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EEG-NEUROFEEDBACK TRAINING AND QUALITY OF LIFE OF INSTITUTIONALIZED ELDERLY WOMEN: A PILOT STUDY

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This pilot study attempted to study the applicability of neurofeedback for elderly persons living in nursing homes. We hypothesized an improve of cognitive functioning and the independence in daily life (IDL) of elderly people by using low beta (12–15HZ) EEG neurofeedback training (E-NFT). The participants (active E-NFT group, *n* = 10; control group, *n* = 6) were community living elderly women without dementia. Neurofeedback training was adjusted ten times within 9 weeks, with a training duration of 21 minutes by use of a single electrode, which was centrally placed on the skull surface. Executive functioning (measured with the Rey and fluency tasks), memory capacity (measured with the 15 words test), and IDL (measured with the Groningen Activity Restriction Scale) were measured before and after ten E-NFT sessions in nine weeks. No effects were found for IDL nor executive functioning. Interestingly, performance on the memory test improved in the experimental group, indicating a possible positive effect of E-NFT on memory in elderly women. This study demonstrates that E-NFT is applicable to older institutionalized women. The outcome of this pilot-study justifies the investigation of possible memory effects in future studies.

Key words: neurofeedback, EEG, elderly, frail population, nursing home, pilot-study, independence in daily life, memory, executive function

In Europe, the life expectancy at birth has increased in the past decennium (2003–2013) from 74,6 to 77,8 years for men and from 80,8 to 83,3 years for women [10]. In 2014, there were 93,7 million people aged 65 or older in Europe [10]. These extra years that people gain, are invariably associated with an increase in age-related problems, such as cognitive decline [33] Some cognitive decline cannot be compensated for by behavioural strategies nor by the environment, which limits the ability to maintain an independent living. Research shows that the decline of social contacts and self-reliance are often the result of cognitive decline, and these are also the strongest factors accounting for a decline in quality of life [38]. Importantly, people in sheltered houses might experience a relatively stronger decline due to a lack of cognitive challenge [29]. Therefore, there is a strong need for methods that might be able to reduce this cognitive decline, especially for people in sheltered houses.

Research has shown that EEG neurofeedback training (E-NFT) might have positive effects on cognition in elderly [27, 30]. E-NFT is a form of biofeedback. Biofeedback is an umbrella term for feedback by an external person or device on processes within the body. Some forms of biofeedback are feedback of heart rate variability, galvanic skin response, muscle traction, temperature of the body. A computer device is connected to a person by means of sensors. The computer provides feedback to the person about the state of the body. In this way, people can learn to control specific elements of their body. If for example the muscle is contracted unconsciously, the feedback mechanism provides the information in an understandable way. After a period of time, the person will start to recognize the contraction of the muscle in a conscious way without the need of an external monitor. In this way, people are also able to achieve postural corrections [12]. E-NFT is a neurophysiological training method for altering brain activity. Like other forms of biofeedback, it is commonly thought to be based on the principle of operant conditioning [32]. Operant conditioning is a key ability of neural systems to link the contingency of the reward signal to the probability of a future reward [1, 16, 20]. In E-NFT, EEG is recorded from scalp electrodes, presented to the subject by means of a monitor. Positive feedback (reward) is presented whenever the subject shows an intended EEG pattern change for a defined duration of time. It is assumed that the brain can hold and stabilize the modulated state of brain activity beyond the temporarily achieved lab outcome; however, the specific underlying mechanisms of E-NFT efficacy are still unclear [16, 17]. Recently, other theories have been generated about the working mechanism of neurofeedback. Ros et al. theorized for example that E-NFT tunes brain oscillations toward a homeostatic set-point which affords an optimal balance between network flexibility and stability [24].

