Can cognitive function be improved with physical and/or mental exercise?

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Abstract

The effect of exercise on cognitive functions has long been explored. Here evidence is gathered to compare the effect of physical exercise with mental exercise on cognitive function in elderly. This thesis concludes that physical exercise as well as mental exercise seem to have a positive influence. Mental exercise is mostly only effective on the specific task practiced, while physical exercise has a more generalized mode of action. Due to this knowledge, hence one can say that physical exercise is a better investment, albeit one can consider them both useful. In order to use the positive aspects of both mental and physical exercise, training programmes with these multimodal exercises are more and more explored. This combination of mental and physical tasks multiplies the effects that can be gained. Exploring this type of exercise combinations may be very meaningful.

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1. Introduction

We all know that our bodies change when we grow older and it is also common knowledge that the brain changes during our lives. As shown in figure 1, our core cognitive functions (also known as fluid intelligence) (**BOX: Glossary**) show a decline over the years. The decline of fluid intelligence is in contrast to crystallized intelligence (which is another term for knowledge), what increases in the process of aging (Park and Bischof, 2013).

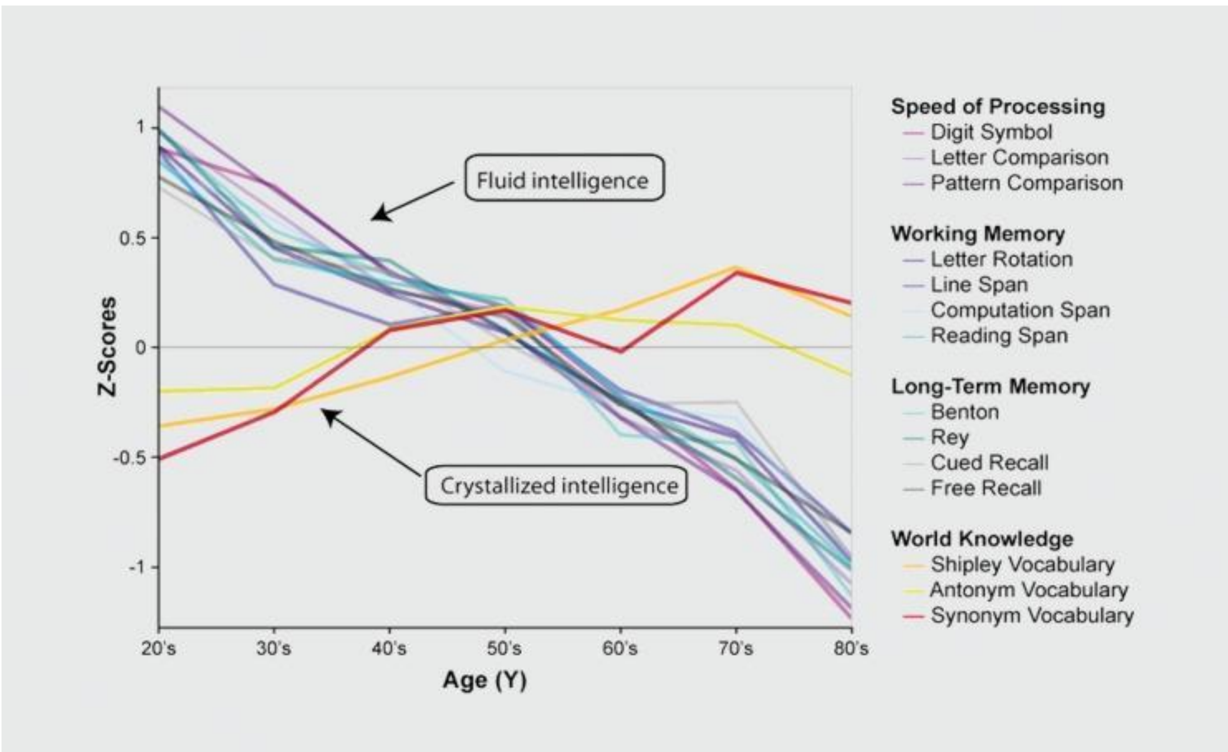

Figure 1. This graph shows cross-sectional aging data of speed of processing performances. Almost all measurements of cognitive functions, also known as fluid intelligence, shows decline with age. Only world knowledge or crystallized intelligence, demonstrates improvement (Park and Bischof, 2013).

This reduction of cognitive function is a natural occurring process; nevertheless research is done to find ways to reduce this decline. What is the best way of keeping our mental state or cognitive function healthy, or in other words: what is the best way of preventing mental decay? It is well known that sporting and physical exercise is good for your body and health. Also playing games, like board games, chess, brain games and mind games are assumed to raise our cognition and keep our mental health stable. Can cognitive function be improved with physical or mental exercise? Here evidence is gathered to find if there is cognitive improvement by exercise, physically or mentally.

This knowledge can be of great importance. Think about senior citizens, can they better perform sports, perform yoga or walk for a while or can they better play some chess, computer games or make some cognitive tasks to enhance their cognition? In this age category sporting has a relative high injury risk; elderly have a greater chance of falling or hurting themselves, sometimes elderly are scared of injuries and in addition it takes a great effort to provide sports for elderly who cannot take care of themselves anymore. Another factor is the increasing longevity of the modern man. With the raising of retirement ages, people need to work longer. To support working performance, one can possibly induce their cognition by exercising.

