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Baseline capacities and motivation in executive control training of healthy older adults

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ABSTRACT

Objectives: Normal aging involves progressive prefrontal declines and impairments in executive control. This study aimed to examine the efficacy of an executive-control training focusing on working memory and inhibition, in healthy older adults, and to explore the role of individual differences in baseline capacities and motivation in explaining training gains.

Methods: Forty-four healthy older adults were randomly assigned to an experimental (training executive control) or active control group (training processing speed). Participants completed six online training sessions distributed across two weeks. Transfer effects to working memory (Operation Span test), response inhibition (Stop-Signal test), processing speed (Pattern Comparison) and reasoning (Raven's Advanced Progressive Matrices and Cattell Culture Fair test) were evaluated. Furthermore, we explored individual differences in baseline capacities and assessed motivation during and after the intervention.

Results: The experimental group, but not the active control, showed significant transfer to response inhibition. Moreover, a general compensation effect was found: older adults with lower baseline capacities achieved higher levels of training improvement. Motivation was not related to training performance.

Conclusion: Our results encourage the use of executive control training to improve cognitive functions, reveal the importance of individual differences in training-related gains, and provide further support for cognitive plasticity during healthy aging.

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Aging; cognitive plasticity; training; transfer; individual differences; executive control

Introduction

Aging is typically related to impairments in tasks that require high degree of executive control, such as those that heavily rely on working memory (WM) (Borella, Carretti, Cornoldi, & De Beni, 2007; Delaloye et al., 2008 .) and those where control has to be implemented to overcome dominant responses or ignore distractions (Aguirre et al., 2014; Ortega et al., 2012; Rey-Mermet & Gade, 2017).

In an attempt to compensate – or at least maintain – efficient cognitive functioning into later life, over the past decades we are witnessing a tremendous interest in training executive control in older adults. Substantial training gains have been reported for older adults after completing training programmes targeting WM (Borella et al., 2014; Richmond, Morrison, Chein, & Olson, 2011) and executive functions such as inhibition, dual-tasking or switching (Bherer et al., 2006; Lövdén, Bäckman, Lindenberger, Schaefer, & Schmiedek, 2010). However, transfer effects following process-specific training in older adults are often smaller than in younger adults, or even absent (Brehmer, Westerberg, & Bäckman, 2012; Sala, Aksayli, Tatlidil, Gondo, & Gobet, 2019).

This heterogeneity in terms of training effects could be due to the high variability that characterizes cognitive aging (Zanto & Gazzaley, 2019) and the role that individual differences could play in modulating factors of training effectiveness (Katz, Jones, Shah, Buschkuehl, & Jaeggi, 2016). Variability across individuals in training-derived gains is often very large and, in the case of older adults, evidence suggests that individual differences in baseline cognitive abilities might predict training outcomes. On one hand, several studies indicate that executive control training often results in larger benefits for participants with lower performance at baseline, the so-called *compensation* effect (Borella, Carbone, Pastore, De Beni, & Carretti, 2017; Karbach, Könen, & Spengler, 2017). On the other hand, the so-called *magnification* effect shows that better performing individuals at baseline benefit more from the training (Fu, Kessels, & Maes, 2020; Matysiak, Kroemeke, & Brzezicka, 2019). In the aging field, there is mixed evidence about who benefits most from training and one of the goals of the current study is to provide more insight into the relationship between baseline capacities and training improvement in healthy aging.

Among individual characteristics, participants' motivation is another important source of variability that in young adults has been shown to modulate training and transfer effects (Katz et al., 2016; Könen & Karbach, 2015). Although daily motivation has been positively associated with cognitive performance across different age groups (Ferdinand, Czernochowski, & Ferdinand, 2018), the role of motivation to predict training gains has been scarcely

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investigated in aging (Guye, De Simoni, & von Bastian, 2017). The few published studies that have addressed the effect of motivation in training performance during aging have not specified whether they refer to intrinsic or extrinsic motivation – although their differential effects have been explored in younger adults (Jaeggi, Buschkuehl, Shah, & Jonides, 2014; Mohammed et al., 2017) and in children (Katz, Jaeggi, Buschkuehl, Stegman, & Shah, 2014). In the current study with older adults, our interest was in intrinsic motivation (Ennis, Hess, & Smith, 2013). That is, in the degree to which older adults engage in an effortful cognitive training programme, and in their interest in achieving successful levels of performance to make them function better. Participants in this study were economically rewarded due to ethical requirements. They were informed in advance that they would receive a small stipend for participation but, they were not informed of the exact amount until the intervention was over. Therefore, we expected, if any, an influence of intrinsic motivation on training outcomes. Given its importance and the mix findings from previous studies, there is a need for further investigation on whether intrinsic motivation can predict training performance in the case of older adults.

In this study, we aimed to explore the effects of an executive control training intervention in healthy older adults by newly considering the role of some individual factors (baseline performance and motivation). In particular, our goal was to explore whether WM, inhibition and interference control (IC) mechanisms could be enhanced by means of executive control training targeting these processes (see Miyake & Friedman, 2012 for a theoretical account of executive functions). Healthy older adults were randomly assigned either to an experimental group that engaged in an executive-control training or to an active control group that worked with no-demanding perceptual tasks that only required progressive speeded responses. Both groups were matched in the key characteristics of the intervention and developed the training in comparable conditions (duration, training structure, online environment, and feedback), and they only differed in the process to be trained (executive control or processing speed – both crucial mechanisms in the aging). For the experimental group, we employed the executive-control training used with younger adults in a previous study (Maraver, Bajo, & Gomez-Ariza, 2016), which focuses on WM processes (updating and maintenance), IC-related (inhibition of dominant responses and interference control) and switching processes. Such a procedure was selected as it has already shown promising results in younger adults: WM training led to transfer effects in WM, IC, and the adjustment between proactive and reactive control mechanisms (Braver, 2012), while IC training transferred to the same measures but also to reasoning (Maraver et al., 2016). As WM and IC are impaired in aging, in this study with older adults we decided to combine both process-based trainings so that the experimental group engaged in both training WM and IC. For the active control group, we introduced no-demanding perceptual tasks (only requiring progressive speeded responses) also used by Maraver et al. (2016). Because the experimental training also implied progressive reduction of response time (the only process trained by the active control group) and the intervention conditions were similar in both groups in an attempt to equate their level of motivation, any gains observed in the experimental group would be explained by the training of executive control processes. Both groups completed six 1-h training sessions distributed across two weeks. The control group only differed from the experimental in the trained processes, but both groups were identical in the rest of the training features (i.e. adaptability of task difficulty, training duration or feedback). This allowed us to control for expectations and to perform a fine-grained evaluation of unique training effects.

