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# 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**

3  
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23    The authors declare that they have no conflict 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 ( $70.7 \pm 4.3$  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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63 **Mobile Telepresence Robot as a New Service to Remotely Supervise Older Adults'**  
64 **Physical Activity: Effectiveness, Acceptance, and Perception**  
65

66 **1. Introduction**

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

76 **1.1. Physical activity, autonomous robots, and videoconference in older adults**

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

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

#### 99 **1.1.1. Autonomous robots for older adults' physical activity**

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

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

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

### 121 **1.1.2. Videoconference for older adults' physical activity**

122 Since the Covid crisis, static videoconference is more and more often used to  
123 encourage older adults to practice physical activity. In this context, the APA teacher and the  
124 older adult use a computer, a digital tablet, or a cell phone and the video interactions are  
125 mediated by a fixed webcam with a single vantage point, which must be positioned or moved  
126 by the participant himself/herself [19]. Few studies have demonstrated that physical activity  
127 sessions supervised through static videoconference were effective to improve balance control  
128 [20-22], to reduce fall risk [22], as well as to enhance physical performance in the chair stand  
129 test [20], or to increase muscle mass of lower limbs [23], independent of whether they were  
130 mediated by a tablet, a computer, or a smartphone. However, to our best knowledge, only one  
131 study [24] directly compared a physical training program carried at home by healthy older  
132 adults and delivered via static videoconference and the same program administered face-to-  
133 face. The authors argued that the results supported the "non-inferiority" of the  
134 videoconference training program for improving maximal aerobic power, maximal heart rate,  
135 maximal oxygen consumption, knee extension strength, and lower limb power (but not for  
136 improving handgrip, trunk extension, and knee flexion isometric strength). Moreover, other

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

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

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



158 **1.2.Supervision of older adults’ physical activity through the use of a mobile**  
159 **telepresence robot**

160 **1.2.1. Definition and potential advantages of the mobile telepresence robot**

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

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

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

### 198                   **1.2.2. Effectiveness of MTRs to supervise older adults' physical activity**

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

### 205                   **1.2.3. Acceptance of MTRs to supervise older adults' physical activity**

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

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

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

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

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

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

249         Although the results of the two previous studies allowed to a better understanding of  
250 MTR acceptance before its use, it must be noted that, in the aforementioned studies, the  
251 elderly have never used it. Indeed, MTR was only presented to the elderly either via a video  
252 [38] or via pictures of the technology, in addition to a short explaining text [39]. However, it  
253 is well known that acceptance may significantly evolve after effective use of a technology  
254 [32-34]. Consequently, the reported results need to be completed by investigating older  
255 adults' acceptance of MTR following the effective completion of a physical activity session  
256 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

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

#### 291 **1.2.5. Qualitative analyses on participant's experience and perception**

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

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

### 313 **1.3. Aims and hypotheses of the present study**

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

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

## 338 **2. Methods**

### 339 **2.2. Participants**

340 The participants were recruited within the cohort of the Chair *Active Aging*, which  
341 includes about a hundred of older, autonomous adults, living at home (> 65 years). They  
342 volunteered and gave an informed consent to attend. To be included in the study, potential  
343 participants should meet the following self-reported eligibility criteria: i) to be aged 65 years  
344 or older; ii) living independently at home; iii) to be able to walk without a walking aid; iv) to  
345 be free of any medical treatment interfering with vigilance; v) not to suffer from any  
346 vestibular, neurological, psychiatric, endocrine, or cardiovascular pathology; vi) not to suffer  
347 from any uncorrected oculomotor, auditory, and/or visual disorders. Then, potential  
348 participants performed a cognitive test (Mini-Mental State Examination, MMSE, [49]) to  
349 assess global cognition and potential cognitive impairment, which also allowed to ensure that  
350 they were able to understand oral instructions and to fill out questionnaires. Only the  
351 participants having a MMSE score higher than 26 were included. A total of 40 older adults  
352 ( $70.7 \pm 4.3$  years, 21 women, 19 men) met these criteria and took part in the experiment.  
353 Participants gave an informed consent to be filmed during the learning session. Specific  
354 provisions (see below, Ethics section) were made to protect personal data.



