



Mobile Telepresence Robot as a New Service to Remotely Supervise Older Adults' Physical Activity: Effectiveness, Acceptance, and Perception

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1 **Mobile Telepresence Robot as a New Service to Remotely Supervise Older Adults’**
2 **Physical Activity: Effectiveness, Acceptance, and Perception**

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22 **Conflicts of Interest**

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Abstract

While the benefits of physical activity are well known, many older adults do not have any physical activity because they do not have access to adapted physical activity (APA) structures and teachers. The use of a telepresence to remotely supervise older adults' physical activity may be a suitable solution to break with lack of physical inactivity of older adults. The aim of the present study was to investigate effectiveness, acceptance, and perception of a mobile telepresence robot (MTR) that is remotely controlled by an APA teacher. Forty older adults (70.7 ± 4.3 years, 21 women, 19 men) were randomly divided in two groups of 20 participants who took part in a single individual learning session of a cognitive-motor task either conducted face-to-face with an APA teacher or with the same APA teacher using the MTR. Task performance, acceptance of the MTR, and perception of the APA teacher were assessed with quantitative and qualitative measures. The results showed that using MTR was as effective as a face-to-face intervention to help older adults learning a cognitive-motor task during a single session. The MTR was well-accepted by older adults and the APA teacher using the MTR was perceived warm, competent, adaptive, and sociable. The participants forgot that they were talking to a robot and they clearly put forward the added values of the MTR, especially its specific functionalities that does not exist in other types of devices such as static videoconference. APA sessions supervised by qualified teachers using the MTR may be implemented for isolated older adults who do not benefit from the services dedicated to supervised physical activity.

Keywords: Elderly; physical activity; technology acceptance model; health.

51 **Highlights**

- 52 • Despite all its health benefits, physical activity is not feasible for many older adults
53 because of their isolation.
- 54 • Mobile telepresence robot (MTR) piloted by a teacher may be relevant to remotely
55 supervise older adults' physical activity.
- 56 • Using MTR was as effective as a face-to-face intervention to learn a cognitive-motor
57 task specifically adapted to elderly.
- 58 • The MTR was well-accepted by older adults for supervising a remote physical activity
59 session.
- 60 • The teacher using the MTR was perceived warm, competent, adaptive, and sociable
61 and older adults gradually forgot the MTR.

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Mobile Telepresence Robot as a New Service to Remotely Supervise Older Adults' Physical Activity: Effectiveness, Acceptance, and Perception

1. Introduction

With the increase in life expectancy, the number of older adults aged over 65 years is continually increasing worldwide [1]. In France, they represent 20% of the population and could reach 30% in 2070 [2]. This longevity revolution has significant individual and socio-economic consequences. Indeed, the decline in functional capacities and the occurrence of age-related chronic diseases are aggravated by sedentary lifestyle, which affects most elderly people. Thus, an important challenge for Science and Society is to promote *Healthy Active Aging* that is, to delay or to attenuate age-related alterations of physical and cognitive capacities, to preserve individual's psychological well-being, quality of life, and autonomy as long as possible [3].

1.1. Physical activity, autonomous robots, and videoconference in older adults

To achieve this objective, new services must be provided to encourage older adults to remain physically active and to break with social isolation. Indeed, regular physical activity is one of the most effective and inexpensive solutions for maintaining health and independence in older adults. For instance, it has been reported that even a low dose of moderate to vigorous intensity physical activity allows reducing mortality by 22% in this population [4]. Regular physical activity can also prevent the onset of cognitive disorders associated with normal aging, or delay the development of neurodegenerative pathologies such as Alzheimer's disease, and reduce the risk of cancer, cardiovascular disease, and depression [5]). However, although the beneficial effects of physical activity are now well demonstrated, the prevalence of physical inactivity increases considerably with age -- 67% of older people are physically inactive [6] -- which generates considerable expenses (17 billion euros annually in France).

Social and physical isolation of many older adults is one of the potential explanations of this situation [7]. Indeed, a large number of older adults remain out of the scope of associative or institutional structures [8] or, since they live in isolated territories, they remain distant from daily living facilities and structures [9], while these structures may propose, among other services for older adults, programs of Adapted Physical Activity (APA). Thus, specific services are needed to overcome these obstacles that is, to facilitate access of older adults to effective, adapted, and attractive physical training programs. Technologies offer new opportunities in this respect [10], as attested by the use telepresence, which has dramatically increased during the Covid period, demonstrating real effectiveness in preserving the link between isolated seniors and their surroundings [11]. Remote physical activity can be delivered through different media, such as autonomous robots and videoconference.

1.1.1. Autonomous robots for older adults' physical activity

The use of robots is a becoming growing trend to facilitate daily living of older adults, as pointed out by a recent article published in *Nature* [12]. Promising results have been reported in this respect by studies that used autonomous robots with artificial intelligence (e.g., *Nao*, *Vizzy*) to supervise physical activity sessions in older adults, without the help of a specialized APA teacher (e.g., [13-18]). It has been demonstrated that engaging in physical activity with autonomous robots was more effective than exercising alone [17] or exercising with another technology without human-robot contact [15]. Moreover, autonomous robots are rather well accepted by seniors [13,14,18] and well perceived by seniors. For instance, Čaić et al. [14] have compared a physical activity session that was supervised by a human coach with a session supervised by an autonomous robot coach with artificial intelligence. They showed that i) older adults' scores of perceived warmth and perceived competence of the coach were significantly higher when the session was supervised face-to-face but, ii) perceived warmth

and perceived competence of the autonomous robot were high and, ultimately, slightly lower than those of the human coach.

However, in spite of their assets, they also have a number of limitations to supervise older adults' physical activity. Indeed, previous studies, some seniors reported being anxious and afraid of the robot, not knowing what to say and do, mishearing and misunderstanding the robot's words and intentions, and even not trusting it. Finally, what comes up most often is the lack of adaptability of the robot to the needs and specificities of the older adults during physical activity sessions, which reinforces the differences between the skills of a human coach and an autonomous robot.

1.1.2. Videoconference for older adults' physical activity

Since the Covid crisis, static videoconference is more and more often used to encourage older adults to practice physical activity. In this context, the APA teacher and the older adult use a computer, a digital tablet, or a cell phone and the video interactions are mediated by a fixed webcam with a single vantage point, which must be positioned or moved by the participant himself/herself [19]. Few studies have demonstrated that physical activity sessions supervised through static videoconference were effective to improve balance control [20-22], to reduce fall risk [22], as well as to enhance physical performance in the chair stand test [20], or to increase muscle mass of lower limbs [23], independent of whether they were mediated by a tablet, a computer, or a smartphone. However, to our best knowledge, only one study [24] directly compared a physical training program carried at home by healthy older adults and delivered via static videoconference and the same program administered face-to-face. The authors argued that the results supported the "non-inferiority" of the videoconference training program for improving maximal aerobic power, maximal heart rate, maximal oxygen consumption, knee extension strength, and lower limb power (but not for improving handgrip, trunk extension, and knee flexion isometric strength). Moreover, other

studies showed that videoconference was well-accepted by older adults to supervise physical activity sessions, showing satisfactory levels of compliance, adherence rate, presence, convenience, and satisfaction among older adults [e.g., 21,22,29].

However, the use of videoconference limits the nature of the physical exercises that can be carried out. Indeed, physical activity involves movements, and often displacements, which must be carefully observed by the APA teacher from the best angle of view to make sure that they are correctly performed, and to correct them if necessary. In this respect, static videoconference constrains the APA teacher to use physical exercises performed without displacements, and does not allow him/her to change his/her point of view, as he/she would do if he/she was physically present to provide individual feedback. In the same way, during the realization of physical exercises, the participant may leave the field of the webcam, thereby preventing the supervision of his/her activity by the APA teacher. Finally, collective sessions of physical activity, involving several participants being present and active in the same place, are difficult and even impossible to supervise with videoconference. Indeed, since the available information is dependent on the placement of the computer, tablet, or smartphone, controlled by the participant only, all participants could not be visible on the screen by the teacher or they would appear too small to be able to give precise and adapted feedbacks.

Thus, to overcome the limitations of autonomous robots and videoconference, another promising solution that is, a mobile telepresence robot (MTR), which have shown many benefits for older adults in other domains than physical activity [25] should be envisaged.