Research has shown benefits of E-NFT, such as enhancing beta activity in the frontal brain [8, 39, 40], improving Default Mode Network connectivity [25] as well as improving cognitive functions such as memory [34] and attention [6]. Nevertheless, other studies describe changes in EEG after E-NFT without changes in cognitive performance [9]. Recent publications also question the relevance of E-NFT for clinical treatments [31]. The main question in these critical publications is whether E-NFT is superior to placebo. For the current pilot study, we did not perform sham training, as our main purpose of the study is to examine whether E-NFT is applicable for the frail persons with long term care.

Studies in elderly people found an increasing trend of theta amplitudes for the E-NFT group only [37], an increase of power in the gamma and beta band within training sessions [27], as well as improvement in attention [37], and verbal IQ [3]. However, others found no improvement in attention or memory at all [27]. Current results are inconclusive and a clear overview of the beneficial effects in aging populations is lacking, especially in elderly living in sheltered houses. This is a crucial limitation as elderly in sheltered houses are in general of a very high age and at an increased risk of future cognitive decline [29].

Current research. The present pilot study investigates whether quality of life and cognitive functioning of elderly women can be improved by E-NFT by specifically rewarding central low beta (12—15 Hz) activity [28, 34]. T. Egner et al. found that an increase of 12—15 Hz activity was correlated to a decrease in impulsive responses and p300 amplitudes [6]. For this study, an increase of memory and executive functioning after treatment was hypothesized for participants following E-NFT training, but not for the control group. In addition, as cognition (particularly executive control and memory) is a crucial predictor of independence in daily living [23]. We expected that an improvement in executive function and / or memory would also positively influence independence in daily life (IDL).

Materials and methods

The participants, elderly women without dementia, were recruited in two sheltered houses located in the Randstad area (a modern urban agglomeration), the Netherlands. The mailing lists, which consisted of 67 addresses of both houses, were made available by the managing board. This study as approved by the institutional review board (Scientific and Ethical Review Committee at the Faculty of Psychology and Education — VCWE). An informed consent with an invitation for an information meeting was sent to the included addresses. In the meeting, the experimenter explained the aim of the study and the practical aspects, like how E-NFT is performed, and answered questions of participants. Subsequently, all subjects were individually invited to participate. A total number of 12 persons showed interest in active participation. Although this lead to a selection bias, the researcher decided to include these participants in the experimental group to have a minimum of 10 persons for the E-NFT procedure. Other residents were invited to participate in two assessments of cognitive functioning. Of these residents, 6 agreed to participate in this control condition. This resulted in 12 female subjects in the E-NFT condition and 6 female participants in the control condition.

At the start of the measurement two participants dropped out due to personal reasons. As a result, the study started with 10 participants in the E-NFT condition and 6 — in the control condition. After two training sessions a third participant cancelled for health reasons. However, this one was replaced by a new participant, so that the number of participants remained 10 for the experimental condition. The average age of the participants who completed the study in the experimental condition was 77,9 years (standard deviation — *SD*=7,8) and the average age of the participants in the control condition was 79,2 (*SD*=6,9) years.

Procedure. The measurement for both the E-NFT- and control group consisted of the seven-minutes screening test, the fifteen words test, two verbal fluency tasks, the complex figure of Rey, and the Groningen Activity Restriction Scale [19]. The seven minutes-screening test was only performed to exclude the possibility of including people with dementia. There were no indications for dementia for both the experimental nor control group. Between pre- and post-measurement of cognitive abilities, participants in the control group did not receive any training. The participants in the experimental group were then given ten training sessions of 21 minutes. We based the number of sessions on earlier studies. Research showed that a minimum of eight trainings of fifteen minutes is enough to enhance low beta activity [34]. In other studies with healthy subjects, ten training sessions of fifteen minutes were being performed [6]. The training was done once or twice a week over a period of nine weeks. After all the participants in the E-NFT group finished 10 training sessions, post-assessment evaluations were done. These consisted of the same neuropsychological test battery tests as the pre-measurement, with the exception of the seven minutes-screening test, which was only used as a screening tool for potential dementia.