In line with previous training studies, for the experimental group we expected training benefits as reflected in performance improvements in both trained and non-trained executive control tasks (Lövdén et al., 2010). To test these expectations, we included a number of experimental laboratory tasks that tap into WM (Operation-Span test), response inhibition (Stop-Signal test), processing speed (pattern comparison test) and reasoning (Raven's Matrices and Cattell Culture Fair tests). We selected these tasks as they share comparable cognitive mechanisms with the trained tasks, so transfer effects are theoretically expected (Lövdén et al., 2010; Miyake & Friedman, 2012). In addition, to explore individual differences in training, baseline capacities and motivation were measured and related to training improvement. Based on the few previous studies looking at individual differences in aging (Borella, Carbone, et al., 2017; Karbach et al., 2017), we expected a compensation effect in training performance. Additionally, since motivation during and after training has been scarcely investigated in aging and the only study examining it has failed to show an association (Guye et al., 2017), we had no clear expectations on such a relationship and we aimed to shed light on the role of motivation for cognitive training in healthy older adults.

Methods

Participants

Older adults interested in participating were contacted online and completed a first demographic screening questionnaire for healthy aging. We contacted via email a pool of 200 older adults from the area of Granada. They were part of a database of volunteers' older adults who previously replied to university research advertisements. Those older adults interested in participating were provided with an online form with a brief description of the structure of the study and were asked for their contact information, cognitive status (existent diagnose or pre-diagnose of dementia), visual conditions, preferred training location (home or laboratory) and quality of their home technological equipment (computer and Internet connection). We obtained approximately 80 responses and observed a homogenous distribution regarding the training setting: 49.4% of the respondents preferred to do the training at home, and 50.6% in the lab. Thus, we contacted by phone older adults who met the criteria for participation and recruited them keeping their preferences to perform the training at home or in the lab.

Our final sample included 44 older adults (13 females, $M_{age} = 65.07 \pm 3.91$), all with normal aging (as shown by the Mini-Mental Scale Examination, MMSE, Folstein,

Folstein, & McHugh, 1975) and able to participate at the moment of the study. After each participant completed the pre-test evaluation, we ran a randomization without replacement procedure (sorting random numbers) by which participants were assigned random labels that would allocate them in one of the two training conditions: experimental ($n = 22$, 6 females; $M_{age} = 65.05 \pm 3.87$) or control ($n = 22$, 7 females; $M_{age} = 65.09 \pm 4.03$). Groups did not differ in age ($p = 0.97$, $d = 0.01$), years of education ($p = 0.59$, $d = 0.17$), vocabulary ($p = 0.55$, $d = 0.18$) or cognitive functioning measured by the MMSE ($p = 1.00$, $d = 0.00$). Participants voluntarily chose their preferred training setting (52.3% selected to train at home and 47.7% in the lab). There were no differences in the proportion of participants selecting training at home vs. lab across groups ($X^2(1) = 0.09$, $p = 0.76$), and older adults did not differ in age ($p = 0.73$, $d = 0.11$), years of education ($p = 1.00$, $d = 0.00$), vocabulary ($p = 0.80$, $d = 0.07$) or cognitive functioning ($p = 0.24$, $d = 0.37$) as a function of their training setting. Preliminary analyses revealed that the training setting (home vs. lab) did not modulate the training and transfer results.

At the end of the study, the participants were economically compensated for their involvement with 60€ for those training in the lab, and 30€ for those training at home (economic compensation was advertised but participants did not know the amount of the compensation until the end of the study). None of the participants withdrew from the study although they were informed they could do so if they wished. The study was approved and carried out in accordance with the recommendations of the Research Ethics Committees of the University of Granada. All participants were provided with information about the study and gave written informed consent in accordance with the Declaration of Helsinki (World Health Organisation, 2013).

General procedure

The experimental design consisted of ten sessions distributed across four weeks: two pre-test sessions on the first week, six training sessions across two weeks (three sessions per week preferably in non-consecutive days) and two post-test sessions on the final week. In the pre- and post-testing sessions, all the participants were administered in the following order a battery of tasks to assess: WM (Operation Span test), response inhibition (Stop-Signal test), speed of processing (pattern comparison test) and abstract reasoning (Raven's Advanced Progressive Matrices and Cattell Culture Fair Test).[1] At pre-test, older adults completed a neuropsychological assessment in which they were screened in general cognitive functioning via the Mini-Mental Scale Examination (Folstein et al., 1975) and in vocabulary via the Lextale-Esp vocabulary test (Izura, Cuetos, & Brysbaert, 2013).

The two training groups engaged in four different activities per session (15 minutes per activity). The resulting total training time for each activity was 90 min, which made a total of 360-min training. Participants who trained in the lab worked in individual cabins three days per week, approximately at the same time every day, and an experimenter continuously supervised the procedure and was available to attend to any request. Similarly, participants who trained at home had to complete the training sessions three days per week, approximately at the same time every day, and in a quiet place without interruptions during the session. Even if the environmental factors (i.e. noise) were not exactly the same in both settings, we made a special effort to instruct participants to look for a quiet place and time of the day to complete the activities and to keep participants' supervision as comparable as possible across settings. Experimenters tracked the progress of the training online and contacted the participant by phone once they completed the session to discuss their progress and to solve any possible technical inconveniences or task difficulties that they might have. All participants were provided with a paper booklet that detailed the counterbalanced order of the training tasks that they had to follow in each session and included a six-question motivation questionnaire for each session to assess motivation during the training (Colom et al., 2013). In the last training session and before post-test, participants were asked for a general evaluation of their motivation and satisfaction with the training programme by means of the Intrinsic Motivation Inventory (IMI, Deci, Eghrari, Patrick, & Leone, 1994).