1.2.Supervision of older adults’ physical activity through the use of a mobile telepresence robot

1.2.1. Definition and potential advantages of the mobile telepresence robot

Mobile telepresence robot is a technology that uses interactive two-way video and audio on a mobile embodiment to feel or appear present in a remote location in a relatively high-fidelity manner [26]. Indeed, MTRs “*are typically characterized by their support of videoconferencing and locomotion, which allows operators, the people who are controlling the robots, to see, hear, and move throughout their environment*” (p.1) [27]. Accordingly, the MTR could be relevant to overcome some of the limitations of autonomous robots and videoconference previously identified. First, the lack of adaptability of autonomous robots to the specificities of older adults during physical activity, their difficulties to understand robots’ intention, and the fear of robots that they may experience are not suitable with a MTR because the MTR is driven by a human APA teacher, who, thanks to his/her teaching skills, can i) adapt to the particularities of the seniors throughout the physical activity session, ii) answer their questions if they do not understand the instructions, and iii) reassure them if they feel anxious or demotivated. Moreover, MTRs allows preserving human relationships during APA sessions and, thus, breaking social isolation or detecting eventual domestic problems, which cannot be done (or less easily) by autonomous robots. Secondly, MTRs are different from static videoconference to the extent that, in the latter, video interactions are mediated by a fixed webcam with a single vantage point, which must be positioned or moved by the participant himself/herself [19]. Conversely, MTR allows the teacher to move around the environment of older adults [28], which can be a strong advantage i) to observe the participants from the most appropriate locations, ii) to give more appropriate instructions, and/or iii) to easily adapt the feedbacks provided to participants. Indeed, if the participant leaves the APA teacher’s field of view, the latter can move the robot or the robot head to put

the participant back in the center of his or her field of view so that he or she can observe and give the most appropriate feedback. Group physical activity sessions, difficult and even impossible to supervise with videoconference, may be then feasible with the MTR, thanks to its mobile functionality. Thus, relative to static videoconference, MTR offers new possibilities that videoconference did not permit until now. In particular, it could allow APA sessions to be more adapted to the needs of older adults since teacher interventions might be personalized and closer to face-to-face situations. This aspect is essential because supervised physical activity programs have been demonstrated to be more effective than unsupervised ones to improve functional capacities in older adults [24,29].

According to the above considerations, we contend that MTR remotely controlled by an APA teacher might be a suitable way to provide APA programs to older adults who live in isolated territories and/or who are distant from daily living facilities and structures. However, as prerequisite, effectiveness, acceptance, and perception of MTR must be investigated to gather scientific evidence that could support its use as a new service for supervising older adults' physical activity.

1.2.2. Effectiveness of MTRs to supervise older adults' physical activity

Before comparing the effectiveness of MTR to autonomous robots or videoconference, a critical question is whether MTR is as effective as a usual face-to-face intervention for older participants to experience the benefits of physical activity. However, whether, why, and in which conditions MTR is as effective (or even superior) to similar sessions delivered in presence of the APA teacher is unknown to date. The present study aimed at addressing this issue.

1.2.3. Acceptance of MTRs to supervise older adults' physical activity

In addition to the potential effectiveness of MTR to improve functional capacities, another important issue concerns its acceptance by older adults [7,30]. The notion of

“acceptance” of a technology captures the psychological determinants of the intention to use this technology, either before or after its actual use. In this respect, though older people are becoming more and more familiar with the use of technologies, they seem generally less prone to use them than young people [31]. Thus, despite its potential effectiveness and interest to promote healthy aging, a service using MTR to supervise physical activity could come up against a lack of acceptance.

The Technology Acceptance Model (TAM) is the most used theoretical framework to investigate the acceptance of technologies [32-34]. It has been used extensively to study different types of technologies (e.g., smartphones, computers, virtual reality), with different populations (e.g., students, consumers, older adults), and in different contexts (e.g., education, sport, business). The two main variables considered by the TAM are perceived usefulness and perceived ease of use, respectively. Both are positive predictors of intention to use the technology, which in turn is a positive predictor of its actual use. In other words, the more a person finds a technology useful and easy to use, the more he/she will intend to use it and the more likely he/she will use it. Other variables have been subsequently introduced in the TAM, such as perceived enjoyment, which also positively predicts intention of older adults to use a technology (e.g., [35]). Since the TAM is the most widely used model in the literature on technology acceptance in many settings such as education (for a review, see [36]) or sport (for a review, see [37]), the present study is grounded on this model to investigate acceptance of MTR as a media to deliver a physical activity session supervised by an APA teacher. Older adults generally have also a good acceptance of MTR in many domains [7].

However, whether good acceptance might generalize to the use of MTR to supervise physical activity sessions remains uncertain since studies investigating this issue are scarce. Only two studies investigated this issue. Mitzner et al. [38] showed that community-dwelling older adults’ perceived usefulness and perceived ease of use of telepresence was quite high,

lending credence to the fact that older adults suffering from mobility impairment were prone to accept the use of technology of telepresence for practicing physical activity. However, in this study, though median scores of perceived usefulness and perceived ease of use (i.e., the two main variables of the TAM) were higher than the mean of the self-reported scale, no statistical analyses have been conducted on the data to confirm this hypothesis.

Based on the TAM, the second study was carried out in our research group [39] and investigated older adults' acceptance of the MTR for supervising physical activity, before a first use. The results showed that perceived usefulness, perceived ease of use, perceived enjoyment, and social norms (i.e., influence of the close environment, such as friends and family) were positive predictors of older adults' intention to use the MTR in the future for practicing physical activity. Specifically, as in Mitzner et al.'s [38] study, perceived usefulness, perceived ease of use, and perceived enjoyment were significantly (but slightly) higher than the mean of the scale. In contrast, intention to use the MTR was not different from the mean of the scale, thereby suggesting that older adults had, before a first use, neither intention to use the MTR in general nor intention not to use it in the context of physical activity.

Although the results of the two previous studies allowed to a better understanding of MTR acceptance before its use, it must be noted that, in the aforementioned studies, the elderly have never used it. Indeed, MTR was only presented to the elderly either via a video [38] or via pictures of the technology, in addition to a short explaining text [39]. However, it is well known that acceptance may significantly evolve after effective use of a technology [32-34]. Consequently, the reported results need to be completed by investigating older adults' acceptance of MTR following the effective completion of a physical activity session remains. This is the second objective of the present study.

1.2.4. Perception of MTRs to supervise older adults' physical activity

Technology acceptance may be influenced by users' emotional and cognitive reactions [40]. In social interactions, Humans judge other Humans with whom they interact on warmth (is the other a friend or a foe?) and competence (is the other skilled or ineffective?), which influence their reactions at the emotional, cognitive, and behavioral levels [41]. The emotional and cognitive reactions may be similar or different when older adults are confronted with a robot or a Human. Indeed, social interactions are not for humans only and they can even be considered between a Human and an autonomous robot with artificial intelligence [42]. The study of Čaić et al. [14] conducted with autonomous robots to supervise older adults' physical activity highlighted that i) older adults' scores of perceived warmth and perceived competence of the coach were significantly higher when the session was supervised face-to-face but, ii) perceived warmth and perceived competence of the autonomous robot were high and, ultimately, slightly lower than those of the human coach. Whether similar results could be observed when the physical activity session is mediated by a MTR, instead of an autonomous robot, remains to be determined. This issue is of interest since interactions between two or several Humans mediated by a MTR might be more warmth than those enabled by an autonomous robot. This hypothesis was supported, in the educational domain, by Schouten et al. [43] who showed that students in a telepresence robot condition experienced more warmth than those in the videoconferencing condition. However, studies conducted with MTRs are scarce and until now, no one has investigated this issue in the older adults' physical activity domain.

Two other variables than perceived warmth and perceived competence may be of interest to investigate the perception of the APA teacher using MTR. Indeed, it has been shown that older adults' acceptance of robots was higher when robots' perceived adaptiveness (i.e., the perceived ability of the system to adapt to the needs of the user) and perceived

sociability (i.e., the perceived ability of the system to perform sociable behavior) were also high [44]. In an educational setting, perceived adaptiveness of a telepresence robot positively predicted its perceived usefulness and that perceived sociability positively predicted students' perceived enjoyment [45]. Unfortunately, studies investigating perceived adaptiveness and perceived sociability of MTR in the context of older adults' physical activity are lacking. Consequently, the question arises of whether perceived warmth, perceived competence, perceived adaptiveness, and perceived sociability of the APA teacher would be similar when comparing a physical activity session supervised by a face-to face APA teacher and by an APA teacher using MTR. The present study addressed this third issue.