355           **2.3. Procedure**

356                   **2.3.3. Randomization**

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

363                   **2.3.4. Pre-tests**

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

377                   **2.3.5. Learning session**

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

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

---

Please insert Figure 1

---

397

### 398 **2.3.6. Experimental conditions**

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

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

### 407 **2.3.7. Description of the MTR**

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

---

Please insert Figure 2

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419

### 420 **2.3.8. Experimental procedure**

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

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

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

#### 441 **2.3.9. Ethics**

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

### 446 **2.4. Measurements**

#### 447 **2.4.3. Motor fitness**

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

452                    **2.4.4. Task performance**

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

460                    **2.4.5. Acceptance of the MTR**

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

477 McDonald's omegas [56], internal consistency was high for perceived usefulness ( $\Omega_{pre} =$   
478  $.882$ ,  $\Omega_{post} = .878$ ), perceived ease of use ( $\Omega_{pre} = .908$ ,  $\Omega_{post} = .935$ ), perceived enjoyment  
479 ( $\Omega_{pre} = .955$ ,  $\Omega_{post} = .980$ ), and intention to use ( $\Omega_{pre} = .978$ ,  $\Omega_{post} = .989$ ).

#### 480 **2.4.6. Perception of the APA teacher**

481 Questionnaires assessed perceived warmth, perceived competence [14], perceived  
482 adaptiveness, and perceived sociability [44] of the APA teacher in the two conditions (Face-  
483 to-face, MTR). Questionnaires were filled out three times, just after the completion of each of  
484 the three stepping tasks. Participants answered the three items assessing perceived warmth  
485 (e.g., "*I think the APA teacher is friendly*"), the three items assessing perceived competence  
486 (e.g., "*I think the APA teacher is competent*"), the three items assessing perceived  
487 adaptiveness (e.g., "*I think the APA teacher can be adaptive to what I need*"), and the three  
488 items assessing perceived sociability (e.g., "*I find the APA teacher pleasant to interact with*")  
489 on a 1 (strongly disagree) to 5 (strongly agree) Likert scale. Internal consistency was  
490 satisfactory for perceived warmth ( $\Omega_{Task A} = .788$ ,  $\Omega_{Task B} = .716$ ,  $\Omega_{Task C} = .897$ ), for perceived  
491 competence ( $\Omega_{Task A} = .776$ ,  $\Omega_{Task B} = .902$ ,  $\Omega_{Task C} = .868$ ), for perceived adaptiveness ( $\Omega_{Task A}$   
492  $= .874$ ,  $\Omega_{Task B} = .891$ ,  $\Omega_{Task C} = .904$ ), and for perceived sociability ( $\Omega_{Task B} = .722$ ,  $\Omega_{Task C} =$   
493  $.802$ ), but somewhat weak for perceived sociability assessed after the Task A ( $\Omega_{Task A} = .661$ ).

#### 494 **2.4.7. Self-confrontation interviews**

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

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

## 509 **2.5. Data analyses**

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

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

519 For each participant, the time taken to complete each trial in the different tasks was  
520 recorded. Then, for each participant, time performance recorded in the first four and the last  
521 four trials were averaged and repeated-measures ANOVAs with two factors -- Trials (Trials  
522 1-4, Trials 5-8) and Condition (Face-to-Face, MTR) -- were conducted on the mean  
523 performance of each participant. In case of interaction effects, differences were evaluated  
524 post-hoc with Holm tests. The number of errors was also analyzed in the same way. However,  
525 since the distribution of the data did not meet the assumptions of normality, two non-  
526 parametric tests were used. First of all, Friedman tests were conducted to examine a potential

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

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

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



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

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

### 562 **3. Results**

#### 563 **3.2. Preliminary tests**

564 Prior to the experiment, no significant differences appeared between participants'  
565 scores of the two groups for: i) the MMSE, ( $p = .347$ ,  $M_{Face-to-face} = 27.80 \pm 1.64$ ,  $M_{MTR} =$   
566  $28.25 \pm 1.33$ ), ii) the unipedal balance test ( $p = .885$ ,  $M_{Face-to-face} = 26.65 \pm 24.93$ ,  $M_{MTR} =$   
567  $25.62 \pm 19.37$ ), iii) the Timed Up and Go ( $p = .750$ ,  $M_{Face-to-face} = 7.86 \pm 2.67$ ,  $M_{MTR} = 7.67 \pm$   
568  $1.27$ ), and iv) the maximal handgrip strength test ( $p = .095$ ,  $M_{Face-to-face} = 28.56 \pm 8.97$ ,  $M_{MTR} =$   
569  $33.47 \pm 9.17$ ). These results indicated that the two groups compared in the subsequent  
570 analyses were equivalent at baseline with respect to cognitive and physical performance.

