# THE EFFECT OF PHYSICAL ACTIVITY ON MOTOR COGNITION IN ELDERLY PEOPLE

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Zahra Habibi


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# Abbreviations

| | |
|---|---|
| DT | Dual-task |
| MMSE | Mini-mental status exam |
| MoCA | Montreal cognitive assessment |
| VDS | Verbal digit span |
| MCI | Mild cognitive impairment |
| M | Mean |
| SD | Standard deviation |
| df | Degrees of freedom |
| $\eta^2$ | Eta-squared (effect size between groups) |
| Kg | Kilogram |
| e.g., | For example |
| MD | Mean difference |
| N | Number of samples |
| PST | Psychology software tools |
| ANOVA | Analysis of variance |
| M-SRT | Machine-based stable resistance training |
| F-URT | Free-weight resistance unstable training |
| M-ART | Machine-based adductor/abductor training |
| 1-RM | One repetition-maximum |
| SPSS | Statistical package for social science |
| P-value | Probability value |

# 1. INTRODUCTION

The proportion of 65 years older adults in developed countries will double within the next decades. Furthermore, the life expectancy of this group has changed drastically over the past decades so that more than a quarter of those over 65 expect to live until they are 90 years of age (Weuve et al., 2004). While these changes are well recorded, the determinants of survival in this group are relatively unclear. Numerous investigations have demonstrated a correlation between activity level and survival (Hirsch et al., 2010). Older adults that are active are likely to have a longer lifespan than others who are inactive (Hirsch et al., 2010). Several systems may be involved in the association between activity and lifespan (e.g., Glass, Leon, Marottoli, & Berkman, 1999).

Aging process is accompanied by a decline in the physical abilities and, according to the action- specific perception, people perceive the world in terms of their ability to act such that older adults may see their surrounding environment differently as compared to younger people (Witt, 2011). As the activity declines in older age, bone density, the quantity, and quality of the muscular system decline as well (Metter et al., 1999). These changes are accompanied by decreases in motor function (Seidler et al., 2010), mobility (Tinetti et al, 1986), balance control (Laughton et al., 2003), and increasing falls (Kannus et al, 2005). Muscle strength, especially that in the lower limbs, decline as we age. It has been shown in older adults that body fat increases due to declining activity (Forbes & Reina, 1970). Moreover, researchers have argued that older adults perform inaccurate in comparison to younger adults in situations of their daily life so that aging may be associated with an increased fall risk (Faulkner et al., 2007). However, an increased fall risk seems to be associated with physiological and psychosocial factors which are responsible for these changes with age (Glass et al., 1999). The senses, brain function, and cognition are also affected by aging (Ulfhak, et al, 2002).

The range of changes in cognitive abilities by aging is from a superior performance to an impairment that influences daily life whereas the most harmful effects of these changes appear to be after 65 years old (Ferri et al., 2005). Enough cognition is necessary for individual function and living independently. For example, without adequate cognition, we are not able to find out which action is best for making a cup of tea, reaching for a cup, drinking the tea, and many other simple daily tasks that are crucial for surviving (Kersten, 2006). Embodied cognition has raised increasing awareness within recent years (Glenberg, et al, 2005). Especially the focus on the body, its movement and the interactions with the environment (Glenberg, et al, 2005). The argument that supports embodied cognition is that the motor system influences our cognition, similar as to our mind influences bodily actions. A common example is when participants hold a pencil between their teeth while using the muscles required to smile, it is easier to understand pleasant sentences faster than unpleasant ones, while holding a pencil between their nose and upper lip to use the muscles to frown has the revers effect (Glenberg, et al, 2005). Some evidence has been presented that shows a person's ability to act influences their perception. For instance, as ability increases, hills look less steep, objects look closer, targets look bigger, obstacles look smaller, and target speeds look slower (Witt, 2011). Also, perceivers who must exert more energy to walk to a target see it as farther away (Witt, 2011). Also, hills appear steeper, and distances to targets appear longer when people who wore a heavy backpack, are fatigued, with lower physical fitness, are older adults, or have poor physical health (Proffitt, et al, 1995). In keeping with Witt (2011) aging is accompanied by the decline in physical abilities, so that they may see the world differently than younger people. Given these brain function decreases in aging, there is a decline in the cognitive speed of processing (Salthouse, 2000), attention, and executive functions as well (Greenwood, 2000).

During the aging process, there is a decline in controlling balance which might eventually increase the risk of falling in older adults (Hausdorff, et al 2001). Therefore, balance control can be defined as a crucial component of an independent daily living in older adults. Ten weeks high-intensity strength training by machine on knee muscles in 27 females and males (74-96) years increased performance in the Berg Balance Scale test and the activities-specific balance confidence scale (Hess & Woollacott, 2005). Also, the effect of physical activity as an appropriate lifestyle has been explored and a significant association was shown between physical activity and cognitive abilities. Bielak et al. found that among females and males (20-24, 40-44, and 60-64 years) who had previously engaged in 8 years of physical activity (mild, moderate, and vigorous) increases in the fluency of cognitive tasks (perceptual speed, short-term memory, working memory, and episodic memory) were detected only in those who had vigorously exercised (Bielak, et al, 2014). Liu-Ambrose and coworkers showed that a 12-month resistance training improved selective attention, falls-related self-efficacy, global cognition in line an with improvements in gate speed (Liu-Ambrose et al., 2010a).

Overall, the above studies indicate sunstantial associations between physical activity on one hand and walking speed, step frequency, cadence, in line with other indices of motor performance as well as reductions in the risk of falls on the other hand. In addition, studies showed that motor functions and cognitive functions are associated across the life span and in older adults. However, while various studies showed in normal subjects that physical activity corresponds to motor cognition effects (Kourtzi & Shiffrar, 1999) it remains open whether strength training is associated to motor cognition in the older adults population. Finally, increased information about the impact of physical activity on motor cognition in seniors is necessary.

Therefore, we conducted a cross-sectional and a longitudinal study to determine whether seniors as a specified group benefit from physical activity as well, to gain information on the motor-cognitive benefits that are specified in this age domain. This specific domain takes the preparation and production of actions into account as well as the processes involved in recognizing, anticipating, predicting and interpreting the actions of others (Jackson & Decety, 2004).

According to the structure of this thesis, in chapter 2, the theoretical background of age-related changes in strength, cognition, and embodiment as well as the effect of physical activity on cognitive function and motor cognition throughout aging are presented. Chapter 3 represents general issues and hypotheses. Chapter 4 outlines the cross-sectional study investigating the difference of motor cognitive capability between active and inactive older adults. Based on the results of studies in this context, we hypothesized a significant different in motor cognition between active and inactive seniors. However, there was a need for an evolved and valid method. Therefore, we designed four methods and conducted that through the four experiments in the form of two cross-sectional and longitudinal studies. Chapter 4 examined this issue. Chapter 5 provides an outline of our longitudinal study to investigate the effects of three types of strength training for older adults with a moderate level of physical ability background. Moreover, in the longitudinal study, we hypothesized a significant improvement in motor cognition in the older adults after the strength intervention period. Chapter 6 presents the general discussion of the hypotheses, and finally, in chapter 7 the conclusions of this study are presented in line with recommendations for future research directions. In the appendix, the questionnaires used in this study are listed.

# 2. THEORETICAL BACKGROUND

## 2.1 Aging Characteristics

Aging is an undeniable and natural part of life. However, aging involves complex processes and has a significant impact on our abilities (Signorelli et al., 2017). Also, the way how we have experienced our lifetime influences the aging phenomenon as well (Signorelli et al., 2017). The physical efficiency decreases with aging. These processes can cause broad interventions on activities of daily living (bathing, dressing, feeding, walking etc.) which are necessary for independent living. Aging is accompanied with a significant decrease in abilities and body function so that this reduction caused a lot of disability in seniors. As a result, many older adults lose their mobility and increase the risk of falls and hip fractures, which leads to a dependent life. The ability to cope alone, having control over our lives in old age is the best goal and an essential part of everybody's life (Heikkinen, 1997). Some factors that may impact the health and quality of the older adults life include lifestyle, work, leisure activities and interaction with the environment (Elavsky et al., 2005). Adult people who participated in physical exercise programs reported a reduction of some physical and mental disorders such as cardiovascular disease, obesity, several types of cancers, as well as anxiety and depression (Hillman et al, 2008). In contrast, a sedentary lifestyle is the main cause of dementia and death among the aging society in the United States (Booth et al, 2002). On the other hand, in every developed country around the world, the number of older people is increasing. Age-related changes such as increasing body fat, muscle weakness, decreasing energy expenditure at rest and exercise time, endurance capacity may lead to decreased physical activity and diseases (Hunter et al,2004). According to the researches on aging processes, the maximum potential capacity of human body systems is approximately at the age of twenty. From twenty years on, these functions begin to decrease by about 10% per decade. As a result, at the age of sixty, the human body loses approximately 30% of its functional capacity (Tosato et al, 2007). Also, along with aging, some changes appear in brain structure and function (Fabel & Kempermann, 2008). Falls and weakness are a prevalent problem in many older adults. Almost 45% seniors over the age of 65 years fall once or more yearly (Delbaere et al., 2010). Injuries caused by falls can result in a loss of confidence in older adults and a subsequent decline in physical activity (Sherrington et al., 2008). Reduced mobility is a serious cause for falls in the older adults which, in turn, may have a negative effect on the quality and independence of life for the older adult. On the other hand, inactivity arising from these injuries have a considerable effect on the health care system and costs for medical treatment (Harris, 2018). Given that aging is associated with a decline in physical and mental functions, these negative effects of aging are associated with quality of life in seniors. It is crucial to prevent or postpone these negative effects of the aging process (Chang et al., 2012).Usually regular physical activity improves mental health, emotional, social well-being, and cognitive function. Also, training intervention among the older adults play an important role to promoting public health and clinical issue as well (Langhammer, 2018).

## 2.2 Aging effects on Strength

Mass and physical functioning diminish in skeletal muscle with advancing biological age which impacts the quality of life and well-being (McGregor et al, 2014). Researchers suggest that the muscle strength is reduced from the beginning of forth decade of life (Janssen et al, 1991). It seems that the muscle strength in lower body muscles declines at a greater rate than the upper body muscles, so that the lower body muscles mass reduced from 20 to 70 years of age around 25% (Janssen et al., 2000). The most reason for the age-related decline in strength must be a decline in muscle mass (Young et al, 1985). Other studies showed a 25-35% reduction in the cross-sectional area of the quadriceps muscle in older adults in contrast to young people (Janssen et al., 2000; Young et al, 1985). Physical inactivity is not the only reason for the decline in age-related muscle functioning. The most common causes of age-related muscle mass decline is referred to as sarcopenia (Janssen et al., 2000). The loss of skeletal muscle mass for older adults is associated with a functional impairment and frailty (Janssen et al., 2000). The consequences of age-related sarcopenia in older adults may decrease the quality of their life and the need for a long-term care (Janssen et al., 2000).

Furthermore, another reason for the age-related reduction in strength might be replacing muscles by fat and connective tissue. Rice and colleagues (1989) indicated a 27% increase in connective tissue in the arm muscles flexors, around 45% in the arm muscle extensors, and 81% in the plantar muscle flexors by aging (Rice et al, 1989). Another study showed that weakness of ankle muscle dorsiflexors was one out of the three most important reasons for seniors having suffered from many falls in comparison to older people who had one or no falls (Lord et al, 1994). Therefore, an active lifestyle, especially regular exercise plays a crucial role in mitigate and/or compensate for such age-related deficits in muscle strength.

In the following, we will focus on the effects of strength training on muscle strength, balance, hormones, tendons, joints and brain functions in older adults.

## 2.3 Strength Training and Aging

### 2.3.1 The Effect of Strength Training on Muscle Strength and Aging

In the past, an increased risk of falling in older adults has been observed in conjunction with low muscle strength (Caserotti, 2010). For example, weaknesses in the quadriceps muscles are one of the most prevalent reasons for the decrease in walking ability (Caserotti, 2010). In this regard, Caserotti (2010) showed that 12 weeks of maximal explosive muscle force and muscle power training in knee muscles for older adults between the age of 60-80 years lead to an increase in the rate of force and maximal muscle strength in the training group. Suetta and colleagues (2004) showed that a strength training on lower body has positive effects on strength and walking speed in older adults. There is an extensive body of literature indicating benefits of strength training on muscle strength among older adults (Caserotti, 2010; Suetta 2004; Seynnes, 2004; Hakkinen, 2001). Kongsgaard and colleagues (2004) found that heavy progressive resistance training on knee muscles in 18 females and males between the age of 65-80 years is an effective way to increase maximal muscle strength and enhanced rapid muscle force characteristics. Seynnes and colleagues (2004), having examined 10 weeks progressive resistance training of the knee extensors in 22 older adults, showed that knee extensors strength, stair-climbing power, and chair-rising time increased within the high intensity group and low intensity group. Also, Hakkinen and colleagues (2001) showed that seven months of strength training for the entire body in two age groups (middle age and older adults) provided increases in isometric strength values and explosive strength within a male group of 40 years old and a female group of 70-year old adults and increases in fiber type I cross-sectional areas in the 70-year old female subjects. In another study, 12 weeks of strength training in the knee extensors and knee flexors increased the skeletal muscle mass in 11 females and males aged between 85 and 97 years (Harridge et al. 1999). Overall, studies show that high-intensity exercise has a more substantial effects on health benefits compared with low-intensity exercise (Ellingsen et al., 2017; Seynnes, 2004).

Tracy and colleagues (1999) found that nine weeks of heavy-resistance and high-volume exercise among 14 older adults females and males, improves strength and quadriceps muscle volume in males than in females in the 1RM (one-repetition maximum) test. Also, an increase of muscle quality was observed in both high and low intensity training groups. Sipilä and Suominen (1995) showed that 18 weeks of strength and endurance training in two female groups between the age of 76 and 78 years lead to induced skeletal muscle hypertrophy in the strength group. A study by Brown and colleagues (1990) found that 12 weeks of dynamic elbow flexion training of one arm and bilateral leg press training in 14 males between the age of 60 and 70 years lead to an improvement in weight-lifting capacity, concentric contraction torque of the elbow flexors, evoked muscle contractile properties, and muscle fiber characteristics. In addition, 16 weeks of strength training by machine and power training in 39 males and females between the ages of 65 and 90 years showed an increase in maximal strength (Miszko et al. 2003).

However, high intensity training is associated with an increased risk of injury especially in population with poor physical activity or sedentary. These unfavorable effects originating from high intensity training may lead to frustration and interruption of exercise interventions (Spada et al., 2018). Although, there are some adverse effects of high intensity training, most of these are avoidable.

In addition, age-related reduction in muscle strength may be accompanied by an impairment in the quality of intermuscular and intramuscular coordination (Faulkner et al, 2007). These consequences of these changes result in a substantial impairment in the sensorimotor information exchanges and reduction in the motor function in the older adults. The motor function impairment is associated with loss in strength and balance capacity and increasing gait uncertainties (Faulkner et al., 2007). Numerous studies have shown that strength training has a significant effect on two components of the central nervous system and muscle mass (McCaulley et al., 2009; Stankovic et al., 2013). Also, proper intensity and volume of exercise are important to an optimal neuroendocrine response (Kraemer & Ratamess, 2005).

On the other hand, there is growing evidence that age-related endocrine declines such as anabolic hormones (testosterone, estrogen, growth hormone (GH), and insulin (Drey, 2011; Sattler et al., 2009). Age-related decline in testosterone maybe associated with physical deterioration in older adults (Hyde et al., 2010). There is an abundance of studies indicating increased muscle mass with testosterone treatment in the older adults (Bhasin et al., 2006; Snyder et al., 1999). On the other hand, studies in men indicated that resistance training increase total testosterone concentrations (Ahtiainen et al, 2003; Tremblay et al, 2004).

Maleknia and colleagues (2013) showed that eight weeks of resistance training for all the main muscle groups in 26 females and males between the age of 55-65 years leads to an increase in growth hormone (GH) levels in the resistance training group. Ibanez and colleagues (2005) argued that 20 weeks of resistance training in nine males between the ages of 63-69 years decreased fasting blood glucose and increased insulin sensitivity. Also, Craig and colleagues (1989) showed that 12 weeks of weight training in two group ages (62-64 years and 22-25 years) lead to an increase in the basal level of growth hormone in the younger group and testosterone response in both age groups. Similarly, Miller (2013) showed that 16 of weeks resistance training in 11 males (50-63 years) leads to a decreasing insulin level.

