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Fostering cognitive performance in older adults with a process- and a strategy-based cognitive training

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ABSTRACT

The present study investigates the impact of process-based and strategy-based cognitive training to boost performance inhealthy older adults. Three groups trained with either a dichotic listening-training (process-based training, n = 25), an implementation intention strategytraining (strategy-based training, n = 23), or served as a non-contact controlgroup (n = 30). Our results demonstrated that training participants improvedtheir performance in the trained tasks (process-based training: d = 3.01, strategy-based training: d = 2.6). For untrained tasks, theprocess-based training group showed significant working memory (d = .58) as well as episodic memory taskimprovement (d = 1.19) compared to thestrategy-based training and to the non-contact control group (all d < .03). In contrast, in thestrategy-based training group there was a tendency towards some performancegain in a fluid intelligence test (d =.92). These results indicate that cognitive training can be tailored toimprove specific cognitive abilities.

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Cognitive training; older adults; cognitive performance; strategy training; memory

Average human life expectancy has risen about twenty years in the last one hundred years, and the older population is still growing (Kinsella, 1992; Kontis et al., 2017). With normal aging, changes in cognition occur, above all, a decline in processing speed, a reduction in working memory capacity, and a decay in executive functions (Murman, 2015). Relatedly, well-being decreases also, particularly aspects such as purpose in life and independent living (Salthouse, 2012; Wilson et al., 2013). Encouragingly, neuroscience has discovered that the brain stays malleable throughout the lifespan, and cognitive processes become more efficient with regular exercise (Park & Bischof, 2013). These findings open many possibilities to influence and foster cognitive health, and have the potential to restore earlier levels of cognitive functioning, to slow down cognitive decline, and to support the maintenance of functional independence of older adults (Nguyen, Murphy, & Andrews, 2021; Rebok et al., 2014). Thus, it is a vital issue to investigate effective cognitive interventions.

Process-based training is one approach that enhances the underlying processes of cognitive functions. The approach works by repetitively exercising the underlying core mechanisms (i.e., attention) in a cognitively intensive way with time (Morrison & Chein,

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2011; Studer-Luethi & Meier, 2021). Strategy-based training is another approach that reduces or circumvents cognitive task demands by establishing suitable memory strategies (Hering et al., 2014). This study compares the effects of process-based cognitive training to strategy training on attention, memory, reasoning, and memory functions in daily life in healthy older adults. We hypothesized that process-based training would be particularly suited to boost basic cognitive functions such as attention and memory while strategy-based training may be more suited to improve planning in order to cope with the complexity of everyday life.

Process-based training approach and training studies with older adult

Process-based cognitive training aims to stimulate cognitive reserves and neuronal plasticity. Through the repetitive practice of a training task, cognitive training intends to increase the efficiency of basic cognitive processes (Brehmer et al., 2014). Efficient cognitive processing is crucial in older adults to prolong the time until clinically significant levels of dysfunction are reached (Hertzog et al., 2008). Based on the mismatch model of cognitive plasticity, a rise in demand on cognitive processes can result in increased resources associated with cognitive functioning (Lindenberger, 2014). Effective training tasks typically challenge the attentional and memory capacity to increase the cognitive abilities of trainees. One way to do so is by utilizing computerized cognitive training tasks.

Working memory training seems especially promising, as WM is a cognitive core function related to a high number of critical intellectual skills, such as inhibition, shifting, and working memory (Miyake et al., 2000). That is, working memory tasks are assumed to foster the ability to store and process information simultaneously. Generally, studies demonstrate medium-to-large performance gains in the training task performance and small gains in untrained tasks measuring memory, executive functions or other abilities (Lampit et al., 2014; Teixeira-Santos et al., 2019, for meta-analyses; Melby-Lervåg et al., 2016, for a critical review). The small effect sizes lead to dispute about the potential to enhance older adult's cognitive skills through working memory training (e.g., Sala et al., 2019; Soveri et al., 2017).

Here, we focused on another executive function training task, dichotic listening (DL). In this task, participants need to pay attention to an auditory stimulus source while ignoring another one, thus mimicking the everyday situation of listening to a conversation against background noise. Participants are presented with words simultaneously played to the right and the left ear via headphones (cf., Rothen & Meier, 2017). The DL task has been applied to assess attention, working memory and executive functions (Hugdahl, 2011) and training has been found beneficial for patients with auditory, verbal, and other neurological impairments (Helland et al., 2018; McCullagh & Palmer, 2017; Osisanya & Adewunmi, 2018). Moreover, there is evidence for improvements in attention and attentional control after DL training (Soveri et al., 2013) and in more efficient neuronal attentional control (Tallus et al., 2015). In a sample of 130 younger adults, we recently observed some improvement on memory, choice reaction performance and self-reported mindfulness after a 4-week long DL training relative to a no-training control group (Studer-Luethi & Meier, 2021). However, we found no generalization to daily life memory, in line with other process-based cognitive training studies (cf., Owen et al., 2010; Van Heugten et al., 2016). Moreover, in samples of older adults, there is evidence that DL training decreases the listening deficit (Shahidipour et al., 2021). So far, no study has tested the impact of DL training regarding transfer to other cognitive performance domains in older adults. Promisingly, training studies targeting aural speech increased listening, memory, and related cognitive abilities (Mahncke et al., 2006; G. E. G. E. Smith et al., 2009; Zelinski et al., 2011). Specifically, G. E. Smith et al. (2009) found that older adults who trained with computerized auditory information processing exercises improved memory and attention.

Strategy-based training approach and training studies with older adults

As an alternative to training underlying attention and cognitive speed processes, strategies can be learned and applied to increase memory performance in daily life. Strategy-based interventions use either external or internal strategies. Whereas external strategies use the assistance of external memory aids (e.g., planners, cell phones), internal strategies aim to enhance cognitive performance by optimizing encoding and/or retrieval (Hering et al., 2014). Generally, older adults are less prone to deliberately use internal strategies, they rather rely on external strategies which require less cognitive effort (Bouazzaoui et al., 2010). This deficient strategy application could explain research findings demonstrating that strategy interventions show small to medium performance gains in the trained tasks and executive functions in healthy older adults (Gross et al., 2012; Mowszowski et al., 2016).