#### 571 **3.3. Quantitative results**

##### 572 **3.3.3. Task performance.**

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

576 .001,  $\eta_p^2 = .54$ ), and Task C ( $F(1, 38) = 79.26, p = < .001, \eta_p^2 = .68$ ). Holm post-hoc tests  
577 revealed that time to complete the task decreased in the last four trials, relative to the first four  
578 trials, regardless of the level of task difficulty and conditions ( $ps < .001$  for the three tasks and  
579 for each Condition). Whatever the level of task difficulty, the effect of Condition and the Trial  
580 x Condition interaction effect were non-significant ( $ps > .862$ , and  $ps > .196$ , respectively).

581 No significant effect of Condition (Face-to-face, MTR) on the number of errors was  
582 found ( $ps > .206$  for the three tasks). Moreover, the number of errors did not significantly  
583 decrease between the first four trials and the last four trials, regardless of task difficulty ( $ps >$   
584  $.715$ ). Mann-Whitney tests also showed that number of errors of participants in the Face-to-  
585 face and of the MTR conditions did not differ ( $ps > .212$ ) in the first and last trials, whatever  
586 the level of task difficulty (Task A, Task B, Task C).

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

#### 591 **3.3.4. Acceptance of the MTR – Comparison with the mean of the scale**

592 The results of the one-sample  $t$ -tests showed that perceived usefulness ( $t(19) = 3.96, p$   
593  $< .001, d = 0.88.87, M = 3.98, SD = 1.11$ ), perceived ease of use ( $t(19) = 6.42, p < .001, d =$   
594  $1.44, M = 4.43, SD = 1.00$ ), perceived enjoyment ( $t(19) = 2.92, p = .009, d = 0.65, M = 3.93,$   
595  $SD = 0.49$ ), and intention to use ( $t(19) = 3.04, p = .007, d = 0.68, M = 3.78, SD = 1.15$ ) were  
596 significantly higher than the mean of the scale for the older adults in the experimental group  
597 who have actually used the MTR (Figure 3), indicating that, after a first use, the MTR was  
598 found to be useful, easy to use, and enjoyable and that older adults have intention to use it for  
599 physical activity. Hypothesis 2 was supported.

---

Please insert Figure 3

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### 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

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### 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

624 Task A ( $U = 257.5, p = .032, r_B = .288$ ) and in Task B ( $U = 248, p = .026, r_B = .240$ ), but not  
625 in Task C ( $p = .164$ ). Finally, perceived sociability of the Face-to-face APA teacher was  
626 significantly higher than that of the MTR APA teacher in Task A ( $U = 258.5, p = .023, r_B =$   
627  $.292$ ), in Task B ( $U = 252, p = .018, r_B = .260$ ), and in Task C ( $U = 252.5, p = .017, r_B = .263$ ).  
628 Results are presented in Figure 4. Hypothesis 4 was partially supported, except for perceived  
629 sociability, because no significant differences have been found for perceived competence, no  
630 significant differences have been found for perceived warmth in Tasks B and C, and for  
631 perceived adaptiveness in Task C.