Training procedures

Participants were trained with a battery of tasks from the online training programme of the University of Granada (PEC-UGR; Maraver et al., 2016). The training activities had a game-like scenario, and the levels were built up over runs of trials. Task difficulty increased or decreased progressively adapted to individuals' performance to keep training always at the level of cognitive challenge. In all the activities, participants received feedback based on their performance. The experimental group trained with an *n*-back task, a WM search task, a Stroop-like task and a switching task, while the active control group worked with activities focusing on speeded comparison, speeded categorization, speeded response and speeded visual search. A description of the specific parameters for the training procedures of the experimental and active control groups is detailed in Supplementary Material 1.

Motivation assessment

Two questionnaires were used to examine self-reported motivation. One focused on assessing the degree of involvement, perceived difficulty, challenge of improvement, expectations, effort and usefulness of the activities, and it was administered in every training session by a six-question questionnaire in the participant's training booklet (Colom et al., 2013). The other one, the IMI (Deci et al., 1994) was presented at the end of the intervention and assesses participants' interest/enjoyment, perceived competence, effort, comfort, perceived choice (felt pressure and tension), value/usefulness and relatedness to the investigators (resulting in seven subscales).

Transfer tasks

Stop-Signal

We used the Stop-Signal paradigm to measure response inhibition with the standard parameters of the software

STOP-IT (Verbruggen, Logan, & Stevens, 2008). The primary task is a choice reaction times task where participants are instructed to respond as fast as possible to two different stimuli (circles or square) using the keyboard. In 25% of the trials, an auditory stop-signal (750 Hz, 75 ms) is presented briefly after the visual stimuli onset and requires participants to withhold their response to the current stimulus. The task comprised a first practice block of 32 practice trials and 3 experimental blocks of 64 trials. In every trial, a 250-ms fixation point (white +) was presented on a black screen, followed by the target stimuli (a white square or circle) for 1250 ms with a fixed inter-stimulus interval of 2000 ms. The stop-signal reaction time (SSRT) was the measure of inhibitory efficiency (Verbruggen et al., 2008).

Pattern comparison

To measure perceptual comparison speed (Salthouse & Mitchell, 1990), participants were presented with two pages of pairs of drawings patterns composed of three-, six- or nine-line segments that required the decision of being the same or different. Participant's task was to write S ('Si', yes in Spanish) when the pattern was similar and N ('No'), when it was different. Two matched parallel versions were counterbalanced for pre- and post-test. An index of efficiency was calculated by dividing the percentage of correct responses by the time spent in completing each page.

Operation Span (O-Span)

A Spanish-adapted version of the dual memory span procedure developed by Turner and Engle (1989) was used as a measure of WM (Tokowicz, Michael, & Kroll, 2004). Participants had to solve a sequence of math operations while trying to remember sets of unrelated words of increasing set sizes. The equation–word pairs are presented one at a time and, in every trial, participants' task was to verify a simple mathematical equation (i.e. $(14/2) + 2 = 8$) presented in the centre of the screen for 3750 ms using the keyboard. After that, a word (i.e. 'hotel') was presented for 1250 ms and participants had to maintain it in memory. Operation–word pairs were presented in increasing set sizes from 2 to 6. After each set, a recall test instructed participants to type the words from the previously presented set. The task comprised 2 practice trials and 18 experimental trials (3 trials per set size), and the testing procedure was repeated until the end. We calculated a combined index by multiplying the average proportion of equations correctly solved by the total proportion of correctly recalled words and considered this index as the dependent variable for analysis (Conway et al., 2005; Maraver et al., 2016). We developed two parallel versions for pre- and post-test by randomizing the order of the stimuli, which were counterbalanced between the sessions and across participants.

Raven's Advanced Progressive Matrices (RAPM)

This test provides a measure of abstract reasoning (Raven, 1990) and we employed a computer administered version of the set II of the advanced progressive matrices. 3×3 matrices of geometrics patterns are presented in increasing order of difficulty. In each trial, a bottom-right pattern of the matrix is missing, and participants must select, among eight response alternatives, the one that completes the sequence of patterns. From the 36 matrices of the test, we divided the items to create two parallel versions for pre- and post-test matched in item difficulty following (Jaeggi et al., 2014). Participants had a time restriction of 20 min to complete the set of 18 matrices as fast and accurately as possible. The dependent variable was the proportion of correct responses.

Cattell's Culture Fair Test

The Scale III of the Cattell's Culture Fair Test was used as a measure of non-verbal reasoning that minimizes cultural and educational biases (Cattell & Cattell, 1963). This scale is composed of four abstract reasoning subtests: (i) series; (ii) classifications; (iii) matrices; (iv) conditioning. The maximum score of the whole test was 50 points, and the dependent variable was the proportion of correct responses. Two parallel versions were used and counterbalanced across participants for pre- and post-test.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics v.25. First, to analyse changes in training performance, paired sample *t*-tests were performed for each group and training task on the corresponding dependent variables (conflict score, errors, reactions times or memory load) between the first and sixth training sessions. Second, to analyse transfer effects, univariate analyses of covariance (ANCOVAs) were performed on the dependent variables for each measure at post-test, introducing training group as the factor and the pre-test score as the covariate (Borella, Carbone, et al., 2017). Results are further analysed within the Bayesian framework, to quantify evidence for H_1 (a difference between the training groups at post-test when controlling for the pre-test score) vs. H_0 (no difference between the groups) (van Doorn et al., 2019). Bayesian ANCOVAs were conducted in JASP (JASP Team, 2020) using the default settings; r scale fixed effects $= 0.5$, r scale random effects $= 1$, r scale covariates $= 0.35$, samples = auto (10000).

Finally, following previous studies (Maraver et al., 2016), we calculated a standardized training achievement score for each session (by dividing the average training level reached in each session by the total number of training levels, see Figure 1). To explore the role of individual differences, we calculated the slope of a linear regression model of the training improvement achieved across sessions. Nonparametric Spearman correlations were run between training improvement, cognitive measures at pre-test and motivation separately for each group. A Benjamini–Hochberg correction for multiple testing was applied setting the false discovery rate at 0.10 (Benjamini & Hochberg, 1995).