However, several studies have shown that strength training may compensate age-related deficits in muscle strength (Spada et al., 2018; Miszko et al. 2003; Seynnes, 2004), providing minimum strength exercise is crucial to maintaining strength capacity, future functioning, and independent living in older adults. Furthermore, it needs to be clarified which intensities of training are beneficial and feasible in seniors. Moreover, these results showed that resistance training improves endocrine in seniors, but the mechanism of effect endocrine regulation on muscle strength is unclear. Thus, the question arises whether strength training is appropriate to improve the endocrine regulation in the older adults.

**2.3.2 The Effect of Strength Training on Tendons and Joints and Aging**

The main causes of age-related muscle weakness in the older population are related to an advanced sarcopenia in line with a reduction of locomotor ability. In addition, other factors such as a reduction in physical activity, nutrition, and immunological factors may account for these deficits as well (Narici & Maganaris, 2006). Several studies revealed that age-related reduction in muscle power are associated with changes in muscle structure and tendon mechanical properties (Narici & Maganaris, 2006). The possible decline in tendon stiffness associated with increasing age may reduce maximal skeletal muscle performance (Bojsen-Møller et al, 2005), balance (Onambele et al, 2006). Regular training seems to protect the tendons from the negative age-related effects (Smith et al, 2002). However, the knowledge about influence of strength training and appropriate load on tendons mechanical properties in the older population is limited.

Reeves and colleagues (2004) argued that 14 weeks of progressive isotonic resistance training on knee muscles in females and males between the age of 65 and 77 years may lead to increases in tendon stiffness, maximal muscle force, rate of force development, and metabolic cost of locomotion. A study by Ochala and colleagues (2005) indicates that 24 weeks of strength exercises with machines in 21 females and males between the age of 73 and 83 years lead to a decrease in musculotendinous stiffness. Also, 12 weeks of low resistance and high resistance training in 17 females and males between the ages of 68 and 79 years increased patella tendon properties in high resistance group (Grosset et al., 2014). Although, some studies argued that training with heavy loads have a more pronounced effect on tendon stiffness (Reeves et al., 2004; Grosset et al. 2014), there are other studies showing that a middle and low load training has a positive effect on tendons as well. For example, Kubo and colleagues (2003) demonstrated that six months of low-load squat training in 18 females between the age of 43 and 69 years leads to a decrease in maximal strain and stiffness of the tendon-aponeurosis structures.

Fatouros and colleagues (2002) indicated that 16 weeks of strength training in upper body muscles in 22 males between the ages of 65 and 78 years leads to an increase of isokinetic and concentric strength in the strength training group and the combination of strength and aerobic training group. Furthermore, six-months of universal resistance exercises with machines in three groups (low-intensity resistance training, moderate-intensity resistance training and high-intensity resistance training) showed that strength increases more in upper and lower-body in the high -intensity resistance training group (Fatouros et al. 2002).

These findings suggest that the mechanical properties of the tendon in older adults can be changed with regular strength training. Overall, low-load resistance, mild-load resistance, and high-load resistance training increased the elasticity of tendon structures (Bohm et al, 2015). Last not least, studies have shown. as well, that resistance training over a long duration improves the diameter of the tendon and its mechanical properties, especially in the older population (Eriksen et al., 2019).

### 2.3.3 The Effect of Strength Training on Balance and Aging

An impaired balance is one of the most important risk factors for falls following the decline in the physical activity of the older adults to decrease their independence during daily life (Urushihata et al., 2010). The association between poor balance and falling has led to several types of research concerning strength training to enhance balance in older adults. In this regard, Hernandez and colleagues (2010) showed that six months of stretching activity, weight training, circuits, dance sequences, recreational activities, and relaxation in 16 males between the ages of 72 and 84 years improved the Berg-Balance Scale. Hess and Woollacott (2005) showed that 10 weeks of machine-based high-intensity strength for the knee muscles in 27 females and males between the age of 74 and 96 years increased performance in the Berg-Balance Scale test and improvements in the activity-specific balance confidence scale. In turn, an inactive lifestyle is associated with negative age-related changes (Koopman & van Loon, 2009). These changes refer to a reduction in motor capacity and visual and vestibular abilities (Aagaard et al, 2010). Moreover, a reduction in muscle fibers (type 1 and type 2 fibers), especially in lower-extremity muscles was found to be responsible for the impairments in the muscle functioning such as balance capacity and increasing gait uncertainties (Aagaard et al., 2010). Several studies argued that strength training in lower-extremity muscles provides more stable and stronger legs through the increases in lower body muscle mass and strength (Schlicht et al, 2001). For instance, Lee and Park (2013) showed that 12 weeks of leg extension and curl exercises with a machine in 50 females and males between the age of 65 and 82 years improved lower limb strength and balance in the training group. Similarly, Ribeiro and colleagues (2009) indicated that six weeks of ankle dorsiflexion and ankle plantar flexion exercises using elastic bands in 48 females and males between the ages of 72 and 87 years leads to an improvement in maximal isometric dorsi, plantar flexors strength, balance, and functional mobility in the training group. Moreover, Park and colleagues (2008) showed that 48 weeks of strength training, weight-bearing exercise and balance plus postural correction training in 50 females between the ages of 65 and 70 years leads to an improvement in the 10-meter maximum walk time, maximum step length, eyes-open-one-legged stand time, and body sway in the training group.

In summary, the results in a manifold of studies show a positive influence of strength training program to improve balance in older adults. Thus, strength training is effective when included in a specific training program (exercises that are challenging and safe) and population (i.e., frail, the previous background of physical activity, and individual differences).

### 2.3.4 The Effect of Strength Training on the Brain (neurocognitive) and Aging

The world population is aging (Liu-Ambrose et al., 2011). Therefore, maintaining functional plasticity of the cortex is crucial for the support of healthy and independent living of older adults (Liu-Ambrose et al, 2011). A popular approach to maintaining this function is exercise (Liu-Ambrose et al., 2011), but which type of exercise has more benefits to promote of neurotrophic factors? The most well-known types of exercises are divided into two distinct forms- aerobic training, such as running and resistance training (strength training), such as lifting weights and machine-based weights. One investigation determined that aerobic training increases levels of brain neurotrophic factors (Neeper et al, 1995), such as neuronal survival, synaptic development, and plasticity (Cotman, 2002; Lu & Chow, 1999). However, it is important to note that aerobic training may be regarded as a limitation in older adults, because this form of exercise requires good cardiovascular fitness and healthy joints. In comparison with aerobic exercise, strength training is suitable even for seniors with limited in motor ability and cardiovascular fitness (Liu-Ambrose et al., 2011).

Liu-Ambrose and colleagues (2010b) showed that 12-months of resistance training (machine and free weights, mini squats, mini-lunges, and lungs walk) and balance training (stretching, range of motion, balance and lunge walks) in 135 females between the ages of 65 and 75 years improved selective attention, fall-related self–efficacy, gate speed, and global cognition. Also, Joshua and colleagues (2014) using a six-month resistance training (hip flexors, extensors and abductors, knee flexion and extension, ankle dorsiflexion, and plantar flexion), a traditional balance exercise, and a combination of both in 54 females and males of +65 years showed increased Tinetti Falls Efficacy Scale (FES) scores in all three training groups. However, whether strength exercise may exert an influence on functional plasticity of the brain currently is unclear. Based on human trials, resistance exercises diminished serum homocysteine levels (Vincent et al, 2003). Increases in serum homocysteine levels are associated with the cognitive impairment (Schafer et al., 2005) and Alzheimer's disease (Seshadri et al., 2002). In addition, there is evidence that falling in older adults has a link to white matter hyperintensities (WMH) (Smith et al., 2008). Zheng and colleagues (Zheng et al., 2012) found that non-demented older adults with a greater WMH reported less falling incidences over a 12 month period. In turn, prospective evidence suggests that vigorous physical activity during leisure could slow down the age-related white matter decline in non-demented seniors (Colcombe et al., 2006). Thus, the question arises whether exercise interventions, especially strength training, are a proper training modality to enhance brain health factors in older adults.

## 2.4 Cognition and Aging

Research on cognitive skills and risk factors for reduced cognitive function is crucial for the daily living of older adults. It is now clear that some of these cognitive functions (e.g., memory, problem-solving activities, or speed processing) decline with normal aging (Salthouse, 2011). Older adults require sufficient perceptual and cognitive skills for self-care and to accomplish complex tasks (Yogev-Seligmann, Hausdorff, & Giladi, 2008). For example, walking, as a repetitive human movement, requires more attention in older adults compared with young people (Woollacott & Shumway-Cook, 2002a). Older adults experience significant decrements in the control of gait owing to a decline in their sensory-motor information processing. Therefore, they need more attention to prevent gait unsteadiness. (Bloem et al, 2003). There is an abundance of interest in clinicians to investigate age-related gait changes as dual-task related gait changes are associated with a high risk of falling in the older adult (Bloem et al., 2003; Verhaeghen & Cerella, 2002). Based on dual-task studies, some tasks require high levels of attention for two tasks at the same time such as crossing a street while communicating through a cell phone (Neider et al., 2011). Overall, attentional resources are significantly impaired with age causing older adults to experience impairments in dual-tasking (Neider et al., 2011). Given that the rate and extent of age-related attention deficits may be unavoidable there is a considerable need for specific interventions to improve and/or limit an age-related loss in cognitive functioning and prevent the risks of dementia.

In addition, some aspects of memory and learning abilities, such as tests requiring more than the short-term memory capacity (e.g., six to seven units of information), were found to be impaired in older adults as compared to younger adults while tests on other memory capacities did not exhibit differences (Lezak, 2012).

Furthermore, other domains of memory evaluated by delaying a free recall or learning requiring mental operations (working memory) were found to decline with age (Lezak, 2012). In this regard, working memory refers to the brain ability to provid temporary storage and processing of information necessary to maintain an interconnection between perceptions and memories such as learning, language comprehension, and reasoning. Mentally adding and multiplying numbers are examples of working memory tasks (Salthouse, 2000). Executive cognitive functions include decision making, planning, problem solving, and multitasking declines with age as well (Lezak, 2012). Already, Willoughby and colleagues (1929) found a reduction in the recall ability using digit-symbol pairs as a memory indicator with aging (Willoughby, 1929). Moreover, researchers found an age-related decline in the ability to perceive spatial orientation and visuoperceptual judgment (Murman, 2015). Furthermore, there is evidence that fluid intelligence reflecting the interconnection of neurological formations in the brain will be reduced after the neural maturity (adolescence) unless some sort of intervention has taken place (Baltes, 1993). Similarly, other age-related cognitive declines refer to fluid intelligence (Gard et al., 2014). Fluid intelligence (or conative mechanics) is considered necessary information processing including cognitive functions such as speed and accuracy of elementary processing, visual and motor short- and long-term memory, discrimination, comparison, and categorization (Cattell, 1963). Information processing controls the speed and accurate processing of stages which are conducted (Cattell, 1963). The most famous intelligence tests that are used for the adult population is the Wechsler Adult Intelligence Scale (Saklofske and Schoenberg, 2011). In turn, emerging evidence suggests that speech and language function are stable into advanced age (Murman, 2015).

Given an increasing number of adults suffering from and an increasing prevalence of age-related neurodegenerative dementia it is vital to find out about approaches that could decrease the negative effects of aging on cognition. There is evidence that socially integrated networks, cognitive leisure activity, and regular physical activity have a significant impact on the slowing rate of the negative effects of aging on cognition (Fratiglioni et al, 2004). Findings from cognitive intervention studies suggest that among lifestyle elements, physical activity is more beneficial than others to improve the cognitive performance and reduce the effects of age decrement (Hertzog et al, 2008). Healthy individuals with an active lifestyle are able to perform better on cognitive tests, such as memory and executive functioning compared to people with a sedentary lifestyle and smaller health indexes (Kramer et al, 2006). Thus, it is vital to find out about the possibility to slow down the negative age-related effects on cognitive domains.

### 2.4.1 Aging, Physical Activity, and Cognitive Function

Aging is accompanied with decline in physical ability so that older adults may see their surroundings differently compared with young people (Witt, 2011). Age-related physical ability declines is associated with decreasing their bone density and the quantity and quality of the muscular system (Laughton et al., 2003). Consequently, these changes are accompanied by a reduction in motor function (Seidler et al., 2010), mobility (Tinetti et al, 1986), balance control (Laughton et al., 2003), and increasing fall (Kannus et al, 2005). While muscle strength declines with age, there is a decrease in the recruitment and activation of motor units (Thomas et al., 2002). Also, the senses, brain function, and cognition are affected in aging (Ulfhak et al, 2002). Given the fact that these brain functions decrease with age, there is a decline in cognitive processing speed (Salthouse, 2000), attention, and executive functions as well (Greenwood, 2000).

Although cognitive decline is inevitable when aging, common principles in cognitive aging studies demonstrated different changes, but some older people maintain their cognitive function better than other seniors and perform as well or even better than younger people (Salthouse, 2000). Moreover, the decline is not equal within cognitive domains. For example, some older adults have a tremendous episodic memory function, but diminished executive functions, and conversely (Salthouse, 2000). Even though there are explicit interactions among cognitive domains, it seems as these interactions may be more or less sensitive to aging in different individuals (Glisky et al, 1995). These individual differences may be related to health-related, environmental, and lifestyle factors and mechanisms (Grady et al, 2002; Reuter-Lorenz et al., 2000). Researches showed that an active lifestyle and aerobic exercise are more beneficial to cognitive function especially when performing tasks requiring executive control (Liu-Ambrose & Donaldson, 2008). Such results are interesting to researchers and older adults who want to keep their cognitive function into their later years. As a result, it is not surprising that, over the past 20 years, important investigations were conducted on the relationship between health and cognition (Altman & Das, 1965; Grady et al., 2002; Liu-Ambrose & Donaldson, 2008; Reuter-Lorenz et al., 2000). Although there is ongoing debate on the effect of physical activity on protecting cognition and prevention of cognitive dementia, several studies have shown that regular exercise plays an important role in health promotion to delay the cognitive disorders (Larson et al., 2004; Liu-Ambrose & Donaldson, 2008). Previous investigations have reported that aerobic physical activity improves mood (Zoladz & Pilc, 2010), self-esteem (Hanson & Nedde, 1974), cognitive function, and reduces cognitive decline among seniors. Also, a study by Aichbeger showed a reduction in cognitive dementia after two and a half years in individuals who engaged in any type of physical activity (Aichberger et al., 2010).

As an general goal, it is important to find out about that which type of exercise has more effect on cognitive abilities promotion in older adults. Researchers who have studied the relationship between resistance training intensity and cognition have found that high-intensity exercises improve the speed of processing, whereas moderate intensity exercises have more effect on executive functions (Elavsky et al., 2005). Dorner et al. (2007) indicated that 10 weeks strength training (Thera-bands and soft weights) and balance training (exercise balls, balance discs and blocks) in 45 females and males above 75 years of age improves cognitive functions (Mini-Mental State Exam) in training groups (Dorner et al., 2007). The results arising from these studies imply an effect of exercise on several cognitive domains. Therefore, exercise intervention might be considered to be a tool to improve different aspects of cognitive function in older adults. To date, the most studies have focused on the benefits of aerobic based exercise on cognition (Colcombe et al., 2006; Colcombe & Kramer, 2003). In contrast, there is a limited number of studies that examined the effect of strength training on cognition among seniors. An additional benefit of strength training compared with aerobic training is that strength training increases the muscle mass so to moderate the age-related sarcopenia and prevent the deleterious consequences of sarcopenia such as falls in older adults (Borst, 2004). An investigation by Colcombe indicated that a combination of aerobic-based training and resistance training is associated with a more positive effect on cognition than aerobic exercise only (Colcombe & Kramer, 2003). Furthermore, emerging evidence also suggests that exercise positively impact cognitive functioning in older adults with mild cognitive impairment. For example, a 24-week home-based physical activity had a significant positive effect on Alzheimer’s disease in older adults with mild cognitive impairments based on an assessment in a cognitive subscale (ADAS-Cog) (Lautenschlager et al., 2008). From this point of view, some key questions remain unanswered as, firstly, the role of strength training in the prevention and the slowing down of cognitive performance among seniors and, secondly, the optimal intensity, duration, and mechanical loading to achieve the best cognitive benefits in seniors.