---

Please insert Figure 4

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632

633 **3.3.7. Perception of the MTR APA teacher – Comparison with the mean**  
634 **of the scale**

635 The results of the one-sample  $t$ -tests showed that perceived warmth of the MTR APA  
636 teacher ( $t(19) = 30.72, p < .001, d = 6.87, M = 4.83, SD = 0.27$ ), its perceived competence  
637 ( $t(19) = 30.78, p < .001, d = 6.88, M = 4.87, SD = 0.27$ ), its perceived adaptiveness ( $t(19) =$   
638  $15.10, p < .001, d = 3.38, M = 4.66, SD = 0.49$ ), and its perceived sociability ( $t(19) = 16.67, p$   
639  $< .001, d = 3.73, M = 4.68, SD = 0.45$ ) were significantly higher than the mean of the scale  
640 (Figure 5), indicating that the APA teacher who conducted the APA session using the MTR  
641 was found to be highly warm, competent, adaptive, and sociable. Hypothesis 5 was supported.

---

Please insert Figure 5

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642

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

---

Please insert Table 2

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645           **3.4. Qualitative analyses**

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

650                   **3.4.3. Typical experience in the cognitive-motor task SSE**

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

659                   **3.4.4. Typical experience with the APA teacher**

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

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

#### 680 **3.4.5. Specific typical experience in the MTR condition**

681 The results also highlighted the specific typical dynamics of the participants' experience  
682 in the MTR condition, gradually making the MTR transparent to the benefit of the APA teacher  
683 who piloted it. The relationship with the APA teacher in telepresence evolved rapidly as the  
684 experiment progresses to finally lead to the very positive perception of the APA teacher  
685 previously described. Initially, the participants did not focus on the APA teacher who piloted  
686 the MTR, they focused instead directly on the MTR. The first reaction when seeing the MTR  
687 was surprise, they say "*we're not used to it*". This experience generated different perceptions  
688 among the participants. Some lived it positively by telling themselves that they were "*in the*  
689 *future*". Other participants perceived the atmosphere as cold, "*it's freezing*", the MTR scared  
690 them by updating negative experiences they have already had with technologies. Then in use,  
691 they focused on the APA teacher who piloted the MTR and they perceived the MTR as  
692 ultimately friendly and useful. This excerpt is an example of the experience of the participants:  
693 "*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.

#### 718 4. Discussion

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

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

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



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

748         The second objective of the study was to investigate how the MTR was accepted by  
749 older adults following the completion of a remote physical activity session. First, the study  
750 investigated the magnitude of acceptance. The results showed that after a first use, the MTR  
751 was found to be significantly useful, easy to use, and enjoyable, and that older adults had  
752 intention to use it for physical activity. These results are in line with those of other studies  
753 [38,39] that have highlighted that the MTR was found to be useful and easy to use, and that  
754 perceived usefulness, perceived ease of use, and perceived enjoyment were significantly (but  
755 slightly) higher than the mean of the scale. These results add to previous findings which  
756 concerned the acceptance of the MTR before a first use, while in the present study acceptance  
757 was measured for the first time after an effective use of the MTR during an APA training  
758 session.

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

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

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

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

### 803 **5. Limitations of the present study**

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

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

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

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

## 837 **6. Conclusion**

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

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

850

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

852

### 853 **Compliance with Ethical Standards**

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

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### 859 **Conflict of Interest**

860 The authors declare that they have no conflict of interest.

861

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1053 21(1):1-9. <https://doi.org/10.1186/s12877-021-02390-9>  
1054

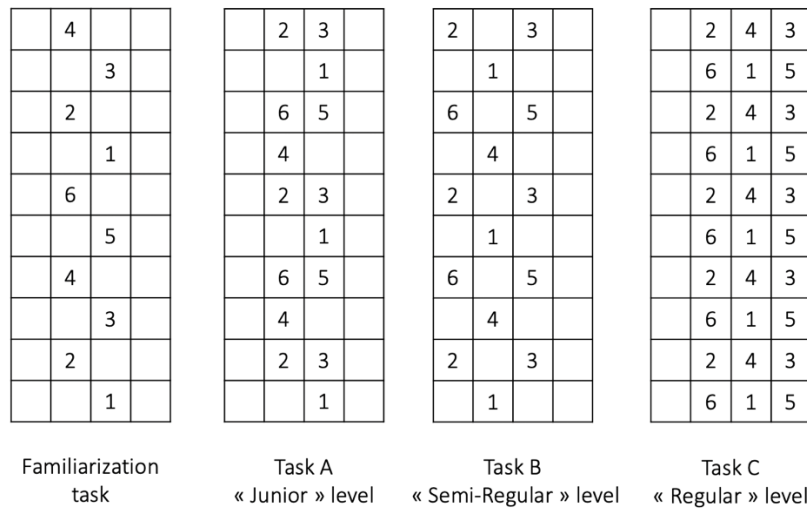
1055 Figure 1.