This is a question which is of economical interest as well as of social interest. Especially now the proportion of elderly people in western countries is growing, it is important that healthy aging is being explored and therefore being able to control the spiralling health costs and to provide for the emotional well-being of both elderly as well as their families. The main question what is to be answered is: What kind of exercise is most appropriate in improving cognitive function at old age: Physical exercise, mental exercise or maybe a combination of both? To answer the question, physical and mental exercise will be explored with recent information and thereafter results will be compared. The background information used comes from textbooks and articles, the rest of this thesis will mostly be based on recent articles from 2012 or more recent. In this thesis, the focus lies on the effects of physical exercise on cognition in non-pathologic humans above an age of 55. The

BOX: Glossary

Cognition = Cognition is a term paraphrasing mental or intellectual processes whereby an individual becomes aware of something or obtains knowledge. In general it is the faculty for processing of information, which can occur consciously or unconsciously (Boundless, 2013). Cognitive functions define metal functions (like memory and perception) and mental processes (like thoughts and problem solving). Cognitive thinking is a state which indicates intelligent entities (Blomberg, 2011).

Processing speed (PS) = Processing of speed, also known as speed of processing is an cognitive ability measuring the speed with which one individual executes a cognitive task. Mostly is processing speeds measured on elementary cognitive tasks (Takeuchi and Kawashima, 2012).

Stroop test = Stroop test or Stroop task is an test wherein the subject must read a list of words or identify colours presented with varying instructions and different degrees of distraction (Barella et al., 2010). The Stroop test is a widely used assessment tool for testing executive function and cognitive quickness, which is generally accepted (Levine et al. 1995).

articles are classified by the type of study. First general influence of (physical or mental) exercise will be discussed, using reviews and meta-analyzes. Secondly the influence of (physical or mental) life-long practice, long-term practice and one-off exercise or activity will be described using recent articles.

2. Physical exercise

There is a wide range of studies that examine the connection between cognitive function and physical exercise. A distinction can be made between types of physical exercise. Aerobic, stamina, flexibility and balance training are merged as one side of the spectrum. Strength and muscle training is another type of physical exercise. If possible, depending on the presence of adequate articles, a comparison between strength and aerobic training will be made.

2.1. General findings considering Physical Exercise

The correlation between physical exercise and cognition has been studied extensively. Even with MeSH-filters, searching yields 534 hits using "Cognition" and "Physical exercise" in the search engine "Pubmed" (08-07-14). Most of the studies have similar results, namely that physical exercise has a positive effect on cognition. A predominant number of review articles revealed that physical exercise, including resistance training as well as aerobic training, might reduce or prevent cognitive declines (Colcombe and Kramer, 2003; Brisswalter, Collardeau, and Arcelin, 2002; McMorris and Graydon, 2000).

The role of physical exercise on cognition is nowadays well studied and documented, however the effect of physical exercise on cognition in elderly is still under debate. Ample reviews have been written to gather, compare and criticize this particular area of interest (Gligoroska et al*.,* 2012; Snowden et al., 2011; Tseng et al., 2011; Shoshana et al., 2012; Chang et al., 2012; Smith et al., 2010; Sofi et al., 2011). This topic is a bit more specific than the overall influence of exercise on cognition, nevertheless the great plurality of the reviews and articles have corresponding findings. Different reviews collected and criticized articles that were published in previous years and all concluded that physical exercise was beneficial for cognition, mostly improvements in executive function, memory, attention and processing speed (Chang et al., 2012; Tseng et al., 2011; Shoshana et al., 2012). One review even concluded that all levels of physical activity significantly protects against the occurrence of cognitive impairment (Sofi et al., 2011).

A meta-analysis found that physical exercise in general was beneficial for cognition in untrained elderly (Shoshana et al., 2012). This positive correlation was supported by some reviews. One focussed only on resistance training (Chang et al., 2012) and other reviews focussed on aerobic exercise only (Tseng et al., 2011; Smith et al. 2010), however they all confirmed the positive correlation between physical exercise and cognitive improvement.

Although most of the articles and reviews render that exercise has a positive effect, one should not to jump to conclusions. Researchers found that there was not enough evidence to validate the positive effect of exercise on cognition. Mostly because of the low quality of the research programmes or extremely small sample sizes (Snowden et al., 2011). One other review concluded that no serious robust evidence was found for exercise-dependent structural changes in elderly. The only established evidence, not influenced by failures in statistical methods, experimental design and methodological artefact, is the appearance of changes in the anterior hippocampal volume correlated to training (Thomas and Baker, 2013). Also the effectiveness of resistance training is being criticised. One review did conclude that aerobic training was effective, however resistance training did not show to have enough evidence (Gregory et al., 2013). These reviews can point out that research is done insufficiently or that the influence of exercise is possibly less potent than was assumed all the time.

Considering the fact that reviews use published articles, it can occur that older information can be used to make a statement. For instance, Snowden et al. (2011) used articles ranging from 1985 till 2008. Due to this, older information or the lack of new information, can possibly change statistics and indirectly influence the outcome of the review and create a distorted view. One using reviews should consider this and be aware of the fact an study or review cannot be completely unbiased. Furthermore while reviewing the articles, the authors, institutions and journals were not blinded, whereby biases possibly could have occurred (Snowden et al., 2011). This shows that also reviews are not fully reliable, which might mean that articles that were rejected by the reviewers, were eventual still useful.

Logically newer articles are not yet included in these reviews, but can nevertheless still contain interesting information. To give voice to new publications, a solid amount of various, new articles will be shown below.

2.2. Life-long physical exercise

To investigate the long lasting impact of exercise, researchers examined if former master athletes had a reduced decrease of brain area density and cognitive impairment. One research compared fMRI scans and behavioural tests from elderly master athletes, with sedentary elderly and healthy young controls (Tseng et al., 2013). They found that although brain volume, density and cognition was impaired compared to the young control group, the master athletes still had a major advantage over the sedentary elderly. They found that the gray and white matter density in master athletes was significant higher than in sedentary elderly. Also in the cognitive tests the athletes outperformed the sedentary elderly. Notwithstanding the small sample size, this study is evidence for a relationship between exercise and cognitive function (Tseng et al., 2013).