Results

Training effects

For the experimental group, there was a general and straightforward improvement in all the executive control training activities from the first to the last session. Two-tailed dependent sample *t*-tests showed that after the

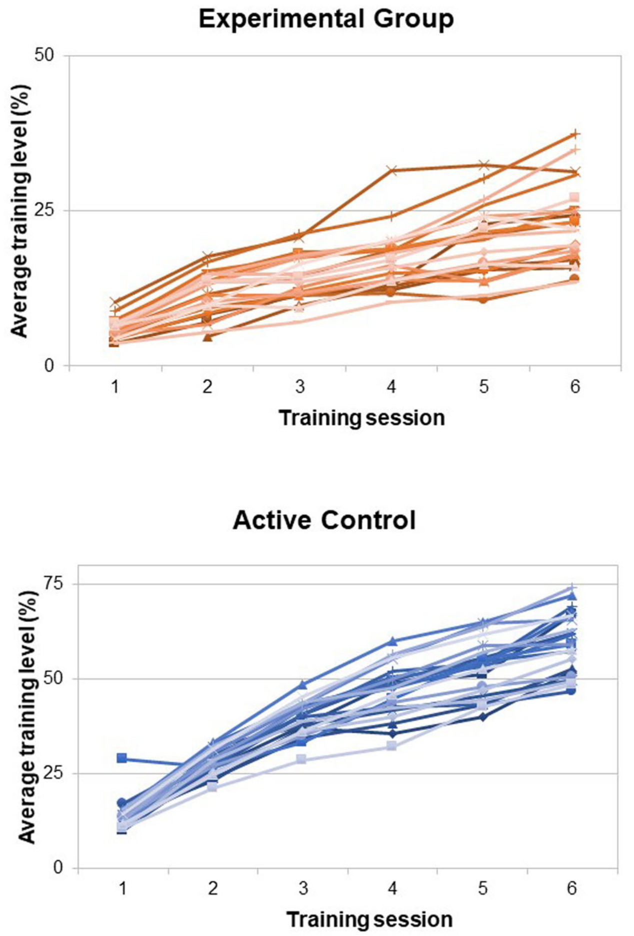

Figure 1. Individual training improvement for the experimental and control groups. Data represent the individual training performance (average of the four training tasks) over the six sessions. Upper pannel: experimental group (executive control training); Lower pannel: active control (speed training). In all the cases, *y*-axes represent the averaged (of the four training tasks) relative level of training improvement.

training, participants (a) were more able to maintain and update larger memory loads (N-back set size: S_1=1.14 ± 0.35, S_6=1.91 ± 0.43; $p < 0.01$, Cohen's d_z =1.50; WM search set size: S_1=1.05 ± 0.21, S_6=2.32 ± 0.65; $p < 0.01$, d_z =2.36), and (b) reduced their conflict effects (S_1=118.52 ± 95.09, S_6 = 56.88 ± 56.68; $p = 0.01$, d_z =0.60) and their switching error rates (S_1=0.44 ± 0.16, S_6 = 0.15 ± 0.13; $p < 0.01$, d_z =1.32). For the active control group, reliable changes appeared in three out of the four practiced activities. Like their experimental counterparts, participants went forward across speed levels. In this case, the improvement across levels occurred exclusively in relation to presentation speed and response time. In three out of the four tasks, participants revealed faster responses by the end of the intervention, indicating a benefit from the activities in reducing their response speed (speeded categorization: S_1=3005.91 ± 428.97, S_6=2740.55 ± 293.35; $p = 0.04$, d_z =0.47; speeded comparison: S_1=3600.59 ± 1310.48, S_6=3108.41 ± 514.91; $p = 0.10$, d_z =0.37; speeded response: S_1=1567.14 ± 218.80, S_6=688.36 ± 63.91; $p < 0.01$, d_z =4.38; Speeded visual search: S_1= 5530.64 ± 1596.05, S_6=3586.95 ± 512.73; $p < 0.01$, d_z =1.36).

Transfer effects

Table 1 summarizes the descriptive data of the outcome measures for the experimental and active control groups for pre- and post-test. As shown in the table, the two groups did not differ significantly in any of the measures at pre-test (all *ps* > 0.50).

Response inhibition (Stop-Signal)

The ANCOVA on the SSRT (Verbruggen & Logan, 2008; Verbruggen et al., 2008) revealed a main effect of group, with better performance for the experimental one ($F(1,43) = 6.83$, $p = 0.01$, $\eta^2_p = 0.14$) and a non-significant effect of the pre-test covariate ($F(1,43) = 0.13$, $p = 0.72$, $\eta^2_p < 0.01$). Since the Bayes factor has a transitive relationship, we compared the model including the group factor and the pre-test covariate ($BF_{10} = 1.33$) with the model including only pre-test as the covariate ($BF_{10} = 0.30$). The ratio between the models resulted in evidence for H_1 (1.33/ 0.30 = 4.43), what provides evidence for a group effect after explaining the variance corresponding to the pre-test scores (van Doorn et al., 2019).

Speed processing (Pattern Comparison)

The ANCOVA on the measure of efficiency in comparing perceptual patterns (hits/reaction times) showed a close to significant effect of group with better scores for the experimental group, ($F(1,43) = 3.64$, $p = 0.06$, $\eta^2_p = 0.08$), and a significant effect of pre-test, ($F(1,43) = 40.46$, $p < 0.01$, $\eta^2_p = 0.50$). In this case, the division between the Bayes factor of the model including group and pre-test ($BF_{10} = 221517.83$) and the model only including the pre-test covariate ($BF_{10} = 167118.61$) provided only anecdotal evidence ($BF_{10} = 1.32$), given that BF values between 1 and 3 are considered to be weak and inconclusive.

Working memory (Operation Span)

The ANCOVA performed on the combined index revealed better performance for the experimental group ($F(1,43) = 4.95$, $p = 0.03$, $\eta^2_p = 0.11$) and a significant effect of pre-test ($F(1,43) = 45.60$, $p < 0.01$, $\eta^2_p = 0.53$). The Bayesian ANCOVA only provided very modest support of H_1 relative to H_0 (($BF_{group+pre\text{-}test} = 134475.48$)/($BF_{pre\text{-}test} = 72067.05$) = 1.86), what suggests that not enough data were included for this analysis.

