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The Social and Cognitive Online Training (SCOT) project: A digital randomized controlled trial to promote socio-cognitive well-being in older adults

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HIGHLIGHTS

- Preventive interventions for socio-cognitive functioning in aging are still limited.
- SCOT is a new experimental intervention to improve socio-executive functioning.
- Socio-executive significant improvements in both SCOT and active control group.
- SCOT subjects who performed best during training improved in recognizing emotions.

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ABSTRACT

Objectives: Effective prevention programs targeting risk factors for cognitive decline in the elderly are recommended given the progressive increase in the aging of the general population. The Social and Cognitive Online Training (SCOT) project is a randomized, controlled, parallel clinical trial designed to prevent the age-related decline in executive and social functions.

Methods: The study included 60 cognitively healthy older adults (age = 71.8±5.3, education = 12.3±3.7, MoCA = 25.1±2.4). Participants underwent a baseline clinical and neuropsychological assessment and were then assigned to either an experimental group (SCOT) or a non-specific cognitive training group (CON). Both 8-week digital interventions included two individual cognitive training sessions and one group meeting per week. Post-intervention assessment evaluated the efficacy of the training on specific outcome measures: the Tower of London for executive functioning, the Ekman-60 Faces test, and the Mini-Social cognition & Emotional Assessment battery for social cognition. A measure of loneliness was included as an exploratory outcome.

Results: Baseline demographic and neuropsychological characteristics were balanced between SCOT (n = 29) and CON (n = 28) groups. Pre-post-intervention analyses showed improvements in executive functioning and social cognition in both groups, without significant interaction effects. Exploratory post-hoc analyses stratifying the SCOT group by training performance showed significant post-training improvements in executive functioning, emotion recognition, and cognitive theory of mind for high-performing participants.

Discussion: Results provide preliminary evidence for the beneficial effects of SCOT training, particularly for those who performed best during the training. The SCOT training could represent a new intervention to promote socio-cognitive well-being in the context of active ageing and dementia prevention.

1. Introduction

Data reported by the United Nations in recent years clearly show that the world is undergoing profound demographic change, with a progressive aging of the population affecting countries around the world, regardless of the level of development. In particular, the World Health Organization (WHO) estimates that the global population of people aged 60 and over will double by 2050, reaching up to 2 billion

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people (Nichols et al., 2022). This significant increase has placed the prevention of cognitive decline and dementia at the top of global mental health priorities (World Health Organisation, 2017), as the impact of dementia extends beyond patients and their families to include high economic costs to society as a whole (Nichols et al., 2022).

1.1. Computerized cognitive training as a possible strategy to prevent dementia in healthy older adults

In response to this rapid expansion of the older population, effective policies and strategies are needed to manage the impact on economies and health systems and to develop comprehensive solutions that promote healthy and active ageing. Several modifiable risk factors have been identified to account for around 40 % of the risk of developing dementia (Livingston et al., 2020), including cognitive inactivity and social isolation, and have become important targets for multi-modal prevention interventions (Andrieu et al., 2017; Kivipelto et al., 2020; Ngandu et al., 2015; van Charante et al., 2016). Indeed, a broader approach to dementia prevention includes strategies to promote and maintain cognitive reserve in old age by engaging in cognitively stimulating activities and social interactions, and a growing body of research supports the protective effects of cognitive stimulation and social contact on dementia incidence (Livingston et al., 2020; Sommerlad et al., 2023).

Recent systematic reviews and meta-analyses have reported positive effects of cognitive-orientated interventions in healthy older adults, particularly on general cognitive function, attention, working memory, processing speed and executive functions (Chiu et al., 2017; Gates et al., 2019; Sanjuán, Navarro, & Calero, 2020). As technology advances and the accessibility of digital tools continues to increase, several studies have addressed the question of the beneficial effects of computerized cognitive training in cognitively healthy older adults (Bonnechère et al., 2020; Gates et al., 2019; Kueider et al., 2012; Lampit et al., 2014). Although efficacy varies by cognitive domain and intervention design (Lampit et al., 2014), and although the current evidence is inconclusive due to the variability and low quality of meta-analyses and individual clinical trial results (Gates et al., 2019), the use of PCs, game consoles, smartphones and tablets has shown promising results, bringing significant improvements in executive functions, processing speed, working memory and reasoning skills (Bonnechère et al., 2020; Rute-Pérez et al., 2023; Vaportzis, Martin, & Gow, 2017; Wilson et al., 2022).

1.2. Socio-cognitive training in healthy older adults and their potential benefits

Interestingly, most of these interventions have focused on the main cognitive domains (e.g., memory, executive functions) but have not included social cognition, despite the literature showing significant changes with advancing age. In particular, significant declines in mentalizing and basic emotion recognition have been reported and attributed to structural and functional changes in the prefrontal cortex (Fernandes et al., 2021; Gourlay et al., 2022), one of the areas most affected by age-related decline (Zanto & Gazzaley, 2019), which also contributes to executive dysfunctions in this population (Circelli, Clark & Cronin-Golomb, 2013; Yıldırım, Büyükişcan, & Gürvit, 2020).

Although the debate on the relationship between social cognition and executive functions remains open due to conflicting results and the multi-component nature of the domains themselves (Baksh et al., 2018), there is now substantial literature demonstrating that normal adult aging is associated with changes in both social (specifically, declines in theory of mind [ToM] and social perception) (Grainger et al., 2023) and executive domains (Ferguson, Brunsdon & Bradford, 2021), which share, at least in part, the prefrontal brain areas as a neuroanatomical substrate. Emerging evidence suggests that socio-cognitive training interventions may have beneficial effects in healthy older people by improving socio-cognitive skills and social functioning (Roheger et al., 2022). In particular, results from a small number of Italian studies investigating training focused on ToM tasks and conversations about mental states in adults aged over 60 years showed that interventions were highly effective in improving ToM in this age group (Cavallini et al., 2015; Rosi et al., 2016). Furthermore, a conversation-based ToM intervention conducted with cognitively healthy nursing home residents was found to be effective in improving socio-cognitive skills in both practiced and non-practiced tasks (Cavallini et al., 2021). However, it is worth noting that the use of online social cognitive interventions has been explored in other populations, such as individuals with schizophrenia (Nahum et al., 2014, 2021), autism (Golan & Baron-Cohen, 2006; Rosenblau et al., 2020) or traumatic brain injury (Westerhof-Evers et al., 2019), with encouraging results reported for social skills, social functioning, and motivation. These findings across diverse populations provide a broader context for understanding the potential benefits and challenges associated with online interventions targeting cognitive and social cognitive skills.