To support the assumption that higher fitness benefits cognitive function, researchers examined the link between overall fitness and cognition. Maximum walking speed as overall fitness level was measured. Each participant applied for 5 different cognitive tests, whereby 2 of the tests (IST and TMT-A) found a significant correlation between a low maximum walking speed and a lowered score in psychomotor speed and verbal fluency. They also found that participants with a lower maximum walking speed baseline had a greater reduction in cognitive function over seven years (Soumaré et al., 2009).

Another study from Netz et al. (2011) confirmed the positive effect of physical fitness on cognition in elderly. 38 elderly performed a computerized cognitive task and an exercise test, where after they were divided into fitness level, by VO_2 (the maximum oxygen consumption) and physical activity level. A significant correlation has been found between executive function, attention, global cognitive score and VO_2. Furthermore a significantly better score on reaction time and global cognition score was achieved by the moderately-fit group compared to the low-fitness group (Netz et al., 2011). These findings confirm that elderly, even in advanced age, with increased aerobic fitness are associated with a raised cognitive function.

All these articles above point out to be strong evidence confirming the prevailing theory of improvement of cognition by long-term exercise. According to these findings, even at old age, exercising pays off for increasing cognitive function.

2.3. Long-term physical exercise

Muscari et al. (2010) examined the influence of long-term chronic endurance training in healthy older adults (Muscari et al., 2010). A group of 120 healthy elderly were categorized in a control group and an endurance exercise training (EET) group. The exercise group trained three times a week for one hour per training for one complete year. In advance of the experiment the exercise and control group both made a Mini Mental State Examination (MMSE) and also after the experiment a MMSE was made by both groups (Tombaugh and McIntyre, 1992). Although the exercise group did not show improvement in results, comparing the MMSE of both groups, the control group did show a reduction of cognitive abilities compared to the exercise group. The control group especially had a dramatic impairment in: language (performing a written command and reading), attention and calculation and temporal orientation. These findings show that long-term exercise may decrease the progression of cognitive decline by age (Muscari et al., 2010).

Muscari and co-workers showed that endurance training can improve cognitive abilities, but other researchers like Fallah et al. (2013) show that resistance training can induce cognitive improvement as well. They made a likewise twelve-monthly clinical trial whereby 155 women between 65 and 75 years were randomly grouped in resistance training or balance and tone training. The performance on the Stroop test (**BOX:**

BOX: What is plasticity?

Cajal (1894) conceived the idea that the dynamic changes in the brain were related to mental processes and activity and called this process plasticity (Mora et al., 2007). The concept of neuroplasticity developed over the years. Now brain plasticity, also known as neuroplasticity is an umbrella concept referring to changes in neural pathways and neural connections due to changes in neural processes, behaviour, environment and physical injury (Pascual-Leone et al., 2005). The term neuroplasticity includes synaptic plasticity and non-synaptic plasticity, as well as cellular changes due to learning or large-scale transfer of function, also called functional plasticity. Plasticity enables the nervous system to modify function and structure in response to environmental requirements. Input cause the brain to change via the strengthening, weakening, pruning, or adding of synaptic connections and by promoting neurogenesis (Mora et al., 2007; Pascual-Leone et al., 2005).

Researchers have found that plasticity varies with age, whereby plasticity in average gets reduced in the aging brain. Although the reduction of neuroplasticity is linked to development of diseases, ageing however is not a disease. Healthy ageing is the process wherein an individual ages without the manifest of diseases. The ageing of the brain is a complex physiological process that can develop without the appearance of simultaneous diseases, although it is linked to the subtle decline of motor, sensory and cognitive functions (Mora et al., 2007; Pascual-Leone et al., 2005; Pascual-Leone et al., 2011; Burke and Barnes, 2006).

Glossary) was scored in pre-trial and post-trial. The individuals in the balance and tone training demonstrated a significantly worsened performance on the Stroop test to the resistance group. Especially conflict resolution and selective attention was improved in women in the resistance training than the balance and tone training. Another interesting result they found was that women with a greater baseline cognitive function responded stronger to the trial resulting in general better Stroop test scorings. This higher baseline cognitive function is known to be correlated to higher education (Van der Elst et al., 2006) and to higher Stroop test scorings after exercise (Fallah et al., 2013). Soumaré et al. (2009) found similar results of stronger regression in individuals with a lowered baseline. These taken together are strong indicators for different cognitive decline depending on cognitive function baseline. Therefore it can be possible that different types of exercise or strategies are needed to target different groups and patients.

The results of Fallah et al. (2013) were confirmed by the findings of Liu-Ambrose et al. (2012); resistance training promotes functional plasticity (**BOX: What is plasticity?**) in elderly. Plasticity is important for improving cognitive function by alternating structure and function in response to some type of external stimuli (Park and Bischof, 2013). Maintaining cortex plasticity is essential for seniors and ageing in a healthy manner. Two regions of the cortex, associated with response inhibition, were functionally changed after twice-weekly, twelve months resistance training. This was detected together with a significant improvement in the Flanker task performances, what registers the hemodynamic activity in the cortex regions which are associated with response inhibition processing. This suggests that the Flanker task performance is improved by the decrease of response inhibition (a component of executive function) deposition and that there is a higher involvement of response inhibition when needed. This taken together suggests that resistance exercise has a positive influence on functional cortical plasticity. The increase of functional plasticity was only seen by participants who trained twice a week, however participants who trained only once a week did not show significant effects on the Flanker tasks and hemodynamic activity in the cortex (Liu-Ambrose et al., 2012).