The *Seven minutes screening test* is originally designed to detect persons at high risk of Alzheimer's dementia but also detects other dementias [22]. It consists of a number of questions tapping orientation, a memory test in which images have to be remembered, clock drawing and verbal fluency.

Category and letter fluency. The participant is asked to name as many words within a particular category or starting with a specific letter. For this study, animals (word fluency) or words starting with the letter N were used (letter fluency). Fluency tasks are seen as executive function tasks [5]. For the post training test, a parallel list of the test was used, in order to reduce learning effects.

The auditory verbal learning test (RAVLT) is an auditory verbal learning test in which the experimenter reads aloud 15-words of different categories and unrelated to each other. The subjects are asked to memorize the words and reproduce them (immediate recall, RAVLT-ir). The total scores of the 5 trials are summed. Unexpectedly, the experimenter asks to recall the words again after 20 minutes (delayed recall, RAVLT-dr). For the post training test, a parallel list of the test was used, in order to reduce learning effects. The test is designed to detect memory problems, both in the short- and long term.

The complex figure of Rey is a test in which the figure of Rey must be redrawn unexpectedly after a short presentation to the participant [35]. The subject is given a card with the figure, a blank sheet of paper and a pencil. The experimenter calculates a score on the basis of the order of drawing, the number of deletions, and the number of interruptions. The complex figure of Rey is seen as an executive function task.

Groningen Activity Restriction Scale. This scale measures IDL, including both the ability to perform «Activities of Daily Living» (ADL), such as toileting, as well as «Instrumental Activities of Daily Living» (IADL), such as cooking, and is measured by 18 questions that can be scored on a 4-point scale ranging from «yes, I can do it fully and independently without any difficulty» (1) to «no, I cannot do it without someone's help» (4) [26]. The scale was developed by the Northern Centre for Healthcare Research as part of the Groningen Activities Restriction Scale (GARS) [19].

Experimental setup. A 4-channel Deymed BFB III system was used for the neurofeedback training. A 1 Hz high-pass- and 60 Hz low-pass filter and notch filter of 50 Hz were used, impedance was kept below 5 kΩ. The sampling rate was 128 Hz, the system was connected to a laptop computer via BFB III software and output was projected to a LCD monitor. Training was aimed to enhance 12—15 Hz beta activity (low beta) within the range of one centrally located electrode (location Cz according to the international 10—20 system for electrode placement [18]). In order to control for rewarding for possible facial muscle contractions, an increase of 35—45 Hz frequency band activity overruled the increasing 12—15 Hz activity. In case artefacts of EMG or EOG were too prominent according to the trainer, people were instructed to relax. There was no averaging of EEG data, which practically meant that subjects received real-time EEG feedback as long as the state continues for a minimum of at least 1 second. Each training session took approximately 21 minutes, consisting of 7 different three-minute game sessions. There were fixed individual parameters and participants were encouraged to score as many points as possible. Parameters were set in the first training session, where each participant reached a score of 15 points during the game session.

Both discrete and continuous auditory and visual feedback of EEG parameters was offered to the subjects. An example of continuous visual feedback is a videogame in which a dolphin swims as soon as the activity of both 12—15 Hz is increased and 35—45 Hz is inhibited for at least 1 second. If this situation endures for longer than one second, a score of one is being earned, which is accompanied by an auditory rewarding sound. The latter is known as discrete feedback.

Design. A 2×2 mixed design was used for the current study, with group (experimental group and control group) as between subject factor and time (pre- and post-intervention) as within subject factor. Scores on the neuropsychological tests were used as dependent variable.