1.3. Research gap and rationale for the SCOT project

To the best of our knowledge, no study has yet tested the effects of online computerized training on improving socio-executive functioning in healthy older people.

This kind of intervention might be of particular relevance, considering that age-related social cognition changes might significantly impact everyday social functioning.

Against this backdrop, we conducted the Social and Cognitive Online Training (SCOT) project, a randomized, parallel, double-blind, controlled clinical trial (ClinicalTrials.gov identifier: NCT05023187), which aimed to evaluate the efficacy of a multidimensional online intervention, as compared to non-specific cognitive stimulation, in improving socio-executive functioning in healthy older people. Besides, considering that socio-cognitive alterations have been associated with increased loneliness (Cacioppo, 2009; Morese & Palermo, 2022), and that the latter represents a risk factor for the development of dementia (Bransby et al., 2024; Livingston et al., 2020), we also assess the effect of the training on this psychological dimension.

This paper describes the methods and results of the SCOT project in accordance with the CONSORT (CONsolidated Standards Of Reporting Trials) guidelines (Moher et al., 2010) (see Supplementary data - Table S1 for CONSORT checklist for reporting a randomized trial).

2. Methods

2.1. Participants

Between January 2021 and December 2021, 60 healthy older adult volunteers aged 64 to 85 years were enrolled at the Neurocognitive Rehabilitation Centre (CeRiN) of the Center for Mind/Brain Sciences (University of Trento). All participants underwent a medical history interview and cognitive screening to verify eligibility criteria.

To be included in the study, participants had to be aged ≥64 years (up to 90 years old) and have a Montreal Cognitive Assessment (MoCA) adjusted score ≥19.501, within normal limits according to Italian normative values (Conti et al., 2015). Exclusion criteria were a diagnosis of major or mild neurocognitive disorder according to the Diagnostic and Statistical Manual of Mental Disorders (Fifth Edition, DSM-V) and based on the results of a comprehensive neuropsychological assessment (see Supplementary data - Table S2), a history of current or past neuropsychiatric disorders, and/or substance abuse.

All participants provided informed consent for the study, which was conducted following the ethical guidelines of the local ethics committee (University of Trento Research Ethics Committee, protocol 2020-036) and the Declaration of Helsinki (World Medical Association, 2013). Participant inclusion and randomization are represented in Fig. 1.

The sample size planning was conducted using G*Power 3.1 (Erdfelder et al., 2009) based on an effect size for a 24-session intervention

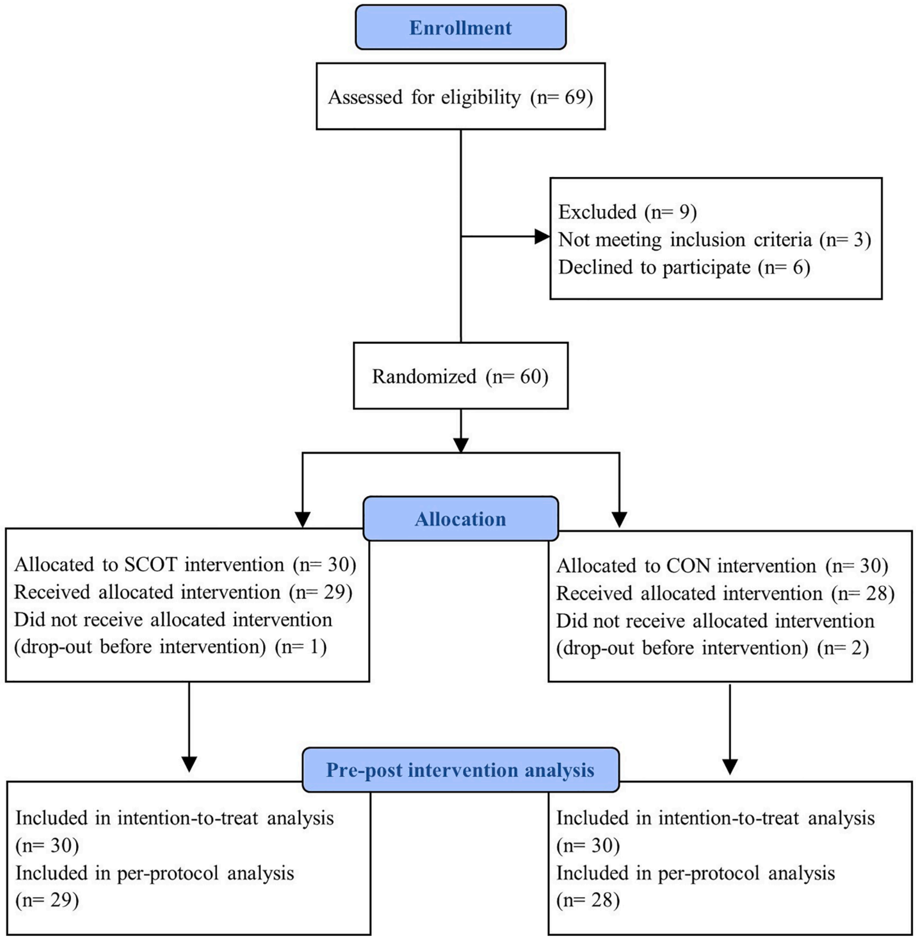

Fig. 1. Flow diagram of the SCOT project (adapted from CONSORT 2010 flow diagram, Moher et al., 2010).

(effect size: 0.697) (Chiu et al., 2017) and power of 0.80. The results indicated that for a two-group design at least 27 participants per group were needed to detect a significant result. Considering a possible drop-out of 10 %, 30 subjects per group were enroled.