Trained memory strategies can either help people to remember things (i.e., retrospective memory, such as the shopping list) or help people to "remember to remember" things (i.e., prospective memory, such as the intention to do something). These latter strategies are essential for older adults, as prospective memory performance is more disrupted by aging than retrospective memory (Henry et al., 2004; Kliegel et al., 2016). In addition, approximately one-third of all older adults must regularly take three or more medications (West & Craik, 1999). Therefore, effective strategies which help to remember intended actions are relevant for an independent life. One of the most prominent internal strategies which increases the chance of executing one's intention is the implementation intention strategy (P. M. Gollwitzer & Sheeran, 2006). The strategy draws on the insights from motivational psychology that specifying implementation intentions is more effective to goal attainment compared to simply forming a goal intention. Implementation intentions involve specifying how, where, and when one will perform a particular action (Gollwitzer, 1999). To make the strategy more effective, the situation in which the specific intention should be executed is vividly imagined. The planned behavior is mentally rehearsed such that when one encounters the appropriate situation, the execution of the intended behavior is automatically triggered (Brandstätter et al., 2001; Liu & Park, 2004).

Research shows that applying memory strategies can be particularly profitable for older adults. Zimmermann and Meier (2010) found that older adults benefited more from forming implementation intentions than adolescents and young adults. Other studies found that older adults who learnt to apply implementation intentions showed improved memory performance in laboratory tasks, such as prospective memory and inhibition tasks (Burkard

Burkard et al., 2014a; Chasteen et al., 2001; Lee et al., 2016; McFarland & Glisky, 2012; Schnitzspahn & Kliegel, 2009). Similarly, older adults who formed implementation intentions improved daily life tasks, such as taking a blood pressure reading or monitoring glucose (Brom et al., 2014; Liu & Park, 2004).

Comparison of process- and strategy-based training

Some studies with older adults indicate that process-based training reaches more promising transfer effects on cognitive performance than strategy-based training (Ball et al., 2002; Ball et al., 2007; Karbach & Verhaeghen, 2014; Rebok et al., 2014). However, a recent review concluded that both process- and strategy-based training can transfer to enhance COGNITIVE functions in older adults, but not necessarily to the same cognitive functions. For example, process-based cognitive training most consistently transferred to cognitive speed and working memory, and strategy-based cognitive training most consistently transferred to immediate word recall (Sprague et al., 2019).

Whereas cognitive process interventions target the training of basal cognitive processes and cognitive gains, internal strategy interventions are application-oriented and target real-life improvements. Indeed, a study that applied training with an adapted task-switching task compared to a strategy training using implementation intentions revealed that the strategy- training but not the process-based training positively affected everyday life prospective memory performance (i.e., blood pressure monitoring) in a group of older adults (Brom et al., 2014). However, there is some evidence that process-based training can enhance the performance of everyday activities and that long-term cognitive training can maintain or even enhance self-reported functional independence in daily life (Ball et al., 2007; Rebok et al., 2014). Also, recent studies on prospective memory training comparing process- and strategy-based approaches reported only limited efficacy (e.g., see, Henry et al., 2021).

The present study

There is a lack of studies comparing process-based cognitive training to strategy-based training approaches regarding effects on different areas of cognitive performance in older adults. With the present study we intended to fill this gap and to contribute to the question whether and which training approach effectively fosters older adults' cognitive abilities compared to a not trained control group. More specifically, we investigated whether a four-week dichotic listening training leads to differential cognitive improvement in attention, memory, reasoning, and daily life memory performance, compared to a four-week strategy-based training using implementation intentions, and compared to a passive (i.e., no-contact) control group.

Based on the existing literature, we expected two results. First, the process-based training will increase related cognitive abilities measures, such as working memory and episodic memory, by training basic cognitive abilities. Thus, we expected the process-based training to increase performance in basic cognitive abilities more than the strategy-based training and the no-contact control group. Second, we expected the strategy-based training of everyday planning to result in more applied effects and that therefore memory performance in everyday life will increase by boosting planning abilities.

Methods

Participants

A total of 80 older adults (42 females) with a mean age of 70.5 years (SD = 7.38; range = - 60–90) participated in the study. The training groups were recruited via an advertisement in a local public newspaper and via word of mouth. They were assigned to one of the trainings based on a single sequence of random assignments. The control group was recruited by students of a research method class with the information that the study is on the effect of repeated testing on cognitive performance in older adults. Inclusion criteria were participant's age (at least 60 years), self-reported good health, and, for the training groups, internet access at home. The participants received no payment for participation, but they received a collection of our computerized training tasks and a brochure of brain facts after completing study. Two participants were excluded, one participant did not finish the training due to technical problems, and one did not show up for the posttest. The final sample therefore consisted of 78 participants, twenty-five (mean age = 72.45, SD = 7.12, 9 female) in the process-based training, twenty-three (mean age = 72.39, SD = 7.50, 9 female) in the strategy-based training, and thirty (mean age = 72.10, SD = 7.01, 14 female) in the passive control group. All participants reported normal vision and hearing and gave informed consent.

Design

The study consisted of a 2 × 3 mixed design with the between-subjects factor group (i.e., training condition: process-based training, strategy-based training, control group) and the within-subjects factor time (i.e., pre- and posttest).