### 2.4.2 Executive Functions and Aging

Executive functions are defined as a top level of a set of human cognitive processes needed for the coordination and adjustment of cognition, emotion, and behavior (Spreen & Strauss, 1998). Despite a manifold of studies, in this regard, many aspects of executive functions are still open to research. One of these aspects that are crucial to be investigated relate to the exploration of changes in the executive functions across the adult life span. Findings from the literature show that aging is associated with several risks of diseases and cognitive impairments (Stuck et al., 1999). Generally, aging is accompanied by a decline of executive functions and these impairments lead to wrong decision-making, error judgment, and inappropriate social behavior (Lustig & Jantz, 2015). The result of an investigation showed a great impairment in components of the executive functions such as memory, learning ability, and cognitive flexibility with age (Spencer & Raz, 1994). Also, these deficits were in judgment ability and decision-making in people over 80 years of age and with a low educational level within the population (Yang et al., 2006). Decrements in the speed of information processing as being part of the executive functions was found to be related to individual differences (Yang, Krampe, & Baltes, 2006). In addition, the absence of sufficient cognitive capacity was found tro be associated with a risk for falls (Liu-Ambrose et al, 2008b). Older adults with lower scores in cognition tests such as the Mini Mental State Examination and the Montreal Cognitive Assessment reported more falls (Liu-Ambrose et al., 2008b). Falls are considered as a consequence of chronic impairments among the aging population related to muscle weaknesses, gait and balance difficulties, and cognitive dysfunctioning whereas a significant domain of cognitive functioning including executive functions (Tinetti et al., 1988). Overall, the impact of age on executive functions seems to depend on the type of task (Verghese et al., 2002). Executing a complex task such as dual-task walking was found to increase the risk of falls (Verghese et al., 2002). A considerable reduction in falling has been observed when improving gait speed over a 12-month period in older adults (Hardy et al., 2007). All in all, research is still ongoing to understand the effects of interventions to improve gait speed on survival. In contrast, other studies argued that lower executive functions are associated with a decline in gait speed (Inzitari et al., 2007). These results support a close relationship between cognitive and physical functions. In addition, falls related to impaired executive functions are associated with fall-related injuries (Nevitt, Cummings, & Hudes, 1991), balance abnormalities (Maki et al. 2001; Dault et al. 2001; Maki et al. 2001; Dault et al. 2001), impaired gait (Kuo & Lipsitz, 2004), and limited obstacle avoidance capability (Brauer et al., 2001). In turn, self-efficacy may play an important role to improve gait speed (Liu-Ambrose et al, 2008).

Fall-related impairments in self-efficacy in older adults are generally associated with poor gait performance. Therefore, interventions are needed to improve gait speed (Liu-Ambrose et al., 2006). Also, falls occur more often when older adults individuals are performing simultaneous tasks while unable to adjust and control their gait pattern (Hausdorff et al, 2008).

Proper lifestyle may reduce the risk of falls (Wang et al., 2010). As a result, people with intact executive functions while having lost considerably in their cognitive functioning otherwise are still able to live an independent life (Lezak, 1982). In this regard, a study by Fratiglioni and coworkers (2004) showed that the participation in a social network, cognitive leisure activity, and regular physical activity can reduce cognitive impairments. Moreover, studies show that regular physical activity is the most essential factor in slowing down the aging process and preventing age-related cognitive impairments (Fratiglioni et al., 2004). Bielak and colleagues (2014) showed that among females and males between the ages of 20 and 24, between 40 and 44, and between 60 and 64 years who had previously engaged in 8 years of physical activity (mild, moderate, and vigorous) improvements in the fluency of cognitive performance (perceptual speed, short-term memory, working memory, and episodic memory) where observed only in those subjects who had engaged in vigorous physical activity. By walking one-quarter of a mile or climbing 10 steps without resting, females and males between the ages of 70 and 79 years showed an increase in cognitive test score of the Mini-Mental Status Exam and the Digit Symbol Substitution (Watson et al., 2010). Moreover, a randomized controlled trial of resistance training (12 months) in 135 community-dwelling older women between the ages of 65 and 75 years improved fall-related self-efficacy and consequently improved the quality-adjusted life years test (QALYs) (Davis et al., 2011). There are numerous studies showing that progressive resistance training has a significant effect on the mental health scale of the SF-36 (Kimura et al., 2010), the selective attention and conflict resolution as compared with balance and tone exercises (BAT) (Liu-Ambrose et al., 2010c).

All in all, while there are many findings showing that physical activity plays an essential role in executive function promotion there is a lack of research dealing with the effect of strength training on executive functions in the aged population. Moreover, it remains unclear which aspect of executive functioning who benefit more from the strength interventions.

### 2.4.3 Executive Function Measurements in Older Adults

In the literature, three following tests are often used to evaluate executive functions in older adults: The Mini-Mental- State- Examination (MMSE), Montreal Cognitive Assessment (MoCA), and the Verbal Digit Span forwards and backward (VDS).

#### *2.4.3.1 Global Cognition*

Global cognition is often assessed using the Mini-Mental State Examination (MMSE) (Folstein & McHugh, 1975). The MMSE is widely used to assess cognitive functions aging studies including clinical settings. It consists of a questionnaire with 30 items to assess cognitive functions, such as orientation, attention, calculation ability, short-term memory, and language. The total score of the MMSE lies between 0 and 30, whereas a score less than 27 shows cognitive impairment with a sensitivity and specificity of 0.89 and 0.91, while a cutoff score of 24 reports cognitive impairment. This test takes between three to four minutes to administer. Generally, the MMSE is used to detect cognitive impairment for treatments of dementia in older adults. A re-test reliability scores of 0.887 was found when conducted twice and 24 hours apart by the same examiner in both examinations (O'Connor et al. 1989). In addition, the reliability and validity of the MMSE have been investigated in other studies as well. A review including fourteen papers showed reliability score between 0.80 and 0.95 for the MMSE in the test-retest assessments of participants with and without age-related cognitive disorders (Tombaugh & McIntyre, 1992).

#### *2.4.3.2 Montreal Cognitive Assessment*

The MoCA is a screening tool for mild cognitive impairment (MCL) with high sensitivity and specificity (Appendix Ⅲ). MCL is not considered as a type of dementia but rather a transition stage between normal aging and dementia. MoCa tests assess multiple cognitive domains such as memory, language, executive functions, visuospatial skills, calculation, abstraction, attention, concentration, and orientation based on paper and pencil assessments taking approximately 10 minutes to complete. It has a total of 30- points to evaluate the given domains. One extra point is added for participants who have 12 years or fewer of an educational background. A score of 26 or above is considered normal. Aside from clinical settings it is used for educational purposes as well.

#### *2.4.3.3 Verbal Digit Span*

Verbal-digit forward and backward tests measure the central executive component of working memory. Both tests consist of seven pairs of random number sequences and the score recorded ranging from 0 to 14. The verbal digit span is commonly administered in two parts of the digit span (digits forwards and digits backward) separately. In the digits forwards version, the participants need to repeat a series of orally presented digits, while in digits- backward version they repeat the digits in exact reverse order (Liu-Ambrose et al, 2008). Digits should be given by the examiner at the rate of one per second. In addition, the examiner should recite digits in an even monotone way without any variation in the pitch of the voice. The sequence begins with three digits, and when a participant failed in both attempts at the one level, the test is ceased.

## 2.5 Embodied Cognition and Aging

In the recent past, there has been an increasing interest in embodied cognition with focus on the body, its movements, and the interaction with the environment (Engel et al, 2013). Furthermore, embodied cognition represents the argument that the motor system influences our cognition, just as the mind influences bodily actions. For example, when participants hold a pencil in their teeth engaging the muscles in a smile, they comprehend pleasant sentences faster than unpleasant ones. While holding a pencil between the nose and upper lip to engage the muscles in a frown, the reverse effect is achieved, with the participants comprehending rather unpleasant sentences faster that pleasant ones (Glenberg et al, 2005). There is evidence indicating that a person's physical abilities influence their perception. For instance, as physical ability increases, hill slopes are perceived less steep, objects look closer, targets look bigger, obstacles look smaller, and target speeds look slower (Witt, 2011). Also, walking subjects carrying large loads to exert more energy perceive their goal target as located farther away (Witt et al. 2011). Furthermore, the distances to targets appear longer to people who are wearing a heavy backpack, are fatigued, have lower physical fitness, are older adults, or have poor physical health (Proffitt et al., 1995). In keeping with Witt (2011), aging leads to declining physical abilities so that older adults may perceive the world differently than younger people. As older adult's activities decline their bone density as well as the quantity and quality of the muscular system decrease (Metter et al. 1999). These physical declines are accompanied by a decrease of motor function (Seidler et al., 2010), mobility (Tinetti et al. 1986), balance control (Laughton et al. 2003), and an increase in falls (Kannus et al., 2005). In addition, the senses, brain function, and cognition are affected by aging (Ulfhak et al., 2002). For example, while muscle strength declined with aging decreases in the recruitment and activation of motor units were detected as well (Thomas et al. 2002). In contrast, aspects of cognition, such as language, semantic memory, and automatic aspects of attention or memory remain stable (Glisky, 2007). Some neuropsychological tests on motor performance showing faster execution and improved coordination are associated with higher scores in the video-gaming test in aging (van Muijden et al 2012). In contrast, during aging, slowing of motor performance occurs earlier than decreases in sensory processing (Yordanova et al, 2004). Another important cause for deficits in both motor and cognitive abilities, such as attention and executive function, relates to the dopamine depletion in the brain during aging (Bäckman et al, 2005). Moreover, healthy cardiovascular functioning is associated with increased cognition based on brain functioning (Debette et al., 2011). There is a manifold of evidence showing that physical activity enhances cognition in all age groups (Hillman et al., 2008) even in people with a Mild Cognitive Impairment (MCI) and dementia (Scherder et al, 2007). Human cognition benefits not only from a long-time practice of sports (Colcombe & Kramer, 2003) but also from the novelty in physical exercise programs during healthy aging and in MCI as well (Heyn et al, 2004). As a result, a higher health status in individuals can explain enhanced levels of physical activity and performance as well as in cognitive functioning and vice versa. For example, healthy older adults were less accurate than younger people when estimating the weight lifted by a performer (Maguinness et al, 2013). Moreover, the loss of muscle strength within the aging community is associated with a decline in the capability to lift objects and consequently leads to an overestimation of the lifted weight. Although, a growing number of studies have focused on cognition in young adults, there is less evidences in this field concerning older adults. Thus, investigations to explore embodiment effects for older adults may evolve to new clinical applications to maintain or improve cognitive functions when aging.

### *Perception-Action-Coupling and Anticipatory Behavioral Control*

Perception-Action-Coupling has been demonstrated in several studies related to the Ideomotor Principle. A first idea of the corresponding theory is rooted in James´ Ideomotor Principle (James, 1913) stating that movement contributes to establishing a mental tendency to execute that specific movement. In addition, an action is executed as soon as there is no contrary mental imagining taking place simultaneously (James, 1913). According to the theories on perception-action couplings there is an interconnection between perception and action representations in the brain so that perceptual representations contribute to action and vice versa (James, 1913). Evidence for this common coding idea was provided through experimental correspondences between an action code and its perceptual events such that action codes will be activated when an observer perceives that action or even derivatives from it (motor-simulation hypothesis) (Prinz, 1997). According to this view, the observer´s motor system affects the visual analysis of the actions performed by another person. As a result, people's visual sensitivity is interlinked to the actions carried out by other people even when influenced by the biomechanical constraints of their own bodies.

For a large part, human behavior is considered intentional leading to specific action outcomes (Hoffmann et al., 2007). For example, people cross the street, open a door, turn on the radio to attain specific purposes. Hence, Hoffmann and colleagues suggested model to account for this goal driven behavior (Hoffmann et al., 2007). This model proposes that any behavioral effect that meets an anticipated outcome will strengthen the corresponding action-effect relation. Consequently, learning is not only driven by the satisfaction of needs only but also by the affirmation of action goal anticipations which can flexibly refer to any future event or state (Hoffmann et al., 2007). The model further considers the given evidence that voluntary behavior is primarily determined by action-effects instead of stimulus-response associations (Hoffmann et al., 2007). Last not least, an explanation of stimulus-driven habitual behavior is covered, as the model assumes that action-effect relations become contextualized and can be evoked by the typical contexts in which they are experienced (Hoffmann et al., 2007).

## 2.6 Motor Cognition, Activity, and Aging

Embodied cognition claims that the body and its activity play a central role in shaping the mind (Wilson, 2002). In other words, the mind requires a body to work on problems. This concept of embodied cognition has emphasized that sensory and motor functions are crucial for proper interaction with the surroundings (Wilson, 2002). Physiological abilities and experiences related to action are the reference for our perception of the spatial layout. For example, participants suffering from backpacks perceived a slope to be steeper than normal subjects (Bhalla & Proffitt, 1999). Basketball players exhibited better performance and higher activation in the premotor cortex when observing occluded video displays of free throws in basketball as compared to coaches or commentators (Aglioti et al, 2008). According to behavioral studies, athletes not only show better sensory and motor performance than non-athletes but they are also able to better anticipate and predict the other actions. However, the neural mechanisms of these higher level perceptual-motor abilities remain unclear (Rizzolatti et al, 2001).

In addition, many daily activities include multiple tasks simultaneously with most of these tasks requiring motor activity and memory. Numerous studies argued that sensory-motor functional declines with normal aging (Yan & Zhou, 2009). For example, the result of a study on healthy older adults aged 65 years or older indicated a deterioration in movements, such as longer reaction times (RTs), lack of stability in RTs, longer movement times (MT), and disordered movements when compared to younger subjects (Yan, 2000). Thus, performing concurrent motor and cognitive tasks at the same time is more difficult for older adults (Verhaeghen & Cerella, 2002). Similarly, aging is accompanied by changes in cognitive (Sorel & Pennequin, 2008), physical (Cao et al, 2011) and perceptual-motor functioning (Ribeiro & Oliveira, 2007). In addition, studies demonstrated deficits in perceptual-motor performance (e.g., the accuracy, speed, efficiency, or quality of responses) along the cognitive aging process (Yan & Zhou, 2009). These deficits referred to sensory functioning, cognitive resources, processing speed, inhibition, and recollection (Yan & Zhou, 2009). There are numerous behavioral domains showing a reduction in cognitive and motor performances of older adults. Particularly, reductions in the sensory processing of visual and auditory stimuli, reaction times, and episodic memory were found (Yan & Zhou, 2009).

For the aging adult, the level of habitual utilization of motor-cognitive functioning is considered to determine the degree of deficits found in this domain (Ribeiro & Oliveira, 2007). Physical activity is considered to compensate or to slow down the cognitive and motor impairments. Therefore, a regular exercise interventions may decrease the rate of deterioration (Richeson et al, 2007). Hauer and colleagues showed that three months of physical exercise (walking, climbing stairs, sitting down and standing up) in 122 females and males between the ages of 65 and 80 years improved walking speed, step frequency, cadence, stair-climbing performance, and test scores in the Performance Oriented Motor Assessment and the Timed-Up-and-Go test (Hauer et al., 2012). Similarly, another study showed that 1,5 h of amateur dancing per week in 62 females and males between the ages of 65 and 84 years increased cognitive performance, reaction time, and performance in the Timed-Up-and-Go task (Kattenstroth et al., 2010).

Pichierr and colleagues (2012) investigated the effect of 12 weeks of progressive strength and balance training supplemented with additional dance video gaming on 31 females and males between the ages of 82 and 91 years. The results showed an increase in gait velocity and single leg support time in the dual-task condition group (Pichierri et al, 2012). In this regard, McGough and colleagues (2011) found that slower gait speed in 201 females and males older than 71 years of age lead to lower executive function performance. Moreover, associations were found between the Timed-Up-and-Go test, the executive functions and the Stroop-Interference measures (McGough et al., 2011). These findings showed a strong association between resistance training and walking speed, step frequency, cadence, the performance-oriented motor assessment, and Timed-Up and Go test (Kattenstroth et al., 2010; McGough et al., 2011; Pichierri et al., 2012). In addition, studies showed, as well, that physical activity corresponds to motor cognition effects in healthy subjects (Kourtzi & Shiffrar, 1999). However, it remains unclear to date whether and how strength training may be linked to motor cognition in the older adult.

# 3. GENERAL ISSUES AND HYPOTHESES

There is a manifold of studies indicating significant associations between physical activity and walking speed, step frequency, cadence, and other indices of motor performance and the risk of falling. Also, studies showed that motor functions and cognitive functions are associated across the life span and in the older adult. However, while various studies showed a correspondence between physical activity corresponds and motor cognition effects in healthy subjects, it remains unclear whether embodied perception differs in seniors depending on the amount and the quality of their physical activity.

