books can enhance participants' state of pleasure, and the Anti-Sedentary Robot was effective in mediating the participants' arousal level, which reveals a psychological benefit from the health application of a social robot. As a moderate arousal state leads to optimal work performance [45], performance in the arithmetic tests improved after the RGI, with a significant improvement in test completion time.

We observed consistency between the results of intrinsic motivations and acute benefits. The RGI facilitated by the Anti-Sedentary Robot increased users' adherence to the intervention due to heightened enjoyment and autonomy, which led to mental relaxation and improvement when performing mentally challenging tasks.

4.2. Interview Results

4.2.1. Benefits of Anti-Sedentary Robot

According to the interviews, we found that the majority of our participants (15/18) preferred the RGI condition. The reasons for their choice are summarized as follows. First, most of them believed that this design concept can bring substantial psychological benefits, e.g., *"Interacting with the robot is very interesting."* (P1), *"This method is very novel, and I like it very much."* (P6). Many participants also expressed their wishes to use this type of system for a longer-term intervention. As P2 indicated, *"It will be quite exciting to have this system in our daily lives."*

Second, participants thought this type of health intervention can help them maintain motivation toward a healthier lifestyle. For example, *"I often sit for a long time and forget to stand up. I think it can remind me, which is very considerate."* (P2); *"I feel that I can get quite relaxed after doing this, which will help me keep doing so."* (P14); *"It is necessary to use such technologies to remind me to relax after reading for a long time."* (P6).

Third, many participants indicated that the Anti-Sedentary Robot had the potential to help them avoid embarrassment while being reminded of unhealthy working conditions in the public space. As P5 mentioned, *"Interacting with this robot allows me to avoid talking to people in this open working area"*. Moreover, P3 found that our design created a suitable scenario for exercising in a shared workspace: *"As I follow the robot, everyone will think I'm returning the book, and will not pay much attention on my strange movements."*

Fourth, our participants also expressed that engaging in the voluntary service of returning books allowed them to build reciprocal relationships with both the robot and the shared working environment. For instance, P7 stated the experience facilitated by the Anti-Sedentary Robot also contributed to the shared workspace: *"Putting the book back in the right place makes the space tidier, which makes me feel very satisfied."* P11 perceived completing the task as helping the robot with physical exercise: *"Helping the robot return books gives me a sense of accomplishment after stretching and walking."*

4.2.2. Design Challenges

Seven participants provided suggestions for the improvement of our system design. First, we received several suggestions on enhancing the system interaction of the robot. For example, *"When I concentrate on something, I might not notice whether it runs towards me, so perhaps you can put an ambient light on the desk to notify me when the robot comes."* (P14); *"It may be interesting if I perform some exercises and then the robot is led by me."* (P9); *"Sometimes the exercise guidance was a bit tedious and unclear, so I hope this can be improved so that I will be able to follow it smoothly on the move."* (P11).

Second, some participants offered several new ideas that could be leveraged to enrich the diversity of the voluntary tasks in future service design. As P11 suggested, *"Maybe I can help the robot deliver coffee in the space."* (P11). P7 thought the system might integrate its exercise trigger with a certain work-related demand, e.g., *"I think this robot can be combine with the working facility management system, where I can check the location of a certain book and learn how to fetch it."*

Third, we also received advice on user options and system rewards for the voluntary task, which would be helpful to strengthen the reciprocal bonding between the user and the robot. For example, P5 suggested we develop a mechanism of accumulating bonus points that can be exchanged for gifts. P4 wanted us to realize a function where the user could easily express their availability and willingness to engage in the voluntary service in real-time.

5. Discussion

Social support can play a decisive role in combating unhealthy behaviors in a shared workspace [13,14]. Social robotics may create additional advantages in terms of persuading people to engage in healthy workstyles and producing health benefits during workdays [24]. This paper has reported a design study that investigated the application of a social robot system, called the Anti-Sedentary Robot, in promoting physical exercise after prolonged sitting periods in the shared workspace. Based on a within-subject user study, our quantitative findings showed that the Anti-Sedentary Robot produced higher intrinsic motivations than the human-guided intervention, with significantly improved exercise enjoyment and perceived choice and reduced task effort. We also found that using a social robot for vitality promotion in the shared workplace could contribute to relaxation and improve mental performance. Qualitative data confirmed that a social robot can create persuasive effects in health promotion through system interactivity and reciprocity, which is consistent with prior studies [46–48]. Based on our findings, we propose the following design implications to better leverage social robots for fitness promotion in the shared workspace in the future.