Procedure

Pre- and posttests took place with each participant individually in a room at the university. They consisted of computer-based and paper-pencil tests. After completing the pretest, the participants of the two training groups received oral and written information about the intervention. They were instructed to schedule a training session every weekday for four weeks, resulting in 20 training units (see, Figure 1). Participants in the two training conditions trained individually, the control group underwent no training at all. Posttests took place three to six days after the last training session of each participant or after four to five weeks (control group). After posttest testing, participants were informed about the study's primary goal and – after request – about their results in the cognitive tests, and they were able to ask pending questions.

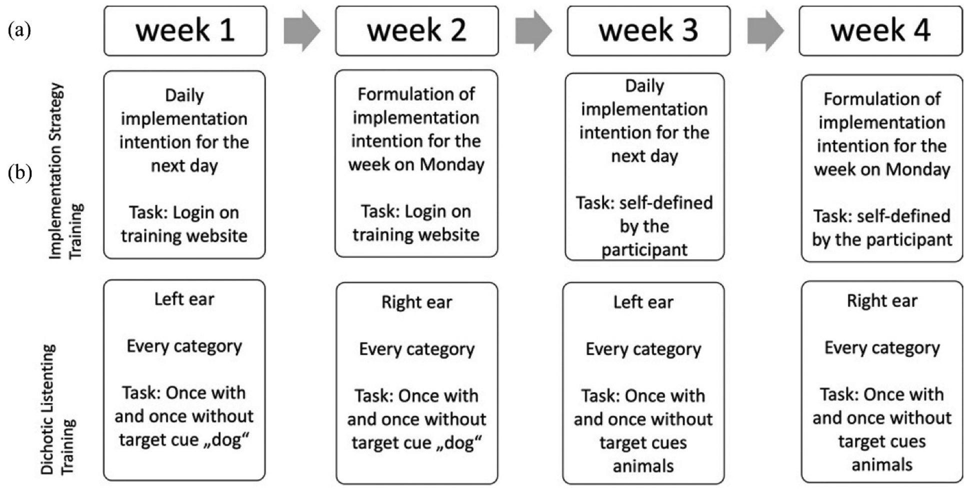

Figure 1. Training plan with the a) strategy-based training using implementation intention strategy tasks and the b) process-based training applying dichotic listening tasks.

Measures

Cognitive Tasks

Simple reaction task: This task required the participant to press a key as fast as possible whenever a visual stimulus (i.e., a cross) appeared on the screen (presentation time of max. 5000 ms, interval between 300–500 ms, followed by a 500 ms blank screen). The reaction time served as the dependent variable. Retest reliability was .58.

Choice reaction task: In this task, arrows pointing to the right or left were presented on the screen (presentation time of max. 5000 ms, interval between 300–500 ms, followed by a 500 ms blank screen). The participants were required to press a corresponding keyboard arrow as fast as possible, depending on which direction the arrow was pointing. The reaction time served as the dependent variable. Retest reliability was .73.

Working Memory: Working memory capacity was assessed with the Reading Span Task (RST; Daneman & Carpenter, 1980). Participants were instructed to read a set of unrelated sentences aloud and to indicate for each sentence whether it was meaningful by pressing the 1-key (meaningful) or the 0-key (not meaningful). After each set of sentences (starting with a set of two, and subsequently increasing the number of sentences by one), participants were asked to recall the last word of each sentence from the set. Depending on performance, the number of sentences increased up to six depending on the number of correct recalled sets (each set level was presented three times). The number of correct responses served as dependent variable. Retest reliability was .91.

Episodic Memory: The study used the Auditive Verbal Learning and Memory Task (AVLGT; an adaption of the Rey Auditory Verbal Learning Test (Smidt, 1996) as a test of verbal episodic memory. It consists of five study-test cycles of a list of fifteen verbally presented non-related words and a 30-minutes delayed recall. Two sets of different words (e.g., set A and B) were used for the pre-and posttest, respectively. At the end of each trial and after 30 minutes, participants were asked to recall as many words as possible accurately. The sum of accurately recalled words served as a dependent variable (i.e., "verbal memory learning sum"), retest reliability was .85. The accurately recalled words at the delay served as a second dependent variable (i.e., "delayed verbal memory"), retest reliability was .78.

Prospective Memory: A prospective memory task was embedded in an ongoing lexical decision task (Meier & Zimmermann, 2015; Smith, 2003; Walter & Meier, 2017). The prospective memory task was defined as pressing a specific key whenever a word from a particular category appeared. The lexical decision task consisted of 50% words and 50% non-words. Participants were informed that letter strings would appear, and they would have to decide as quickly as possible whether a letter string is a word (by pressing the B-key) or not (by pressing the N-key). After ten practice trials during which potential questions could be clarified, a block of 100 baseline lexical decision trials was administered. Then participants were informed about the prospective memory task. Specifically, they were instructed to press the Q-key whenever a word from the animal category (pretest) or the category of musical instruments (posttest) occurred during the lexical decision task. Six exemplars of the target category were presented among the next block of 306 lexical decisions. The dependent variable was the accuracy of prospective memory responses. Retest reliability was .78.

Fluid Intelligence: We tested fluid intelligence using the Raven's Progressive Matrices (RPM; Raven, Raven, & Court, 1998), separated into two forms of 30 items (items were split into odd and even sets and counterbalanced across testing times) and with a time limit to complete the task of 10 minutes. Participants saw a 3 × 3 matrix of shapes presented with the last shape missing. Their task was to choose the item that completed the pattern from a set of six to eight options. The number of correct answers served as dependent variable. Retest reliability was .80.

Self-reported measures

Memory in everyday life: The study used the Prospective and Retrospective Memory Questionnaire (PRMQ) to determine perceived memory performances in daily life (G. Smith et al., 2000). This instrument consists of sixteen questions. There are eight prospective memory-related (e.g., Do you forget appointments if you are not prompted by someone else or a reminder such as a calendar or a diary?), and eight retrospective memory-related questions (e.g., Do you fail to recall things that have happened to you in the last few days?). Participants responded on a five-point-Likert scale. The results for each subscale served as dependent measures and retest reliabilities were .78 and .76 for the prospective and retrospective memory scales, respectively.