1.2.5. Qualitative analyses on participant's experience and perception

A common thread ran through the three objectives of the present study. While most studies conducted with MTRs use quantitative methods to measure their effectiveness (e.g., performance on standardized tests such as the Timed Up and Go [46]) as well as their acceptance and perception (e.g., self-reported questionnaires), a number of studies have also used qualitative methods. The review of Isabet et al. [7] highlighted that several studies have identified a decrease of older adults' loneliness and isolation with a qualitative assessment when using a MTR. Interviews have specifically showed that MTRs increase communication, interaction, and connectedness in different samples of older adults. In the domain of older adults' physical activity using MTRs (presented through a video), the only study conducted by Mitzner et al. [38] showed that older adults appreciated to see facial expressions and to have the opportunity to imitate the teacher, which could have not been identified using self-reported questionnaires. In this respect, it is noticeable that in Mitzner's study, the seniors have never used the robot, which was only presented through a video. Their actual experience with the MTR could therefore not be examined.

In sum, following the recommendations of Pino et al. [47], investigating effectiveness, acceptance, and perception of a MTR by combining quantitative and qualitative methods might provide additional information and, accordingly, improve our understanding of the interest of MTR in the context of physical activity supervision. In the present study, qualitative measures arising from the analysis of self-confrontation interviews were additionally used to cross quantitative results and participants' experiences and lived perceptions [48].

1.3. Aims and hypotheses of the present study

The first aim of the present study was to investigate the effectiveness of the MTR intervention, compared to the same face-to-face intervention, to supervise a single session of physical activity, specifically adapted for older adults. We hypothesized that there would be no significant difference in performance on a motor-cognitive task, after a single learning session, between the two modes of interventions (Hypothesis 1). If this hypothesis was verified, it would mean that teaching APA using the MTR would maintain the effectiveness of the intervention and that isolated seniors, who do not benefit from physical activity supervision, could in turn participate in APA sessions remotely supervised by a professional using the MTR. The second aim of the study was to examine how acceptance of the MTR by older adults evolved following the completion of the physical activity session, compared to a control group, which was only confronted to a written description and pictures of the MTR. According to the existing literature, we hypothesized that acceptance of the MTR by older adults would be high (Hypothesis 2) and higher than acceptance of older adults who have never used the MTR (Hypothesis 3). If these hypotheses were verified, it would mean that older adults would find the supervision by an APA teacher using a MTR useful, including specific MTR benefits related to its mobile functionalities. Finally, the third aim of the study was to compare older adults' perception of the (same) APA teacher, either after the face-to-

face intervention or the MTR one. We hypothesized that perceived warmth, perceived competence, perceived adaptiveness, and perceived sociability after the face-to-face intervention should be higher than after the MTR condition (Hypothesis 4). We also hypothesized that the scores of those variables would be high after the MTR condition (Hypothesis 5). If these hypotheses were verified, it would mean that the human relationship with the APA teacher, which is particularly important for older adults, would be maintained even when the APA teacher uses the MTR.

2. Methods

2.2. Participants

The participants were recruited within the cohort of the Chair *Active Aging*, which includes about a hundred of older, autonomous adults, living at home (> 65 years). They volunteered and gave an informed consent to attend. To be included in the study, potential participants should meet the following self-reported eligibility criteria: i) to be aged 65 years or older; ii) living independently at home; iii) to be able to walk without a walking aid; iv) to be free of any medical treatment interfering with vigilance; v) not to suffer from any vestibular, neurological, psychiatric, endocrine, or cardiovascular pathology; vi) not to suffer from any uncorrected oculomotor, auditory, and/or visual disorders. Then, potential participants performed a cognitive test (Mini-Mental State Examination, MMSE, [49]) to assess global cognition and potential cognitive impairment, which also allowed to ensure that they were able to understand oral instructions and to fill out questionnaires. Only the participants having a MMSE score higher than 26 were included. A total of 40 older adults (70.7 ± 4.3 years, 21 women, 19 men) met these criteria and took part in the experiment. Participants gave an informed consent to be filmed during the learning session. Specific provisions (see below, Ethics section) were made to protect personal data.

2.3. Procedure

2.3.3. Randomization

Two groups were constituted that is, a face-to-face and a MTR groups, respectively. Participants were randomly allocated to one of the two groups according to the following procedure: a number was assigned to each participant and a computer made a random draw to distribute them in each group. This was done independently for men and women. Finally, 13 women and 7 men (70.5 ± 3.8 years) were included in the face-to-face group, and 8 women and 12 men (70.9 ± 4.9 years) were included in the MTR group.

2.3.4. Pre-tests

Before attending to the learning session, the participants performed motor fitness tests to assess eventual differences between the two groups. Three motor fitness tests were used: Timed Up and Go [46], grip strength [50], and unipedal balance [51]. The Timed Up and Go allowed to assess functional mobility: the participant sits on a chair and after a “go” signal, must stand up, walk 3m, go around a cone placed on the ground, walk back, and sit on the chair. The time to complete the task is measured. The maximal handgrip strength was assessed using a hand dynamometer (JAMAR hand dynamometer, Chicago, IL, USA). Maximal handgrip strength is currently considered a proxy of general strength, indicative of sarcopenia and of global physical performance in older adults [52]. The unipedal balance test required participants to keep a stable equilibrium on their preferred leg for as long as possible (maximum 1 min), with the foot of the free leg placed on the knee of the supporting leg. Rest periods (2 minutes) were provided to participants between the tests and after the full completion of the three tests.

2.3.5. Learning session

All the participants were instructed by the teacher to learn a complex cognitive-motor task that is, the Square Stepping Exercise (SSE), which was specifically designed for

improving lower-extremity functional coordination and consequently, might help preventing fall occurrence among older adults [53,54]. The SSE consisted of walking lengthwise by reproducing a sequence of steps, carried out on a mat (2.50m long x 1m large) squared into 40 squares of 25cm side (Figure 1) thereby requiring cognitive control of speed-accuracy tradeoff. Specifically, the participants started the movement sequence by placing their right foot on the home location number 1, then had to move their left foot on the number 2, the right foot on the number 3, and so on until they reached 6, and finally moved outside the mat. Participants were instructed to perform the task as fast as possible, while making as few errors as possible. An error was defined as a wrong sequence of numbers on the mat or putting the foot on the front and side of a square. Four different SSE tasks were practiced in the following order: i) a familiarization task whose objective was to discover and understand the task and the instructions (4 trials), ii) a task of low level of difficulty (“Junior level”, [54]), with forward steps only (8 trials), iii) a task of medium level of difficulty (“Semi-regular level”), with forward, lateral, and oblique steps (8 trials), and iv) a task of a higher level of difficulty (“Regular level”) with forward, backward, lateral, and oblique steps (8 trials). A rest period was provided between each task to ensure that fatigue did not influence participants’ performance.

Please insert Figure 1

2.3.6. Experimental conditions

The two groups of 20 participants took part in a single individual learning session either conducted face-to-face with an APA teacher (Face-to-face condition) or with the same APA teacher viewed in telepresence, using the MTR (MTR condition). The APA teacher received prior familiarization to effectively pilot the MTR. The instructions given by the APA teacher to the participants and the movements of the teacher/the robot around the mat were

standardized and similar in the two groups. Each APA session was filmed and recorded via a wide-angle camera that allowed viewing the participant, the mat, and the APA teacher throughout the session.

2.3.7. Description of the MTR

We used the MTR “*Ubbo*” (Figure 2) developed by the company *Axyn*, which measures 1.60m and may move multi-directionally in space according to the actions of the distant operator. Specifically, the MTR can move forward, backward, or even turn, in complete safety thanks to its collision avoidance sensors. Interactions between the participants and the operator (i.e., the teacher) are ensured thanks to a microphone and to cameras. The pilot’s face is broadcasted in real time on the MTR’s “head”, composed of a screen and a camera, which can rotate up and down and from right to left, to adjust the point of view. Consequently, participants could see and hear the APA teacher who is physically present in a distant place. This device can be controlled remotely (even from several thousand kilometers away) through a Wi-Fi or 4G network, from an interface on a computer, tablet, or smartphone.

Please insert Figure 2

2.3.8. Experimental procedure

An assistant, member of the research staff, greeted the participant and administered the pre-tests in the experimental room. The experimenter then informed the participant that the session would be supervised by an APA teacher. Depending on the condition (face-to-face condition or MTR condition), the teacher was introduced to the participants either by physically entering the room or by having the robot enter it. The whole APA session was then supervised either directly by the teacher or via the MTR. Although the conditions for carrying out the different tasks and supervising the session were standardized (e.g., moving around the

mat quite similarly in the two conditions), the teacher was free to place herself in the most appropriate place to watch the participant performing the task with the swivel head of the MTR. Also, the teacher was able to move around the environment of older adults and was free to give personalized instructions to each participant in order to facilitate learning. In particular, she made sure to give positive feedback, encouragements, and instructions aimed at accelerating learning (e.g., instructions on how to perform the movement to reduce errors).