Data analyses. The data were analyzed using SPSS version 22.0. A Mann—Whitney *U*-test was used to check for differences in age between the two groups. After the pretest, equality of the groups for the outcome neuropsychological testing was analyzed by means of MANOVA. The data were further analyzed by Bonferroni corrected repeated measures ANOVA analysis, with group as between subject factor, time (pre-, post-intervention) as within subject factor, and neuropsychological test performance as dependent variable. After, these repeated measures analyses were repeated for each group separately. The scores on the Rey were converted. Therefore, a higher score meant enhanced performance for all tests. A $p>0,05$ was considered significant in all analysis.

Results and discussion

A Mann-Whitney test indicates equality of the age within the groups (Mann-Whitney $U=25$, $N1=10$, $N2=6$, $p=0,64$, two-tailed). Prior to the E-NFT training, the experimental group and the control group both underwent baseline measurement. There was no difference between the groups in terms of performance on the neuropsychological test battery (F (5,10)=0,74, $p=0,61$; Wilks' Lambda=0,71) at baseline.

The repeated measures ANOVA test showed no main effect of group and also no interaction effect between group and time for any of the performed tests (RAVLT-ir, RAVLT-dr, Word fluency, Letter fluency, Figure of Rey and IDL), see *Table*.

Due to the low number of participants, the experimental power is low. A further analysis therefore looked at the differences between baseline and post-test within the separate groups by means of repeated measures analysis of neuropsychological test results. For the E-NFT group, a significant difference was found between baseline and post-test for respectively the RAVLT during both immediate recall and delayed recall F (1,9)=3,91, $p=0,07$, $\eta^2=0,30$, F (1,9)=6,86, $p=0,05$, $\eta^2=0,43$. No difference was found for the control group; F (1,5)=2,64, $p=0,165$, $\eta^2=0,35$ for immediate recall and F (1,5)=1,875, $p=0,23$, $\eta^2=0,27$ for delayed (see *Figure*). The aims of this pilot study were to investigate whether E-NFT is applicable for frail elderly and whether the quality of life and cognitive functioning of elderly can be improved by using E-NFT. We can conclude that E-NFT is applicable for the group of elderly who live in nursing homes. No interaction effects between the E-NFT and control group were found for the cognitive tests while analysing both groups at the same time. This means that further analysis is not justified to claim any training effects. However, as the nature of this research is a pilot investigation, the effects for both groups were also separately calculated. A significant increase of immediate recall of new words of the 15-words test was found, as well as for the delayed recall process, specifically for the E-NFT group, when analysing the effects for both groups separately. This suggests that there is reason for further studies with more participants to prove whether E-NFT could have a positive effect on memory in the group of institutionalized elderly women. This would be in accordance to the findings of a transferable effect of E-NFT on verbal IQ [4] and contradicts the suggestion that the effect of E-NFT on brain activity is not transferrable to performance on cognitive tasks [27].