Also a shorter fitness program of three months twice-weekly results in improvement in cognitive function. 65 randomized participants anticipated a progressive resistance and balance training, which was designed to strengthen muscle groups and increase balance capacity and 54 of the participants contributed as control group. Both groups performed mental health tests and task-switch reaction time trials. Kimura et al. (2010) found that mental health scale was significantly improved for the fitness group compared with the control group. However the response rate and corresponding task-switch reaction time did not improve. This indicates a modest effect of cognition due to short-term strength training (Kimura et al., 2010). Of note, this contradicts the findings of Pennington and Hanna (2013).

2.4. One-off physical exercise

According to the articles below, getting improvements in cognition, one does not necessary has to train for long periods of time: even shorts bouts of exercise do have an effect on cognition. Pennington and Hanna (2013) showed that cognitive performances in healthy older individuals can be improved by acute exercise. 30 older adults participated, whereby one training of 40 minutes of moderate aerobic exercise was performed. To acquire speed of decision making, speed of thought and reaction time, each participant made a Stroop test in advance of the exercise and afterwards. Comparing the results of the pre- and post exercise tests, exercise shows to have an increasing effect on mental processing speed and a reduction of reaction time. All subject showed an improvement in the test scores, indicating an improvement in cognitive ability. These results were confirmed by Barella et al. (2010), whereby participants randomly were assigned to do twenty minutes of exercise and make a Stroop test pre and post exercise. Also in this study participants performed better after exercise in making colour tests. However they did find significant differences in inhibition test performances. They suggest that short bouts of exercise in old people only has short-term benefits in speed of processing, but does not improve other aspects of cognitive function (Barella et al., 2010).

3. Mental Exercise

In contrary to the influence of physical exercise, the influence of mental exercise is oddly enough barely examined. The lack of research is perhaps due to the complexity of making a sufficient experimental design or perhaps to the fact that more interest is in other fields of science, nevertheless mental exercise is still an exciting domain to explore.

To get enough articles to compare with physical exercise, the terms “mental exercise” as well as “mental activity” has been used to find proper related articles. The difference in definition consist in the fact that mental exercise is a knowingly action taken place intended to enhance cognitive function. Examples of mental exercise used are brain games or exercises designed to investigate mental exercise on cognition. Mental activity on the other hand can be interpreted as activity performed by the unconscious part of the brain for keeping fundamental functions operating. This form of activity is not being examined in this thesis. Mental activity can also be described as activity performed by an individual whereby cognitive function is required while not intending to enhance it. Examples of mental activity are playing or listening to music, playing chess, making a crossword or another kind of puzzle. The distinction of activity and exercise is not always clear, while someone can for instance play a crossword puzzle intending to enhance his or her cognitive function. Therefore is this thesis based on the influence of exercise and will where possible use mental exercise as fundament. There can be revert to mental activity if few articles are extant.

3.1. General findings considering Mental Exercise

A broad range of various examinations has been done on cognition and how to improve it with exercises. Ranging from exercises like chess and playing music till specialised cognitive tasks guided by professional neurospecialists. Mostly studies have focused on training a certain type of cognitive skill through practice, and in the end of the training period, comparing the measurements on improvement. Most of the studies focus on the behavioural improvement, like working memory capacity or speed of processing, although also studies have been done on the physical changing of neural tissue and activity (Park and Bischof, 2013). Meta-analysis found that cognitive function can be enhanced with training (Gross et al., 2012; Park and Bischof, 2013) unfortunately these gains were only limited to the specific trained tasks. An improvement of tasks which use similar processes, was likely to be possible, but evidence was strongly limited (Park and Bischof, 2013).

A systematic review found that computer based exercises were sufficient enough to improve cognitive function. Thereby elderly did not necessarily have to have technical knowledge to benefit from computer based training. These computer based exercises were in general more effective than traditional paper-and-pen exercises (Kueider et al., 2012). Inconsistently other research found that engaging challenging activities, which active core cognitive processes, are probably more effective than computer-based techniques (Park and Bischof, 2013). In this matter Kueider et al. (2012) seems to be more reliable because of the strict elimination of articles and critical view, while Park and Bischof (2013) only reflects the articles used.

Even though it is not completely clear which technique is most effective, it might be possible that training which provided moderate strategies is associated with larger memory improvement. It seems that the total number of taught strategies was linked to the enhancement of task results. Although this finding was not significant after adjustments for comparisons (Gross et al., 2012). This finding corresponds with the finding that more variety in a study protocol causes a larger scope of results, which leads to the hypothesis that more strategies in memory training causes to have more robust effects (Gross et al., 2012).

However, these are the only and most fitting articles in this specific area of interest, summarizing and reviewing other articles. To create a better overview of existing studies done in cognitive function induced by mental training, short recaps of recent findings will be displayed.

3.2. Life-long mental exercise

Unlike studies in physical exercise, the influence of life-long mental training on cognition has not yet been examined. Probably because of the relative new area of study, hence it is not possible to examine life-long influences of cognitive training in elderly. Nevertheless it is possible to compare elderly who have practiced cognitive demanding tasks intensively over their life, with regular elderly. For instance: comparing retired professional chess players or highly educated professors with common retired elderly in a cross-sectional study. This particular kind of research is lacking.

Nonetheless research did reveal that cognitive gains by mental exercises did maintain over a longer period. Even till five years after the training period, results were still remained (Gross and Rebok, 2011; Ball et al., 2013). Memory gains were maintained, however reasoning and speed of processing lost more than half of their original gains after five years (Jones et al., 2012).
These five years of enhancement could even be amplified by monthly boosting with a computerized cognitive intervention, designed for enhancing mental processing speed. Participants who anticipated in the boosting sessions had approximately a 2.5 higher standard deviation and one boosting session counteracted for 4.92 months of age-related decline (Ball et al., 2013).