The assistant was present during the session but had no direct interactions with the participants; she only recorded performance in the tasks and administered the questionnaires during rest periods. After the learning session, 10 participants in the Face-to-face condition and 10 participants in the MTR condition were randomly invited to a reflexive self-confrontation interview with another investigator, carried out in a different room. This interview was based on commenting their own behavior viewed on a film recorded during the learning session.

2.3.9. Ethics

The present study was carried out in accordance with the Declaration of Helsinki and has been approved by the National Ethics Committee (N°IRB00012476-2021-10-03-93). Data were processed anonymously and stored in a secure server. Only the authors had access to the complete data set.

2.4. Measurements

2.4.3. Motor fitness

Two trials of the Timed Up and Go task were performed and averaged. For the maximal handgrip strength, the performance of the six trials (three per hand, alternating right and left hand) were averaged. Two trials were performed in the unipedal balance test. Their durations were recorded and averaged.

2.4.4. Task performance

The time taken to complete each trial and the number of errors were recorded. The trial started when the participant put his/her right foot on the first square of the mat and stopped when he/she put a foot outside the mat after crossing the whole mat. The participants were asked to respect the order of the squares (from 1 to 6) in the placement of their feet during their locomotion on the mat and not to cross the front line of each square, which was counted as errors. The mean time to complete the first four trials and the last four trials of each task was calculated, as well as the mean number of errors.

2.4.5. Acceptance of the MTR

Acceptance was measured using a self-reported questionnaire adapted from other studies [32, 33]. Participants were asked to answer the three items assessing perceived usefulness (e.g., *“I think this MTR could be useful for physical activity”*), the three items assessing perceived ease of use (e.g., *“I think I would find this MTR easy to use”*), the three items assessing perceived enjoyment (e.g., *“I think using this MTR would be fun”*), and the three items assessing intention to use (e.g., *“If I had the possibility to have easy access to this MTR, I would like to use it”*) on a 1 (strongly disagree) to 5 (strongly agree) Likert scale. Firstly, participants of both groups filled out the acceptance questionnaire at the beginning of the experiment. Following the usual procedure [e.g., 55], participants read a short text with photos presenting the MTR used for APA with older adults. Then, they scored their acceptance of the MTR before a first use. Participants in each group were blinded to the study objectives and therefore did not know which group they would be in when they first completed the acceptance questionnaire. At the end of the experiment, participants filled out the same questionnaire. In the Face-to-face condition, participants read again the same text with photos (control group). In the MTR condition, participants rated their acceptance of the MTR after their effective use during the APA session (experimental group). Using

McDonald's omegas [56], internal consistency was high for perceived usefulness ($\Omega_{pre} = .882$, $\Omega_{post} = .878$), perceived ease of use ($\Omega_{pre} = .908$, $\Omega_{post} = .935$), perceived enjoyment ($\Omega_{pre} = .955$, $\Omega_{post} = .980$), and intention to use ($\Omega_{pre} = .978$, $\Omega_{post} = .989$).

2.4.6. Perception of the APA teacher

Questionnaires assessed perceived warmth, perceived competence [14], perceived adaptiveness, and perceived sociability [44] of the APA teacher in the two conditions (Face-to-face, MTR). Questionnaires were filled out three times, just after the completion of each of the three stepping tasks. Participants answered the three items assessing perceived warmth (e.g., *"I think the APA teacher is friendly"*), the three items assessing perceived competence (e.g., *"I think the APA teacher is competent"*), the three items assessing perceived adaptiveness (e.g., *"I think the APA teacher can be adaptive to what I need"*), and the three items assessing perceived sociability (e.g., *"I find the APA teacher pleasant to interact with"*) on a 1 (strongly disagree) to 5 (strongly agree) Likert scale. Internal consistency was satisfactory for perceived warmth ($\Omega_{Task A} = .788$, $\Omega_{Task B} = .716$, $\Omega_{Task C} = .897$), for perceived competence ($\Omega_{Task A} = .776$, $\Omega_{Task B} = .902$, $\Omega_{Task C} = .868$), for perceived adaptiveness ($\Omega_{Task A} = .874$, $\Omega_{Task B} = .891$, $\Omega_{Task C} = .904$), and for perceived sociability ($\Omega_{Task B} = .722$, $\Omega_{Task C} = .802$), but somewhat weak for perceived sociability assessed after the Task A ($\Omega_{Task A} = .661$).

2.4.7. Self-confrontation interviews

Comprehensive qualitative methodology embedded in the "enactive phenomenological" research program [48, 57] was also conducted to identify the typical lived experience of the participants during the two sessions, using videos and self-confrontation interviews. The 20 self-confrontation interviews were performed just after the learning session, 10 in the MTR condition and 10 in the Face-to-face condition (length 60min +/- 10). During each interview, participant was confronted with his own audio-video recording to help him/her to re-live an experience closer than previous experience and to access to his/her

experience [58]. Different components of the experience were investigated during those directive interviews: perceptions, intentions, knowledge in action. Questions focused on the video to allow participant to describe, comment on, and show his/her own lived experience step by step. The initial question was: “*What are you doing here (pointing to the video image)?*”, then: “*What do you perceive at this moment?*”, “*What are your intentions?*”. According to the participant’s response, the questioning goes deeper, starting from the participant’s evocation, as suggested for phenomenological research [59].

2.5. Data analyses

Quantitative analyses were conducted using the JASP software (version 0.14.1). The chosen level of significance was $p < .05$. Univariate normality was checked with skewness and kurtosis. Variables non-normal in distribution had values $\geq |2|$ for skewness and $\geq |7|$ for kurtosis [60]. Effect sizes were calculated using Cohen’s d for t -tests, partial eta-squared (η_p^2) for repeated-measures ANOVAs, and rank biserial correlation (r_B) for Mann-Whitney U-tests.

Independent samples t -tests were used to analyze the potential differences in physical performance (unipedal balance, Timed Up and Go, grip strength) between participant in the Face-to-Face and the MTR conditions. The MMSE score, initially used as an inclusion criterion, was also used as a cognitive test to compare the two groups at baseline.

For each participant, the time taken to complete each trial in the different tasks was recorded. Then, for each participant, time performance recorded in the first four and the last four trials were averaged and repeated-measures ANOVAs with two factors -- Trials (Trials 1-4, Trials 5-8) and Condition (Face-to-Face, MTR) -- were conducted on the mean performance of each participant. In case of interaction effects, differences were evaluated post-hoc with Holm tests. The number of errors was also analyzed in the same way. However, since the distribution of the data did not meet the assumptions of normality, two non-parametric tests were used. First of all, Friedman tests were conducted to examine a potential

effect of Condition (Face-to-face, MTR) on the evolution of the number of errors between the first four trials and the last four trials of each task. Secondly, Mann-Whitney U-tests for independent samples were conducted to compare the number of errors in Trials 1-4 and in Trials 5-8 in each task (Task A, Task B, Task C), as a function of Condition (Face-to-face, MTR). For the Mann-Whitney tests, the alternative hypotheses specified that number of errors of participants in the Face-to-face condition would be lower than those of the MTR condition.

Several one-sample *t*-tests were used to investigate potential differences between the theoretical mean of the scale (i.e., 3 for a 5-point Likert scale) and the scores of perceived usefulness, perceived ease of use, perceived enjoyment, and intention to use the MTR. These analyses were conducted only for the participants in the MTR condition after the effective use of the MTR. The alternative hypothesis specifies that the mean would be different from 3. Repeated-measures ANOVAs with the factors Time (Before, After) and Condition (Face-to-face, MTR) were also conducted on the scores of MTR acceptance (perceived usefulness, perceived ease of use, perceived enjoyment, and intention to use the MTR) to determine whether significant differences occurred between the experimental group and the control group.

Since the distribution of the data did not meet the assumptions of normality, Mann-Whitney U-tests for independent samples were conducted on each variable assessing the perception of the APA teacher (perceived warmth, perceived competence, perceived adaptiveness, perceived sociability) according to Condition (Face-to-face, MTR) and Task (Task A, Task B, Task C). For all tests, the alternative hypotheses specified that scores of participants in the Face-to-face condition were greater than those of the MTR condition. Similar data analyses than for acceptance scores were also carried out to examine potential differences between the theoretical mean of the scale and perception of the APA teacher along

the APA session (perceived warmth, perceived competence, perceived adaptiveness, perceived sociability).