Training

The dichotic listening training tasks are part of a cognitive training task collection designed for application on tablets and smartphones (Studer-Luethi et al., 2017). We also integrated the implementation intention strategy training in the training platform to ensure that both trainings are applied according to the same technical requirements. The two training conditions were also comparable with regard to duration of instruction, number of sessions, as well as estimated time per session.

Process-based training

The process-based training is based on research with the dichotic listening task and on selective attention (Kimura, 1967; Soveri et al., 2013; Tallus et al., 2015). On each trial, the participant was presented with two different words to each ear over the headphones. In week one and three, participants were instructed to focus attention to the left ear and to ignore the word presented on the right ear, and to classify the word into one of two categories by touching the corresponding button on the right or the left side of the screen (see, Figure 1B). In weeks two and four, the focus of attention was reversed. During the 20 training sessions, the categories changed between concrete/abstract word, English/German word, male/female voice, natural/artificial sound, object smaller/bigger than a soccer ball, and the to-be-attended ear (i.e., left vs. right). In the second part of the task, a prospective memory task was added by instructing participants to react to a predefined word (i.e., "dog," weeks one and two) or category (i.e., animal, weeks three and four) by pressing the shift key. That is, task demands varied within each session and across the different sessions, independent of the trainee's training performance. Difficulty increased within session to keep the training challenging. Materials differed across session to keep the training stimulating. Each part of the task consisted of 90 words and lasted approximately 20 min. The participants were provided with Sennheiser© headphones to ensure the quality of the sound. Before each training, there was a brief presentation of a single stimulus to each ear to ensure that the headphones were correctly set. Dependent variables concerning training performance were mean classification times as well as accuracy in the dichotic listening task.

Strategy-based training

The implementation intention strategy training is based on the insights about forming action plans with specific and concrete "if-then" statements about to be performed tasks (Gollwitzer & Sheeran, 2006). In the first training session, participants were introduced to the method of formulating implementation intention instead of goal intention to attain one's goals. For each week, participants were asked to think about their plans for the particular week and to select a specific planned activity by indicating the time and place. They then were asked to define their planned activities before or after this targeted activity and, finally, to formulate a specific "if-then"-sentence to specify the intention (e.g., "When I finish drinking my morning coffee, I will write a letter to my friend"). Finally, they were asked to close their eyes and visualize their intention as vividly as possible (cf., Brewer et al., 2010; Chen et al., 2015). In weeks one and three, they were requested to log in daily to a specific internet site and type in the intention for the particular day. In weeks two and four, they were also requested to log in daily to the internet site, but they were requested to type in the intentions for each day of this particular week on Monday (see, Figure 1A). Success of implementation intentions was assessed by asking daily about the implementation of the intention formulated at the previous day. Participants spent 15 minutes on the training per day.

Data analysis

The study used 2 × 3 repeated measures analyses of variance (ANOVAs) to measure the effects of the memory interventions for each dependent variable (i.e., cognitive measures) using the within-subject factor time (i.e., pre- and posttest performance, respectively), and the between-subject factor group (i.e., process-based training, strategy-based training, and control group).

If a significant ($p < 0.05$) main effect for time or group or a significant interaction effect between time and group was found, post hoc analyses of differences of means were calculated, corrected for multiple comparisons using Bonferroni correction. In addition, effect sizes for mean differences between pre- and posttests for each training condition were determined. Outliers were detected higher than 3 or lower than −3 SD. These values (a total of 9 points) were replaced with the value corresponding to 2.5 SD. With this procedure, all participants could be included in the following statistical analyses.

Results

Means and standard deviations of pre- and posttests and corresponding effect sizes for each variable and condition are presented in Table 1 and Figure 1. The Greenhouse-Geisser corrected alpha-level values are reported for all repeated measures effects (cf. Verma, 2015). Overall descriptive statistics and correlations for pretest variables are reported in Table 2. One-way between subjects ANOVAs of baseline levels for each condition and dependent variable were calculated in order to evaluate group randomization. There was no significant effect of condition on any variable (all $F < 2.5$) giving indication of successful randomization (see supplementary material, Table 1).

Process-based training performance

Dichotic listening accuracy improved across blocks from .87 to .93, $F(3, 54) = 7.445$, $p < .001$, $\eta_p^2 = .293$. Moreover, reaction times improved across the four weeks from 2205 ms to 1558 ms, $F(3,24) = 25.315$, $p < .001$, $\eta_p^2 = .584$, as depicted in Figure 2.

Strategy-based training performance

The average number of logins to the program and completion of the task to formulate the implementation intentions increased across the four weeks from 4.30 to 4.83, $F(3, 25) = 4.145$, $p < .05$, $\eta_p^2 = .153$, as depicted in Figure 2.

Transfer performance

Simple reaction time task

The ANOVA of median reaction times of the simple reaction task revealed no significant main effect for time, $F(1, 55) = 0.469$, $p = .496$, $\eta_p^2 = .008$, a significant main effect for group, $F(2, 55) = 3.707$, $p = .031$, $\eta_p^2 = .119$, and no time x group interaction, F(2,

Table 1. Means (M) and Standard Deviations (SD) of Pre- and Posttests and Corresponding Effect Sizes.