3.3. Long-term mental exercise

New articles examining cognitive functions mostly zoom in on physical effects detectable in brain areas, for instance changes in action potentials, amplitudes and microscopic changes. Here studies are discussed which are recently published and thereby examine physical or behavioural effects in the brain by cognitive training that lasts longer than one session. One study showed that cognitive training which is related to everyday life can enhance multiple functions. This learning therapy improved various cognitive functions like processing speed, executive functions, attention, reading ability, working memory, episodic memory and short-term memory.

Almost all cognitive functions decline with age. Results of previous studies have shown that cognitive training related to everyday life (reading aloud and solving simple arithmetic calculations), namely learning therapy, can improve two cognitive functions (executive functions and processing speed) in elderly people. However, it remains unclear whether learning therapy engenders improvement of various cognitive functions or not. (Nouchi et al., 2012).

To examine the effect of cognitive exercise on mental health researchers used an electrophysiological study. They measured the change in electrical properties, evaluating event related potentials (ERPs). ERPs were taken, in front of and after the 10 weeks of speed of processing training, by completing visual search tasks. After ten weeks the N2pc- amplitude, which indicate the allocation of visual attention, and the P3b-amplitude, which indicate the capacity of categorization of a target, were both enhanced. This indicates that speed of processing training may be successful in enhancing selective attention in age-related declines (O'Brien et al., 2013).

This improvement of cognitive and sensory function was also found in behavioural trials. Attention was raised after eight weeks of background sensory stimuli training, whereby elderly had to suppress irrelevant auditory and also visual stimuli. They found that participants in the training group had not only improvements in the trained functions, but also showed larger improvements in the not-trained domains, like dual-task completion and speed of processing. This indicates a general improvement of cognitive function by the modality-specific attention training programme (Mozolic et al., 2011). This finding is comparable with Edwards et al. (2013). They found that a divided attention task enhanced the results of speed of processing. This suggest that everyday performance could be functionally improved, leading to a higher speed of process for divided attention (Edwards et al., 2013).

These findings above agree with the review of Takeuchi and Kawashima (2012). They found that the effects of speed of process training are robust. However the training effects stick to functions that are similar to the training tasks. Occasionally effects are found in non-similar tasks, but these are mostly not very robust or researchers fail to find consistent proof for non-speeded measurements. They did find that differences in effects could occur depending on the training tasks and stimuli (Takeuchi and Kawashima, 2012).

Researchers found that frontal mean diffusivity increased after ten weeks of cognitive training. Diffusive MRI-scans showed that anterior white matter regions had more effect on the cognitive training than posterior regions. This difference in diffusion was likely caused by the cognitive training. The rate of change of the anterior regions was correlated with the improvements made in the verbal memory training, which is a validation of the efficiency of mental training (Engvig et al., 2012). Other studies using MRI-scans showed that memory training was positively correlated with activity changes bilateral in the hippocampus and changes in the left lateral and prefrontal temporal regions. Considering the results they suggested that training-related improvements in cognitive functions could be due to changes in hippocampal activity (Kirchhoff et al., 2012).

Not all researchers found positive effects of cognitive training. Raz et al. (2013) found that only the cerebellum had a reduction in shrinkage over hundred days of training. Against expectations they did not find an association of cognitive inducement in the other brain regions, some of which (like the hippocampus) played notable roles to fulfill the given exercises (Raz et al., 2013). This is an interesting finding, because of the fact that the cerebellum is the region which is most vulnerable to aging (Andersen et al., 2003). This in line with the principle that brain structures with the highest degree of plasticity show the greatest impact of aging (Raz, 2000). Greater shrinkage of cerebellum region was also associated with a history of hypertension problems (Raz et al., 2013).

TRNS-training, which stands for transcranial random noise stimulation training, causes after five consecutive days of training an enhancement of speed of calculation and an enhancement of speed of arithmetic memory-recall-based learning. The blood flow to the left dorsolateral prefrontal cortex is increased providing with neurovascular coupling for the activity related to the cognitive training. These physical and behavioural enhancements were still detectable six months after the training, revealing long-lasting modifications due to cognitive exercise (Snowball et al., 2013).

Also non-professional exercises like a custom-designed video game, a similar version of NeuroRacer, can benefit untrained cognitive control. EEG showed that multitasking performance was raised after six months of playing a resemblance of NeuroRacer, resulting in enhanced working memory and sustained attention (Anguera et al., 2013).

Except for examinations in physical changes, behavioural changes by mental exercise in elderly have also been examined. For instance the rehearsal or simulation of an action without the actual performance, called motor imagery, is shown to have a positive effect on the sensor motor system. This form of repetition can help elderly individuals reduce motor function decline (Saimpont et al., 2013). It is a cognitive exercise whereby only selective functions will be enhanced. Nevertheless by enhancing motor function, elderly could improve their physical abilities, reducing the danger of falling and creating possibilities for physical exercise.

Also behavioural tests on verbal working memory confirmed the positive correlation between memory training and progress in cognition. The trained elderly performed better in the criterion task (verbal working memory test) than the control group, demonstrating fewer intrusion errors. This benefit even persisted till the eight-month follow-up, validating ability of plasticity at old age (Borella et al., 2013).

3.4. One-off mental exercise

Using the search engine on “Pubmed” did not yield studies deepening the effects of one-off mental exercises on cognitive function in elderly. Comparable research has been done in elderly suffering from mental decline or physical issues. However this thesis focuses on the effect of mental exercise on healthy elderly, hence these articles were excluded. Possibly articles have been published, covering this region of interest. These articles could have been overlooked, because they were not free accessible or perhaps did not include the right keywords. Nonetheless the lack of hits and related articles indicates that this part of cognitive training still has to be discovered.

Only one article was fitting, although they used two age-categories of which one was under the age boundary that was set for this thesis. For all that one of the categories was under age; both of the categories had the same results, excluding major age-effects. The researchers found that ten hours of visual speed of processing training improving or stabilizing several cognitive functions till one-year follow-up (Figure 2.). They found that almost equal results were obtained in home training and at-site training. This may indicate that as long as people have sufficient instructions, the setting does not influence the effect of the training. The increase of effects could be raised by the participation of boosting sessions, providing for better results after the one-year follow-up (Wolinsky et al., 2013).