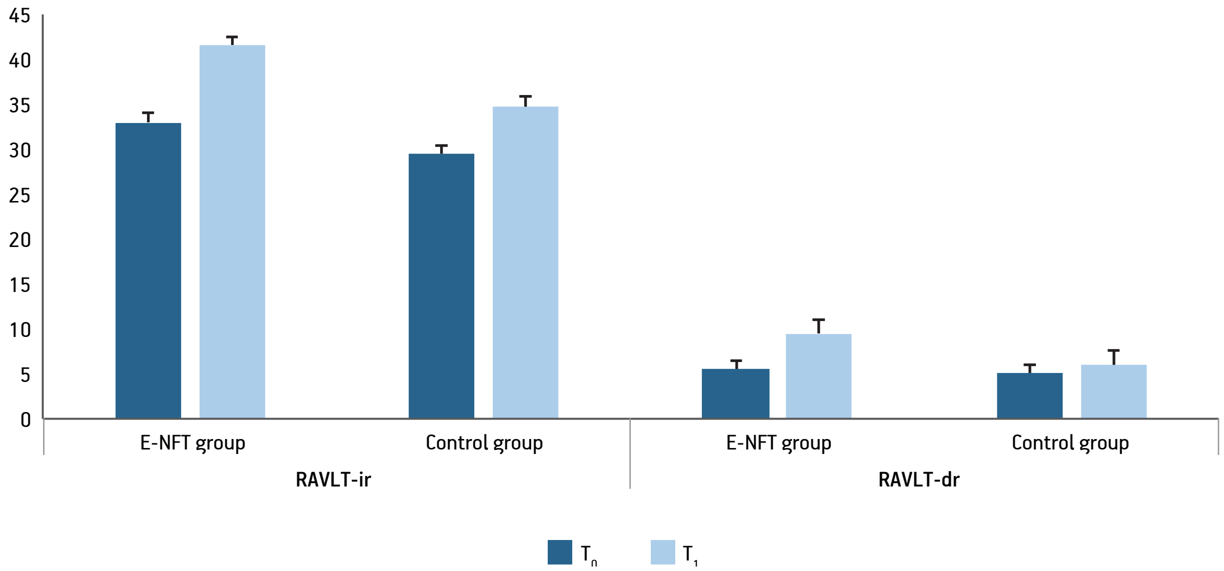
This study did not find an effect on executive functioning, like others did [37]. Furthermore, the difference in improvement on IDL between the experimental and the control group was not significant. The lack of significant results might have been influenced by the lack of power in this experiment due to the relatively low number of participants. It could also be that E-NFT has a more subtle effect on executive functioning or IDL (perhaps via its effect on memory).

There are limitations to this study. We used a pseudo experimental design without randomization to measure the effects of E-NFT on cognitive function

Average scores and results of the repeated measures analysis per test

Test	T_0 E-NFT	T_1 E-NFT	T_0 controls	T_1 controls	$F_{interaction}$	p	η^2
RAVLT-ir inculcation	33,0 (6,9)	41,6 (15,7)	29,5 (13,4)	34,7 (13,4)	0,31	0,59	0,02
RAVLT-dr	5,5 (3,1)	9,5 (4,8)	5,0 (3,2)	6,0 (4,2)	2,09	0,17	0,10
Word fluency	18,9 (5,3)	17,8 (7,1)	20,2 (3,3)	19,0 (2,9)	0	0,98	0
Letter fluency	9,1 (4,6)	10,1 (5,0)	10,7 (5,0)	9,7 (2,7)	1,09	0,31	0,08
Rey	6,7 (2,6)	9,4 (9,7)	8,3 (1,4)	7,3 (2,3)	1,12	0,31	0,07
IDL	32,6 (15,1)	31,6 (16,4)	33,0 (12,4)	32,7 (12,1)	0,14	0,71	0,01

Notes. Scores at T_0 and T_1 represent mean ± standard deviation; RAVLT-ir — Auditory verbal learning test immediate recall; RAVLT-dr — Auditory verbal learning test delayed recall; Rey — Complex figure of Rey; IDL — Independence in daily life; E-NFT — beta 1 EEG neurofeedback training; T_0: pre-intervention; T_1: post-intervention; η^2 — Effect size (Eta squared).



Difference between baseline (T_0) and post-training (T_1) performance on the RAVLT, immediate recall (RAVLT-ir) (left) and delayed recall (RAVLT-dr) (right), for both the E-NFT and control group.

Error bars represent standard error of the mean. E-NFT — beta 1 EEG neurofeedback training; RAVLT — auditory verbal learning test; T_0 — pre-intervention; T_1 — post-intervention

and independency in daily life. For ethical reasons, to avoid burden for the frail group of participants, there was no active sham group and participants were asked to choose between receiving E-NFT or the control treatment. This may have caused a selection bias, as subjects in the E-NFT group might have been more motivated to perform well on tasks and are probably more active in trying to improve their cognitive functioning than the control group. Furthermore, the researcher was not blinded for the research condition either, which might have led to experimenter's bias. In addition, the sample size was low, as only ten subjects were part of the E-NFT group and only six for the control group.