Reasoning (RAPM + Cattell)

The corresponding ANCOVA on the average reasoning scores[2] failed to show a significant effect of group ($F(1,43) = 2.94$, $p = 0.09$, $\eta^2_p = 0.07$), while revealing an effect of pre-test ($F(1,43) = 42.04$, $p < 0.01$, $\eta^2_p = 0.50$). After computing the ratio as in the previous measures, the Bayes factor ($BF_{10} = 0.92$) confirmed that H_1 was only poorly favoured over H_0.

Individual differences

In this section, analyses on the levels of motivation during and after the training as a function of group are reported, and then, individual differences in relation to training improvement, baseline capacities and motivation are described.

When looking at possible between-group differences in motivation, analyses revealed that both groups reported

Table 1. Descriptive statistics of pre- and post-test.

	Experimental		Control	
	Pre-test	Post-test	Pre-test	Post-test
Stop-Signal: SSRT (ms)	285.82 ± 52.52	249.84 ± 40.56	274.61 ± 94.46	280.24 ± 36.23
Speed Processing (efficiency in pattern comparison)	1.30 ± 0.22	1.42 ± 0.19	1.20 ± 0.38	1.25 ± 0.32
Operation Span: Words recalled × Equations hits	0.38 ± 0.24	0.53 ± 0.23	0.42 ± 0.18	0.46 ± 0.20
Reasoning (RAPM + Cattell)	0.37 ± 0.13	0.41 ± 0.12	0.38 ± 0.11	0.37 ± 0.10

Mean ± standard deviations for the outcome measures in the pre- and post-test as a function of training group. Two-tailed independent samples *t*-tests showed that both groups were comparable in performance at pre-test (SSRT: $t(42) = 0.49$, $p = 0.63$; Pattern comparison: $t(42) = 1.10$, $p = 0.27$; O-Span: $t(42) = 0.56$, $p = 0.58$; Gf: $t(42) = 0.32$, $p = 0.75$). SSRT: Stop-Signal Reaction Time; RAPM: Raven's Advanced Progressive Matrices.

Table 2. Matrix of zero-order two-tailed nonparametric Spearman correlations separately for each group (experimental $n = 22$; control $n = 22$).

		Experimental training improvement	Control training improvement
Motivation	During training	0.162	−0.446
	After training	0.195	−0.186
Baseline capacities	Gf	−0.506*	−0.468
	WM	−0.526*	0.068
	Processing speed	−0.315	−0.572*
	Response Inhibition	0.198	0.518*

Asterisks (*) represent significant correlations after applying the Benjamini–Hochberg correction for multiple testing setting the false discovery rate to 0.10.

similar levels of motivation during and after the training sessions (see Supplementary Material 2). Moreover, the motivation level during the training was positively correlated with motivation after the intervention in the experimental ($\rho = 0.72$, $p < 0.01$) as well as in the control group ($\rho = 0.69$, $p < 0.01$).

To explore the role of individual differences, nonparametric correlations between training improvement (training slope), motivation (during and after the training) and baseline capacities (pre-test score for reasoning, WM, speed of processing and response inhibition) were ran separately for each group (experimental and control).

As shown in Table 2, the results revealed a compensation effect for both groups. In the experimental group, those participants with lower scores in reasoning and WM at pre-test were those who reached higher levels of performance during the training ($\rho_{reasoning} = -0.51$, $p_{reasoning} = 0.02$; $\rho_{WM} = -0.53$, $p_{WM} = 0.01$). In the control group, larger training improvement was correlated with worse performance in processing speed ($\rho = -0.57$, $p < 0.01$) and inhibition ($\rho = -0.52$, $p = 0.01$).

Discussion

We examined here the effectiveness of an executive-control training programme, which combines two adaptive process-based trainings relying largely on WM and IC, in a sample of healthy older adults. We did so by looking at potential transfer effects to different cognitive domains in comparison with an active control group. The role of individual differences in training improvement as a function of baseline capacities and motivation was also and newly examined. The question of who benefits the most from cognitive training, and under which conditions, is in fact still open, with very few studies addressing it in aging.

In relation to training effects, as recommended by the literature but rarely done, we compared an experimental group that was trained in executive control (WM and IC) with an active control group that received similar practice sessions, but with low-demanding executive control activities that created difficulty by increasing processing speed. As expected, both the experimental and control groups showed specific across-session improvements; namely, the control became faster in responding, while the experimental group showed increments in their ability to deal with larger executive-control demands.

Furthermore, most views on transfer effects suggest that the likelihood and strength of transfer vary as a function of the similarity in processing demands between the training and transfer tasks (Lövdén et al., 2010; Morrison & Chein, 2011). Thus, one would expect to observe enhanced performance in a variety tasks that, although untrained, share similar or some of the cognitive operations with the targeted trained processes. Despite the small number of training sessions employed here, the experimental group outperformed the active control in response inhibition. Based on the previous transfer effects observed in younger adults training either WM or IC (Maraver et al., 2016), we expected to find similar transfer effects in older adults when combining WM and IC training. However, the results from Bayesian analyses suggested that there was not enough evidence to claim for the presence or absence of transfer to WM, processing speed or reasoning, and our hypothesis of transfer has only been confirmed for the case of response inhibition. Different factors could have contributed to this specific benefit for response inhibition. First, a number of studies have proven the sensitivity of the Stop-Signal task to experimental manipulations (Verbruggen et al., 2019) as well as to individual differences in inhibitory control (Matzke, Verbruggen, & Logan, 2018). Moreover, some of the training activities from our executive control programme largely relied on interference suppression processes that may share neural substrates (i.e. right inferior frontal cortex) with the capacity that is measured by the Stop-Signal task (for a meta-analytic review see Xu, Xu, & Yang, 2016). In fact, a similar transfer effect has been already shown with a sample of younger adults after IC training (Maraver et al., 2016), and comparable results have also been observed in children with very similar training procedures highly loading in inhibitory control (Pozuelos et al., 2019). Considering our small sample size and a lower sensitivity of the other transfer tasks employed in our study, only the Stop-Signal task provided enough evidence for transfer as a fine-grained measure of response inhibition. This result is in line with the literature showing training improvement in inhibitory control across the lifespan (Manuel, Bernasconi, & Spierer, 2013; Wilkinson & Yang, 2016) and is especially relevant in the case of older adults for allowing them to successfully adapt to rapidly changing situations.