## 3.1 Study Goals

### 3.1.1 Overall goal

The overall goal of this Ph.D. thesis is to analyze the effect of physical activity on motor cognition in older adults.

#### 3.1.2 Specific Issues

- Is there a relationship between physical activity and perceiving distance in seniors with, and without a handbag?
- Is there a relationship between physical activity and time estimates for walking in older adults with, and without a handbag?
- Is there a relationship between carry a load and estimation distance and time for walking in older adults?
- Is there a relationship between physical activity and estimation of weights carried in point-light video displays?
- Is there a relationship between physical activity and rating of perceived effort in older adults?
- Can physical activity improve the executive functions factors in older adults?
- Can strength training reduce motor cognition disorders in seniors?

### 3.2 Hypotheses

In the following, the hypotheses that arise from these issues are outlined.

#### 3.2.1 Hypothesis 1

**Accuracy in the rating of perceived distance and time needed for walking with - and without - a loaded handbag corresponds to the level of physical activity.**

During the aging process, there is a decline in balance control associated with an increased risk of falling in the older adult. Declined mechanical muscle function and dysfunction in combination to a decrease in muscle mass and an increase in fat mass are age-related changes to increase the risk of falling (Caserotti, 2010). However, studies have argued that these changes are not the result of age only, but, in addition, may originate from alterations in physical activity as well (Lesser et al., 1980; Lesser & Markofsky, 1979; Moritani & deVries, 1980). There is scientific evidence that regular physical activity (i.e., 30 minutes / day) such as walking, climbing stairs, biking, or gardening increases bone density, functional ability, and independence (DiPietro, 2001). In general, authors claim that regular physical activity is increasing overall health and improves life quality (Rejeski & Mihalko, 2001). Moreover, according to the Action-Specific Perception Account (e.g., Witt 2011), the perception of our environment is strongly influenced by our abilities in many ways. Therefore, a relationship between physical activity and perceiving distance is plausible. Recent studies of embodied perception have shown that distance perception is not only a function based on optical information but also a function of the observer's ability to act in physiological and psychological conditions. For example, people with poor physical fitness or older adults perceived hills as steeper as compared to normal adults (Proffitt et al., 2003). Similarly, distance perception is influenced by the energetic cost required to act in an environment. People who are tired or encumbered by carrying a heavy backpack (Bhalla and Proffitt 1999) or patients suffering from pain overestimated the distance and judged hills to be steeper (Picavet et al, 2002). Also, the perception of distance was found to be closely associated to the surface type such that older adults perceived distances further away on smooth surfaces than rough surfaces. In turn, these results were found in younger adults (Sugovic & Witt, 2013). Further, subject who had thrown heavy balls perceived target objects as further away as compared to throws with light balls (Witt et al., 2004).

Perceiving distance is generally influenced by the training status and the quality of motor abilities on different days. Athletes who had a good training day perceived targets bigger and closer than on a bad training day when targets look smaller and further away (Witt et al., 2004). The accurate perception of the surrounding environment is an important issue in life as physical activities such as walking, climbing stairs and crossing the street are associated with the accurate perception of distance. For example, city residenta are in need of a skill to estimate the distance between themselves and an approaching car while crossing the street. It could be argued that improvement in distance perception leads to the prevention of risk situations in older adults. In other words, an obscured distance estimation when moving around in a city can be harmful to seniors. Therefore, improvement in older adults's perception system can promote the quality of life in older adults (Sugovic & Witt, 2013). Moreover, research has provided insight that when executing cognitive-motor tasks in everyday situations such as walking, carrying objects, climbing stairs and crossing the street coordination in the processing of corresponding external information is needed (Hausdorff et al, 2001). However, such cognitive-motor phenomena may be constricted when the processing of motor information interferes with cognitive processing (Woollacott & Shumway-Cook, 2002b). According to the Ideomotor Theory, individuals often perform worse, slower, and/ or less accurate when performing two such tasks simultaneously (Ondobaka & Bekkering, 2012). This phenomenon is attributed to a bottleneck in the response selection stage of information processing (Pashler, 1994) resulting in serial rather than parallel processes with one task to completed consecutive to the other. Charlton (2009) argued that although motor and cognitive tasks can be executed successfully there is significant interference in both tasks in most cases. For example, talking on the phone while driving, both telephone conversation and driving performance may be impaired. In particular, executing cognitive-motor tasks may become difficult if a person's resources are limited, for instance, when people lose their muscle strength and/ or mobility through the aging process (Caserotti, 2010). To summarize, these examples indicate that abilities needed for human action may influence the perception of the environment. As a consequence, the effects of physiological and psychological factors on distance perception have been studied in connection within the concept of embodied perception. And one of these physiological factors that are considered to influence distance perception is the effect of age. In turn, there is a limited number of studies on how or whether age has an influence on perceiving distance. Owsley (2013) and Salthouse (2012) concluded that older people show a decline in body functioning such as mobility problems and a decrease in working memory, divided attention, and processing speed. Moreover, aging is associated with muscle and brain atrophy. Also, a decrease in physical ability during aging might be linked to decreasing cognitive factors (Clouston et al., 2013). Researchers are still investigating how physical activity affects brain function. One of the strategies to postpone aging consequences is regular body activity. Many types of research have dealt with the effect of the types of body activities on muscle power, in bones, joints, and strength. Bielak et al. (2014) reported that in a large population of 7000 male and female subjects physical activity had a positive effect on fluid cognitive ability, perceptual speed, short-term memory, working memory, and episodic memory across various age cohorts. The regular performance of a physical activity or skill can influence cognitive abilities such as distance estimation, speed estimation, the stability of attention, ability to form spatial topographic representation, and self-control. These cognitive abilities play an important role in the promotion of personal efficiency and performance both of which are linked to other socio-professional activity, in general (Vasilica et al., 2013). However, there are important questions that remain to be answered. For example, it is still unclear whether there is any relationship between physical activity and perceiving distance in seniors.

A corresponding experiment was conducted Proffitt and his colleagues (Proffitt et al., 2003). These authors found that observers estimated the distance to be larger when carrying a heavy backpack as compared to carrying no backpack. Hence, seniors in a carrying a handbag condition may exhibit larger distance estimates than seniors in no-handbag condition (in both active and inactive groups). In this respect, as physical activity was previously found to influence perception, we would speculate that physical activity older adults may moderate this given load effect when perceiving distances.

### 3.2.2 Hypothesis 2

**Physically active older adults are able to more accurately estimate weights carried by actors in point-light videos than physically inactive older adults.**

Interpreting other people's actions does not only depend on the visual cues available for the actions but may also rely on the individual’s mental and motor abilities. In other words, there a common coding system may exist to understand an action understanding and action execution (Gallese et al., 2004; Knoblich & Sebanz, 2006). On the other hand, changes related to aging affect both perceptual and motor abilities. However, there is little research about these changes that may affect the ability to interpret other people's movements. Among other goals, this P.h.D. project aims to investigate the effect of physical activity of older adults on their perception of weights carried by persons in point-light displays. So far, researchers have found that information on the size of an object cannot provide a reasonable judgment about the weight of the object. In other words, the perception of an object weight does not depend on the size of the object only (Charpentier, 1891). In his early studies, Charpentier showed that, from the participants’ view, two objects with the same weight but different sizes were perceived as differently heavy. The spacially smaller object was perceived as heavier, and the bigger object was perceived as lighter. Also, the material and the color of the object can influence the perception and the estimation of the objects weight (Charpentier, 1891). A good proportion of research was conducted on the neural mechanisms of weight judgments. Johnson (2009) showed that our perception and judgment of an object’s weight may help to properly handle or apply force to lift the object. This process proceeds without any need for time-consuming feedback to find a suitable force to lift that object. In other words, spacially larger objects of a certain material are lifted with a larger force than smaller objects consisting of the same material (Johansson & Flanagan, 2009).Therefore, a close to correct weight estimation is necessary for the manipulation of an object. An important source of information about the features of an object may be based on the observation of other people when lifting objects (Torriero 2007). Corresponding studies were conducted by providing the subjects with different sources of information on the motor processes of a object manipulation. For example, an interesting issue for researchers was whether an athlete could perform as a motor model for another person to determine his own motor output in sports such as badminton and squash (Abernethy, 1990; Abernethy & Russell, 1987). The research by Johannson (1973) claimed that showing motor information of a animal movement in a point-light display without extra information on the shape of the animal, was still sufficient for a categorization of the animal. In this respect, Johannson claimed that the kinematic patterns of a movement offer more comprehensive information to the observer than other information such as the real shape of the animal. These studies initiated expanding research in this field. One area of research concerned the perception of lifting movements. For example, Runeson and Frykholm (1981) showed that observing subjects could judge the amount of weight lifted and carried by another person only through showing point-light displays (Runeson & Frykholm, 1981). In this research, the subjects seeing the moving actors's small point-light markers on a dark screen only accurately judged actors movements through his kinematic point-light patterns. Moreover, running was found to provide special kinematic movement features clearly different from walking (Todd, 1983). Also, using a weightlifting experiment with point-light patterns, Bingham (1987) showed that, as the observer aims to estimate the weight of the smaller object, light weights are harder to accurately detect than heavier weights. He argued about the decreasing lifting speed when lifting a light object so that the observation of a heavy weight may be easier (Bingham, 1987). Shim et al. (2004) showed that, as the observers estimate a weight lifted, they predominantly rely on the effort or change in lifting kinematics. In other words, the ability and kinematic performance to execute an action influences the judgment and perception of the target of that action. The more intensive the action is for the person observed the harder the perception of its action is and the farther it is to reach the target. For example, the softball players hitting the ball skillfully see the size of the ball as larger than less skillful players (Witt et al. 2011). This phenomenon is reflected as well in a comment by a professional tennis player when indicating that, in the match, he feels things rather slow, and for the ball to be a little bigger and he has more time to hit the ball (McEnroe & Kaplan, 2003). Similarly, Dennis Scott, a basketball player, reported that throwing the ball into the basket is like throwing a stone into the ocean (Noble & Robertson, 1996). According to the theory of Embodied Perception, the higher level of sports skill the bigger the ball is perceived (Fodor, 1983; Pylyshyn, 1999). According to the theory of the Effect of Task Difficulty, if a sports skill difficulty changes, the target perception changes too. For example, if a golf player aims to hit a ball to a longer distance the hole is perceived as smaller (Witt, 2011). These results emphasize the role of the observer's own body and his abilities for using it.

Interestingly, humans are often accurately able in predicting what others will do. For example, when receiving a box from another person we use motor information to estimate the weight of the box (Hamilton et al., 2007). In this respect, the observers may use their motor system to simulate the observed motor actions to increase their perception (Gallese & Goldman, 1998). There is evidence obtained from the above-mentioned researches indicating that the observers' perception and action dealing with the distance, the hill slope, the object's weight, and/ or the size depends on their ability to act upon these objects. Importantly, a factor to restrict one's abilities for actions concerns age and aging and older adults are a large part of society. Therefore, our research project aims to determine the effect of bodily activities at older age on the perception of weights lifted by observed actors. Although studies did show that, as age increases, body activities decrease, likewise, people's perception and judgment will be influenced as well. However, the question remains which particular activity in seniors may increase the perception and judgment on object's weights when lifted by observed actors.

#### 3.2.3 Hypothesis 3

**Active older adults show a better score in executive functions in standard tests than inactive older adults.**

Executive functions are known as a complicated part of the human mental processes (Strauss et al., 2006) such that researchers have not yet reached an agreement for a generally accepted definition (Jurado & Rosselli, 2007; Miyake, Emerson, & Friedman, 2000; Salthouse, 2005; Strauss et al., 2006). For example, it has been suggested that executive functions may be considered as a collection of cognitive abilities to coordinate basic cognitive processes such as perception, attention, language, and memory (Alvarez & Emory, 2006; Elliott, 2003b; Strauss et al., 2006; Wecker, Kramer, Wisniewski, Delis, & Kaplan, 2000). In other words, the ability is highlighted to manage our live including abstract thinking, planning, and executing activities such as making an appointment and getting ready for it. As such, executive functions comprise of cognitive processes that are responsible for controlling, organizing, completing, and maintaining a cognitive capability (Stuss & Alexander, 2000). Also, short-term planning such as selecting the daily outfits, long-term planning, as saving money for a trip, repairing our car or purchasing a new one, and planning to retirement period refer to executive functions (Zelazo & Mller, 2002). Executive functions have been defined, as well, as a set of executive skills to settle novel problems, adjusting our behavior depending on new challenges, planning and executing complex purposive actions (Elliott, 2003a). Executive functions have been shown to be controlled by the frontal lobes, the prefrontal cortex, and neuronal cell assemblies in the brain that guide many body functions. These functions also include motor functions, meeting goals, emotions, motivation, making decisions, judgment, abstract reasoning, working memory, planning and completing tasks. Executive functions develop across adolescence and continue to develop into adult life (Elliott, 2003a). Generally, it was found that people with poor performance in executive function tests exhibit poor performances in their everyday activities. However, it is not yet clear how the scores of laboratory tests may properly reflect problems in a patient’s real life. As a result, a comprehensive understanding of the executive functions is essential for clinical neuropsychology to detect and improve cognitive dysfunction by providing suitable tools. In the following, definitions of the most critical components of executive functions are listed that have been mentioned above.

- Working memory and recall enable us to maintain and manipulate information in our minds for a while and then organizes and retains this information for future purposes (Wager & Smith, 2003).

- Attention is a cognitive ability so that the mind can choose a stimulus among several other stimulus (Embree & James, 1983).

- Judgment is the ability to consider appropriate limits on behavior, according to past experiences and considering values (Zinn et al., 2004).

- Planning is the ability to organize and do all the activities to reach a goal that can be broken down into detailed objectives (Lurija, 1997).

A frontal lobe dysfunction and loss of the prefrontal cortex and limbic system may be associated with a decline in executive function ability. Certain types of dementias such as Alzheimer´s and frontal dementia relate to the slow progressive decline, and in some progressive memory disorders, abilities may waver. The decline in executive function is considered to originate from brain cell changes leading to memory interference, bad judgments, and the difficulty to properly respond owing to poorly regulated attention. Especially older adults with executive dysfunction are not able to solve problems appropriately, learn a new task, organize their environment, make a right decision, for example while driving, and cannot recognize their mistakes (Reader et al., 1994).

Investigating age-related changes in executive functions and the relationship between physical activity and executive functions have recently received considerable attention in the scientific community. Exploring and understanding the positive effects of interventions that may help to maintain or progress executive functions throughout the aging process would of superior importance. Executive functions are included in a series of cognitive abilities such as planning and executing goal-directed behaviors, abstract reasoning, and judgment (Lezak, 1995). Moreover, studies indicate that poor executive functions may be associated with functional impairment and a dependent life affecting all aspects of our everyday life (Lezak, 2012; Strauss et al., 2006). There is a great deal of research attention on cognitive abilities in seniors as compared to young people. Further, results of cross-sectional studies indicate that age-related differences in executive functions between younger adults and active older adults are reduced as compared to inactive older adults (Abourezk & Toole, 1995). Also, cross-sectional studies revealed that people with a higher level of cardiorespiratory fitness showed higher cognitive functions (Abourezk & Toole, 1995; Spirduso, 1975). Other research showed that lower scores on executive function tests provide a increased risk for falling in subjects with minimal balance impairments. This effect is attenuated in individuals with an overall poor balance (Buracchio et al., 2011). Li and coworkers reported that lower levels in the fear of falling are significantly related to higher levels of falls self-efficacy and functional outcomes (Li et al, 2016). The fall-related feeling of self-efficacy is considered to mediate the influence of the fear of falling on functional outcomes (Fuzhong et al., 2002). Overall, improved selective attention, conflict resolution, and fall-related self-efficacy are independently associated with improved gait speed (after accounting for age, global cognition, baseline gait speed, and change in quadriceps strength). Also, 12 months of resistance training once or twice a week increased the executive functions concerning selective attention and conflict resolution among senior women (Liu-Ambrose et al., 2010a; Liu-Ambrose et al., 2010b). Previous studies have indicated that while some adults experience substantial changes in cognition performances during their aging process for others such changes may be less dramatic (Christensen et al., 1999). The observed differences in cognitive performances may provide insight into the individuals decline in cognition, particularly with respect to the factors dealing with an age-related decline in executive functions.