Finally, analyses were conducted on the qualitative data according to a five steps procedure. First, the enactive interviews were transcribed. Secondly, the elements of the participants' experience during the task performance were identified: perception, intention, knowledge in action. Thirdly, the typical experiences of each participant were analyzed in correspondence with their frequency and the importance in the experience of the actor [61]. Fourthly, the identification of typical experiences of all the participants in each condition was performed by comparing all the individual typical experiences. Finally, a comparison of the MTR condition and the Face-to-face condition was performed, identifying the common and singular aspects of the typical experiences.

3. Results

3.2. Preliminary tests

Prior to the experiment, no significant differences appeared between participants' scores of the two groups for: i) the MMSE, ($p = .347$, $M_{Face-to-face} = 27.80 \pm 1.64$, $M_{MTR} = 28.25 \pm 1.33$), ii) the unipedal balance test ($p = .885$, $M_{Face-to-face} = 26.65 \pm 24.93$, $M_{MTR} = 25.62 \pm 19.37$), iii) the Timed Up and Go ($p = .750$, $M_{Face-to-face} = 7.86 \pm 2.67$, $M_{MTR} = 7.67 \pm 1.27$), and iv) the maximal handgrip strength test ($p = .095$, $M_{Face-to-face} = 28.56 \pm 8.97$, $M_{MTR} = 33.47 \pm 9.17$). These results indicated that the two groups compared in the subsequent analyses were equivalent at baseline with respect to cognitive and physical performance.

3.3. Quantitative results

3.3.3. Task performance.

For trial duration, the results of the ANOVAs with repeated measures on the factors Trials (Trials 1-4, Trials 5-8) and Condition (Face-to-face, MTR) showed a significant effect of Trial for Task A ($F(1, 38) = 76.05$, $p < .001$, $\eta_p^2 = .67$), Task B ($F(1, 38) = 44.30$, $p <$

.001, $\eta_p^2 = .54$), and Task C ($F(1, 38) = 79.26, p = < .001, \eta_p^2 = .68$). Holm post-hoc tests revealed that time to complete the task decreased in the last four trials, relative to the first four trials, regardless of the level of task difficulty and conditions ($ps < .001$ for the three tasks and for each Condition). Whatever the level of task difficulty, the effect of Condition and the Trial x Condition interaction effect were non-significant ($ps > .862$, and $ps > .196$, respectively).

No significant effect of Condition (Face-to-face, MTR) on the number of errors was found ($ps > .206$ for the three tasks). Moreover, the number of errors did not significantly decrease between the first four trials and the last four trials, regardless of task difficulty ($ps > .715$). Mann-Whitney tests also showed that number of errors of participants in the Face-to-face and of the MTR conditions did not differ ($ps > .212$) in the first and last trials, whatever the level of task difficulty (Task A, Task B, Task C).

The decrease in time between the two sets of four trials during each task combined with a maintenance of the number of errors highlighted the learning of the task by the elderly, which validated Hypothesis 1. Descriptive statistics of time and number of errors are presented in Table 2.

3.3.4. Acceptance of the MTR – Comparison with the mean of the scale

The results of the one-sample t -tests showed that perceived usefulness ($t(19) = 3.96, p < .001, d = 0.88.87, M = 3.98, SD = 1.11$), perceived ease of use ($t(19) = 6.42, p < .001, d = 1.44, M = 4.43, SD = 1.00$), perceived enjoyment ($t(19) = 2.92, p = .009, d = 0.65, M = 3.93, SD = 0.49$), and intention to use ($t(19) = 3.04, p = .007, d = 0.68, M = 3.78, SD = 1.15$) were significantly higher than the mean of the scale for the older adults in the experimental group who have actually used the MTR (Figure 3), indicating that, after a first use, the MTR was found to be useful, easy to use, and enjoyable and that older adults have intention to use it for physical activity. Hypothesis 2 was supported.

Please insert Figure 3

3.3.5. Acceptance of the MTR – Evolution

The results of the repeated-measures ANOVAs with the factors Time (Pre-test, Post-test) and Condition (Face-to-face, MTR) conducted on the four TAM variables revealed no significant effects of Condition and no significant Time x Condition interaction effects for perceived usefulness ($p = .323$ and $p = .534$, respectively), perceived enjoyment ($p = .635$ and $p = .367$, respectively), and intention to use ($p = .189$ and $p = .743$, respectively). For perceived ease of use, a significant effect of Time was found ($F(1, 38) = 12.79, p = < .001, \eta_p^2 = .25$), but no significant effect of Condition and of Time x Condition interaction ($p = .537$ and $p = .414$, respectively). Contrary to Hypothesis 3, all the results indicated that no significant differences of acceptance of the MTR have been found between participants in the MTR condition (experimental group) and participants in the Face-to-face Condition (control group), especially after the actual use by the experimental group.

All the descriptive statistics of perceived usefulness, perceived ease of use, perceived enjoyment, and intention to use the MTR are presented in Table 1.

Please insert Table 1

3.3.6. Perception of the APA teacher – Comparison between Face-to-Face and MTR conditions.

The results of the Mann-Whitney U-tests firstly showed that perceived warmth of the Face-to-face APA teacher was significantly higher than that of the MTR APA teacher in Task A ($U = 252.5, p = .027, r_B = .263$), but that there were no longer any significant differences in Task B ($p = .192$) and in Task C ($p = .149$). No significant differences have been found between perceived competence of the Face-to-face APA teacher and the MTR APA teacher in Task A ($p = .491$), in Task B ($p = .210$), and in Task C ($p = .286$). Perceived adaptiveness of the Face-to-face APA teacher was significantly higher than that of the MTR APA teacher in

Task A ($U = 257.5, p = .032, r_B = .288$) and in Task B ($U = 248, p = .026, r_B = .240$), but not in Task C ($p = .164$). Finally, perceived sociability of the Face-to-face APA teacher was significantly higher than that of the MTR APA teacher in Task A ($U = 258.5, p = .023, r_B = .292$), in Task B ($U = 252, p = .018, r_B = .260$), and in Task C ($U = 252.5, p = .017, r_B = .263$). Results are presented in Figure 4. Hypothesis 4 was partially supported, except for perceived sociability, because no significant differences have been found for perceived competence, no significant differences have been found for perceived warmth in Tasks B and C, and for perceived adaptiveness in Task C.

Please insert Figure 4

3.3.7. Perception of the MTR APA teacher – Comparison with the mean of the scale

The results of the one-sample t -tests showed that perceived warmth of the MTR APA teacher ($t(19) = 30.72, p < .001, d = 6.87, M = 4.83, SD = 0.27$), its perceived competence ($t(19) = 30.78, p < .001, d = 6.88, M = 4.87, SD = 0.27$), its perceived adaptiveness ($t(19) = 15.10, p < .001, d = 3.38, M = 4.66, SD = 0.49$), and its perceived sociability ($t(19) = 16.67, p < .001, d = 3.73, M = 4.68, SD = 0.45$) were significantly higher than the mean of the scale (Figure 5), indicating that the APA teacher who conducted the APA session using the MTR was found to be highly warm, competent, adaptive, and sociable. Hypothesis 5 was supported.

Please insert Figure 5

All the descriptive statistics of perceived warmth, perceived competence, perceived adaptiveness, and perceived sociability are presented in Table 2.

Please insert Table 2

3.4. Qualitative analyses

Qualitative analyses showed that, in both conditions, the participants' typical experience was similar regarding the task and the APA teacher's perception. On the other hand, the typical experience was specific in the MTR condition, gradually leading to a form of disappearance of the MTR in favor of the APA teacher.

3.4.3. Typical experience in the cognitive-motor task SSE

The 20 participants in the two conditions (Face-to-face and MTR) structured their experiences in the same way. Five stages were identified for the cognitive-motor task SSE: (1) for each new task, their typical perceptions were shared between curiosity and fear of failure, (2) as soon as they understood what they had to do, they entered a phase of memorization by mentally repeating the movement, (3) during the first trial, they intention were "to do the exercise well" and to explore the task, (4) during the other trials they were more and more confident and they build different strategies to better perform the task, and (5) finally their experience in the task was structured by an alternation between risk taking and safety.