One of the main goals of the current study was to explore the role of individual differences in training during aging. On the one hand, we did not have clear expectations on the relationship between motivation and training gains. The only study examining it failed to show an association (Guye et al., 2017), and our results are in line with it. We did not observe a relationship between motivation and training improvement with older adults, in contrast to Maraver et al. (2016) who observed that the higher the motivation, the larger the training improvement was in younger adults.

As for baseline capacities, we observed a clear compensation effect, which is also in line with other studies on aging (Borella, Carbone, et al., 2017; Karbach et al., 2017), so that the lower the scores of older adults were at pre-test, the greater was their training improvement. While this is not always observed in younger adults who frequently show magnification effects (Guye et al., 2017; Lövdén, Brehmer, Li, & Lindenberger, 2012; Maraver et al., 2016), older adults and children seem to be more prone to compensation phenomena (Borella, Carbone, et al., 2017; Karbach et al., 2017). The other side of the compensation effect is that it implies that individuals with higher capacities would benefit less from training, since they are already performing at their optimal level and have less room for improving. However, patterns of magnification have also been recently observed in older adults (Fu et al., 2020; Guye et al., 2017). It seems that the presence of magnification or compensation effects could depend on the type of training presented (i.e. strategy vs. process-based), the procedure employed, and the overlap between the baseline cognitive assessments. Within the limits of our experimental design, our study provides evidence for the compensation account suggesting that older adults with lower cognitive capacities show larger training improvements than those with stronger capacities, given that they have more room for improvement. However, executive-control training gains only transferred to response inhibition, suggesting a limited generalization to untrained cognitive tasks.

An interesting feature of our design was the voluntary choice of the training setting, what made the intervention more accessible and comfortable for the elderly. Despite the environmental differences, we kept the supervision conditions as comparable as possible between the settings, and continuous telephone contact with those participants training at home was done. However, future studies should make the effort to investigate if, and to which extent, the absence of the experimenter at home impact training performance, transfer effects and participants' motivation.

Several limitations of our study are worth acknowledging. First, our sample was too small to provide a reliable measure of change. Even if several reports have recently concluded evidence for transfer with a similar (Fu et al., 2020) or even smaller sample sizes (Brum, Borella, Carretti, & Yassuda, 2020), the Bayesian analyses revealed that we did not have enough power to claim for either presence or absence of transfer effects in three out of the four cognitive measures that we assessed. Due to the time restrictions of the design and the availability of participants, it was not possible to recruit a larger sample. Therefore, the present work can be considered as an efficacy study (Shawn Green et al., 2019) but because of its low sample size, further attempts should replicate our design with a larger sample in order to provide stronger evidence. Second, except for reasoning, we used single measures to assess transfer and this also limits the generalization of training effects (Shipstead, Redick, & Engle, 2012). Third, without follow-up assessments it is not possible either to precisely know whether the training gains would remain over time or how long the effects may last. Finally, although most training studies have focused on laboratory-based measures in older age, one of the most desired applications of training is its potential transfer to everyday life. Therefore, future studies should also include measures of daily life functioning to assess the generalization of training interventions in older adults (Borella, Cantarella, Carretti, De Lucia, & De Beni, 2019). Despite their limitations, our results contribute to the understanding of some of the mechanisms underlying cognitive training. Individual differences are particularly critical in aging. Older people are characterized by high heterogeneity at the cognitive as well as the neural level (Zanto & Gazzaley, 2019), and analysing group means might overshadow individual strengths and weaknesses. Studying factors that relate to individual differences, as done here, could allow researchers to identify possible subgroups of individuals who are more or less responsive to cognitive training and would be a step forward in the development of individually tailored interventions to maximize training gains.

Notes

1. In the second pre and post-test session, participants performed a cognitive control task (AX-CPT) and an episodic memory task (Retrieval-Practice) in which their electrophysiological brain activity was also recorded and whose data are not reported in the present article.
2. As RAPM and Cattell tests – at pre-test – had a moderate correlation $\rho = 0.43$, $p < 0.01$, we computed an average of the two scores.

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Authors' contributions

This work is part of the thesis dissertation of the first author. All authors developed the concept of the study together. MJM contributed to data collection, data analysis, and manuscript writing. MB and CG-A supervised the process of accomplishing the study. MJM wrote the first draft of the article. All authors reviewed and approved the last version of the manuscript.

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References

Aguirre, C., Gómez-Ariza, C. J., Bajo, M. T., Andrés, P., & Mazzoni, G. (2014). Selective voluntary forgetting in young and older adults. *Psychology and Aging*, *29*(1), 128–139. doi:10.1037/a0035598. 24660801

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society: Series B (Methodological)*, *57*(1), 289–300. doi:10.1111/j.2517-6161.1995.tb02031.x

Bherer, L., Kramer, A. F., Peterson, M. S., Colcombe, S., Erickson, K., & Becic, E. (2006). Testing the limits of cognitive plasticity in older adults: Application to attentional control. *Acta Psychologica*, *123*(3), 261–278. doi:10.1016/j.actpsy.2006.01.005

Borella, E., Cantarella, A., Carretti, B., De Lucia, A., & De Beni, R. (2019). Improving everyday functioning in the old-old with working memory training. *The American Journal of Geriatric Psychiatry: Official Journal of the American Association for Geriatric Psychiatry*, *27*(9), 975–983. doi:10.1016/j.jagp.2019.01.210

Borella, E., Carbone, E., Pastore, M., De Beni, R., & Carretti, B. (2017). Working memory training for healthy older adults: The role of individual characteristics in explaining short- and long-term gains. *Frontiers in Human Neuroscience*, *11*, 99. doi:10.3389/fnhum.2017.00099