Nevertheless, this study gives some indication of a positive effect of E-NFT on memory and provides proof of willingness of elderly subjects to try E-NFT.

Further research should consider including comparison of resting state versus post-training neuroimaging measurements or an active sham training for the control group. For our present study we cannot be certain that the provided training successfully changed 12–15 Hz activity. For some aspects of cognitive decline in elderly, another E-NFT protocol might be more effective. For the specific age related cognitive decline there might be other possible protocols, depending on the health state of the person. For example, there are several studies which indicate an association between increased theta activity to cognitive decline [11, 14, 15]. M. Grunwald, for example, found a negative correlation between theta power and hippocampal volume in elderly in different stages of cognitive decline. On the other hand, there have also been studies which show a positive correlation between theta power and cognitive performance in healthy elderly [2, 21, 36]. S. Elmsthåhl and I. Rosén found that low beta-band power activity is associated with vulnerability for future cognitive decline in the population of elderly women [7]. Beta band power in the occipital regions is related to visual attention according to the studies of M. Gola et al. [13].

Future studies including neuroimaging can be helpful to track possible changes in brain activity to understand more about the direct and indirect effects of E-NFT. Besides, more specific executive capabilities tests should be used to exam the effect of E-NFT on executive functioning in more detail, such as the n-back or a Go- NoGo-task, as executive functioning consists of multiple dimensions. In addition, a larger sample is necessary to compare groups by age and to avoid a lack of power; potentially, neurofeedback may actually enhance cognition and independence of daily life to a stronger extent than was demonstrated in the current study. Finally, as only female participants volunteered for and completed this study, it is unknown whether the current findings pertain to older male adults as well. Future studies should try to incorporate both male and female participants.

Conclusion

The current study provides proof of willingness of elderly subjects to try E-NFT. The study provides some indication of a positive effect of E-NFT on memory and therefore justifies further investigation in future studies. Both cognitive health aspects of participants and individual goals should be taken in account for future E-NFT studies or experimental clinical treatments.

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ТРЕНИНГ НЕЙРОБИОУПРАВЛЕНИЯ И КАЧЕСТВО ЖИЗНИ ЖЕНЩИН ПОЖИЛОГО И СТАРЧЕСКОГО ВОЗРАСТА: ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ

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В этом экспериментальном исследовании предпринята попытка изучения применимости тренинга нейробиоуправления для пожилых людей, живущих в домах престарелых. Мы предположили, что использование низкочастотной составляющей ЭЭГ (бета-версия 12–15 Гц) и обучение биологической обратной связи (Э-БОС) улучшит когнитивные функции у пожилых людей и увеличит их независимость в повседневной жизни. Участники (экспериментальная группа Э-БОС, $n = 10$; контрольная группа, $n = 6$) — женщины пожилого и старческого возраста без деменции, проживающие коллективно. Тренинги нейробиоуправления был проведены в течение 9 нед 10 раз — продолжительность занятия 21 мин с использованием одного электрода, размещенного на поверхности черепа в центре. Функции памяти и мышления (определяли по тесту Рея и заданиям на беглость речи), объем памяти (измеряли с помощью теста 15 слов) и независимость в повседневной жизни (определяли по шкале Гронинген ограничения активности) были измерены до и после десяти занятий Э-БОС в течение 9 нед. Влияния на независимость в повседневной жизни и когнитивные функции выявлено не было. Интересно, что результативность в тесте памяти улучшилась в экспериментальной группе, что указывает на возможный положительный эффект от занятий Э-БОС на память у женщин пожилого и старческого возраста. Данное исследование доказало возможность применения методики Э-БОС для пожилых женщин. Результаты этого пилотного исследования обосновывают дальнейшее изучение возможных эффектов на улучшение памяти.

Ключевые слова: *нейробиоуправление, ЭЭГ, пожилые люди, ослабленное население, дома престарелых, пилотное исследование, независимость в повседневной жизни, память, когнитивные функции*