Only few studies have explored the differences in cognitive abilities between active and inactive older adults individuals. For example, cross-sectional studies suggested that older adults with lower scores in executive functions suffer from larger functional impairments (Cahn-Weiner et al., 2000; Carlson et al., 1999; Grigsby et al., 1998). Additionally, other studies reported that age-related cognitive declines may be limited by physical activity (Abbott et al., 2004; Weuve et al., 2004). However, these investigations did not distinguish between several kinds of physical activity, e.g., resistance training. On the other hand, a number of investigations on age-related changes in executive functions were inconclusive (Cahn-Weiner et al., 2000; Grigsby et al., 1998; Weuve et al., 2004). Therefore, inter-individual variability in performance with age and especially the effect of physical activity on executive functions in older adults requires further investigation. The present thesis aims to investigate the effect of physical activity on executive functions in seniors and specially to find out about a effective exercise types to maintain or improve the executive functions in older adults. Therefore a longitudinal study was conducted to examine the effects of three resistance training programs on executive functions throughout a 10-week training program in a sample of older female and male adults.

### 3.2.4 Hypothesis 4

**Physically active older adults show better measure of confidence to master physical activities presented in image displays on situations with different demands for postural control, strength, and coordination in indoor and outdoor daily tasks than physically inactive older adults.**

Coping with daily tasks was summarized as cognitive and behavioral efforts of persons to manage life's problems (Lazarus & Folkman, 2015). For the older population, this issue is particularly important and globally acknowledged. Many older adults believe that declining functional abilities and suffering from diseases are responsible for their decreased abilities to cope with their situations of daily living and losing the independence of their life (Andersson et al., 2008). Also, the increase of the older population is accompanied by larger concerns on how to keep older adults living an independentl life at home. At old age, carrying out activities of daily living and meeting everyday needs becomes harder and more personal (Pietila & Tervo, 1998). Coping with such daily tasks is a multidimensional phenomenon including many factors affecting everyday life, such as physical, psychological and social factors (Pietila & Tervo, 1998). According to Lazard and Folkman, people make a set of cognitive and behavioral efforts, depending on specific demands to avoid threatening their well-being, and which may be accompanied by the consequence of better or worse changes in comparison to the initial situation (Lazarus & Folkman, 2015). Effort perception is the most common method to detect and interprets the sense emerging from the body during physical activity (Noble & Robertson, 1996). The perceived effort provides the information to assess and adjust the intensity of exercise (Edelman & Mandle, 1998). Also, many studies have indicated a positive association between the rating of perceived effort and the metabolic indexes in adults (Chen et al., 2002; Noble & Robertson, 1996). According to Bandura's Emotional Arousal Theory people show be encouraged to perceive their physiological and psychological arousal before performing a task in a positive way and to enhance their self-efficacy to eventually perform the task (Bandura, 1977). Self-efficacy is considered a belief in our abilities to perform a task that gives us adequate control over difficult experiences in our life (Bandura, 1977). For example, if people facing difficulties believe in their capabilities to execute the task they would be more likely to overcome the given obstacles. In turn, the feeling of self-efficacy increases through the performance of a pleasurable behavior (Bandura, 1977). Another study emphasized that positive self-esteem has a positive effect on stressful life events (Kling et al., 1999). This positive esteem is considered as an essential component of mental health to cope with everyday tasks. On the other hand, perceived effort and self-efficacy are related to physical activity (McAuley & Courneya, 1992). McAuley and collogues (1992) found higher pre-exercise self-efficacy to result in a significant decrease in the perceived effort during exercise. This association became more significant when increasing task difficulty. In the same line, high rates of perceived effort were associated with more discomfort during exercise. Overall, existing literature in the field suggests that an adequate mental preparation is an essential prerequisite for an effective performance in terms of a relationship between the physical ability of the people and their psychological condition with the environment providing an ideal setting to develop both physical abilities and psychological features. During the aging process, the physical condition and general health may influence perceived effort to a larger extent than the aging process itself (Groslambert & Mahon, 2006; McAuley & Courneya, 1992). In this regard, another study confirmed that older adults who were involved with different activities such as social, cultural, educational and sport were more found more independent and active than others not involved in such activities (MacKean & Abbott-Chapman, 2012).

Scientific evidence suggests that exercise has a positive effect on the accuracy to rate the perceived effort in estimation and production tasks (Eston & Williams, 1988). Here, however, studies investigated the effect of the aging process on perceived effort only. Therefore, there seems to be a need for investigations to compare the rate of perceived effort within active versus inactive older adults. On the other hand, maintaining and enhancing the functional abilities in older individuals has a positive effect on their coping ability to live their life independently and to promote quality of life. In fact, widespread studies on the quality of life exist (Pavot & Diener, 1993) particularly for older adults (Khan & Pegues, 1998). Since many seniors live alone or with a likewise older partner, these individuals may have larger problems with their primary daily living tasks such as cooking, taking a shower and basic mobility than older adults who live with their children. As a result, older people often need multiple care requirements (Andersson, Burman, & Skär, 2011). Kim et al. (2013) found that life satisfaction of older adults may be affected by their perceived health status, self-esteem, depression, age, and their monthly pension. Among these factors, self-esteem along with depression has been known to be a stable component of personality interlinked to life satisfaction. In other words, a higher level of self-esteem and a lower level of depression are associated with a high level of life satisfaction among older people (Hong & Giannakopoulos, 1994). Also, there is a need for research on older adults for example after suffering from chronic diseases as these individuals would like to cope with their daily activities and good quality of life across their lifespan. Recently, there have been clinical arguments and evidence that physical and cognitive activity increase the quality of life among older adults. Hence, the purpose of this PhD study was to examine the association between rating of perceived effort when aiming to cope with briefly presented images of daily indoor and outdoor tasks with the level of physical activity in older adults. Such analysis may provide some insights into the expectations of the abilities to cope with during older adults daily living based on their rate of perceived self-efficacy (confidence level arising from their physical abilities). We assumed that males and females perceive effort in a similar manner (Mihevic, 1983).

# 4. CROSS-SECTIONAL STUDY

In this cross-sectional study, we examined individuals at one point in time. Moreover, a brief overview of the subject, exercise protocols, and motor cognitive tests are included.

## 4.1 Distance Estimation Study

### 4.1.1 Method

**Participants**

Forty old people, ranging in age from 65 to 80 years (20 active (M=75.8 y, SD=3.62), 20 inactive (M=78.05 y, SD=1.73)) and twenty students from the University of Kassel as a control group (M=25.1 y, SD=2.31) participated in this study. The design of this study wa adopted from a study by Proffitt (Proffitt, Stefanucci, Banton, & Epstein, 2003). The sample size calculation for the number of participants was based on the means of the sample and the standard deviations in the Proffitt study ($\alpha$=0.05; Power-value= 0.80). The older subjects in our study were subdivided into an active and an inactive group based on the Freiburg Questionnaire (Appendix Ⅱ) for Physical Activity[1] (Frey et al., 1999). Participants were recruited and interviewed from the exercising older adults in the fitness studio of the University of Kassel and written consent was obtained from them. They were informed about their participation in three related experiments without further knowledge about the purpose of the experiments. A score of $\geq$ 24 on the Mini-Mental State Examination (MMSE) and a normal or corrected-to-normal vision were inclusion criteria for the study. All participants were

1 <15 MET h/week = “Not active enough”, 15-30 MET h/week = active, >30 MET h/week = aatisfactory active; MET= Metabolic Equivalent of Task

treated according to the ethical standards in the latest version of the Declaration of Helsinki (October 2013). Also, participants were asked to eat a meal before the test, as a carbohydrate manipulation may cause decreases in distance estimates (Zadra et al, 2016).

**Apparatus and Stimuli**

The experiment was conducted on the football field of the University of Kassel. Participants estimated the distances in two conditions (with a handbag and without handbag). For the handbag condition, subjects carried a total of one fifth to one six of their approximate weight reported in a questionnaire for handbag condition (Proffitt et al., 2003). The distances ranged from 4 to 16 meter marked by golf tees. The golf tees were hidden on the gras surface so that participants were not able to see them from the distance. Participants were situated at the center of a semicircle. Six golf tees were located at different distance from the center in a radial pattern (Figure 1). The angles between the tees' locations towards the center were set as multiples of 30 degress. For the distance estimation of the individual location a small construction cone was used to mark each participant's distance target.

**Design and Procedures**

The experiment consisted of three parts. In part one, participants made 18 distance estimates for each of the two (with and without) handbag conditions (6 practice trials and two blocks of 6 test trials). The targets for the practice distance trial estimates were located 2, 5, 7, 11, 13, and 16 meters away from the subjects' position and the test trial distances were 2, 4, 6, 8, 10, 12, and 14 meters (Table 1). In the second part, subjects estimated the required time to walk the distance to the target. Finally, they walked the distances to the target, while their walking time was measured by the experimenter. The arrangement of presentation of six stimulus distances on six radians was at random (to minimize a possible use of the environmental features as a reference distance from one trial to the next).

Experiment 2 was conducted within two consecutive weeks owing to number of participants and their avialability between 10 to 13 o'clock (to minimize the interference effect of temperature and sunlight). Participants stood at the center of the six radii while holding a one-meter ruler as a scale reference. At the beginning of each trial, participants were asked to face away from the field while the experimenter was changing the placement of target cones. Then, subjects turned around facing the field and reported, as accurately as possible, the distance (in meter ±50 cm) between themselves to the cone. In conditions two and three, participants were asked to imagine walking the distance to the target.

**Table 1**. Serial arrangement of distance stimuli (m) within practice and test trials

| Practice | Test | |
|---|---|---|
| Block 1 | Block 2 | Block 3 |
| 2 | 4 | 4 |
| 5 | 6 | 6 |
| 7 | 8 | 8 |
| 11 | 10 | 10 |
| 13 | 12 | 12 |
| 16 | 14 | 14 |

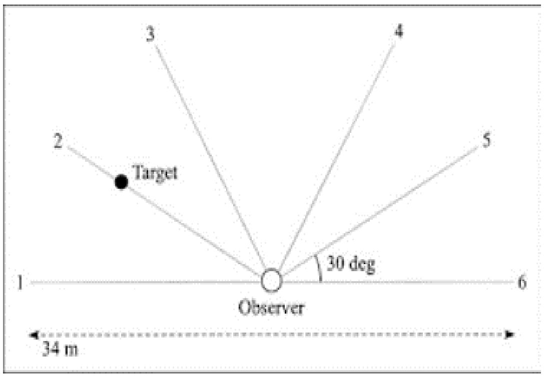


**Figure 1**. Target stimuli at six different angles

They were asked to verbally estimate, as accurately as possible, the time required to walk to the target. Following the entry of their estimations in the trial protocoll, subjects were asked to walk (with and without handbag) to the target while the experimenter measured their walking time. No time limit was set to enforce the participants' judgments. Each subject testing started with the practice trial to establish a common baseline for the distance estimates in the experiment. After the practice trials, participants were told that the practice trial was over in order to start the two test trials as soon as they felt ready.

### 4.1.2 Results

The results were organized in the following manner. At first, a statistical analysis was performed using Microsoft Office Excel 2010 and SPSS 23 (SPSS Inc., Chicago, IL, USA). For data management, Excel spreadsheets were used for the correction of typing errors and for detecting missing values. Then, the data was transferred into an SPSS data base for further analysis. Here, the difference between the estimated walking distance and the actual walking distance was calculated for all tested distances (4, 6, and 8 m as a short distance and 10, 12, and 14 m as a long distance). Then, the mean of these values (as a distance estimation error) was evaluated through an ANOVA.

T**able 2.** Descriptive statistics of distance estimation errors for short and long distances for the groups

| | Group | N | M | SD |
|---|---|---|---|---|
| DWL-Short- Error | Sports students | 20 | 0.82 | 0.85 |
| | Active Older adults | 20 | 0.82 | 0.52 |
| | Inactive Older adults | 20 | 1.87 | 0.58 |
| | Total | 60 | 1.17 | 0.82 |
| DWOL- Short-Error | Sports students | 20 | 0.97 | 0.76 |
| | Active Older adults | 20 | 0.80 | 0.35 |
| | Inactive Older adults | 20 | 1.19 | 0.40 |
| | Total | 60 | 0.98 | 0.55 |
| DWL-Long-Error | Sports students | 20 | 1.30 | 1.32 |
| | Active Older adults | 20 | 1.92 | 1.30 |
| | Inactive Older adults | 20 | 2.44 | 0.80 |
| | Total | 60 | 1.88 | 1.24 |
| DWOL-Long-Error | Sports students | 20 | 1.39 | 0.90 |
| | Active Older adults | 20 | 1.37 | 0.92 |
| | Inactive Older adults | 20 | 1.41 | 0.72 |
| | Total | 60 | 1.39 | 0.84 |

**Note.** DWL: Distance with the load; DWOL: Distance without load; N: Number; M: Mean; SD: Standard Deviation

According to the results of table3, “There was a significant effect of physical activity on the estimated distance at the $p<.05$ level for the three groups $F(2, 57) = 4.53$, $P = 0.01$. We used the Tukey's Post Hoc Test to compare the three groups with each other’s pairwise; the results (Table 4) Showed that sports students had less distance estimation error.

**Table 3.** Interaction effects between ANOVA factors influenceing estimated walking distance

| | SS | F | Sig. | Mean square | df | Partial $\eta^2$ |
|---|---|---|---|---|---|---|
| Distance | 18.79 | 36.39 | 0.00 | 18.79 | 1,57 | 0.39 |
| Distance* Group | 2.34 | 2.26 | 0.11 | 1.17 | 2,57 | 0.07 |
| Load | 6.94 | 21.6 | 0.00 | 6.94 | 1,57 | 0.27 |
| Load* Group | 9.59 | 14.96 | 0.00 | 4.79 | 2,57 | 0.34 |
| Distance* Load | 1.42 | 9.04 | 0.00 | 1.42 | 1,57 | 0.13 |
| Distance* Load* Group | 0.55 | 1.75 | 0.18 | 0.27 | 2,57 | 0.05 |
| Group | 16.84 | 4.53 | 0.01 | 8.42 | 2,57 | 0.13 |

**Note. SS: Sum of Squares**; df: degrees of freedom; $\eta^2$: Partial Eta Squared (effect size between groups)**,** Sig: Error Probability

**Table 4. ANOVA** pairwise comparisons of distance estimation error between groups

| Group | Group | Mean difference between groups | Std.Error | Sig. | 95% Confidence Interval for Difference | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| | AE | -0.10 | 0.21 | 1.00 | -0.64 | 0.42 |
| SS | IE | -0.60* | 0.21 | 0.02 | -1.14 | -0.07 |
| AE | IE | -0.50 | 0.21 | 0.07 | -1.03 | 0.00 |

**Note.** SS: Sports students; AE= Active Older adults; IE= Inactive Older adults, Sig: Error Probability

Post hoc comparisons using the Tukey HSD test indicated a significant difference between the three groups. The mean difference show that the inactive older adults group has overestimated the distance more than the other two groups. Moreover, the graphical illustration below indicate that the active older adults group has estimated the distance by the approximately the same amounts as the sports student´s. Furthermore, the load condition had a significant effect on distance estimation error such that the distance estimation errors increased with larger loads. Also, there a significant interactive effect was found between the load condition and the group factor.

For the interaction effect between the group factor and the load factor, the results show that distance estimation error was higher in the load condition as opposed to without load. According to the following diagrams, distance estimation error was higher for the long distances in comparison to the short distances in all the three groups (with and without load condition).