	Pretest		Posttest			
	M	SD	M	SD	*t*	d_{RM}
Process-based training group (*N* = 20)						
Simple Reaction Time Task	314	97.52	288	46.20	1.51	−0.31
Choice Reaction Time Task	513	111.57	514	85.19	−.02	0.00
Verbal Memory Learning sum	46.20	10.84	52.25	10.36	−5.40***	1.19
Delayed Verbal Memory	9.00	3.21	9.30	3.76	−.45	0.11
Working Memory	23.85	10.95	28.45	11.43	−4.23***	0.97
Prospective Memory	4.60	1.67	4.35	1.87	1.38	−0.11
Fluid Intelligence	4.10	2.29	5.20	2.44	−2.46**	0.57
Prospective Memory in Daily Life	19.70	3.79	19.50	3.41	1.69	−0.06
Retrospective Memory in Daily Life	18.75	3.26	19.20	3.47	.61	0.21
Strategy-based training group (*N* = 18)						
Simple Reaction Time Task	279	45.78	281	37.16	−.37	0.08
Choice Reaction Time Task	477	41.25	476	29.87	.15	−0.03
Verbal Memory Learning sum	48.89	9.51	50.11	10.54	−.67	0.17
Delayed Verbal Memory	9.22	3.44	10.00	3.88	−1.25	0.32
Working Memory	20.33	11.76	23.22	10.86	−1.89*	0.43
Prospective Memory	4.78	1.93	4.83	1.79	−.08	0.02
Fluid Intelligence	4.56	3.13	6.44	3.26	−3.85***	0.92
Prospective Memory in Daily Life	18.00	2.95	18.94	3.08	−1.75*	0.42
Retrospective Memory in Daily Life	17.94	3.47	18.33	3.76	−.57	0.14
No-contact control group (*N* = 20)						
Simple Reaction Time Task	326	79.48	380	200.67	−1.38	0.68
Choice Reaction Time Task	556	140.32	598	197.93	−1.12	0.32
Verbal Memory Learning sum	45.25	10.88	47.50	8.36	−1.24	0.26
Delayed Verbal Memory	7.60	4.11	8.10	3.51	−.60	0.13
Working Memory	22.55	11.79	22.30	14.02	.14	−0.04
Prospective Memory	4.60	1.54	3.10	2.49	2.40**	−0.73
Fluid Intelligence	4.30	2.58	4.80	3.00	−.87	0.21
Prospective Memory in Daily Life	19.25	3.93	18.90	3.28	.51	−0.11
Retrospective Memory in Daily Life	19.25	3.29	18.70	2.76	.71	−0.15

Note. Measurements are explained in the Methods. All values are rounded to two digits after the decimal point. *p < .1, **p < .05, ***p < .01.

55) = 2.561, $p = .086$, $\eta_p^2 = .085$. Post hoc analyses revealed that the main effect for group represented the fact that the strategy-based training group was significantly slower in the task than the control group, $F(1, 36) = 5.652$, $p = .023$, $\eta_p^2 = .136$. All the other group differences were nonsignificant ($F < 2.1$).

Choice reaction time task

The ANOVA for median reaction times of the choice reaction task revealed no significant main effect for time, $F(1, 55) = 0.839$, $p = .364$, $\eta_p^2 = .015$, a significant main effect for group, $F(2, 55) = 4.627$, $p = .014$, $\eta_p^2 = .144$, and no significant time x group interaction, $F(2, 55) = 0.885$, $p = .419$, $\eta_p^2 = .031$. Again, post hoc analyses revealed that the main effect for group represented the fact that strategy-based training group exhibited significantly slower reaction times compared to the control group, $F(1, 36) = 7.723$, $p = .009$, $\eta_p^2 = .177$. All the other group differences were nonsignificant ($F < 1.8$).

Table 2. Descriptive Statistics and Correlations for Pretest Variables.

Variable[a]	*n*	*M*	*SD*	1	2	3	4	5	6	7	8	9	10
1. Simple Reaction Time Task	58	307.84	79.34	-									
2. Choice Reaction Time Task	58	517.23	110.78	.21	-								
3. Choice Reaction Task accuracy	58	0.96	0.03	.18	.26	-							
4. Verbal Memory Learning Sum	58	46.71	10.39	−.23	−.37**	.11	-						
5. Delayed Verbal Memory	58	8.59	3.62	−.24	−.32*	.00	.73**	-					
6. Working Memory	58	22.31	11.38	−.09	−.35**	.13	.53**	.30*	-				
7. Prospective Memory	58	4.66	1.68	.03	−.10	.26	.09	−.04	.08	-			
8. Fluid Intelligence	58	4.31	2.63	−.15	−.15	.26	.46**	.47**	.27*	−.15	-		
9. Prospective Memory in Daily Life[b]	58	19.02	3.61	.12	.05	−.14	−.21	.05	−.34**	−.20	.07	-	
10. Retrospective Memory in Daily Life[b]	58	18.67	3.32	.07	.29*	.02	−.12	.08	−.18	−.12	.12	.57**	-

Note. n = sample size; M = mean; SD = standard deviation. All values are rounded to two digits after the decimal point.
[a]Variables as described in the method section (see Cognitive Measures for detailed commendation).n
[b]Variables represent subjective measures.
* p < 0.05. ** p < 0.01.

Working memory

The ANOVA for the number of accurately remembered items in the reading span task revealed a significant main effect for time, $F(1, 55) = 8.068$, $p = .006$, $\eta_p^2 = .128$, but not for group, $F(2, 55) = 0.832$, $p = .441$, $\eta_p^2 = .029$. There was a marginally significant time x group interaction, $F(2, 55) = 2.893$, $p = .064$, $\eta_p^2 = .095$. Further exploratory analyses revealed no significant time x group interaction when comparing process-based and strategy-based training, $F(1, 36) = 0.860$, $p = .360$, $\eta_p^2 = .023$, but a signification interaction when comparing process-based training and control group, $F(1, 38) = 5.641$, $p = .023$, $\eta_p^2 = .129$. This result indicates a significant benefit for the process-based training group in comparison to the control group (see, Figure 3).