2.2. Randomization and intervention

Participants were randomly allocated to either an experimental (Social and Cognitive Online Training - SCOT) or an active control group (CON) using a covariate adaptive randomization method (Colavincenzo, 2012) stratifying participants for age, education and sex. The cut-off assignment strategies for age and education were $\leq$ or $>$ 70 years old and $\leq$ or $>$ 13 years of education, respectively. Both participants and investigators were blinded to group allocation. Both interventions were delivered remotely via investigator-provided tablets and lasted eight weeks, during which, participants completed two individual sessions

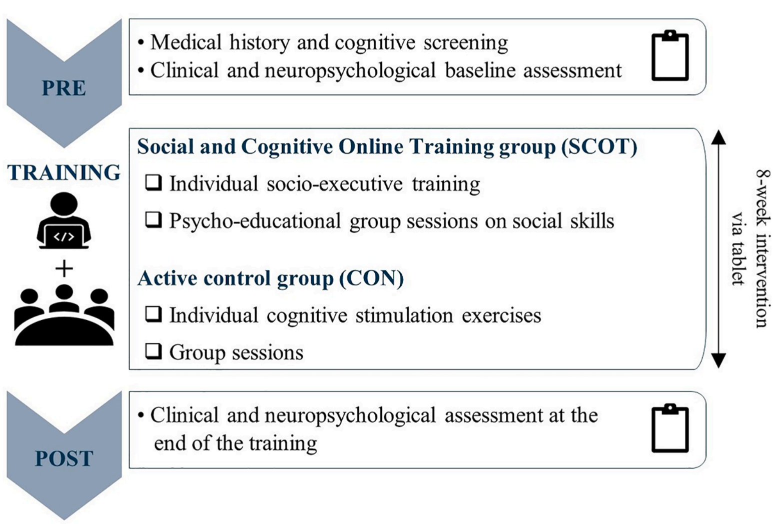

Fig. 2. Study design.

and one group meeting video call per week (24 sessions total, ~60 min each, in accordance with literature evidence (Chiu et al., 2017)). Details of the study design are shown in Fig. 2.

The interventions were designed and delivered by qualified psychologists who provided all participants with detailed instructions before the intervention began. They also offered remote support to participants throughout the training period to help them complete the planned activities.

The SCOT group received an online social and executive intervention consisting of two individual sessions of adaptive online cognitive training and one psychoeducational group session per week. The individual training sessions consisted of six tasks selected from Posit Science's BrainHQ© Program 2020 (https://www.brainhq.com), which have previously been shown to be effective in randomized clinical trials (Smith et al., 2009; Tennstedt & Unverzagt, 2013) and chosen to improve attention-executive functions (i.e., "Double Decision" for visual processing speed, "Divided Attention", "Mind Bender" for cognitive flexibility and executive control and "Card Shark" for working memory) and social skills (i.e., "Face to Face" for emotion recognition and "Face Facts" for social memory).

Online psychoeducational group sessions led by psychologists included discussions and practical exercises focusing on social skills such as emotion recognition and attribution, ToM, empathy, and social behavior.

The active comparison group (CON), on the other hand, received a non-specific and non-adaptive online cognitive intervention consisting of two individual sessions of cognitive stimulation and one group session per week aimed at improving knowledge of cognitive functioning. Specifically, the individual sessions included digital exercises on memory, attention, language, executive function, perception, financial literacy, social skills, and creativity/divergent thinking, which were reviewed, discussed, and commented on during the group sessions with psychologists.

Throughout the intervention, the presence/absence of participants in the different components of the training was tracked to have a measure of adherence to the intervention.

Finally, to reduce the risk of dropping out, strategies according to Dziura et al. (2013) were implemented, including weekly reminders and/or assistance with the digital device.

2.3. Outcome measures

The primary outcome measure was the Tower of London (ToL) test (Boccia et al., 2017), which assesses executive functioning. This test covers different aspects of executive functioning such as planning, problem-solving, and processing-speed (Shallice, 1982; Sullivan, Riccio, & Castillo, 2009) and it is frequently reported as an outcome measure in clinical trials (Specht et al., 2023; Van Balkom et al., 2019). In clinical setting, performance is usually assessed separately in terms of accuracy, measured as the number of trials solved correctly in the minimum number of moves, planning and execution times (Boccia et al., 2017). Although the use of all these parameters is recommended in the literature, no index exists that combines the information provided by each of them and optimises the assessment of each patient's performance. Then, we proposed a ToL index that simultaneously considers accuracy, planning time, and execution time in participants' performance to further explore the efficacy of the intervention on executive functioning.

$$ToL - \ index = \left(\frac{ToL\ Accuracy_{sbj}}{ToL\ Accuracy_{Max\ score}}\right) \times \left(1 - \frac{\overline{ToL\ planning\ time}_{sbj}}{(\mu + 6\sigma)_{ToL\ planning\ time}}\right) \times \left(1 - \frac{\overline{ToL\ execution\ time}_{sbj}}{(\mu + 6\sigma)_{ToL\ execution\ time}}\right)$$

According to this formula, the higher the index, the better the subject's performance in terms of high accuracy, fast planning time and fast execution time. Overall, this index is therefore more representative of overall performance than individual scores. In addition, social cognition was assessed through the Ekman-60 Faces test (Ek-60F test, secondary outcome) (Dodich et al., 2014) as a basic emotion recognition task, and the Faux-Pas Recognition Test of the Mini-Social cognition & Emotional Assessment battery (Mini-SEA, explorative outcome) (Bertoux et al., 2013). Specifically, four scores were derived, representing the ability to detect inappropriate behaviour (faux pas detection), the cognitive and affective components of ToM, and a score representing the control condition. Finally, to assess the possible effect of training on social functioning, the total score on the Italian Social and Emotional Loneliness Scale (ISELS) (Zammuner, 2008) was used, where higher scores indicate worse outcomes in terms of perceived loneliness (the higher the score, the more loneliness the person reports).

All outcome measures were assessed at baseline and at the end of the 8-week intervention.