**Table 5**. Effect of load on the distance estimation error

| Load | Estimated Distance Mean | Std. Error |
|---|---|---|
| With Load | 1.53 | 0.10 |
| Without Load | 1.19 | 0.080 |

**Table 6.** Walking distance estimation error between the groups at short distances

| Distance | Estimated Distance Mean | Std. Error |
|---|---|---|
| Short Distance | 1.08 | 0.07 |
| Long Distance | 1.62 | 0.12 |

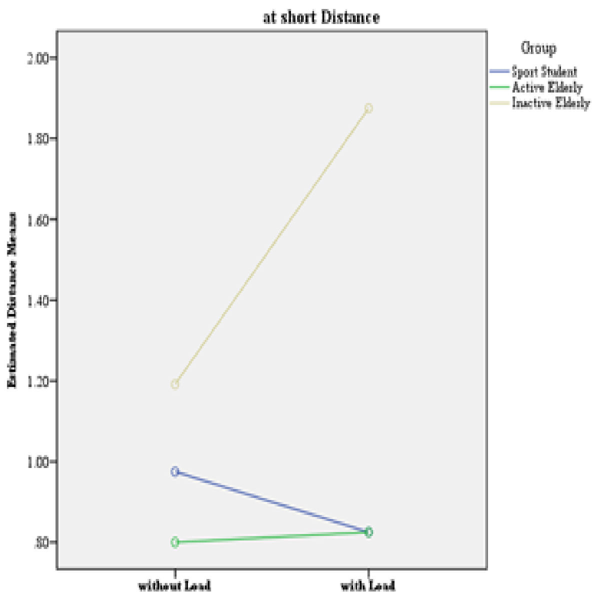


**Figure 2.** Walking distance estimation error between the groups at short distances

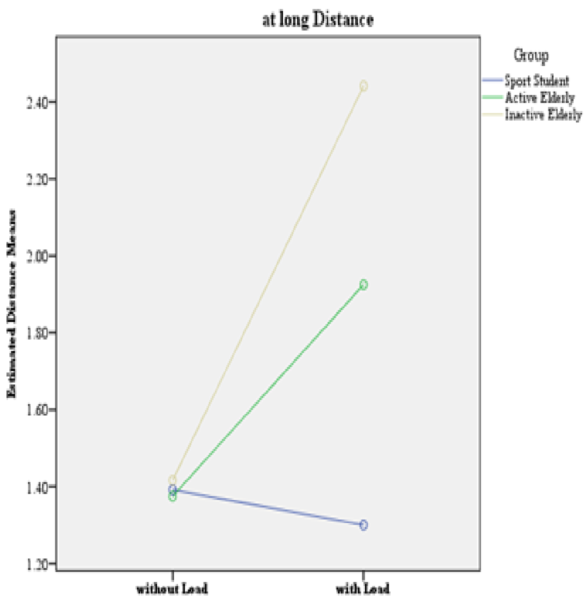


**Figure 3.** Walking distance estimation error between the groups at long distances

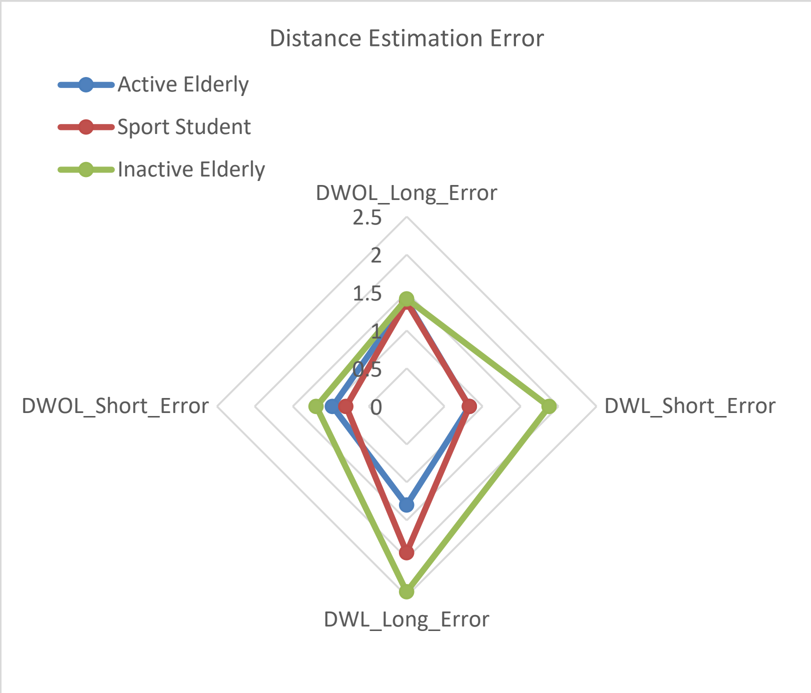


**Figure 4.** Distance Estimation Errors depending on long and short distance lengths

**TNote:** (DWL_Short_Error: Distance with Load_Short Distance_Error, DWOL_Short_Error: Distance without Load_Short Distance_Error, DWL_Long_Error: Distance with Load_Long Distance_Error, DWOL_Long_Error: Distance without Load_Long Distance_Error)

Moreover, the difference between the estimated walking time and the actual walking time was analyzed as a walking time estimation error for short distances (4, 6, and 8 meters) as compared to long distances (10, 12, and 14 meters) with and without load. Then mean walking time estimation error analysed through an ANOVA.

According to Table 9, no significant effect on the walking time estimation error between the three groups was detected. However, load and distance factors had a significant effect on this time estimation error. In particular, further investigation showed that the time estimation error was longer with load condition.

**Table 7.** The effect of load on walking time estimation error

| Load | Time Estimation Error Mean | Std. Error |
|---|---|---|
| With Load | 2.00 | 0.17 |
| Without Load | 1.68 | 0.16 |

**Table 8.** Descriptive statistics of time estimation error for the three groups

| | Group | N | M | SD |
|---|---|---|---|---|
| TWL-Short- Error | Sports students | 20 | 1.40 | 1.05 |
| | Active Older adults | 20 | 1.02 | 0.64 |
| | Inactive Older adults | 20 | 1.26 | 0.89 |
| | Total | 60 | 1.22 | 0.87 |
| TWOL-Short- Error | Sports students | 20 | 1.22 | 0.92 |
| | Active Older adults | 20 | 0.81 | 0.71 |
| | Inactive Older adults | 20 | 1.01 | 0.77 |
| | Total | 60 | 1.02 | 0.81 |
| TWL-Load-Error | Sports students | 20 | 2.54 | 2.10 |
| | Active Older adults | 20 | 3.00 | 2.06 |
| | Inactive Older adults | 20 | 2.80 | 1.68 |
| | Total | 60 | 2.78 | 1.93 |
| TWOL-Long-Error | Sports students | 20 | 2.40 | 2.37 |
| | Active Older adults | 20 | 2.14 | 1.51 |
| | Inactive Older adults | 20 | 2.46 | 1.61 |
| | Total | 60 | 2.34 | 1.84 |

**Note.** TWL: Time with Load; TWOL: Time Without Load; N: Number; M: Mean; SD: Standard Deviation

**Table 9.** Pairwise comparisons of walking time estimation error between groups

| | Sum of Squares | F | Sig. | Mean square | df | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Distance | 123.98 | 69.23 | 0.00 | 123.98 | 1 | 0.54 |
| Distance * Group | 2.55 | 0.71 | 0.49 | 1.27 | 2 | 0.02 |
| Load | 6.31 | 11.47 | 0.00 | 6.31 | 1 | 0.16 |
| Load *Group | 1.44 | 1.31 | 0.27 | 0.72 | 2 | 0.04 |
| Distance * Load | 0.83 | 2.23 | 0.14 | 0.83 | 1 | 0.03 |
| Distance* Load* Group | 1.35 | 1.81 | 0.17 | 0.67 | 2 | 0.06 |
| Group | 1.34 | 0.93 | 0.91 | 0.56 | 2 | 0.03 |

**Table 10**. Walking time estimation error for short and long distances

| Distance | Time Estimation Error Mean | Std. Error |
|---|---|---|
| Short Distance | 1.24 | 0.10 |
| Long Distance | 2.56 | 0.23 |

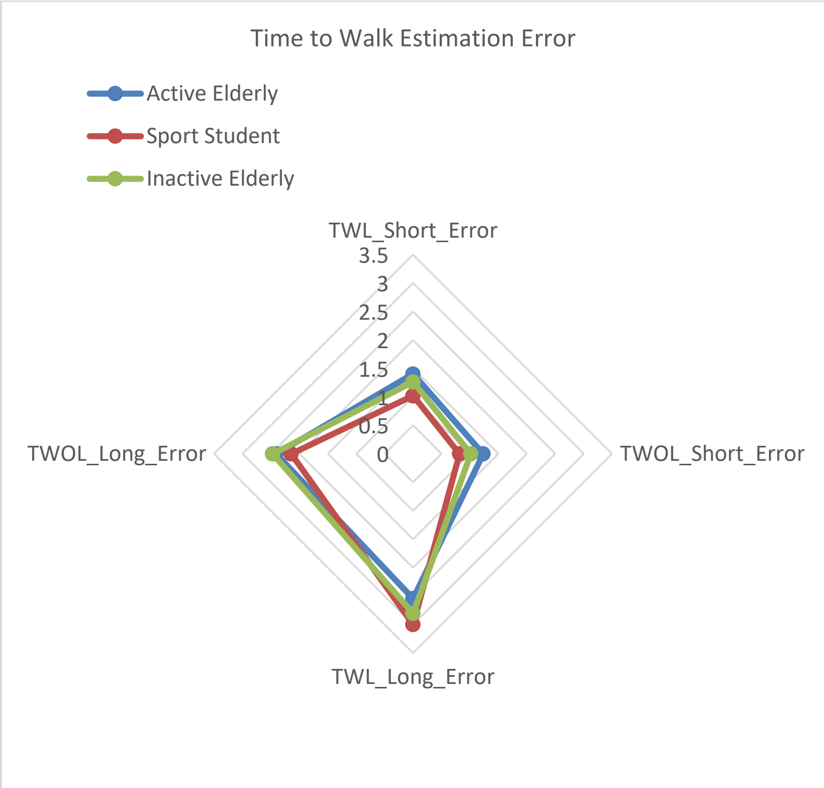


**Figure 5.** Comparison of time estimation error in short and long distances with and without load

**TNote:** WOL-Long_Error: Time without Load_ Long Distance_Error, TWL_Long_Error: Time with Load_Long Distance_Error, TWOL_Short_Error: Time without Load_Short Distance_Error, TWL_Short_Error: Time with Load_Short Distance_Error

## 4.2 Weight Estimation Study

Based on the above outline of the literature on the influences of weight estimations we hypothesize that the physical activity is a determinat for weight estimations in older adults. Sport students weight estimations were used as a control reference.

Hypothesis: Physically active seniors show better weight estimates for weights carried in point-light video displays than inactive seniors.

### 4.2.1 Method

Participants

A total of sixty volunteers participated in this study. Twenty sports students (M=25.1, SD=2.31) from the University of Kassel, twenty active older adults (M=75.8, SD=3.62) from the fitness studio of the Kassel the sports institute, where they regularly exercised, and finally, twenty inactive older adults (M=78.05, SD=1.73) from nursing homes, were recruited for the analysis. Inactive older adults were recruited through a newspaper advertisement. The sample size calculation for the number of participants was based on the primary outcome measure in the previously outlined Proffitt study (Proffitt et al, 2003). Older adults were subdivided into an active and an inactive subgroup by employing the Freiburg Questionnaire for Physical Activity (Folstein et al., 1975). A score of ≥ 24 on the Mini-Mental State Examination (MMSE) and a normal or corrected-to-normal vision were used as inclusion criteria for the study. Subjects were not informed about the goals of the experiment. All participants gave their written consent to participate in the study. The experiment was conducted in respect of the ethical standards listed in the latest version of the Declaration of Helsinki (October 2013).

Apparatus and Stimulus

For our study, a similar presentation method as used by Grierson and colleagues including point-light walkers as stimulus material was adopted (Grierson et al., 2013). The point-light stimulus of an actor lifting boxes of various sizes and weights was available to observers. This manipulation was conducted in order to influence observer's weight estimation. As compared to Grierson and coworkers, the same pivot points were utilized to represent the foot. However, here, three points (to create a realistic gait pattern) instead of two points as in the Grierson et al. study were used with the head being respresented by one point. For our experiment (90̊ to the object), a sagittal view was used for the stimulus presentation. For stimulus presentation, both sides of the body were displayed. Otherwise, a difference could possibly evolve between the types of movement (lifting & lowering vs. pulling & pushing). All stimuli were presented on a laptop (Fujitsu Lifebook, windows 7 SPI). EPrime 2.0 (Psychology Software Tools (PST), Inc., and Sharpsburg, USA) was used to present the stimuli and to record the responses. As stimulus material, a male actor (180 cm, 81 kg, 27 years) performed different whole-body actions (pulling, pushing, lifting, and lowering) with three different weights each (lift &lower: 12, 24, and 36 kg) adopted from Grierson et al (pull & push: 9, 15, and 21 kg). There were two movements to be tested. To exclude laterality effects, especially for the recording of pulling and pushing actions), each stimulus video was mirrored horizontally. Thus 4 (movement) ×3 (weight) ×2 (direction) conditions were presented. Videos were presently with a frame rate of 50 Hz in real time. Owing to the different tasks, not all videos had the same length. For example, the movement time for a step cycle in the pushing task was different (21kg - 4.5s, 15kg - 4s, and 9kg - 3.5s) leaving it open, the weights could have, at least theoretically, been identified by the different video lengths. Therefore, random no-action time periods were included between the video start and the beginning of the movement action. All videos were produced in the same mp4 format (1280×720 pixels) and with the same movement direction. The weights were determined with a traction measuring system (luggage scale) by the experimenter. Point-lights figures were generated by attaching markers on selected body locations: toe, heel, ankle, knee, hip, shoulder, elbow, wrist, and head. The movements were captured by a body-centered camera system. The camera view angle was 90̊ and the distance between the camera and the target was three meters.

For all videos, the camera set-up was kept constant. Thus, no change of perspective was possible. Point-light displays were produced on the basis of the 3-D marker coordinates. The background was kept black with all points presented in white. The participants observed the point-light movements from a lateral perspective with a camera position of 1.7 meters in vertical height and three meters apart from the actor. In the first frame, the actor was shown in an upright standing posture while the object was located in front of him (the object was not visible in the video). Next, the beginning of the downward acceleration towards the object was presented. For all lifting tasks presented, the actor already grasped the object before starting to lift. The beginning of the upward acceleration was shown next. The duration for the lifting movements was shorter than for the lowering movements.

Design and Procedure

The experiment was conducted in the biomechanics laboratory of the University of Kassel, Germany. Sixty subjects subdivided in three groups (20 active older adults, 20 inactive older adults and 20 sports students) had volunteered to participate in the experiment. The active older adults participants ranged in age from 65 to 80 years (M= 75.8, SD= 3.62) and inactive older adults (M: 78.05, SD: 1.73). The age range for the sports student group was between 20 to 30 years (M=25.1, SD= 2.31).

For the computer-based experiment, participants were seated at approximately 50 cm to the monitor. At the beginning of the experiment, subjects received information guidelines about the production of the point-light videos by showing them the real person (prepared with markers) lifting, lowering, pulling, or pushing a box simultaneously with a corresponding point-light figure carrying out the same actions. An experimental block with 3 ×72 trails was presented to the participants in a random order. Four anchor videos for the lifting, lowering, pulling, and pushing tasks (middleweight) were presented at the beginning of the block as a reference. Participants were informed about the weight presented in the reference videos. Then, they were asked to estimate the weight of the box in the point-light display as precise as possible in the following display before showing the anchor again. Participants used keys (5 = light; 3= middle; & 1= heavy) from the numeric keypad on a response box (Psychology Software Tools, Mode: 200 A) to enter their judgements. Their response time was not limited. The experiment contained two breaks such that participants were able to continue as soon as they were ready.

### 4.2.2 Results

This paragraph shows the main results of this second experiment. Statistical analysis was performed using Microsoft Office Excel 2010 and SPSS 23 (SPSS Inc., Chicago, IL, USA). For data management, Excel spreadsheets were used to correct for typing errors and to detect missing values. Then, the data was transferred to SPSS for further statistical analysis. All in all, this study aimed to provide evidence for better weight estimates in point-light displays in active seniors weight as compared to inactive seniors.

To statistically evaluate the data, as a first step, mean correct answers (estimates) of each person for each weight and each task were extracted from 216 estimations and recorded as the score of that person (score 1 for a correct answer and score zero for incorrect answer). Then, a repeated measures analysis of variance was conducted with the factors: group (sports student, active older adults, and inactive older adults) × weight (12, 24, and 36 kg) × task (lifting, lowering, pulling, and pushing).