Episodic memory

For the verbal memory learning sum, the ANOVA revealed a significant main effect for time, F(1, 55) = 11.65, p < .001, ηp2 = .175, but neither for group, F(2, 55) = 0.651, p = .526, ηp2 = .023, nor a time x group interaction, F(2, 55) = 2.506, p = 0.091, ηp2 = .84. The main effect of time represents the fact that learning sums significantly increased for each group at posttest time interval in relation to pretest time interval (see, Figure 3). Further exploratory analyses revealed significant time x group interaction effects such that there were greater benefits for process-based compared to strategy-based training, $F(1, 36) = 5.278$, $p < .028$, $\eta_p^2 = 1.28$, but not compared to controls, $F(1, 38) = 3.185$, $p = .082$, $\eta_p^2 = .077$.

For delayed verbal memory, the ANOVA revealed no significant main effects for time, $F(1, 55) = 1.582$, $p = .214$, $\eta_p^2 = .028$, group, $F(1, 55) = 1.480$, $p = .237$, $\eta_p^2 = .051$, or time x group interaction, $F(2, 55) = .107$, $p = .898$, $\eta_p^2 = .004$.

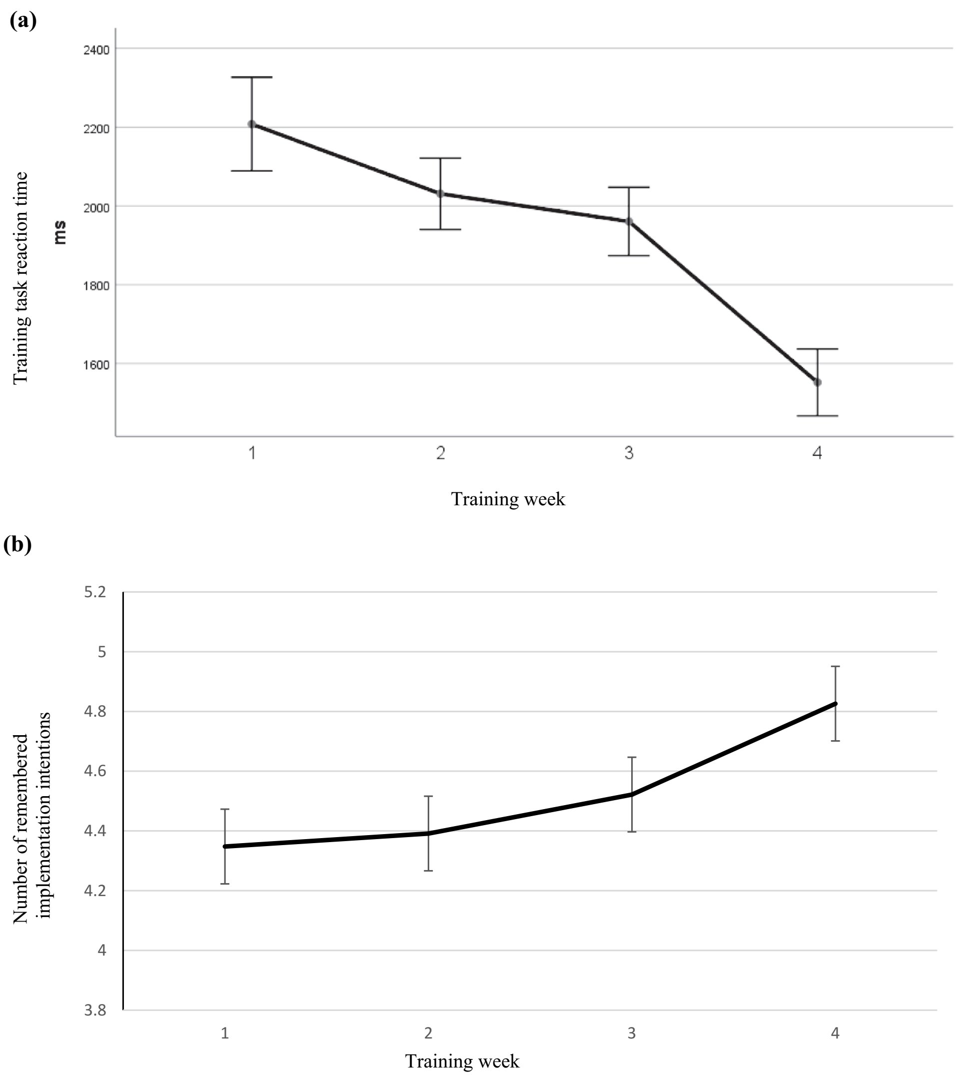

Figure 2. Training performance during the 4 training weeks in the a) process-based training: reaction time in the dichotic listening task, b) strategy-based training: number of remembered intentions in the implementation intention task.

Prospective memory

For prospective memory performance, the ANOVA revealed no effects for time, $F(1, 55) = 2.527$, $p = .118$, $\eta_p^2 = .044$, group, $F(2, 55) = 2.502$, $p = .091$, $\eta_p^2 = .083$, or time x group interaction, $F(2, 55) = 1.806$, $p = .174$, $\eta_p^2 = .062$.

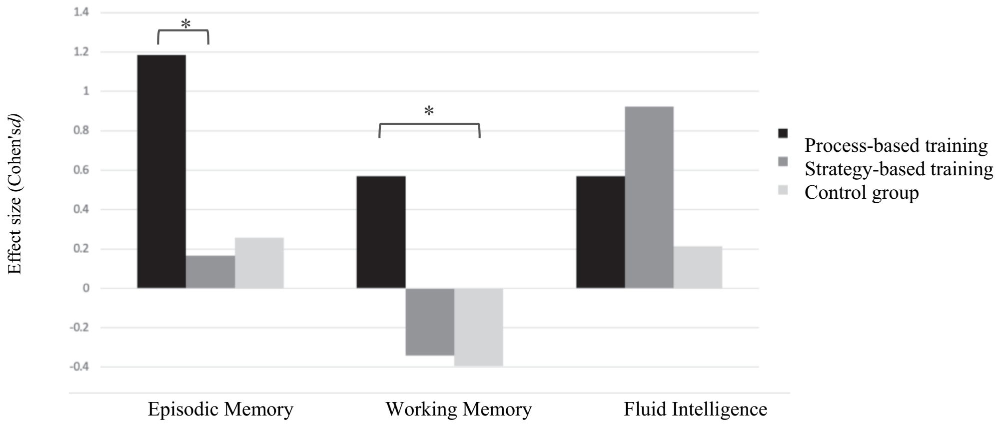

Figure 3. Effect sizes of pre- to posttest performance change in episodic memory, working memory, and fluid intelligence for the training and control groups. Note. The marked group effects were statistically significant ($p < .05$). There were no group effects regarding simple and choice reaction time, prospective memory, and memory in daily life