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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1061

1062 Figure 2.

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

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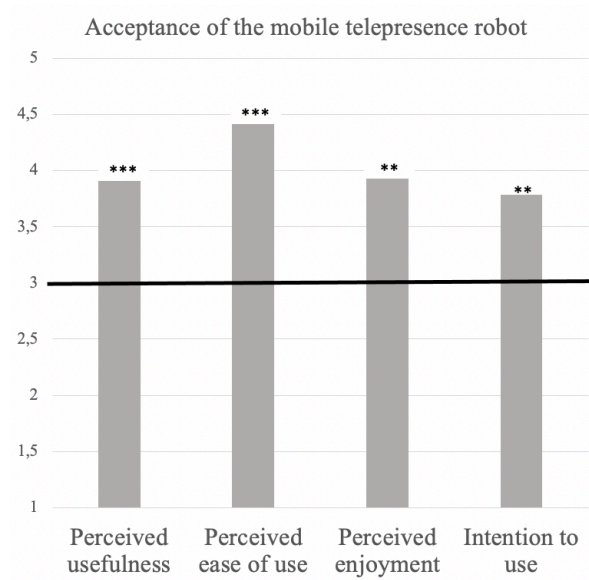
1069

1070

1071 Figure 3.

1072 Comparison of scores of perceived usefulness, perceived ease of use, perceived enjoyment,  
1073 and intention to use with the mean of the scale.