**Table 11.** Means (M) and Standard Deviations (SD) of weight estimation for the 4 tasks in the three groups

| | Active Older adults | | | Sports students | | | Inactive Older adults | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | SD | N | M | SD | N | M | SD | N | M | SD | N |
| Lift-LW | 13.40 | 4.057 | 20 | 10.00 | 4.104 | 20 | 8.05 | 5.155 | 20 | 10.48 | 4.925 | 60 |
| Lower-LW | 2.00 | 2.513 | 20 | 2.80 | 2.648 | 20 | 1.65 | 3.617 | 20 | 2.15 | 2.956 | 60 |
| Pull-LW | 14.35 | 3.014 | 20 | 10.85 | 4.545 | 20 | 10.55 | 3.873 | 20 | 11.92 | 4.175 | 60 |
| Push-LW | 4.65 | 4.368 | 20 | 11.45 | 4.407 | 20 | 8.30 | 4.879 | 20 | 8.13 | 5.283 | 60 |
| Lift-MW | 7.65 | 2.720 | 20 | 8.85 | 4.017 | 20 | 8.50 | 3.832 | 20 | 8.33 | 3.545 | 60 |
| Lower-MW | 11.70 | 2.618 | 20 | 10.55 | 3.348 | 20 | 9.15 | 2.907 | 20 | 10.47 | 3.105 | 60 |
| Pull-MW | 4.45 | 3.300 | 20 | 4.75 | 2.712 | 20 | 6.45 | 4.513 | 20 | 5.22 | 3.636 | 60 |
| Push-MW | 7.90 | 4.844 | 20 | 13.20 | 3.563 | 20 | 4.95 | 4.174 | 20 | 8.68 | 5.395 | 60 |
| Lift-HW | .80 | 1.642 | 20 | 1.75 | 2.552 | 20 | 3.10 | 3.447 | 20 | 1.88 | 2.775 | 60 |
| Lower-HW | 6.05 | 3.845 | 20 | 4.75 | 3.596 | 20 | 8.45 | 5.094 | 20 | 6.42 | 4.435 | 60 |
| Pull-HW | 5.75 | 4.541 | 20 | 10.65 | 4.030 | 20 | 12.20 | 4.786 | 20 | 9.53 | 5.190 | 60 |
| Push-HW | 17.65 | .745 | 20 | 15.20 | 2.608 | 20 | 17.40 | .754 | 20 | 16.75 | 1.945 | 60 |

**Note:** LW= Light Weight; MW= Middle Weight; HW= Heavy Weight; M= Mean; SD= Standard Deviation; N= Number of samples

**Table 12.** The interaction effect between variables on correct weight estimation

| Source | F | Sig. |
|---|---|---|
| weight | .714 | .492 |
| weight * group | 5.788 | .000 |
| group | 3.942 | .025 |
| task | 99.160 | .000 |
| task * group | 8.219 | .000 |
| weight * task | 108.007 | .000 |
| weight * task * group | 8.897 | .000 |

The results of the repeated measures analysis of variance presented in Table 12 show that no significant difference exists for the errors in the estimation of different weight categories. However, significant differences were detected between the three subject groups analyzed and between the different tasks (pulling, pushing, lifting, and lowering) ($P<0.05$). In addition, the interaction effects between these factors were found to be significant as well. Moreover, the results of Tukey's post-hoc test showed that the weight estimation (regardless of the weight category and the task) in the sports students' group more precise than in both groups of older adults. In particular, a statistically significant difference was found between the sports students’ and active older adults (Table 13).

**Table 13.** Multiple comparisons between groups using Tukey HSD Post Hoc

| (I) group | (J) group | Mean Deviation (I-J) | Sig. |
|---|---|---|---|
| Active Older adults | Sports students | -.70* | .023 |
| | Inactive Older adults | -.20 | .721 |
| Sports students | Inactive Older adults | .50 | .134 |

To further investigate about the statistical meaning of the group factor, the task factor, and the interaction between group and task, a repeated measure ANOVA as conducted for each weight category separately (Table 14).

**Table 14.** Within- and between-subjects effects using ANOVA with repeated measures

| | Light | | Middle | | Heavy | |
|---|---|---|---|---|---|---|
| | F | Sig. | F | Sig. | F | Sig. |
| Group | 2.790 | .070 | 8.004 | .001 | 7.043 | .002 |
| Task | 80.896 | .000 | 20.868 | .000 | 296.110 | .000 |
| Task * Group | 9.931 | .000 | 7.767 | .000 | 8.131 | .000 |

As shown in Table 14, there were no significant effects between the three groups in the lightweight; however, that was a significant difference in tasks and groups. The significant main effects and the interaction effect in Table 12 remained when analyzing the different weight categories separately. Employing Tukey's post-hoc test, we found that sports students in the middleweight had a significantly better estimate than the other two groups (Table 15). However, the inactive older adults group had a considerably better estimation than the active older adults group in heavyweight.

**Table 15**. Multiple comparisons of weight estimation between the groups using Tukey HSD

| (I) group | (J) group | Middle | | Heavy | |
|---|---|---|---|---|---|
| | | Mean Difference (I-J) | Sig | Mean Difference (I-J) | Sig |
| Active Older adults | Sports Students | -1.41* | .027 | -.53 | .775 |
| | Inactive Older adults | .66 | .429 | -2.73* | .002 |
| Sports Students | Inactive Older adults | 2.08* | .001 | -2.20* | .016 |

The impact of the task and the interaction effect of the group and task are also significant in all weights. This means that differences between tasks between differs in groups. Also, the interaction effect of the groups and tasks is also significant in all weights. In other words, the significant difference observed between tasks differs from one group to another group. For this reason, a variance analysis test with repeated measurements was performed to compare tasks between the groups and each weight that the results are presented in the Table 16The Bonferroni post Hoc analysis was again performed in a separate task for further examination of the effect of weight on the correct estimation of weights in the groups.

**Table 16.** Pairwise comparisons between tasks using Bonferroni post-hoc tests in the three groups

| Group | Task (I) | Task (J) | Light | | Middle | | Heavy | |
|---|---|---|---|---|---|---|---|---|
| | | | MD (I-J) | Sig. | MD (I-J) | Sig. | MD (I-J) | Sig. |
| Active Older adults | Lift | Lower | 11.400* | .000 | -4.050* | .000 | -5.250* | .000 |
| | | Pull | -.950 | 1.000 | 3.200* | .007 | -4.950* | .001 |
| | | Push | 8.750* | .000 | -.250 | 1.000 | -16.850* | .000 |
| | Lower | Pull | -12.350* | .000 | 7.250* | .000 | .300 | 1.000 |
| | | Push | -2.650 | .209 | 3.800* | .011 | -11.600* | .000 |
| | Pull | Push | | 0.00 | -3.450 | .229 | -11.900 | 0.00 |
| Sports Students | Lift | Lower | 7.200* | .000 | -1.700 | .613 | -3.000* | .004 |
| | | Pull | -.850 | 1.000 | 4.100* | .001 | -8.900* | .000 |
| | | Push | -1.450 | 1.000 | -4.350* | .022 | -13.450* | .000 |
| | Lower | Pull | -8.050* | .000 | 5.800* | .000 | -5.900* | .000 |
| | | Push | -8.650* | .000 | -2.650 | .200 | -10.450* | .000 |
| | Push | Push | | 1.00 | -8.450* | 0.00 | -4.550* | 0.00 |
| Inactive Older adults | Lift | Lower | 6.400* | .000 | -.650 | 1.000 | -5.350* | .000 |
| | | Pull | -2.500 | .130 | 2.050 | .941 | -9.100* | .000 |
| | Lower | Push | -.250 | 1.000 | 3.550 | .155 | -14.300* | .000 |
| | | Pull | -8.900* | .000 | 2.700 | .458 | -3.750* | .009 |
| | | Push | -6.650* | .003 | 4.200* | .005 | -8.950* | .000 |
| | Pull | Push | 2.250 | .458 | 1.500 | 1.00 | -5.200 | 0.00 |

**Note**: MD: Mean Difference

**Table 17.** The interaction effects of groups and weight on tasks

| | Lift | | Lower | | Pull | | Push | |
|---|---|---|---|---|---|---|---|---|
| | F | Sig. | F | Sig. | F | Sig. | F | Sig. |
| Group | 2.156 | .125 | 1.055 | .355 | 5.242 | .008 | 10.429 | .000 |
| Weight | 66.836 | .000 | 66.938 | .000 | 34.036 | .000 | 125.187 | .000 |
| Weight* group | 4.806 | .000 | 3.395 | .014 | 7.435 | .000 | 18.818 | .000 |

**Table 18.** Comparisons between the groups using Tukey HSD

| (I) group | (J) group | Pull | | Push | |
|---|---|---|---|---|---|
| | | Mean Difference (I-J) | Sig. | Mean Difference (I-J) | Sig. |
| Active Older adults | Sports students | -.57 | .476 | -3.22* | .000 |
| | Inactive Older adults | -1.55* | .006 | -.15 | .981 |
| Sports students | Inactive Older adults | -.98 | .114 | 3.07* | .001 |

The results of Table 17 show that the correct estimation of weights in two pull and push tasks between the groups is significant, but in the other two tasks, there is no difference between the groups. Using Tukey's post Hoc test (Table 18), it was found that there was also a significant pairwise difference between the groups. In addition to the weight effect, the interactive impact of weight ×group is significant as well as. This means that any difference between the effects of the weight on the correct amount of weight estimation differs between groups.

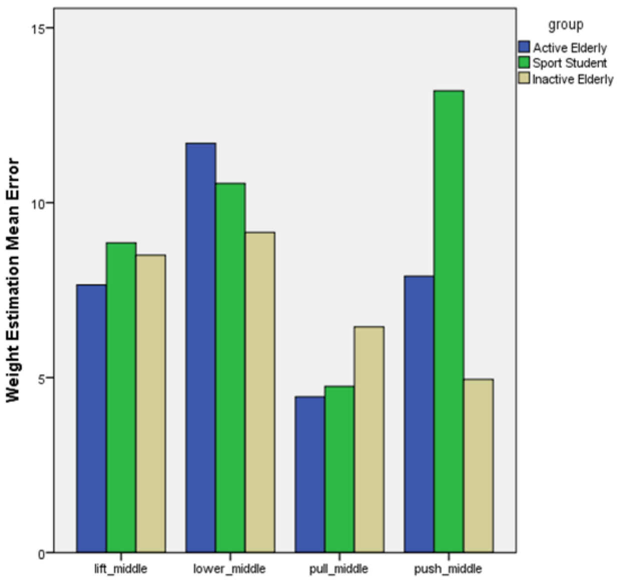


**Figure 7.** Mean Weight Estimation Errors for the middle weight (24 kg) in the subject groups depending on the task

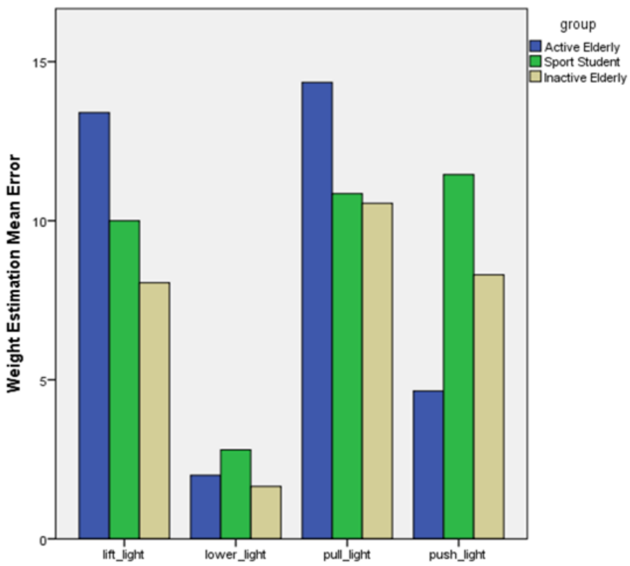


**Figure 6.** Mean Weight Estimation Errors for the light weight (12 kg) in the subject groups depending on the task

**Table 19.** Pairwise comparisons between weights using Bonferroni Post Hoc in the three groups

| | | | Lift | | Lower | | Pull | | Push | |
|---|---|---|---|---|---|---|---|---|---|---|
| Group | Weight (I) | Weight (J) | MD(I-J) | Sig. | MD(I-J) | Sig. | MD(I-J) | Sig. | MD(I-J) | Sig. |
| AE | Light | Middle | 5.75* | .002 | -9.70* | .000 | 9.90* | .000 | -3.25 | .056 |
| | | Heavy | 12.60* | .000 | -4.05* | .016 | 8.60* | .000 | -13.00* | .000 |
| | Middle | Heavy | 6.85* | .000 | 5.65* | .000 | -1.30 | .756 | -9.75* | .000 |
| SS | Light | Middle | 1.15 | 1.000 | -7.75* | .000 | 6.10* | .002 | -1.75 | .171 |
| | | Heavy | 8.25* | .000 | -1.95 | .284 | .20 | 1.000 | -3.75* | .006 |
| | Middle | Heavy | 7.10* | .000 | 5.80* | .000 | -5.90* | .000 | -2.00 | .119 |
| IA | Light | Middle | -.45 | 1.000 | -7.50* | .000 | 4.10* | .034 | 3.35* | .017 |
| | Middle | Heavy | 4.95* | .028 | -6.80* | .001 | -1.65 | 1.000 | -9.10* | .000 |
| | | Heavy | 5.40* | .000 | .70 | 1.000 | -5.75* | .005 | -12.45* | .000 |

**Note:** AE= Active Older adults; SS= Sports students; IE; Inactive Older adults, MD= Mean Difference, Sig: Significant

In other words, the significant differences observed between the weights differs from one subject group to the other. For this reason, a repeated measures analysis of variance was conducted to compare between the estimates for the different weights for each group and each task separately. The results are presented in the following Table 19.

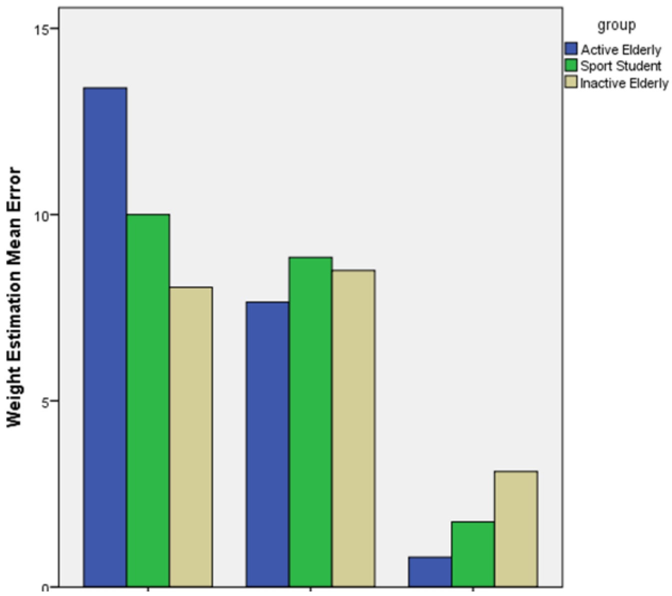


**Figure 9.** Mean Weight Estimation Errors in the subject groups depending on amount of weight (light (12 kg), middle (24 kg), and heavy (36 kg)) in the lifting task

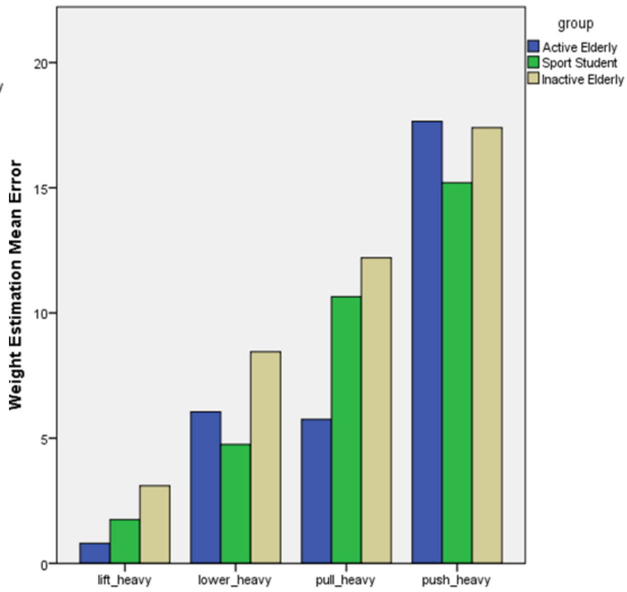


**Figure 8.** Mean Weight Estimation Errors for the heavy weight (36 kg) in the subject groups depending on the task

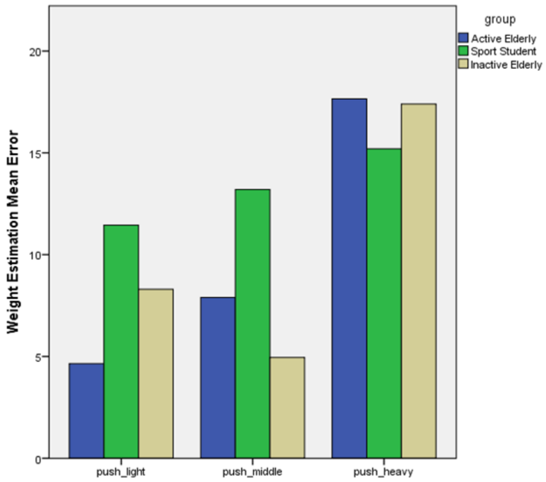


**Figure 10.** Mean Weight Estimation Errors in the subject groups depending on amount of weight (light (12 kg), middle (24 kg), and heavy (36 kg)) in the pushing task