Fluid Intelligence

The ANOVA for the Raven's Matrices Test revealed a significant main effect for time, $F(1, 55) = 15.674$, $p < .001$, $\eta_p^2 = .222$, but no significant main effect for group, $F(2, 55) = 0.776$, $p = .465$, $\eta_p^2 = .027$, or time x group interaction, $F(2, 55) = 1.835$, $p = .169$, $\eta_p^2 = .063$. The main effect for time represented the fact that in all conditions, scores in the test improved from pre- to posttesting (see, Figure 3).

Memory in daily life

For the prospective memory in daily life scale of the PRMQ, there was no significant main effect of time, $F(1, 55) = 0.119$, $p = .732$, $\eta_p^2 = .002$, and group, $F(2, 55) = 0.620$, $p = .541$, $\eta_p^2 = .022$, and no significant time x group interaction, $F(2, 55) = 4.671$, $p = .337$, $\eta_p^2 = .039$. Similarly, for the retrospective memory in daily life scale there were no significant main effects for time, $F(1, 55) = 0.062$, $p = .804$, $\eta_p^2 = .001$, or group, $F(2, 55) = 0.482$, $p = .620$, $\eta_p^2 = .017$, and time and group interaction, $F(2, 55) = 0.722$, $p = .490$, $\eta_p^2 = .026$.

Due to the relatively small number of participants and the resulting low statistical power, we conducted an effect size analysis of the pre- to posttest performance change for the dependent variables of interest, namely episodic memory, working memory, and fluid intelligence. A visualization of the effect sizes can be found in Figure 3. The effect sizes demonstrate the trend for an advantage of the process-based training group regarding changes in working memory and episodic memory, and the advantage of the strategy-training group regarding change in fluid intelligence.

Discussion

Previous research has identified cognitive decline as one of the most important risks for reduced well-being in healthy aging (Lawton et al., 1999). This study aimed to investigate the potential benefits of process-based and strategy-based memory training on processing speed, working memory, episodic and prospective memory, fluid intelligence, as well as memory performance in daily life. A group of 80 older adults participated either in a 4-week process-based training using dichotic listening tasks, a strategy-based training using implementation intentions strategy, or in no intervention (control group). Results demonstrate a selective positive effect of the process-based training on working memory and verbal episodic memory performance in comparison to the strategy-based training and the control groups. We also observed a selective effect of the strategy-based training group for fluid intelligence in comparison to the other experimental groups. Moreover, although there was no increase in prospective memory after training, both training groups maintained prospective memory performance from pre- to posttest, while the control group showed a marked decline in prospective performance. Notably, in the pretest participants prospective memory targets were defined as the category of animals while in the posttest they were musical instruments. We suspect that detecting musical instruments was more difficult than detecting animals. Accordingly, the lack of a performance gain for the training groups seems to indicate that they were at least able to maintain their performance level. In contrast, this was not the case for the control group. That is, when the target category switched, training participants were able to flexibly adapt to the new task requirement. None of the trainings demonstrated a generalization to everyday memory performance. In sum, these findings align with other cognitive training regimes in older adults, demonstrating process-based training's potential to enhance memory performance (cf., Zokaei et al., 2017), whereas strategy-based training can rather enhance analytic reasoning (Wieber et al., 2009).

Cognitive training performance

Participants in the process-based training group showed significant performance gain in the training tasks over the four weeks. That is, they increased their accuracy, and more importantly, their reaction time, representing increased processing speed ($d = 3.01$). These improvements were especially pronounced in the fourth week and are comparable to those found in a 4-week dichotic listening intervention with adults aged 18 – 55 years (Studer-Luethi & Meier, 2021). These effects are also in line with training targeting visual perception which demonstrated significant improvements in both speed threshold and detection accuracy (Ball et al., 2007; Berry et al., 2010; Wolinsky et al., 2013).

Considering the mechanisms behind such performance improvements, studies with older adults demonstrated that an increase in auditive processing through auditory training was accompanied by neural changes (see, Anderson & Kraus, 2013, for a review). According to studies measuring the cortical response, stimulus-specific and general effects of auditory cognitive training target attention efficiency rather than the perceptual processing or speed of processing of older adults (O'Brien et al., 2017; Tremblay et al., 2009).

Regarding the strategy-based training, the amount of remembered implementation intentions was comparable in the first two weeks, but the trainees showed significant performance gain in weeks three and four (d = 2.6). Thus, participants benefited from the implementation intention strategy introduced in the training task and increased their ability to remember everyday life intentions (cf., Farzin et al., 2021)

Transfer to other cognitive domains

Notably, overall, the lack of significant interactions between group and time seemed to provide no meaningful training benefits. Nevertheless, given the small sample size and the arbitrary cutoff of .05 for significance tests, further exploratory analyses were conducted which provided suggestive evidence that the null-effect may not represent the whole story. We discuss these results below. However, we recognize that the interpretation is speculative and that further research is necessary to replicate our results.