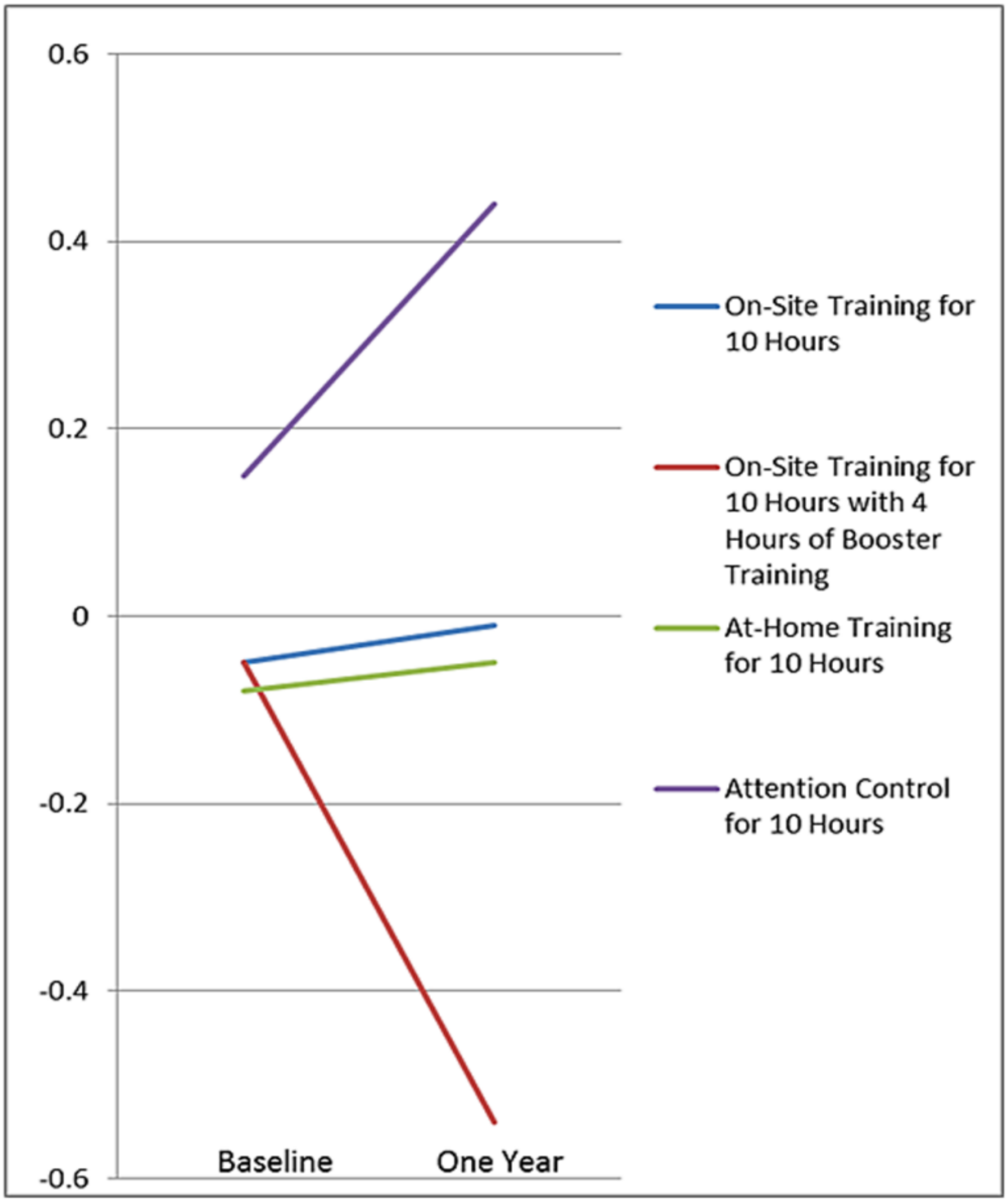

Figure 2. Four groups were randomly divided: three exercising groups which trained speed of processing with computerized visual (10 hours on-site, 10 hours at-home or 14 hours on-site) and one on-site control group making computerized crossword puzzles). Different cognitive tests were made and transformed with a Blom rank transformation. These data show that training, no matter what the setting is, does increase cognitive abilities. These abilities were maintained till the year after and with boosting sessions this increase could even be raised (Wolinsky et al., 2013).

4. Discussion and Conclusion

Cognitive functions can be improved in healthy elderly with both mental and physical exercise, considering all the gathered information in this thesis together. While reading this thesis, one has to pay attention to the fact that no calculations have been applied and therefore statements are not based on significant analysis. Nonetheless this survey of articles gives a good example of the current status of research.

There seems to be major evidence for the positive influence of physical exercise on cognition in elderly. Numerous articles have been written about this theme and although some of the articles have been proven not to be sufficient, reviews still confirm the positive, significant correlation between physical exercise and cognitive gain (Gligoroska et al., 2012; Snowden et al., 2011; Tseng et al., 2011; Shoshana et al., 2012; Chang et al., 2012; Smith et al., 2010; Sofi et al., 2011). Greater baseline cognitive function, which is correlated to higher education, responded stronger to physical trials. This may indicate that the effects of physical training is depending on the amount of mental practice one individual already gained (Van der Elst et al., 2006; Fallah et al., 2013; Soumaré et al., 2009).