1074



1075

1076 Notes. \*\*  $p < .01$ , \*\*\*  $p < .001$ , the bold horizontal line indicates the mean of the scale.

1077

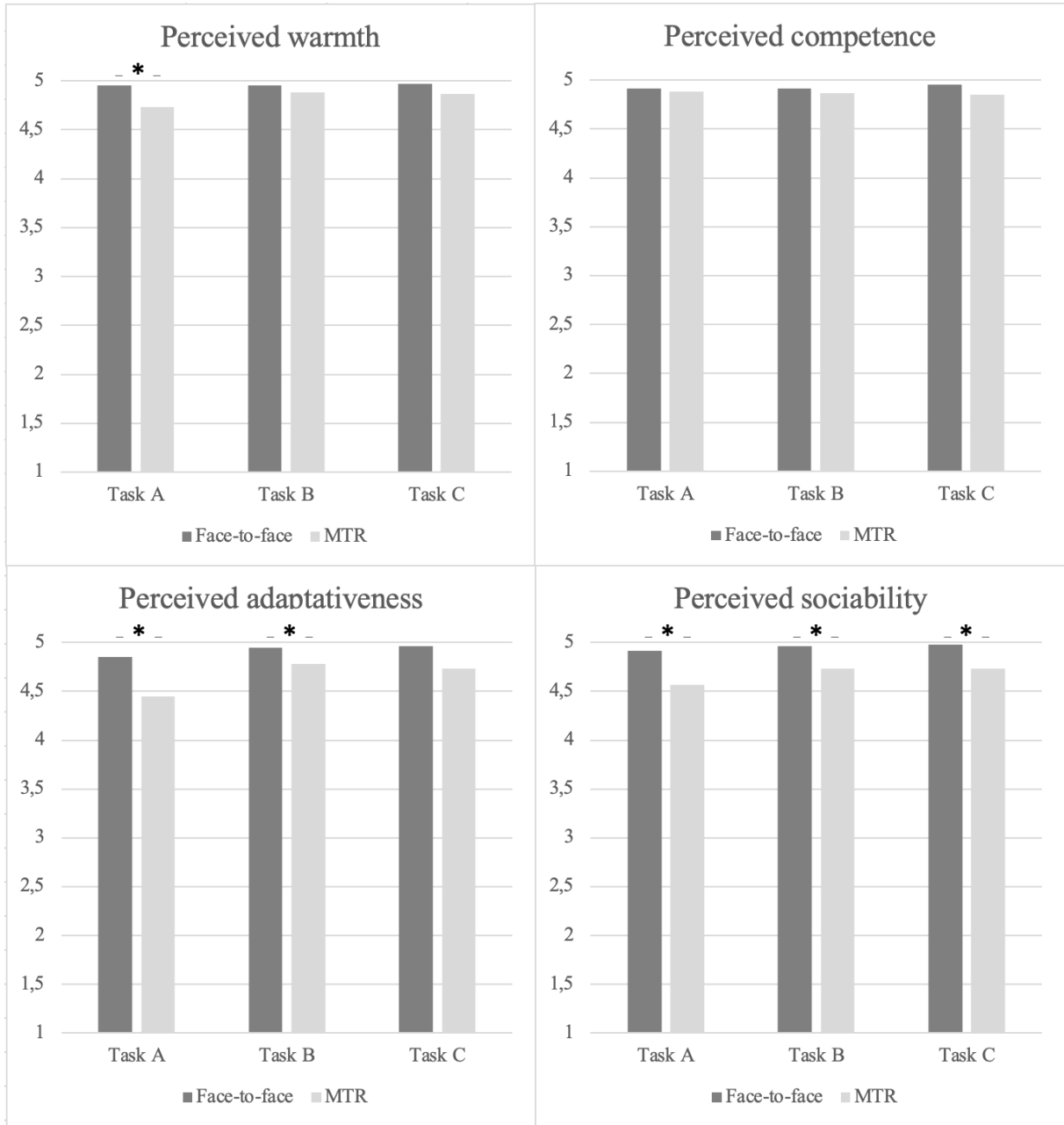
1078



1079 Figure 4.

1080 Comparison of scores of perceived warmth, perceived competence, perceived adaptiveness,

1081 and perceived sociability according to condition (Face-to-face vs. MTR) and tasks.



1082

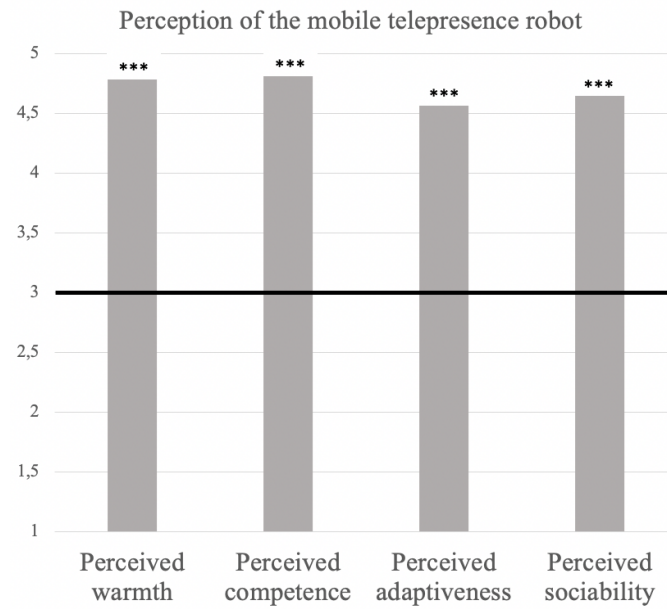
1083 Notes. \*- indicates a significant difference at  $p < .05$  between the Face-to-face and MTR  
1084 conditions; the error bars are not represented on the graph, but the exact values of the standard  
1085 deviations are indicated in table n°2.

1086

1087 Figure 5.

1088 Comparison of scores of perceived warmth, perceived competence, perceived adaptiveness,

1089 and perceived sociability with the mean of the scale.



1090

1091 Notes. \*\*\*  $p < .001$ , the bold horizontal line indicates the mean of the scale (i.e., 3).

1092

1093 Table 1.

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

1095

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

1098 Table 2.

1099 Descriptive statistics, skewness, and kurtosis for the perception of the APA teacher and for

1100 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

1101 *Notes.* *M* = Mean, *SD* = Standard Deviation, Cond. = Condition, Sk. = Skewness, Ku. =  
 1102 Kurtosis. The time and number of errors scores are presented for each condition on the top  
 1103 row for the trials 1-4 and on the bottom row for the trials 5-8.

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1105

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