2.4. Statistical analyses

Statistical analyses were checked for underlying assumptions. The normal distribution of the data was assessed using the Shapiro-Wilk test, which allowed for the appropriate application of parametric or non-parametric statistical techniques. The efficacy of the randomization procedure was tested by comparing demographic, clinical, and neuropsychological characteristics of the SCOT and CON groups at baseline using either the Student's *t*-test or the Mann-Whitney U test, depending on data distribution. Then, the efficacy of the experimental training in modifying executive and socio-cognitive functioning was tested using a mixed ANOVA comparing the performance of the SCOT and CON participants who completed the 8-week training (*per-protocol approach*), analyzing the effect of time, group and interaction. Pre-post comparison analyses were performed on outcome measures, using Tukey's test as a post-hoc analysis. The efficacy of the intervention was also tested using the *intention-to-treat approach* with *'mean imputation'* per group.

Additionally, to account for the online nature of the intervention and participants' intrinsic motivation, which may have influenced the effects of the training, the SCOT group was further divided into "HIGH PERFORMANCE" and "LOW PERFORMANCE" subgroups, based on their performance in the individual training (according to the median number of levels achieved on the BrainHQ platform used for training). A mixed design ANOVA was then performed as a post-hoc analysis to compare the performance of the SCOT HIGH PERFORMANCE, SCOT LOW PERFORMANCE and CON groups before and after the intervention on the variables of interest. This analysis tested the hypothesis that those subjects who performed best during the intervention would achieve a greater improvement in the outcome measures.

Statistical analyses were performed using Jamovi 2 (Jamovi, 2021) with a significance level <0.05.

3. Results

Sixty-nine individuals were screened, and 60 were randomly assigned to either the experimental group (SCOT n=30) or the active control group (CON n = 30). Of these, 57 (95%) completed the entire allocated training period and underwent the post-intervention evaluation, while 3 subjects (1 SCOT, 2 CON) dropped out of the study before the start of the intervention due to difficulties in participation.

3.1 Baseline assessment of SCOT and CON groups.

Analysis of demographic and clinical characteristics, as well as performance on the social and cognitive tests at baseline, showed no significant differences between the SCOT and CON groups (Table 1). No harm or adverse events related to the intervention were reported by participants, and adherence to intervention was very high for both groups (CON mean 93.92%; SCOT mean 98.06%).

Table 1
Baseline assessment of SCOT and CON groups.

Demographic data	SCOT (n = 30)	CON (n = 30)	Statistics
Sex (F/M)	18/12	20/10	χ(1)= 0.3, p= 0.6
Age	71.8(5.2)	71.7(5.5)	U= 428, p = 0.8
Education	12.2(4.2)	12.3(3.0)	U= 444, p = 0.9
Clinical & neuropsychological assessment			
Montreal cognitive assessment (MoCA)	25.1(2.3)	25.1(2.5)	t(58)= 0.1, p = 0.9
CIRS – Severity index (SV)	0.4(0.3)	0.5(0.2)	U= 416, p = 0.6
CIRS – Comorbidity index (CM)	1.3(1.3)	1.7(1.4)	U= 370, p = 0.2
Digit span Forward	5.9(0.8)	5.8(0.6)	U= 416, p = 0.5
Digit span backward	4.3(0.8)	4.6(1.0)	U= 340, p = 0.2
Corsi block-tapping test	5.2(1.0)	5.2 (0.9)	U= 445, p = 0.9
Trail-making Test – A	42.8(14.0)	40.3(13.6)	U= 401, p = 0.5
Trail-making Test – B	97.1 (26.6)	106.7(35.4)	t(58)= 1.2, p = 0.2
Trail-making Test – B-A	54.3 (19.2)	66.4(30.8)	t(58)= 1.8, p = 0.1
Phonemic verbal fluency task	41.2(12.2)	42.7(11.0)	t(58)= 0.5, p = 0.6
Semantic verbal fluency task	46.0(8.0)	46.3(7.9)	t(58)= 0.1, p = 0.9
Rey auditory verbal list immediate recall	46.8(10.2)	46.5(9.7)	t(58)= -0.1, p = 0.9
Rey auditory verbal list delayed recall	9.5(3.7)	9.4(2.6)	t(58)= -0.0, p = 1.0
Rey-Osterrieth complex figure copy	32.1(2.6)	31.1(3.2)	U = 361, p = 0.2
Rey-Osterrieth complex figure delayed recall	16.4(4.9)	16.8(6.4)	U = 427, p = 0.7
Stroop task – Time	19.7(6.5)	23.6(9.7)	U = 330, p = 0.1
Stroop task – Errors	0.7(1.4)	1.0(1.3)	U = 380, p = 0.4
State-Trait Anxiety Inventory (STAI-Y)	37.5(8.5)	36.7(7.0)	t(58)= -0.4, p = 0.7
Geriatric Depression Scale (GDS)	2.6(2.4)	2.6(1.9)	U= 424, p = 0.7
Mobile Device Proficiency in Older Adults (MDPQ-16)	61.8(15.4)	57.2(16.7)	U= 371, p = 0.2
Cognitive Reserve Index questionnaire (CRIq)	113.9(14.8)	115.4(15.5)	t(58)= 0.4, p = 0.7
Outcomes measures			
Executive functions			
Tower of London (ToL)– Accuracy	36.6(3.9)	35.5(4.4)	t(58)= -1.0, p = 0.3
Tower of London (ToL)– Index	0.3(0.1)	0.3(0.1)	t(58)= 0.0, p = 1.0
Social cognition			
Ekman-60 Faces test (Ek-60F test)	47.6(4.5)	46.2(6.0)	U= 392, p = 0.4
Mini-Social cognition & Emotional Assessment battery (Mini-SEA) – Faux pas Detection	13.5(1.2)	13.9(1.0)	U= 376, p = 0.2
Mini-Social cognition & Emotional Assessment battery (Mini-SEA) – Cognitive ToM	12.6(3.8)	13.7(3.4)	t(58)= 1.3, p = 0.2
Mini-Social cognition & Emotional Assessment battery (Mini-SEA) – Affective ToM	3.3(1.0)	3.5(1.1)	U= 417, p = 0.6
Mini-Social cognition & Emotional Assessment battery (Mini-SEA) – Control stories	19.7(0.7)	19.7(0.6)	U= 438, p = 0.8
Italian Social and Emotional Loneliness Scale (ISELS)	33.2(7.7)	34.5(8.0)	U= 396, p = 0.4

Note. Data are reported as mean ± standard deviation (SD).
Parametric or non-parametric statistical techniques were applied for each assessment based on the data distribution. The parametric Student's *t*-test (t) was used for variables with a normal distribution, while the non-parametric Mann–Whitney U test (U) was used for variables with a non-normal distribution.