3.4.4. Typical experience with the APA teacher

The results showed that four typical perceptions of the APA teacher are similar for all participants in both conditions (Face-to-Face and MTR). First, the APA teacher's interventions were experienced as reassuring, explanatory, comprehensive, allowing progress, and surpassing oneself. Reassuring, because they allowed them to de-dramatize the error and put the participants at ease in relation to their worry of failure. Positive feedback, while pointing out errors, restored confidence in participants even when they failed. They felt valued and thought that they were capable to succeed. Secondly, another typical perception common to different participants in both groups was that the APA teacher explained patiently. This perception was significant for the participants and allowed them to organize their action in the task. These elderly people were embarrassed to be repeated or not to understand. They perceived that the

APA teacher spent time to explain in detail and listening to them. Thirdly, the fact that the APA teacher was understanding was also typical in their experience. In their interactions, they perceived that the APA teacher build knowledge on their way of functioning, on their health problems, and their limitation to do certain exercises. These perceptions motivated participants to engage in the task. Finally, the APA teacher was typically perceived as resource to progress and surpass oneself. The APA teacher allowed them to self-regulate in the task due to various personalized feedback, useful to perceive errors that they had not seen in action or to point out effective strategies. These perceptions of progress and help in progress were experienced very positively by the participants. Thus, they wanted to surpass themselves and did things that they would never have done on their own.

3.4.5. Specific typical experience in the MTR condition

The results also highlighted the specific typical dynamics of the participants' experience in the MTR condition, gradually making the MTR transparent to the benefit of the APA teacher who piloted it. The relationship with the APA teacher in telepresence evolved rapidly as the experiment progresses to finally lead to the very positive perception of the APA teacher previously described. Initially, the participants did not focus on the APA teacher who piloted the MTR, they focused instead directly on the MTR. The first reaction when seeing the MTR was surprise, they say "*we're not used to it*". This experience generated different perceptions among the participants. Some lived it positively by telling themselves that they were "*in the future*". Other participants perceived the atmosphere as cold, "*it's freezing*", the MTR scared them by updating negative experiences they have already had with technologies. Then in use, they focused on the APA teacher who piloted the MTR and they perceived the MTR as ultimately friendly and useful. This excerpt is an example of the experience of the participants: "*I'm not a fan (of technology)... but... but there, in use... uh, it helps me a lot, it's not complicated*"

694 *robot, I found it very interactive and very... very interesting. And... and I think that... indeed,*
695 *that... it's fine... it can help a lot the... people to work uh... physically.”*

696 Beyond the first apprehensions of the start, in use, the participants appreciated
697 interacting with the MTR which they found playful. In action, they were particularly sensitive
698 to certain characteristics such as its displacement in space or the rotation of the screen. They
699 lived these peculiarities of the MTR as very interesting because the MTR followed them and
700 can therefore better see what they were doing, with more precise feedback. A participant
701 specified for example *“She... She puts herself in the right place to... to be able to see my*
702 *exercise clearly and to be able to correct me, to say the mistakes I have made. I found that*
703 *great... I really liked it.”*

704 *In fine*, as the interactions progressed, the MTR became more and more transparent in
705 the experience of the participants to make way for the APA teacher. This tendency has been
706 found in all the participants who, in the interview, no longer talked about the MTR that helped
707 them, but about the APA teacher. For example, this participant said: *“Here (showing the video),*
708 *I come back to the coach (the robot's screen where we see the image of the women coach), I*
709 *discuss with her as if I had in front of me a face-to-face being”*, another clearly explained this
710 transparency of the MTR for the benefit of the APA teacher *“At that moment, I completely*
711 *concealed that it was a robot, huh! (Laughter) I assure you. I saw, it's ... this pretty young girl*
712 *in front of me, and we were chatting both”*.

713 The bad quality of the sound on the MTR was the only negative experience mentioned
714 by all the participants. They perceived the sound as sharp, choppy, unpleasant. These sound
715 problems made them perceive the situation as uncomfortable, particularly in the familiarization
716 task (at the start) and in task C (the most difficult) due to comprehension problems. Notably
717 however, this negative perception of sound was not present during the easier tasks A and B.

4. Discussion

The present study aimed at investigating the potential of MTR as a new service to remotely supervise older adults' physical activity.

To fulfil this objective, we first investigated learning effectiveness of the MTR intervention compared to the face-to-face intervention. Results showed that participant succeeded in learning the tasks in both conditions. Indeed, the time to complete the different tasks decreased from the first four trials to the last ones, while error rates were unchanged. This result suggests that participants aimed at preserving accuracy, while focusing on improving speed of motor execution. Thus, increase in performance reflected better coordination of stepping and more efficient management of the cognitive-motor resources required to perform the tasks. Importantly, no significant difference was found in older adults' performance (time and errors) between the sessions supervised face-to-face and via the MTR. Qualitative analyzes confirmed the similarity of the two intervention conditions, with respect to the subjective experience of individuals. For instance, participants experienced the same five steps, in the two conditions, when they performed the motor-cognitive task SSE, namely: curiosity about the MTR, fear of making errors while performing the task, memorization of the instructions, doing their best in the task, and managing the risk/security relationship.

In summary, in the present study, the face-to-face and the MTR interventions showed comparable effects. However, it can be argued that, in real life, MTR may provide secondary benefits for the participants. Indeed, it may help distant older adults to access to supervised physical activity, while the structures allowing to accommodate this kind of service are not accessible to older adults in isolated geographical areas. Of course, such an argument also applies to static videoconference [24]. However, the qualitative analyses suggested that participants identified added values of the MTR, that do not exist with videoconference. For instance, participants mentioned that they were positively sensitive to the displacement of the

MTR and to the rotation of its screen, the rotation of the head, which gives it a “human” appearance, and which allows the APA teacher to observe the participants and give precise feedback. Thus, the mobile functionality of the MTR, recognized by all the interviewed participants, seemingly constituted a real superiority of mobile telepresence compared to fixed videoconference.

The second objective of the study was to investigate how the MTR was accepted by older adults following the completion of a remote physical activity session. First, the study investigated the magnitude of acceptance. The results showed that after a first use, the MTR was found to be significantly useful, easy to use, and enjoyable, and that older adults had intention to use it for physical activity. These results are in line with those of other studies [38,39] that have highlighted that the MTR was found to be useful and easy to use, and that perceived usefulness, perceived ease of use, and perceived enjoyment were significantly (but slightly) higher than the mean of the scale. These results add to previous findings which concerned the acceptance of the MTR before a first use, while in the present study acceptance was measured for the first time after an effective use of the MTR during an APA training session.

Overall, our results are consistent with those reported by Isabet et al. [7] in their review. Indeed, these authors concluded that older adults generally have a good acceptance of MTR in many domains (e.g., teleconsultation, breaking isolation and loneliness). This is also the case in the APA domain, as confirmed by the analyses of the participants’ discourses during their self-confrontation interviews. Indeed, they experienced the MTR as friendly, playful, and useful. If the term “useful” has already been identified in different studies on the use of videoconference to remotely supervise older adults’ physical activity [e.g., 21,22], the terms “friendly” and “playful” have not been used in these studies, whereas they are used here by seniors to characterize the reasons that lead them to accept the MTR. The study also

examined whether acceptance by older adults of the MTR after effective use was higher than acceptance of older adults who have never used the MTR (control group). Contrary to our prediction, no significant differences appeared. This was certainly due to the fact that the scores for each variable of the TAM were high for all participants at the first measurement time and remain so at the second measurement time. In any case, they were higher in the present study than in the only study that investigated the MTR acceptance before first use for older adults' physical activity [39]. These high initial scores probably prevented observing a significant difference between the participants who have used the MTR and the participants who did not in the control group.

The third aim of the study was to compare older adults' perception of the APA teacher in the Face-to-face condition and in the MTR condition. Results showed that the scores observed in the Face-to-face condition were higher than those observed in the MTR condition for perceived sociability, for perceived warmth in Task A, and for perceived adaptiveness in Tasks A and B. On the other hand, no significant differences were found for perceived competence, for perceived warmth in Tasks B and C, and for perceived adaptiveness in Task C. These differences can be explained thanks to qualitative analyses. Indeed, the results of the self-confrontation interviews showed that the robot was very quickly forgotten by the participants, leading them to interact more with the APA teacher than with the MTR. In other words, the robot became "transparent" to the participants in the MTR condition, so that the participants mainly evaluated their perception of the APA teacher, instead of the MTR, thereby explaining that it was the same as in the Face-to-face condition. Notably, these results strongly suggest that the MTR is a device that allow interactions with the APA teacher, which is an important finding. The differences highlighted for perceived sociability may be, at least partially, explained by the bad quality of the sound provided by that MTR, which likely limited the perception of a sociable relationship. Regardless, scores on all the four variables

were very high for the APA teacher in the MTR condition, indicating that the APA teacher using the MTR was very well appreciated by the older adults to supervise remote physical activity. Moreover, the displacement of the MTR, the possibility of calling the MTR to come and meet the participant, the human size of the robot (1.60m) which facilitates communication and discussion, the possibility that the MTR can follow the participant throughout the motor task to give advice and encouragement were widely emphasized by the interviewed participants, which certainly contributes to this very positive perception of the APA teacher who piloted the robot. All these elements, identified as important in the participants' experience with the MTR during the APA session, are added values of this type of device that are not found in other types of devices such as videoconference.