Borella, E., Carretti, B., Cantarella, A., Riboldi, F., Zavagnin, M., & De Beni, R. (2014). Benefits of training visuospatial working memory in young-old and old-old. *Developmental Psychology*, *50*(3), 714–727. doi:10.1037/a0034293

Borella, E., Carretti, B., Cornoldi, C., & De Beni, R. (2007). Working memory, control of interference and everyday experience of thought interference: When age makes the difference. *Aging Clin Exp Res*, *19*(3), 200–206. doi:10.1007/BF03324690

Braver, T. S. (2012). The variable nature of cognitive control: A dual mechanisms framework. *Trends in Cognitive Sciences*, *16*(2), 106–113. doi:10.1016/j.tics.2011.12.010

Brehmer, Y., Westerberg, H., & Bäckman, L. (2012). Working-memory training in younger and older adults: Training gains, transfer, and maintenance. *Frontiers in Human Neuroscience*, *6*(March), 63–67. doi:10.3389/fnhum.2012.00063

Brum, P. S., Borella, E., Carretti, B., & Yassuda, M. S. (2020). Working memory training format in older adults: Individual versus group sessions. *Aging Clinical and Experimental Research*, *32*(11), 2357–2366. doi:10.1007/s40520-019-01468-0

Cattell, R. B., & Cattell, A. K. S. (1963). *Cattell test of "g": Culture Fair*. Champaign, Ill.: Institute for Personality and Ability Testing.

Colom, R., Román, F. J., Abad, F. J., Shih, P. C., Privado, J., Froufe, M., … Jaeggi, S. M. (2013). Adaptive n-back training does not improve fluid intelligence at the construct level: Gains on individual tests suggest that training may enhance visuospatial processing. *Intelligence*, *41*(5), 712–727. doi:10.1016/j.intell.2013.09.002

Conway, A. R. A., Kane, M. J., Bunting, M. F., Hambrick, D. Z., Wilhelm, O., & Engle, R. W. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin & Review*, *12*(5), 769–786. 10.3758/BF03196772

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating internalization: The self determination theory perspective. *Journal of Personality*, *62*(1), 119–142. doi:10.1111/j.1467-6494.1994.tb00797.x

Delaloye, C., Ludwig, C., Borella, E., Chicherio, C., & De Ribaupierre, A. (2008). L'Empan de lecture comme épreuve mesurant la capacité de mémoire de travail : normes basées sur une population francophone de 775 adultes jeunes et âgés. *European Review of Applied Psychology*, *58*(2), 89–103. doi:10.1016/j.erap.2006.12.004.

Ennis, G. E., Hess, T. M., & Smith, B. T. (2013). The impact of age and motivation on cognitive effort: Implications for cognitive engagement in older adulthood. *Psychology and Aging*, *28*(2), 495–504. doi:10.1037/a0031255

Ferdinand, N. K., Czernochowski, D., & Ferdinand, N. K. (2018). Motivational influences on performance monitoring and cognitive control across the adult lifespan. *Frontiers in Psychology*, *9*, 1018. doi:10.3389/fpsyg.2018.01018

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, *12*(3), 189–198. doi:10.1016/0022-3956(75)90026-6

Fu, L., Kessels, R. P. C., & Maes, J. H. R. (2020). The effect of cognitive training in older adults: Be aware of CRUNCH. *Aging, Neuropsychology, and Cognition*, *27*(6), 949–962. doi:10.1080/13825585.2019.1708251

Guye, S., De Simoni, C., & von Bastian, C. C. (2017). Do individual differences predict change in cognitive training performance? A latent growth curve modeling approach. *Journal of Cognitive Enhancement*, *1*(4), 374–393. doi:10.1007/s41465-017-0049-9

Izura, C., Cuetos, F., & Brysbaert, M. (2013). Lextale-Esp: A test to rapidly and efficiently assess the Spanish vocabulary size. *Psicologica: International Journal of Methodology and Experimental Psychology*, *35*(1), 49–66.

Jaeggi, S. M., Buschkuehl, M., Shah, P., & Jonides, J. (2014). The role of individual differences in cognitive training and transfer. *Memory & Cognition*, *42*(3), 464–480. doi:10.3758/s13421-013-0364-z

JASP Team (2020). JASP (Version 0.14)[Computer software]. https://jasp-stats.org/faq/how-do-i-cite-jasp/

Karbach, J., Könen, T., & Spengler, M. (2017). Who benefits the most? Individual differences in the transfer of executive control training across the lifespan. *Journal of Cognitive Enhancement*, *1*(4), 394–405. doi:10.1007/s41465-017-0054-z

Katz, B., Jaeggi, S., Buschkuehl, M., Stegman, A., & Shah, P. (2014). Differential effect of motivational features on training improvements in school-based cognitive training. *Front Hum Neurosci*, *8*(April), 242. doi:10.3389/fnhum.2014.00242

Katz, B., Jones, M. R., Shah, P., Buschkuehl, M., & Jaeggi, S. M. (2016). Individual differences and motivational effects. In T. Strobach & J. Karbach (Eds.), *Cognitive training: An overview of features and applications* (pp. 157–166). Cham: Springer International Publishing. 10.1007/978-3-319-42662-4_15

Könen, T., & Karbach, J. (2015). The benefits of looking at intraindividual dynamics in cognitive training data. *Frontiers in Psychology*, *6*(May), 615–617. doi:10.3389/fpsyg.2015.00615

Lövdén, M., Bäckman, L., Lindenberger, U., Schaefer, S., & Schmiedek, F. (2010). A theoretical framework for the study of adult cognitive plasticity. *Psychological Bulletin*, *136*(4), 659–676. doi:10.1037/a0020080

Lövdén, M., Brehmer, Y., Li, S.-C., & Lindenberger, U. (2012). Training-induced compensation versus magnification of individual differences in memory performance. *Frontiers in Human Neuroscience*, *6*, 141. doi:10.3389/fnhum.2012.00141

Manuel, A. L., Bernasconi, F., & Spierer, L. (2013). Plastic modifications within inhibitory control networks induced by practicing a stop-signal task: An electrical neuroimaging study. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior*, *49*(4), 1141–1147. doi:10.1016/j.cortex.2012.12.009