5.1. Research Implications

Combine smart co-working environments with social robots to support healthy workflow. In this study, we proposed a smart environment embedded with various non-invasive sensors and vitality databases to collect anonymous health data in the shared workspace. Due to the flexible nature of the shared workspace [49], we found it could be redesigned as a living lab with noninvasive sensors and vitality databases for temporal health promotion without continually collecting users' data. As such, the privacy concerns over office vitality might be potentially avoided [50], and thus technology acceptance might be sustained [51]. Moreover, compared to the traditional office settings, open spaces allowed the robot to easily reach different targets and facilitate various interactions with the user. In this way, the social robot has been empowered as a mobile service provider [52] to dynamically interact with different touchpoints of the daily workflow. To improve the adherence to office vitality we suggest a data-driven co-working space could be designed, and the social robot could be adopted to strongly associate anonymized health data with everyday health-promoting services.

Lower the threshold of office vitality through pleasant Human–Robot Interaction (HRI). It has been suggested that proper designs of HRI could bring pleasant user experiences [53,54]. According to the IMI results, the Anti-Sedentary Robot improved exercise motivation intrinsically through forming an enjoyable task experience flow with the user. Similarly, some early studies also indicated that interacting with the robot could be helpful to persuade users to accept new behaviors in certain situations [54,55]. In HCI, design strategies such as playful interactions [56] and persuasive technologies [52] have been widely introduced to optimize HRI for improved health awareness and motivation [57]. In our case study, some participants expressed needs, e.g., playful dialogue (P4), game tasks (P6), etc., to further facilitate public health interventions. Therefore, pleasant HRI should be further investigated for fitness promotion in the shared workspace.

Strengthen reciprocity between workers and robots through workplace incentives. Reciprocity is one of the key determinants of user satisfaction [58], which can greatly lead to behavior change [59]. The reciprocal mechanism of the Anti-Sedentary Robot is inviting users to participate in voluntary tasks, while also offering exercise guidance. Through this type of mutual support activity, we learned that participants became aware of health conditions and were willing to exercise. Palumbo et al. [60] argued that the adoption of rewards can be helpful to sustain bonding between users and technologies. We received similar responses anticipating incentive systems from the robot. As suggested by several earlier office vitality projects, this could be achieved by integrating incentives with various workplace elements, e.g., virtual points hidden in the different locations of the space [61], bonuses that could be obtained and used in pursuing health-related workplace services [62].

5.2. Limitations

The findings from our case study should be cautiously interpreted due to its small sample size, short study period, and specific setup, which might be insufficient to prove the long-term effect of our design in different co-working environments. Moreover, for this case study, the Anti-Sedentary Robot was not fully implemented, and the study was conducted using the Wizard-of-OZ method. Therefore, future work could focus on advancing the technical feasibility, implementing the design implications reported here into a new social robot application, and investigating its potential in fitness promotion in a shared workspace by undertaking longitudinal studies with a diversity of users and shared workspaces. For our future work, we will conduct a field study in a real-world scenario where the robot will be used in an everyday work routine in a shared workplace instead of a research setup.

6. Conclusions

In this paper, we presented a design study of the Anti-Sedentary Robot, a trolley-like robot that could provide an interactive exercise experience flow to sedentary workers by facilitating physically active behaviors in combination with the temporal task of returning items. In a within-subject study, we compared exercise motivations and psychological benefits between two health-promoting interventions. In the robot-guided intervention (RGI), the Anti-Sedentary Robot was used to prompt sedentary behaviors by inviting the user to return items. During the task, the robot accompanied the user and offered guidance for fitness activity. In the human-guided intervention (HGI), the health intervention was entirely facilitated by a colleague rather than a social robot. Comparisons between the two conditions showed the positive effects of RGI in improving the intrinsic motivation of engaging in physical activity in a shared workspace with significantly higher exercise enjoyment and perceived choice and lower task effort than HGI. Based on our design explorations and the user responses in the interviews, we also presented a set of design implications for social robotics to promote physical activity in the shared workplace.

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