5. Limitations of the present study

Some limitations of the present study can be identified, that could be addressed in future studies. First, the MTR was used during a single physical activity session, which had possibly led to a “novelty effect”. Thus, using the MTR throughout a training program lasting several weeks or months might add to the understanding of its effectiveness, acceptance, and perception over a long-term intervention. This would also make possible to evaluate its effectiveness thanks to the tests classically used in the literature to assess training effects in older adults (e.g., Timed Up and Go, handgrip strength, 6-minute walking test). We hypothesize that all the benefits of using the MTR that have been identified in the present study (e.g., mobile functionality, rotation of the screen, rotation of the head, ability to provide more accurate feedback by being closer to the participant) would result in significant positive effects of a longer training program conducted with older adults. For the same reasons, the positive effects of physical activity programs would be greater when delivered through the MTR than when using static videoconference, because the added values of the MTR

identified above are not available when using videoconference. Of course, these hypotheses remain to be tested in future studies.

Secondly, each physical activity session was conducted individually, that is, with the teacher dedicated to each older adult during all the session long. Future studies could be conducted to test collective training sessions, to be closer to more traditional teaching conditions. This type of study could also demonstrate the value of using MTR over videoconference because group physical activity is difficult to supervise in a fixed videoconference session since either not all participants will fit into the camera's view or they will be too small on the APA teacher's screen to be able to give truly relevant and appropriate advice and feedback.

Thirdly, in the present study, we used the motor-cognitive task SSE, which was well-adapted to the teaching remotely physical activity with the MTR and developing capacities necessary to prevent risk of fall. This task would have been much more difficult to supervise in a fixed videoconference session because if the computer screen had been placed at one end of the mat the participant would have been more than four meters away from the camera during the entire first part of the task. Of course, a number of physical activities, among those highly appreciated by older adults cannot be performed with the use of the MTR (e.g., Nordic walking) but some of them, such as Tai Chi, could be investigated with MTR since they are well-suited to telepresence and particularly effective to improve cognitive and motor capacities in older people (e.g., [62]).

6. Conclusion

The purpose of the present study was to examine effectiveness, acceptance, and perception of MTR as a new service to remotely supervise older adults' physical activity. Results showed that using MTR was as effective as a face-to-face intervention to help older adults learning a cognitive-motor task during a single session. They also showed, for the first

time to our knowledge, that the MTR was very well-accepted by older adults and the APA teacher using the MTR was perceived warm, competent, adaptive, and sociable. Finally, the results showed that the participants clearly identified the added values of the MTR, especially its mobile functionalities, that does not exist in other types of devices used for supervising older adults' physical activity, such as autonomous robots and videoconference. All these promising results make it possible to envisage the implementation of APA sessions supervised by qualified APA teachers for isolated older adults who do not benefit from this type of service, so that they too can experience the health advantages of physical activity.

All the data are available on request to the corresponding author.

Compliance with Ethical Standards

The present study was carried out in accordance with the Declaration of Helsinki and has been approved by the National Ethics Committee (N°IRB00012476-2021-10-03-93).

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Conflict of Interest

The authors declare that they have no conflict of interest.

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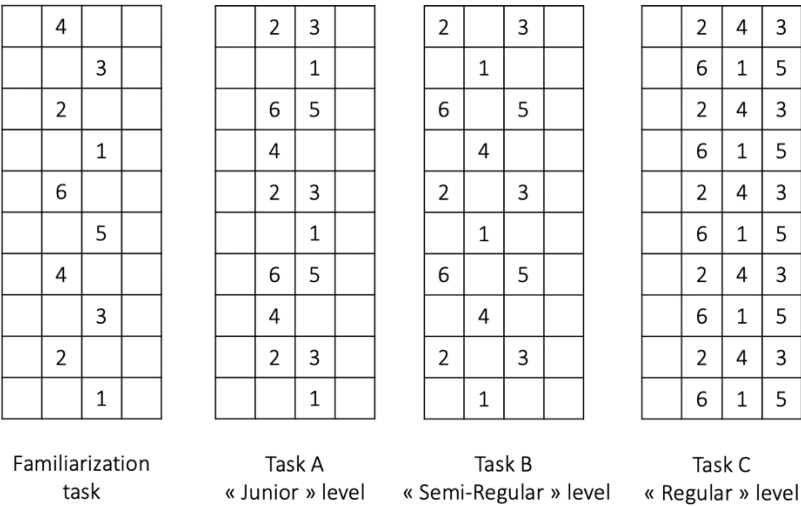
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1055 Figure 1.
 1056 The Square Stepping Exercise (SSE, Shigematsu et al., 2006, 2008; see comments in the text).
 1057 Different tasks were used for: i) familiarization task, and ii) learning, with three levels of
 1058 difficulty.
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1062 Figure 2.

1063 The MTR *Ubbo*. See details in the text.

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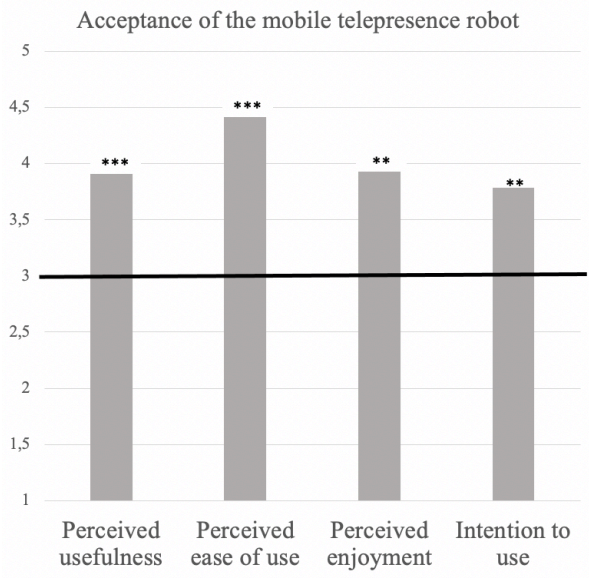
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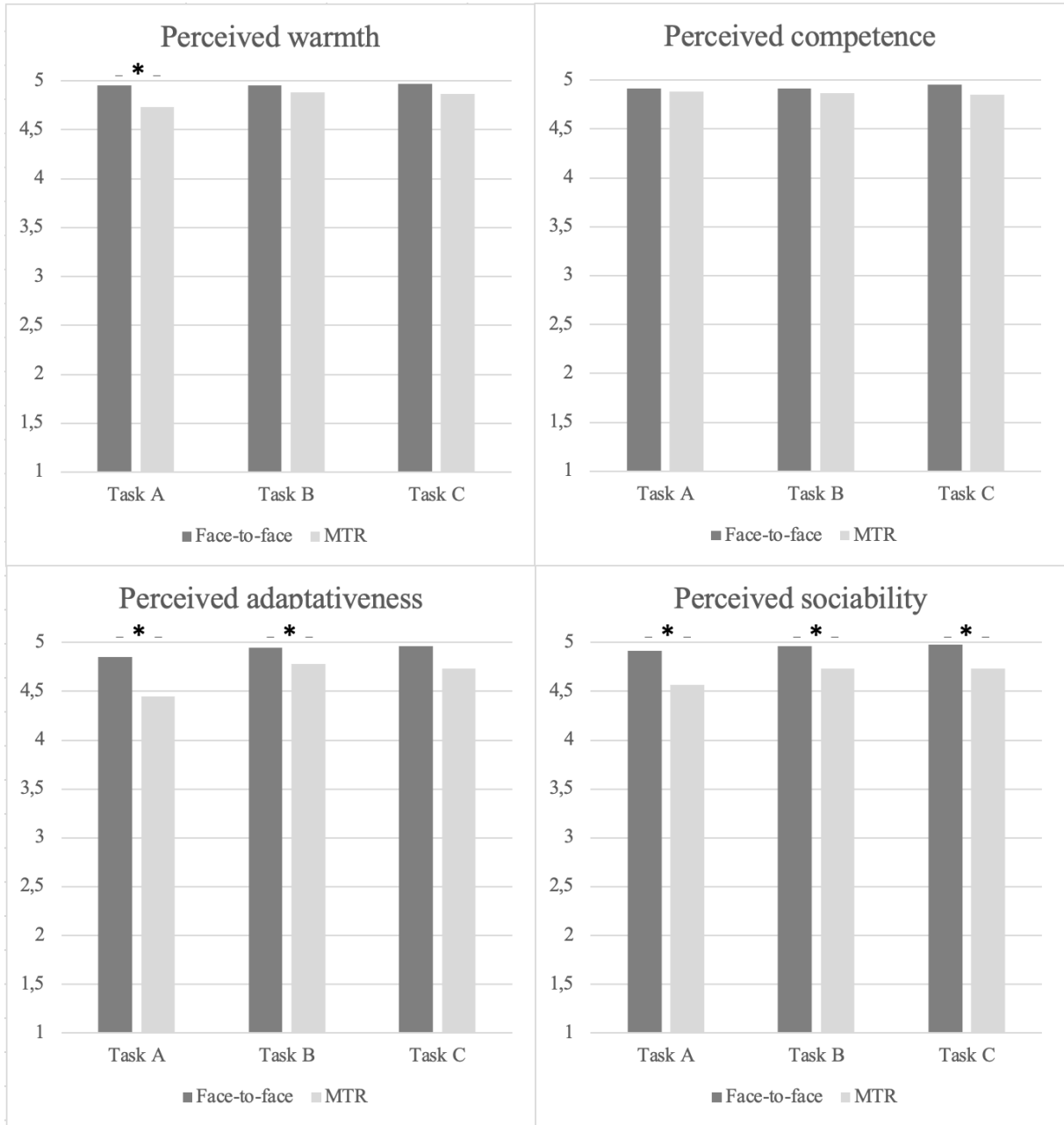
Figure 3.
Comparison of scores of perceived usefulness, perceived ease of use, perceived enjoyment,
and intention to use with the mean of the scale.