3.2 *Pre – post comparison analyses in SCOT* vs *CON groups.*

The pre-post-comparison analyses showed a significant improvement after the intervention in both groups in the ToL Accuracy ($F_{1,55} = 7.19$, $p = 0.010$), in the ToL index ($F_{1,55} = 35.31$, $p < 0.001$) and in the Mini-SEA scores representing Faux Pas detection ($F_{1,55} = 8.50$, $p = 0.005$), cognitive ToM ($F_{1,55} = 25.38$, $p < 0.001$) and affective ToM ($F_{1,55} = 14.71$, $p < 0.001$). However, there were no significant *time*group* interactions for any outcome of interest (Table 2).

3.3 *Pre – post exploratory post-hoc analyses based on training performance.*

The results of the exploratory analysis dividing the experimental group into the subgroups "SCOT HIGH PERFORMANCE" (n = 15) and "SCOT LOW PERFORMANCE" (n = 14) and comparing them with the CON group, confirmed a significant *time* effect on both ToL (Accuracy: $F_{1,54} = 4.38$, $p = 0.041$, Index: $F_{1,54} = 37.83$, $p < 0.001$) and Mini-SEA measures (Faux Pas detection: $F_{1,54} = 8.87$, $p = 0.004$; cognitive ToM: $F_{1,54} = 28.67$, $p < 0.001$; affective ToM: $F_{1,54} = 15.82$, $p < 0.001$) (see Table S3 for baseline features of subgroups and Table 3 for results on the outcomes of interest).

Interestingly, the analyses also showed a significant *time*group* interaction for the EK-60F test ($F_{2,54} = 5.95$, $p = 0.005$) and for the ToL Index ($F_{2,54} = 6.61$, $p = 0.003$), as well as a trend for the Mini-SEA cognitive ToM ($F_{2,54} = 2.62$, $p = 0.082$) (Table 3). Specifically, post-hoc analysis with Tukey's test revealed in the "SCOT HIGH PERFORMANCE" group a significant difference between pre- and post-assessment for executive functioning (ToL – Index: $p < 0.001$; Fig. 3A), emotion recognition (EK-60F test: $p = 0.033$; Fig. 3B) and cognitive ToM (Mini-SEA – Cognitive ToM: $p < 0.001$; Fig. 3C). A significant improvement after the intervention was also found in performance in the ToL index in the CON group ($p < 0.001$; Fig. 3A).

No significant changes were found in the ISELS scale.

The results were confirmed when using the *intention-to-treat approach* with *"mean imputation"* per group.

4. Discussion

Older people who remain socially active and cognitively engaged tend to show higher cognitive function compared to those who are isolated and disengaged (Myhre, Mehl, & Glisky, 2017). Furthermore, digital technologies have developed exponentially in recent years and have shown promise in promoting cognitive well-being in older adults (Lee et al., 2020). The use of online tools facilitates the delivery of preventive interventions remotely, making them accessible to a wide range of users who would not be able to participate in face-to-face activities due to the commitment these activities require (multiple sessions, availability of a caregiver to accompany the person). Within this framework, our study aimed to evaluate the positive effects of a multidimensional social and executive functioning intervention (SCOT) compared to non-specific cognitive stimulation (CON), both delivered via tablets, to promote socio-cognitive well-being in older adults.

Overall, the results comparing the performance of the SCOT and CON groups before and after the intervention showed a significant improvement in both groups in planning, evaluated via the accuracy and total index of the ToL as a comprehensive measure for executive functioning, as well as in faux-pas recognition (i.e., Mini-SEA).

Previous literature reports that attention, processing speed, and executive function appear to benefit from cognitive stimulation in healthy older adults, regardless of whether these functions are specifically trained (Chiu et al., 2017). Thus, it is possible to hypothesize that, in our study, both interventions (SCOT and CON) may have had beneficial effects on these cognitive outcomes. In particular, since both groups included group sessions, this might have a beneficial effect on socio-cognitive functioning. Furthermore, given that the outcome measures differed from the training activities in terms of content and tasks, it is plausible that our results reflect training-related effects rather than the consequences of mere practice. On the other hand, as the experimental design did not include a wait-list control group and parallel versions were not available for the outcome measures, we cannot rule out the possibility that the observed effects on planning and social skills are due to a learning effect, rather than to a specific improvement in these capacities. The length of the intervention (8 weeks) could possibly increase the risk of observing a practice effect, however the training was built on previous meta-analytic evidence (Chiu et al., 2017) that found greater efficacy of 8-week interventions (total training of 24 sessions) in healthy older people.

The results of the exploratory analyses in which the SCOT group was divided according to training performance, revealed interesting results. In particular, the SCOT participants who achieved the highest levels of performance during training did indeed show significant improvements in executive functioning (ToL index) and basic emotion recognition (Ekman 60-Faces test), as well as a trend towards enhanced cognitive ToM, as evaluated by the Mini-SEA. By contrast, these improvements were not found in the SCOT LOW PERFORMANCE and CON groups. To the best of our knowledge, while previous evidence reports the possibility of training and improving executive functions and ToM in healthy older adults (Cavallini et al., 2015, 2021; Rosi et al., 2016; Rute-Pérez et al., 2023; Vaportzis et al., 2017), this is the first study that has directly tested emotion recognition training in older healthy adults (rather than in clinical populations). Our results showed an improvement in emotion recognition in SCOT HIGH PERFORMANCE, which could have positive consequences in real-life scenarios, such as the ability to accurately perceive, understand, and interpret emotional states in others. Indeed, as mentioned above, these skills may decline in older adults, so maintaining them may have beneficial effects, potentially improving social interactions and emotional well-being (Döllinger et al., 2021). Furthermore, our results in emotion recognition are particularly relevant, considering that the training was conducted using an emotion-matching task, where participants had to match pictures with the same emotion expression, whereas we used a simple emotion-recognition task (Ek60 F; Dodich et al., 2014) as an outcome measure. Furthermore, it is important to emphasize the importance of adhering to treatment. The high adherence rates, averaging at 93.92 % for CON and 98.06 % for SCOT, indicate excellent participants involvement. This suggests that the training was not only well-received but also deemed feasible for cognitively healthy older adults, reinforcing the overall success of the intervention.