Maraver, M. J., Bajo, M. T., & Gomez-Ariza, C. J. (2016). Training on working memory and inhibitory control in young adults. *Frontiers in Hum Neuroscience*, *10*, 588. doi:10.3389/fnhum.2016.00588

Matysiak, O., Kroemeke, A., & Brzezicka, A. (2019). Working memory capacity as a predictor of cognitive training efficacy in the elderly population. *Frontiers in Aging Neuroscience*, *11*, 126. doi:10.3389/fnagi.2019.00126

Matzke, D., Verbruggen, F., & Logan, G. D. (2018). The Stop-Signal Paradigm. *Stevens' Handbook of Experimental Psychology and Cognitive Neuroscience*, *5*, 383–428. 10.1002/9781119170174.epcn510

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science*, *21*(1), 8–14. doi:10.1177/0963721411429458

Mohammed, S., Flores, L., Deveau, J., Hoffing, R. C., Phung, C., Parlett, C. M., … Seitz, A. R. (2017). The benefits and challenges of implementing motivational features to boost cognitive training outcome. *Journal of Cognitive Enhancement: Towards the Integration of Theory and Practice*, *1*(4), 491–507. doi:10.1007/s41465-017-0047-y

Morrison, A. B., & Chein, J. M. (2011). Does working memory training work? The promise and challenges of enhancing cognition by training working memory. *Psychonomic Bulletin & Review*, *18*(1), 46–60. doi:10.3758/s13423-010-0034-0

Ortega, A., Gómez-Ariza, C. J., Román, P., & Bajo, M. T. (2012). Memory inhibition, aging, and the executive deficit hypothesis. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *38*(1), 178–186. doi:10.1037/a0024510. 21767066

Pozuelos, J. P., Combita, L. M., Abundis, A., Paz-Alonso, P. M., Conejero, Á., Guerra, S., & Rueda, M. R. (2019). Metacognitive scaffolding boosts cognitive and neural benefits following executive attention training in children. *Developmental Science*, *22*(2), e12756. doi:10.1111/desc.12756

Raven, J. C. (1990). *Advanced progressive matrices: Sets I, II*. Oxford: Oxford University Press.

Rey-Mermet, A., & Gade, M. (2017). Inhibition in aging: What is preserved? What declines? A meta-analysis. *Psychonomic Bulletin and Review*, 1–22. 10.3758/s13423-017-1384-7

Richmond, L. L., Morrison, A. B., Chein, J. M., & Olson, I. R. (2011). Working memory training and transfer in older adults. *Psychology and Aging*, *26*(4), 813–822. doi:10.1037/a0023631

Sala, G., Aksayli, N. D., Tatlidil, K. S., Gondo, Y., & Gobet, F. (2019). Working memory training does not enhance older adults' cognitive skills: A comprehensive meta-analysis. *Intelligence*, *77*, 101386. doi:10.1016/j.intell.2019.101386

Salthouse, T. A., & Mitchell, D. R. D. (1990). Effects of age and naturally occurring experience on spatial visualization performance. *Developmental Psychology*, *26*(5), 845–854. doi:10.1037/0012-1649.26.5.845

Shawn Green, C., Bavelier, D., Kramer, A. F., Vinogradov, S., Ansorge, U., Ball, K. K., … Witt, C. M. (2019). Improving methodological standards in behavioral interventions for cognitive enhancement. *Journal of Cognitive Enhancement*, *3*(1), 2–29. doi:10.1007/s41465-018-0115-y

Shipstead, Z., Redick, T. S., & Engle, R. W. (2012). Is working memory training effective? *Psychological Bulletin*, *138*(4), 628–654. doi:10.1037/a0027473

Tokowicz, N., Michael, E. B., & Kroll, J. F. (2004). The roles of study-abroad experience and working-memory capacity in the types of errors made during translation\n\n. *Bilingualism: Language and Cognition*, *7*(3), 255–272. doi:10.1017/S1366728904001634

Turner, M. L., & Engle, R. W. (1989). Is working memory capacity task dependent? *Journal of Memory and Language*, *28*(2), 127–154. doi:10.1016/0749-596X(89)90040-5

van Doorn, J., van den Bergh, D., Bohm, U., Dablander, F., Derks, K., Draws, T., … Wagenmakers, E.-J. (2019). The JASP guidelines for conducting and reporting a Bayesian analysis. *PsyArxiv Preprint*, (February), 0–31. 10.31234/osf.io/yqxfr

Verbruggen, F., Aron, A. R., Band, G. P., Beste, C., Bissett, P. G., Brockett, A. T., … Boehler, C. N. (2019). A consensus guide to capturing the ability to inhibit actions and impulsive behaviors in the stop-signal task. *eLife*, *8*, e46323. doi:10.7554/eLife.46323

Verbruggen, F., & Logan, G. (2008). Response inhibition in the stop-signal pardigm. *Trends in Cognitive Sciences*, *12*(11), 418–424. doi:10.1016/j.tics.2008.07.005

Verbruggen, F., Logan, G. D., & Stevens, M. A. (2008). STOP-IT: Windows executable software for the stop-signal paradigm. *Behavior Research Methods*, *40*(2), 479–483. doi:10.3758/brm.40.2.479

Wilkinson, A. J., & Yang, L. (2016). Inhibition plasticity in older adults: Practice and transfer effects using a multiple task approach. *Neural Plasticity*, *2016*, 9696402. doi:10.1155/2016/9696402

World Health Organisation. (2013). Declaration of Helsinki World Medical Association Declaration of Helsinki. Ethical principles for medical research involving human subjects. *The Journal of the American Medical Association*, *310*(20), 2191–2194. 10.1001/jama.2013.281053

Xu, M., Xu, G., & Yang, Y. (2016). Neural systems underlying emotional and non-emotional interference processing: An ALE meta-analysis of functional neuroimaging studies. *Frontiers in Behavioral Neuroscience*, *10*, 220. https://www.frontiersin.org/article/10.3389/fnbeh.2016.00220 doi:10.3389/fnbeh.2016.00220

Zanto, T. P., & Gazzaley, A. (2019). Aging of the frontal lobe. *Handbook of Clinical Neurology*, *163*, 369–389. doi:10.1016/B978-0-12-804281-6.00020-3