This is comparable with the reviews and articles discussed in chapter 3 (Mental exercise): with the amount of exercise, cognitive abilities also rises (Wolinsky et al., 2013). Mental exercise in general seems to have a positive effect on cognition (Gross et al., 2012; Park and Bischof, 2013). However the cognitive gains were only limited to the specific trained tasks (Park and Bischof, 2013). By training with a modality-specific attention programme, focussing on universal functions in the brain, general improvement of cognition could be achieved (Mozolic et al., 2011; Edwards et al., 2013). More research should be done in the transfer of cognitive gain in mental function.

Notwithstanding physical and mental exercise both seem to have positive influence. No research has been done yet on the life-long practice of mental exercises on cognition in elderly, so no conclusions can be drawn from it. It is also striking that the proportion of research of physical exercise is very uneven to the research done of mental exercise. It is true that a moderate amount of articles is written about mental exercise. However few reviews are published to criticize this existing knowledge.

To answer the main question asked: What kind of exercise is most appropriate in improving cognitive function at old age: Physical exercise, mental exercise or maybe a combination of both? Both of them seem to have a positive influence. Mental exercise is mostly only effective on the specific task practiced, while physical exercise has a more generalized mode of action. Due to this knowledge, hence one can say that physical exercise is a better investment, albeit one can consider them both useful. In order to use the positive aspects of both mental and physical exercise, training programmes with these multimodal exercises are more and more explored (Pieramico et al, 2012; Legault et al, 2011; Schaefer and Schumacher, 2011; Schneider and Yvon, 2013; Fabre et al, 2002). This combination of mental and physical tasks multiplies the effects that can be gained (Fabre et al, 2002). Exploring this type of exercise combinations may be very meaningful.

5. References

Andersen, B.B. *et al.* (2003) Aging of the human cerebellum: a stereological study. J Comp Neurol. **466(3): 356-65.**

Anguera, J.A. *et al.* (2013) Video game training enhances cognitive control in older adults. Nature. **501: 97-101.**

Ball, K.K. *et al.* (2013) Speed of processing training in the ACTIVE study: how much is needed and who benefits? J Aging Health. **25(8): 65S-84S.**

Barella, L.A. *et al.* (2010) The immediate and delayed effects of an acute bout of exercise on cognitive performance of healthy older adults. J Aging Phys Act. **18(1): 87-98.**

Blomberg, O. (2011) Concepts of cognition for cognitive engineering. *International Journal of Aviation Psychology* **21 (1): 85–104.**

Borella, E. *et al.* (2013) Working memory training in old age: an examination of transfer and maintenance effects. Arch Clin Neuropsychol. **28(4): 331-47.**

Boundless (2013) *Anatomy and Physiology*. Boundless Learning, Incorporated, 2013. p. 975.

Brisswalter, J., Collardeau, M., *and* Arcelin, R. (2002). Effects of acute physical exercise characteristics on cognitive performance. Sports Medicine. **32: 555e566.**

Burke, S.N. *and* Barnes, C.A. (2006) Neural plasticity in the ageing brain. Nat Rev Neurosci. **7(1): 30-40.**

Chang, Y.K. *et al.* (2012) Effect of resistance-exercise training on cognitive function in healthy older adults: a review. J Aging Phys Act. **20(4): 497-517.**

Colcombe, S. *and* Kramer, A.F. (2003) Fitness effects on the cognitive function of older adults: a meta-analytic study. Psychol. Sci. **14: 125–130.**

Edwards, J.D. *et al.* (2013) An Examination of Mediators of the Transfer of Cognitive Speed of Processing Training to Everyday Functional Performance. Psychol Aging. **28(2): 314-321.**

Engvig, A. *et al.* (2012) Memory training impacts short-term changes in aging white matter: a longitudinal diffusion tensor imaging study. Hum Brain Mapp. **33(10): 2390-406.**

Fabre, C. *et al.* (2002) Improvement of cognitive function by mental and/or individualized aerobic training in healthy elderly subjects. Int J Sports Med. **23(6): 415-21.**

Fallah, N. *et al.* (2013) A multistate model of cognitive dynamics in relation to resistance training: the contribution of baseline function. Ann Epidemiol. **23(8): 463-8.**

Gligoroska, J.P. *et al.* (2012) Influence of the Physical Activity on the Cognitive Functions with People Depending on their Age. Med Arh. **66(4): 271-275.**

Gregory, M.A. *et al.* (2013) Brain health and exercise in older adults. Curr Sports Med Rep. **12(4): 256-71.**

Gross, A.L. *and* Rebok, G.W. (2011) Memory Training and Strategy Use in Older Adults: Results from the ACTIVE Study. Psychol Aging. **26(3): 503–517.**

Gross, A.L. *et al.* (2012) Memory training interventions for older adults: A meta-analysis. Aging Ment Health. **16(6): 722-734.**

Jones, R.N. *et al.* (2012) The ACTIVE Cognitive Training Interventions and Trajectories of Performance Among Older Adults. Journal of Aging and Health. **25(8S): 186S–208S.**

Kimura, K. *et al.*(2010) The influence of short-term strength training on health-related quality of life and executive cognitive function.J Physiol Anthropol. **29(3): 95-101.**

Kirchhoff, B.a. *et al.* (2012) Cognitive training-related changes in hippocampal activity associated with recollection in older adults. Neuroimage. **62(3): 1956-64.**

Kueider, A.M. *et al.* (2012) Computerized Cognitive Training with Older Adults: A Systematic Review. PLoS ONE. **7(7): e40588.**

Legault, C. *et al.* (2011) Designing clinical trials for assessing the effects of cognitive training and physical activity interventions on cognitive outcomes: the Seniors Health and Activity Research Program Pilot (SHARP-P) study, a randomized controlled trial. BMC Geriatr. **11: 27.**

Levine, B., Stuss, D.T. *and* Milberg, W.P. (1995) Concept generation; validation of a test of executive functioning in a normal aging population. Journal of Clinical and Experimental Neuropsychology. **17: 740-58.**