Notes. ** $p < .01$, *** $p < .001$, the bold horizontal line indicates the mean of the scale.

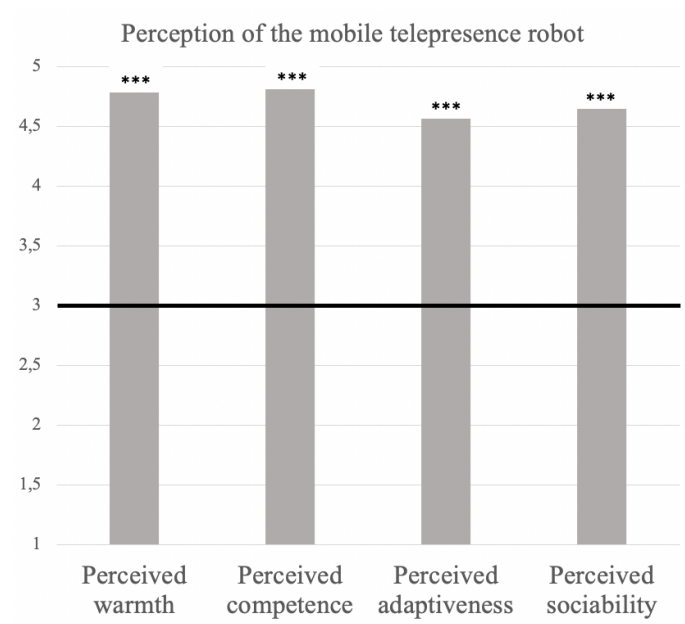
Figure 4.

Comparison of scores of perceived warmth, perceived competence, perceived adaptiveness, and perceived sociability according to condition (Face-to-face vs. MTR) and tasks.



Notes. -*- indicates a significant difference at $p < .05$ between the Face-to-face and MTR conditions; the error bars are not represented on the graph, but the exact values of the standard deviations are indicated in table n°2.

Figure 5.
Comparison of scores of perceived warmth, perceived competence, perceived adaptiveness,
and perceived sociability with the mean of the scale.



Notes. *** $p < .001$, the bold horizontal line indicates the mean of the scale (i.e., 3).

1093 Table 1.

1094 Descriptive statistics, skewness, and kurtosis for acceptance of the MTR.

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Variables	Condition	Pre-test		Post-test	
		<i>M / SD</i>	Sk. / Ku.	<i>M / SD</i>	Sk. / Ku.
Perceived usefulness	Face-to-face	3.58 / 1.22	-0.24 / -1.36	3.73 / 0.95	-0.27 / -0.97
	MTR	3.98 / 1.07	-1.24 / 1.81	3.98 / 1.11	-1.25 / 1.31
Perceived ease of use	Face-to-face	4.15 / 0.82	-0.37 / -1.38	4.48 / 0.72	-1.07 / -0.20
	MTR	3.90 / 0.84	0.27 / -1.63	4.43 / 1.00	-1.47 / 6.98
Perceived enjoyment	Face-to-face	4.05 / 0.91	-0.84 / 0.84	4.18 / 1.07	-1.21 / 0.53
	MTR	3.97 / 1.26	-1.28 / 0.78	3.93 / 1.43	-1.04 / -0.48
Intention to use	Face-to-face	3.47 / 1.45	-0.57 / -1.01	3.32 / 1.29	-0.68 / -0.51
	MTR	4.02 / 1.14	-1.11 / 0.91	3.78 / 1.15	-0.76 / 0.01

1096 *Note.* *M* = Mean, *SD* = Standard Deviation, Sk. = Skewness, Ku. = Kurtosis

1097

Table 2.

Descriptive statistics, skewness, and kurtosis for the perception of the APA teacher and for task performance.

Variables	Cond.	Task A		Task B		Task C	
		<i>M</i> / <i>SD</i>	Sk. / Ku.	<i>M</i> / <i>SD</i>	Sk. / Ku.	<i>M</i> / <i>SD</i>	Sk. / Ku.
Perceived warmth	Face-to-face	4.95 / 0.16	-3.44 / 11.89	4.95 / 0.16	-3.44 / 11.89	4.97 / 0.15	-4.47 / 20.00
	MTR	4.73 / 0.44	-1.47 / 0.73	4.88 / 0.27	-2.50 / 5.95	4.87 / 0.36	-2.82 / 7.21
Perceived competence	Face-to-face	4.92 / 0.21	-2.44 / 4.78	4.92 / 0.26	-3.11 / 9.05	4.95 / 0.16	-3.44 / 11.88
	MTR	4.88 / 0.33	-3.19 / 10.51	4.87 / 0.31	-2.43 / 4.97	4.85 / 0.38	-2.47 / 5.16
Perceived adaptiveness	Face-to-face	4.85 / 0.31	-1.82 / 1.93	4.95 / 0.22	-4.47 / 20.00	4.97 / 0.10	-2.89 / 7.04
	MTR	4.45 / 0.82	-1.78 / 3.21	4.78 / 0.36	-1.34 / 0.23	4.73 / 0.64	-2.54 / 5.82
Perceived sociability	Face-to-face	4.92 / 0.21	-2.44 / 4.77	4.97 / 0.15	-4.47 / 20.00	4.98 / 0.07	-4.47 / 20.00
	MTR	4.57 / 0.63	-1.27 / 0.63	4.73 / 0.07	-1.08 / -0.76	4.73 / 0.47	-1.55 / 1.04
Time (seconds)	Face-to-face	7.16 / 1.92	0.36 / 0.36	7.14 / 2.06	1.00 / -0.05	18.48 / 3.93	0.38 / -1.18
		5.61 / 5.34	1.05 / 1.34	5.48 / 1.16	0.95 / 1.47	13.76 / 3.17	0.02 / -1.09
	MTR	7.23 / 2.17	0.22 / -0.77	7.20 / 2.22	0.44 / -0.24	19.18 / 5.60	0.76 / -0.36
		5.34 / 1.51	0.72 / -0.28	5.47 / 1.48	0.87 / 0.98	12.82 / 2.77	0.84 / -0.45
Number of errors	Face-to-face	0.53 / 0.44	0.65 / -0.42	0.63 / 0.75	2.35 / 7.58	1.90 / 1.19	0.66 / -0.40
		0.39 / 0.48	0.93 / -0.68	0.41 / 0.44	1.12 / 0.80	1.74 / 1.28	1.24 / 1.10
	MTR	0.83 / 1.11	2.16 / 5.61	1.17 / 1.56	1.90 / 2.99	3.16 / 2.20	1.85 / 4.56
		0.41 / 0.48	2.10 / 5.94	0.57 / 0.59	1.04 / 0.65	2.24 / 2.32	1.79 / 2.94

Notes. *M* = Mean, *SD* = Standard Deviation, Cond. = Condition, Sk. = Skewness, Ku. = Kurtosis. The time and number of errors scores are presented for each condition on the top row for the trials 1-4 and on the bottom row for the trials 5-8.