First, as expected, there was an increase in working memory and episodic memory performance in the process-based training group. Significant pre-post training improvements included the reading span working memory task as well as the episodic verbal word learning memory task, while in the strategy-based training or to the control group no such effects occurred. This adds evidence to the few existing training studies that memory improvements can be obtained through cognitive training (Tallus et al., 2015). It is likely that process-based training targets skills relevant for memory (e.g., the ability to pay attention, inhibit distractors), and thus one potential source of these transfer effects is improved attentional focus, processing of stimuli, more efficient inhibition and encoding (cf., Korkki et al., 2021). That is, the cognitive training tasks selectively triggered plasticity or changes in efficiency in the specific neural systems underlying the trained cognitive function or increased general factors such as persistence, focus, willpower, or motivation to use the memory (cf., Reuter-Lorenz & Park, 2014).

Our results align with training studies targeting the auditory speech system, demonstrating substantial improvements in measured memory and related cognitive abilities (G. E. Smith et al., 2009; Mahncke et al., 2006; Zelinski et al., 2011). For example, Anderson and Kraus (2013) found that an auditory-cognitive training led to increased memory and processing speed in a sample of older adults compared to an active control group. Other studies also documented improvements in attention, working memory, and immediate and delayed recall (e.g., Ball et al., 2007; Berry et al., 2010; Wolinsky et al., 2013; see, Toril et al., 2014, for a meta-analysis). However, it cannot be excluded that these effects may have been caused or corroborated by modality-specific effects. Notably, both the working memory and the episodic memory tasks are auditory tests, as both tasks required participants to listen to verbal stimuli and memorize them. Therefore, the process-based training (i.e., the dichotic listening training) may have increased attention to and memory for auditory stimuli and thus provided a modality-specific benefit compared to the less auditory based strategy training[1]

[1]We would like to thank an anonymous reviewer for suggesting this possibility..

Neither the process-based training nor the strategy-based training transferred to prospective memory performance. However, it is worthy to note that both training groups maintained prospective memory performance when, in the posttest, the target category changed, while the control group showed a marked decline in prospective performance. This may indicate an increase in cognitive resources for prospective memory as a beneficial effect from cognitive training. Beside this observation, our study aligns with other cognitive training studies with no to weak transfer findings on prospective memory (e.g., (Brom & Kliegel, 2014) or general findings of null transfer effects of cognitive interventions (e.g., Redick et al., 2013; Thompson et al., 2013).

Regarding fluid intelligence, we found a trend of the strategy-based training participants to increase performance in the Raven matrices test, a measure of abstract reasoning. One possible reason for this improvement may be the requirement of the strategy-based training to link two different and seemingly unrelated cues (i.e., the situation or time and the behavior) in a way that makes the retrieval easier (Reuter-Lorenz & Park, 2014). To do so, cognitive resources need to be enacted successfully (Friedman & Scholnick, 2014). Indeed, several studies revealed the moderating effects of cognitive abilities such as working memory capacity (Burkard et al., 2014b), fluid mechanics (Brom et al., 2014), and executive function (Hall et al., 2014) on the efficacy of implementation intentions. We speculate that participants trained their deductive reasoning skills and the recognition of patterns in daily routines with this strategy training, resulting in increased abstract reasoning test performance. Yet, our finding is the only one known to us, where the effect of an intention implementation strategy training on reasoning was measured and, indeed, found to be enhanced by the strategy training.

Transfer to everyday life memory

In contrast to our expectations, we did not find any evidence of transfer of strategy-based training benefits to self-reported prospective memory in daily life. This somewhat contrasts the fact that the strategy-based training improved remembering everyday life intentions. One possible reason for this could be the fact that only healthy older subjects with no memory deficits participated in the study, which reduces the chance that positive changes are experienced in everyday life, in particular when assessed by self-report.

Even though a recent meta-analysis concluded that memory interventions produce positive effects on perceived memory ability in healthy older adults (Hudes et al., 2019; Weng et al., 2019), our result is in line with other studies which failed to find evidence of transfer to everyday memory performance (e.g., Ball et al., 2002).

Limitations and outlook

Besides our small sample size and the resulting weak statistical power (e.g., Karbach & Verhaeghen, 2014; Lawlor-Savage et al., 2016), one limitation, which is due to time restrictions in our experimental setting, is the use of individual tasks to assess pre–post -training changes instead of using construct-level variables (Colom et al., 2013; Shipstead et al., 2012). Furthermore, as participants absolved the training at home, it was difficult to control adherence to training schedule and the level of investment and motivation (earlier studies found rather poor adherence, e.g., Owen et al., 2010). According to incidental remarks of some participants, the training tasks were not perceived as very stimulating. Thus, the training could be optimized by creating more immersive and entertaining training tasks tailored to the preferences of older individuals (e.g., Basak et al., 2008). Finally, this study applied conceptually different cognitive training tasks, which makes it more challenging to compare effects and possible mechanisms, but instead allows practical implications for implemented cognitive trainings (cf. Studer-Luethi & Meier, 2021).

Our results agree with findings from other studies indicating that the efficacy of diverse process- and strategy-based training tasks on cognitive benefits of older adults is not well understood yet. Findings are still piecemeal, leaving many open questions about the modality-specific and general cognitive training effects as well as related mechanisms and neurological changes. More research is needed to determine critical factors of training tasks and to compare diverse training approaches with large samples and extended duration. For example, new promising interventions include everyday memory and metacognitive training combine restorative and compensatory approaches (Henry et al., 2021; Pearman et al., 2020).

Conclusions

Given our growing older population, one important goal is to investigate ways to enhance cognitive health and prolong the independence of older adults. The current study tested a four-week process-based training using dichotic listening tasks, which was never applied in older adults before. Results show that the training participants reached promising improvements in the training task as well as some tendency for enhanced memory performance when compared to a strategy-based training using implementation intention tasks and a no-contact control group. Whereas participants of the strategy-based training group did not show any memory improvements, they demonstrated a trend for increased fluid intelligence. None of the trainings generalized to prospective memory performance and self-reported memory performance in daily life. In sum, the study shows the potential of process-based cognitive training to foster memory performance.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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