Liu-Ambrose, T. *et al.* (2012) Resistance training and functional plasticity of the aging brain: a 12-month randomized controlled trial. Neurobiology of Aging. **33(8): 1690–1698.**

McMorris, T., *and* Graydon, J. (2000) The effect of incremental exercise on cognitive performance. International Journal of Sport Psychology. **31: 66e81.**

Mora, F. *et al.* (2007) Aging, plasticity and environmental enrichment: structural changes and neurotransmitter dynamics in several areas of the brain. Brain Res Rev. **55(1): 78-88.**

Mozolic, J.L. *et al.* (2011) A cognitive training intervention improves modality-specific attention in a randomized controlled trial of healthy older adults. Neurobiol Aging. **32(4): 655-68.**

Muscari, A. *et al.* (2010) Chronic endurance exercise training prevents aging-related cognitive decline in healthy older adults: a randomized controlled trail. Int J Geriatr Psychiatry. **25(10): 1055-64.**

Netz, Y. *et al.* (2011) Aerobic fitness and multidomain cognitive function in advanced age. Int Psychogeriatr. **23(1): 114-24.**

Nouchi, R. *et al.* (2012) Beneficial effects of reading aloud and solving simple arithmetic calculations (learning therapy) on a wide range of cognitive functions in the healthy elderly: study protocol for a randomized controlled trial. Trials. **13: 32.**

O'Brien J.L. *et al.* (2013) Cognitive training and selective attention in the aging brain: an electrophysiological study. Clin Neurophysiol. **124(11): 2198-208.**

Park, D.C. *and* Bischof, G.N. (2013) The aging mind: neuroplasticity in response to cognitive training. Dialogues Clin Neurosci. **15(1): 109-19.**

Pascual-Leone, A. *et al.* (2005) The plastic human brain cortex. Annu Rev Neurosci. **28: 377-401.**

Pascual-Leone, A. *et al.* (2011) Characterizing brain cortical plasticity and network dynamics across the age-span in health and disease with TMS-EEG and TMS-fMRI. Brain Topogr. **24(3-4): 302-15.**

Pennington, R. *and* Hanna, S. (2013) The Acute Effects of Exercise on Cognitive Performances of Older Adults. Journal of the Arkansas Academy of Science. **67(2013): 109.**

Pieramico, V. *et al.* (2012) Combination training in aging individuals modifies functional connectivity and cognition, and is potentially affected by dopamine-related genes. PLoS One. **7(8): e43901.**

Raz, N. (2000) Aging of the brain and its impact on cognitive performance: Integration of structural and functional findings. Craik FIM, Salthouse TA. Handbook of Aging and Cognition. **pp. 1–90.**

Raz, N. *et al.* (2013) Differential Brain Shrinkage Over Six Months Shows Limited Association with Cognitive Practice. Brain Cogn. **82(2): 171–180.**

Saimpont, A. *et al.* (2013) Motor Imagery and Aging. Journal of Motor Behavior. **45(1): 21-28.**

Schaefer, S. *and* Schumacher, V. (2011) The interplay between cognitive and motor functioning in healthy older adults: findings from dual-task studies and suggestions for intervention. Gerontology. **57(3): 239-46.**

Schneider, N. *and* Yvon, C. (2013) A review of multidomain interventions to support healthy cognitive ageing. J Nutr Health Aging. **17(3): 252-7.**

Shoshana*, B. et al.* (2012) Extended practice and aerobic exercise interventions benefit untrained cognitive outcomes in older adults: a meta-analysis. J Am Geriatr Soc. **60(1): 136-41.**

Smith, P.J. *et al.* (2010) Aerobic exercise and neurocognitive performance: a meta-analytic review of randomized controlled trials. Psychosom Med. **72(3): 239-52.**

Snowball, A. *et al.* (2013) Long-Term Enhancement of Brain Function and Cognition Using Cognitive Training and Brain Stimulation. Current Biology. **23: 987-992.**

Snowden, M. *et al.* (2011) Effect of exercise on cognitive performance in community-dwelling older adults: review of intervention trials and recommendations for public health practice and research. J Am Geriatr Soc. **59(4): 704-16.**

Sofi, F. *et al.* (2011). Physical activity and risk of cognitive decline: a meta-analysis of prospective studies. J Intern Med. **269(1): 107-17.**

Soumaré, A. *et al.* (2009) A cross-sectional and longitudinal study of the relationship between walking speed and cognitive function in community-dwelling elderly people. J Gerontol A Biol Sci Med Sci. **64(10): 1058-65.**

Takeuchi, H. *and* Kawashima, R. (2012) Effects of processing speed training on cognitive functions and neural systems. Rev Neurosci. **23(3): 289-301.**

Thomas, C. *and* Baker, C.I. (2013) Teaching an adult brain new tricks: a critical review of evidence for training-dependent structural plasticity in humans. Neuroimage. **73: 225-36.**

Tombaugh T.N. *and* McIntyre N.J. (1992) The mini-mental state examination: a comprehensive review. J Am Geriatr Soc. **40: 922–935.**

Tseng B.Y. *et al.* (2013) Masters athletes exhibit larger regional brain volume and better cognitive performance than sedentary older adults. J Magn Reson Imaging.**38(5): 1169-76.**

Tseng, C.N. *et al.* (2011) The effectiveness of exercise on improving cognitive function in older people: a systematic review. J Nurs Res. **19(2): 119-31.**

Van der Elst, W. *et al.* (2006) The Stroop Color-Word test: influence of age, sex, and education; and normative data for a large sample across the adult age range. Assessment.**13(1): 62–79.**

Wolinsky, F.D. *et al.* (2013) Cognitive Training Using a Visual Speed of Processing Intervention in Middle Aged and Older Adults. PLoS ONE. **8(5): e61624.**