Overall, these results are consistent with previous research suggesting that the efficacy of computerized cognitive training interventions is closely related to the intensity and quality of training (Butler et al., 2018). In essence, individuals who actively engage and excel in training activities are more likely to experience substantial cognitive gains. Moreover, these findings suggest that participants' intrinsic motivation to carry out the planned activities may have played a significant role in shaping the training outcomes. This highlights the importance of considering inter-individual differences when implementing cognitive training protocols (Tagliabue, Varesio, & Mazza, 2022). Taken together, these observations highlight the complexity underlying the efficacy of

Table 2
Pre – post comparison analyses in SCOT vs CON groups.

Outcome measures	Group	Pre-intervention Mean (St.Dev.)	Post-intervention Mean (St.Dev.)	Statistics *p*-value time	*p*-value group	*p*-value time*group
Executive functions						
ToL– Accuracy	SCOT	36.6(3.9)	37.4(4.4)	F(1,55) = 7.19, p = 0.010**, η^2_p = 0.12	F(1,55) = 0.10, p = 0.756, η^2_p = 0.00	F(1,55) = 1.85, p = 0.179, η^2_p = 0.03
Score range: 0–48	CON	35.5(4.4)	37.9(4.1)			
ToL – Index	SCOT	0.3(0.1)	0.4(0.1)	F(1,55) = 35.31, p<0.001****, η^2_p = 0.39	F(1,55) = 0.04, p = 0.837, η^2_p = 0.00	F(1,55) = 0.00, p = 0.999, η^2_p = 0.00
Score range: 0–1	CON	0.3(0.1)	0.4(0.1)			
Social cognition						
EK-60F Test	SCOT	47.6(4.5)	48.4(5.9)	F(1,55) = 3.10, p = 0.084, η^2_p = 0.05	F(1,55) = 0.39, p = 0.537, η^2_p = 0.01	F(1,55) = 0.19, p = 0.662, η^2_p = 0.00
Score range: 0–60	CON	46.2(6.0)	47.8(6.7)			
Mini-SEA – Faux pas Detection	SCOT	13.5(1.2)	14.1(0.9)	F(1,55) = 8.50, p = 0.005***, η^2_p = 0.13	F(1,55) = 1.21, p = 0.277, η^2_p = 0.02	F(1,55) = 0.53, p = 0.469, η^2_p = 0.01
Score range: 0–15	CON	13.9(1.0)	14.2(1.1)			
Mini-SEA - Cognitive ToM	SCOT	12.6(3.8)	15.3(3.1)	F(1,55) = 25.38, p<0.001****, η^2_p = 0.32	F(1,55) = 0.52, p = 0.476, η^2_p = 0.01	F(1,55) = 2.83, p = 0.098, η^2_p = 0.05
Score range: 0–20	CON	13.7(3.4)	15.2(2.9)			
Mini-SEA – Affective ToM	SCOT	3.3(1.0)	4.1(0.8)	F(1,55) = 14.71, p<0.001****, η^2_p = 0.21	F(1,55) = 0.06, p = 0.810, η^2_p = 0.00	F(1,55) = 1.29, p = 0.260, η^2_p = 0.02
Score range: 0–5	CON	3.5(1.1)	3.9(0.8)			
Mini-SEA - Control Questions	SCOT	19.7(0.7)	19.9(0.4)	F(1,55) = 3.22, p = 0.078, η^2_p = 0.06	F(1,55) = 0.08, p = 0.778, η^2_p = 0.00	F(1,55) = 0.15, p = 0.669, η^2_p = 0.00
Score range: 0–20	CON	19.7(0.6)	19.9(0.3)			
ISELS *Score range:0–57*	SCOT	33.2(7.7)	33.7(8.0)	F(1,55) = 0.62, p = 0.434, η^2_p = 0.01	F(1,55) = 0.09, p = 0.766, η^2_p = 0.00	F(1,55) = 0.99, p = 0.325, η^2_p = 0.02
	CON	34.5(8.0)	33.8(8.8)			

Note. Data are reported as mean ± standard deviation (SD).
GROUP: Refers to the two groups in the study. SCOT (Social and Cognitive Online Training), N = 29 participants; CON (Active Control), N = 28 participants.
Significant p-values from a 2 × 2 ANOVA testing for between groups differences are shown in bold.
Effect sizes are reported as partial eta squared (η^2_p).
$^*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.005$; $^{****}p < 0.0001$.

Table 3
Pre – post comparison analyses in CON vs SCOT HIGH PERFORMANCE & SCOT LOW PERFORMANCE groups.

Outcome measures	Group	Pre-intervention Mean (St. Dev.)	Post-intervention Mean (St.Dev.)	Statistics *p*-value time	*p*-value group	*p*-value time*group
Executive functions						
ToL – Accuracy	SCOT HIGH	36.1(4.2)	37.6(4.1)	F(1,54) = 4.38, p = 0.041*, η^2_p = 0.08	F(2,54) = 0.09, p = 0.910, η^2_p = 0.00	F(2,54) = 1.42, p = 0.250, η^2_p = 0.05
Score range: 0–48	SCOT LOW	37.3(3.8)	37.2(4.8)			
	CON	35.6(4.6)	37.9(4.1)			
ToL – Index	SCOT HIGH	0.3(0.1)	0.4(0.1)	F(1,54) = 37.83, p < 0.001****, η^2_p = 0.41	F(2,54) = 0.08, p = 0.921, η^2_p = 0.00	F(2,54) = 6.61, p = 0.003***, η^2_p = 0.20, □ p < 0.001****, ♢ p < 0.001****
Score range: 0–1	SCOT LOW	0.4(0.1)	0.4(0.1)			
	CON	0.3(0.1)	0.4(0.1)			
Social cognition						
EK-60F Test	SCOT HIGH	48.1(4.2)	51.5(4.8)	F(1,54) = 2.49, p = 0.121, η^2_p = 0.04	F(2,54) = 1.89, p = 0.161, η^2_p = 0.07	F(2,54) = 5.95, p = 0.005***, η^2_p = 0.18, ♢ p = 0.033*
Score range: 0–60	SCOT LOW	47.1(5.1)	45.2(5.3)			
	CON	46.5(6.1)	47.8(6.7)			
Mini-SEA – Faux Pas detection	SCOT HIGH	13.3(1.4)	14.2(1.0)	F(1,54) = 8.87, p = 0.004***, η^2_p = 0.14	F(2,54) = 0.64, p = 0.534, η^2_p = 0.02	F(2,54) = 0.64, p = 0.531, η^2_p = 0.02
Score range: 0–15	SCOT LOW	13.6(1.1)	14.1(0.7)			
	CON	13.9(1.0)	14.2(1.1)			
Mini-SEA – Cognitive ToM	SCOT HIGH	12.0(4.2)	15.7(3.1)	F(1,54) = 28.67, p < 0.001****, η^2_p = 0.35	F(2,54) = 0.26, p = 0.774, η^2_p = 0.01	F(2,54) = 2.62, *p = 0.082*, η^2_p = 0.09, ♢ p < 0.001****
Score range: 0–20	SCOT LOW	13.0(3.4)	14.9(3.2)			
	CON	13.8(3.3)	15.2(2.9)			
Mini-SEA – Affective ToM	SCOT HIGH	3.2(1.2)	4.1(1.0)	F(1,54) = 15.82, p < 0.001****, η^2_p = 0.23	F(2,54) = 0.19, p = 0.830, η^2_p = 0.01	F(2,54) = 0.90, p = 0.413, η^2_p = 0.03
Score range: 0–5	SCOT LOW	3.5(0.8)	4.1(0.6)			
	CON	3.5(1.0)	3.9(0.8)			
Mini-SEA – Control Questions	SCOT HIGH	19.7(0.6)	19.8(0.4)	F(1,54) = 2.48, p = 0.121, η^2_p = 0.04	F(2,54) = 0.43, p = 0.655, η^2_p = 0.02	F(2,54) = 0.07, p = 0.928, η^2_p = 0.00
Score range: 0–20	SCOT LOW	19.8(0.8)	19.9(0.3)			
	CON	19.7(0.7)	19.9(0.3)			
ISELS	SCOT HIGH	32.6(8.3)	32.4(8.6)	F(1,54) = 0.17, p = 0.678, η^2_p = 0.00	F(2,54) = 0.34, p = 0.712, η^2_p = 0.01	F(2,54) = 0.59, p = 0.561, η^2_p = 0.02
Score range:0–57	SCOT LOW	34.6(6.8)	35.0(7.4)			
	CON	34.7(8.2)	33.8(8.8)			

Note. Data are reported as mean ± standard deviation (SD).
GROUP: Represents the three groups in the study stratified by training performance. SCOT HIGH (SCOT HIGH PERFORMANCE), N = 15 participants; SCOT LOW (SCOT LOW PERFORMANCE), N = 14 participants; CON (Active Control), N = 28 participants
Significant *p*-values from a 3 × 2 ANOVA testing for differences between groups are shown in bold; a trend towards a significant p-value is shown in italics.
Tukey HSD post-hoc results: □ PRE CON vs POST CON comparison; ♢ PRE SCOT HIGH PERFORMANCE vs POST SCOT HIGH PERFORMANCE comparison.
Effect sizes are reported as partial eta squared (η^2_p).
*p < 0.05; **p < 0.01; ***p < 0.005; ****p < 0.0001.

cognitive training interventions, with engagement, performance, and intrinsic motivation all contributing to the ultimate success of such programs. Digital tools for cognitive training offer additional advantages, including the widespread availability of the software, increased user enjoyment compared to traditional exercises, performance monitoring with immediate feedback (Bonnechère et al., 2020), low economic cost, avoidance of problems due to reduced mobility and/or limited access to health resources (Rute-Pérez et al., 2023), and equal or greater efficacy than traditional paper-and-pencil methods, while being less labor-intensive (Kueider et al., 2012). In addition, older adults do not necessarily need advanced technological skills, nor prior experience with the technologies (such as video games, computers, smartphones, or tablets) to benefit from training using these novel approaches (Kueider et al., 2012; Vaportzis et al., 2017). On the other hand, the benefits of such training may be limited if carried out unsupervised (absent close monitoring of participant activity during sessions).

Finally, we found no significant effect on loneliness, which refers to the subjective feeling of being alone, separated or apart from others, regardless of the amount of social contact (Veazie et al., 2019). Loneliness represents a complex construct influenced by a variety of socio-demographic, psychosocial, and health-related risk factors (Barjaková, Garnero, & d'Hombres, 2023) that were not modulated in the current intervention.. Although some efficacy of socio-cognitive interventions in reducing loneliness in older people has been documented (Veronese et al., 2021), the lack of significant post-training effects observed in our study is in line with other research suggesting limited efficacy of video calls and/or electronic interventions in reducing social isolation and loneliness in older people (Noone et al., 2020). Given this heterogeneity in the available evidence and the complex nature of loneliness, future research should target older people who exhibit signs of loneliness and/or social isolation, using a more comprehensive approach. These efforts will provide a broader understanding of the efficacy of digital interventions in addressing loneliness and social isolation in older people, a matter of critical importance given its association with cognitive

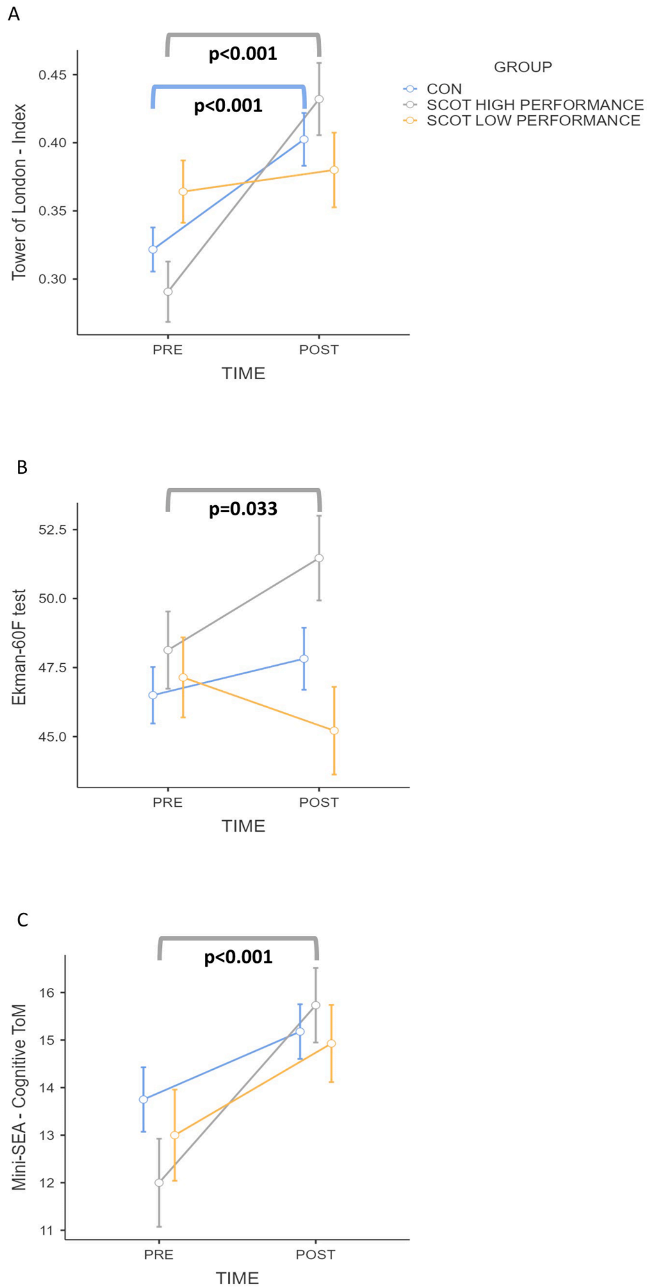

Fig. 3. Pre-post comparison in cognitive and social outcome measures after the intervention.
Note: Estimated mean changes in (A) Tower of London, (B) Ekman 60-Faces test, (C) cognitive subtask of the mini-SEA between baseline and post-intervention assessments. Error bars represent standard errors. The *p*-values in the graphs represent the results of Tukey HSD post-hoc analyses.

decline and dementia risk (Chipps, Jarvis, & Ramlall, 2017).

Our study has limitations that must be acknowledged. First, no specific questionnaires were administered to evaluate the success of double-blind manipulation. Besides, the absence of a wait-list control group prevents us from drawing definitive conclusions about the specific effects of the CON and SCOT interventions. Although the observed improvements in executive functioning and social cognition are suggestive of positive outcomes, they could also be due to the mere passage of time or to the non-specific benefits of engaging in cognitive tasks, as mentioned above. Another limitation of this study is the relatively small sample size of the SCOT HIGH PERFORMANCE and SCOT LOW PERFORMANCE groups. Although our results suggest differential responses between these subgroups, a larger sample size would provide greater statistical power and confidence in the observed effects for both subgroups and general analyses of the main outcomes. Future research should aim to replicate these results with larger participant cohorts to further explore this relationship. In addition, it remains unclear whether the observed improvements in executive functions and social cognition are long-lasting or instead represent short-term effects. Follow-up analyses of our study and other longitudinal studies that follow participants' progress over several months or years could shed light on the duration of these cognitive gains.

5. Conclusions

In conclusion, our study provides valuable insights into the positive effects of the multidimensional online SCOT intervention in improving executive functioning and social skills (emotion recognition and cognitive ToM) in healthy older adults, particularly in those subjects who were more engaged during the training phase and thus performed better. This suggests that subject motivation may influence the efficacy of interventions and should be considered when designing new online interventions in clinical and research settings. Future studies should consider individual motivation as a relevant variable in influencing training success. In addition, the choice of endpoints that represent the construct of interest on which the training intervention is targeted, with good psychometric properties (e.g., no ceiling effects in task performance) and possibly with parallel versions is a desirable aspect. Unfortunately, although there are now new measures of social cognition with parallel versions (e.g., (Terruzzi et al., 2023), the availability of these tests is still very limited and thus represents a research priority.

Overall, efforts to improve socio-cognitive skills in healthy aging are of paramount importance, as poor social skills can significantly influence social behaviour, potentially leading to social isolation, loneliness and reduced quality of life (Cavallini et al., 2021; Roheger et al., 2022). Given this, and the limited availability in the literature of socio-cognitive interventions for healthy older people, particularly in the domain of emotional recognition, SCOT training may represent an innovative program that could be implemented on a larger scale to promote socio-cognitive well-being in older people in the context of active aging and dementia prevention.

Ethics approval

The study was approved by the local ethics committee and conducted following the Declaration of Helsinki.

Informed consent for participation and publication

Informed consent was obtained from all study participants and included the possibility of publication of the data obtained in the study.

Registration of clinical trial

ClinicalTrials.gov identifier (NCT number): NCT05023187
Unique Protocol ID: Protocol 2020-036

CRediT authorship contribution statement

Giulia Funghi: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Claudia Meli:** Writing – review & editing, Methodology, Data curation, Conceptualization. **Arianna Cavagna:** Methodology. **Lisa Bisoffi:** Methodology. **Francesca Zappini:** Writing – review & editing. **Costanza Papagno:** Writing – review & editing, Supervision, Conceptualization. **Alessandra Dodich:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare no competing interests.

Data availability: Datasets generated and analysed in this study are available from the corresponding author on request.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.archger.2024.105405.

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