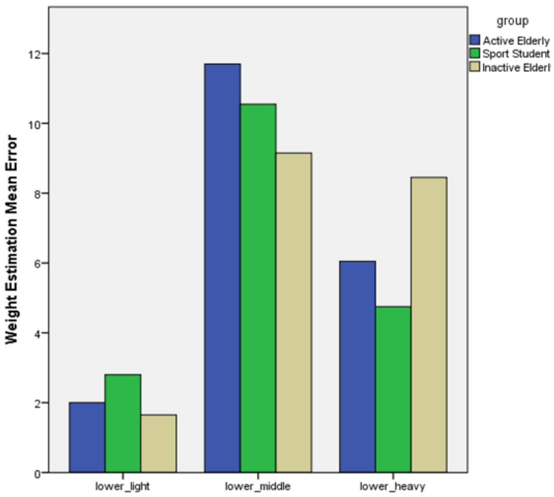


**Figure 11.** Mean Weight Estimation Errors in the subject groups depending on amount of weight (light (12 kg), middle (24 kg), and heavy (36 kg)) in the lowering task

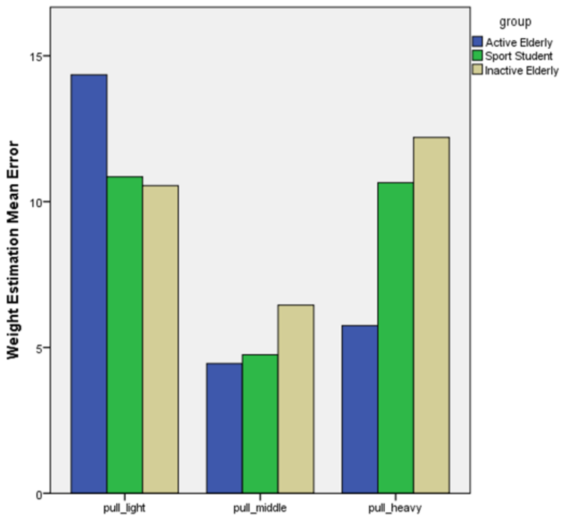


**Figure 12.** Mean Weight Estimation Errors in the subject groups depending on amount of weight (light (12 kg), middle (24 kg), and heavy (36 kg)) in the pushing task

## 4.3 Executive Functions Study

### 4.3.1 Method

Participants

There was a total of sixty volunteers participating in this study. Twenty sports students (M=25.1, SD=2.31) from the University of Kassel and twenty active older adults (M=75.8, SD=3.62) from the fitness studio of the Kassel Sports Institute were examined. Moreover, twenty inactive older adults (M=78.05, SD=1.73) from nursing homes were recruited through the advertisement as a reference group. All seniors were subdivided into an active and an inactive group through a median split according to physical activity levels resulting from the Freiburg Questionnaire for Physical Activity (Frey et al., 1999) (Appendix Ⅱ). A normal or corrected-to-normal vision was used as an inclusion criteria for the study. Subjects were not informed about the goals of the experiment. All participants completed a written consent form. The experiment was conducted according to the ethical standards of the latest version of the Declaration of Helsinki (October 2013).

Apparatus and Stimuli

The Montreal Cognitive Assessment (MoCA) was used as a rapid screening instrument to examine the different cognitive domains including attention and concentration, executive functions, memory, language, vision constructional skills, conceptual thinking, calculations, and orientation (Nasreddine et al., 2005). The completion of this test took approximately 10 minutes. The paper & pencil version of the Montreal Cognitive Assessment with 11 parts was used. Here, the maximum score is set to 30 points; a score of 26 or above is considered normal. Subjects received an additional point for having had 12 years or less of formal education. Instruction on all 11 test parts (appendix 3) was provided to each participant. Moreover, the Verbal Digit Span Test was used to investigate working memory. This test consisted of two parts repeating digits forwards and backwards. The instructor read sequences of numbers out aload (digits were given at the rate of one per second without any variation in the pitch of the voice). The test began with a three digit task and ended with a nine digit task. In part one, participants had to repeat the numbers as precisely precisely as possible as given by the instructor. In part two, subjects were asked to repeat the numbers in a reverse order (twice). For correct answer a score point was given. The test continued until subjects failed on both trials. For final score, points forwards and backwards were added up and converted into a standard score for indexing working memory (Appendix Ⅳ).

To assess the global cognitive functioning, we used the Mini-Mental-State-Examination (MMSE). The MMSE consists of two parts. The first part requires verbal responses. It includes orientation, memory, and attention tasks. Part two includes the ability to name and follow verbal and written commands, spontaneously write sentences on arbitrary issues, and copy two complex and similar polygon curves intersecting each other. The MMSE maximum score is 30. High scores close to this maximum indicate good executive functioning (Appendix Ⅰ).

Design and Procedure

This investigation explored the effect of physical activity on executive function test performances in older adults. Participants were subdivided to an active and inactive senior group based on their results in the Physical Activity Questionnaire in addition to sports students serving as a control group. Subjects were not informed about the study goals. The experiment was approved by the local ethics committee of the University of Kassel. It was conducted in accordance with the ethics standards in the latest version of the Declaration of Helsinki (October 2013). Written consent by all participants was obtained prior to participation. The experiment was conducted in the biomechanics laboratory of the Institute for Sports and Science at the Kassel University, Germany. Xxecutive function tests were administered by one examiner only. Participants completed the three executive function tests on three different days. The examiner was blinded for the underlying scientific hypothesis.

### 4.3.2 Results

In this paragraph, means and standard deviations are reported first. Then, the results of the One-Way ANOVA with between and within group comparisons will be forwarded for each executive function test. All in all, a statistically relevant effect of physical activity on executive function tests was found. All statistical analyses were performed using Microsoft Office Excel 2010 and SPSS 23 (SPSS Inc., Chicago, IL, USA).

**Table 20.** Descriptive data of the executive function tests in the three subject groups

| | Group | N | M | SD | Min | Max |
|---|---|---|---|---|---|---|
| MMSE | Active Older adults | 20 | 28.50 | 0.88 | 26 | 30 |
| | Sports students | 20 | 29.10 | 0.85 | 27 | 30 |
| | Inactive Older adults | 20 | 27.20 | 0.95 | 25 | 29 |
| | Total | 60 | 28.27 | 1.19 | 25 | 30 |
| MoCA | Active Older adults | 20 | 26.25 | 2.51 | 19 | 29 |
| | Sports students | 20 | 27.95 | 1.76 | 23 | 30 |
| | Inactive Older adults | 20 | 24.70 | 1.75 | 20 | 27 |
| | Total | 60 | 26.30 | 2.41 | 19 | 30 |
| VDS score | Active Older adults | 20 | 103.45 | 1.43 | 101.00 | 107.00 |
| | Sports students | 20 | 103.95 | 1.31 | 101.00 | 107.00 |
| | Inactive Older adults | 20 | 102.65 | 1.38 | 100.00 | 105.00 |
| | Total | 60 | 103.35 | 1.45 | 100.00 | 107.00 |

**Note:** MMSE= Mini Mental State Examination; MoCA= Montreal Cognitive Assessment; VDS= Verbal Digit Span; N= number of samples; M= mean; SD= Standard Deviation

A One-Way ANOVA test was used to assess score point differences for each variable between the three groups (Table 21).

**Table 21.** One-way results for the executive functions tests between the groups

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| MMSA | Between Groups | 37.73 | 2 | 18.86 | 23.37 | 0.00 |
| | Within Groups | 46.00 | 57 | 0.80 | | |
| | Total | 83.73 | 59 | | | |
| MoCA | Between Groups | 105.70 | 2 | 52.85 | 12.71 | 0.00 |
| | Within Groups | 236.90 | 57 | 4.15 | | |
| | Total | 342.60 | 59 | | | |
| VDS score | Between Groups | 17.20 | 2 | 8.60 | 4.52 | 0.01 |
| | Within Groups | 108.45 | 57 | 1.90 | | |
| | Total | 125.65 | 59 | | | |

**Note:** MMSE= Mini-Mental –State-Examination, MoCA= Montreal- Cognitive- Assessment, VDS= Verbal Digit Span

Significant differences were found between the three groups for executive function test variables. For a closer look, an examination of the between group differences was conducted using Tukey's post Hoc test (Table 22). Mutual comparisons show that the differences between active and inactive older adults were clearly larger than differences between sports students and active older adults if existent at all.

**Table 22.** Executive function tests between the groups using Tukey HSD

| | (I) Subject | (J) Subject | Mean Difference (I-J) | Sig. |
|---|---|---|---|---|
| MMSA | Active Older adults | Sports students | -0.60 | 0.09 |
| | | Inactive Older adults | 1.30* | 0.00 |
| | Sports students | Inactive Older adults | 1.90* | 0.00 |
| MOCA | Active Older adults | Inactive Older adults | 1.55 | 0.05 |
| | | | 1.70* | 0.02 |
| | Sports students | Active Older adults | 3.25* | 0.00 |
| | | Inactive Older adults | | |
| VDS score | Active Older adults | Sports students | -0.50 | 0.49 |
| | | Inactive Older adults | 0.80 | 0.16 |
| | Sports students | Inactive Older adults | 1.30* | 0.01 |

**Note:** MMSE= Mini-Mental –State-Examination, MoCA= Montreal- Cognitive- Assessment, VDS= Verbal Digit Span

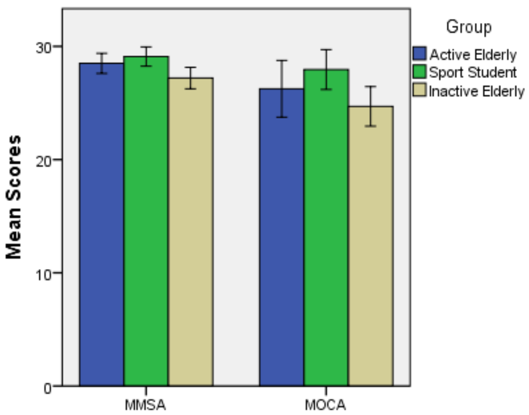


**Figure 13.** Scores points in the MMSE and the MoCA tests for the active and inactive older adults and for the sport students
**Note:** MMSE= Mini-Mental –State-Examination, MoCA= Montreal- Cognitive- Assessment

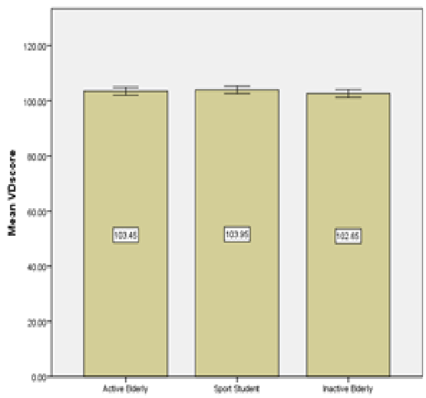


**Figure 14.** Scores points in the Verbal Digit Span tests for the active and inactive older adults and for the sport students

## 4.4 Coping with Indoor and Outdoor Tasks Study

### 4.4.1 Method

Participants

A total of sixty volunteers participated in this study. This was the same subject group as in experiments 1 to 3. Twenty sports students (M=25.01, SD=2.31) enrolled at the University of Kassel, twenty active older adults (M=75.8, SD=3.62) recruited in the University of Kassel fitness facility, and twenty inactive older adults (M=78.05, SD=1.73) from Kassel nursing homes were examined. Inactive older adults were recruited through newpaper ads. All older adults were subdivided in an active and an inactive group based on a median split referring to the results of the Freiburg Questionnaire for Physical Activity (Appendix Ⅱ). A score of ≥ 24 on the Mini-Mental State Examination (MMSE) and a normal or corrected-to-normal vision were used as inclusion criteria for the study. Subjects were not informed about the goals of the study. Written consent was given by all participants. The experiment was conducted in accordance with the ethical standards in the latest version of the Declaration of Helsinki (October 2013).

Apparatus and Stimuli

Photos of indoor and outdoor daily tasks were presented to the subjects on a laptop (Fujitsu Lifebook, windows 7 SPI). E Prime 2.0 (Psychology Software Tools), Inc., Sharpsburg, USA) was used for the presentation of the stimuli and the response recording. The experiment was conducted in two blocks. In the first block, participants were shown 30 photos of daily indoor tasks; each photo was repeated four times within a random order of all stimulus material. The second block consisted of 30 photos of daily outdoor tasks presented four times within a random order of the stimulus material as well. The length of each photo's display was limited to 8 seconds.

Design and Procedure

The study was conducted in the laboratory room designed for stimulus-response experiments at the Institut for Sports and Sport Science, Kassel University, Germany. For the computer-based experiment, participants were seated at approximately 50 cm distance to the monitor. Subjects received an instructed guide about the experimental procedures. At the beginning of each session, subjects were asked to start the experiment by pressing the middle key (number 3) of a 5-key response box (Psychology software tools, Mode: 200A).

A 5-point rating scale (in German language) was used to mark a response:

1 = Bad to cope with

2 = Rather bad to cope with

4 = Rather good to cope with

5 = Good to cope with

Participants were asked to answer at a first glance. The presentation sequence of photos was created in a random order.

### 4.4.2 Results

For the data analysis, the individual means of the response number were aggregated according to the indoor or outdoor content of the photos. A One-Way ANOVA was conducted to statistically analyse the differences between the subject groups.

**Table 23.** Mean values, standard deviations, mininma, and maxima for indoor and outdoor task photos in the three subject groups

| Group | | M | SD | | Min |
|---|---|---|---|---|---|
| Indoor | Active Older adults | 4.87 | 0.37 | 3.33 | 5.00 |
| | Sports students | 4.94 | 0.11 | 4.63 | 5.00 |
| | Inactive Older adults | 3.80 | 0.38 | 3.43 | 5.00 |
| | Total | 4.53 | 0.61 | 3.33 | 5.00 |
| Outdoor | Active Older adults | 4.62 | 0.49 | 2.70 | 5.00 |
| | Sports students | 4.95 | 0.09 | 4.72 | 5.00 |
| | Inactive Older adults | 2.89 | 0.51 | 2.45 | 4.91 |
| | Total | 4.13 | 1.00 | 2.45 | 5.00 |

**Note:** M= Mean; SD= Standard Deviation

**Table 24.** Within- and between group effects in a One-Way ANOVA

| | | Sum of square | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Indoor | Between Groups | 15.94 | 2 | 7.97 | 77.68 | 0.00 |
| | Within Groups | 5.64 | 55 | 0.10 | | |
| | Total | 21.58 | 57 | | | |
| Outdoor | Between Groups | 48.12 | 2 | 24.06 | 138.63 | 0.00 |
| | Within Groups | 9.54 | 55 | 0.17 | | |
| | Total | 57.66 | 57 | | | |

From Table 24, a statistically significant difference between groups for both indoor and outdoor tasks was detected by a One-Way ANOVA for indoor tasks F (2,55) =77.68, P= 0.00 and outdoor tasks F (2,55) =138.63, P=0.00. To find out about differences between the three subject groups, a Tukey post-test was applied. The results are presented in the following table.

**Table 25.** Multiple comparisons of groups for indoor and outdoor tasks using Tukey HSD

| | (I) Group | (J) Group | Mean difference (I-J) | Sig. |
|---|---|---|---|---|
| Indoor | Active Older adults | Sports students | -0.06 | 0.82 |
| | | Inactive Older adults | 1.07* | 0.00 |
| | Sports students | Inactive Older adults | 1.13* | 0.00 |
| Outdoor | Active Older adults | Sports students | -0.33* | 0.44 |
| | | Inactive Older adults | 1.72* | 0.00 |
| | Sports students | Inactive Older adults | 2.06* | 0.00 |

The results in Table 25 show statistically significant differences both indoor and outdoor photos in all group comparisons except for the active older adults versus the sports students. Interestingly, for both older adult groups statistical differences between indoor and outdoor tasks were detected through paired t-tests no such difference was found for the sport students Table 26.

**Table 26.** Paired comparison of indoor and outdoor tasks in three groups

| Group | t | Sig (2-tailed) |
|---|---|---|
| Active Older adults | 5.69 | 0.00 |
| Sports students | -1.72 | 0.10 |
| Inactive Older adults | 15.70 | 0.00 |

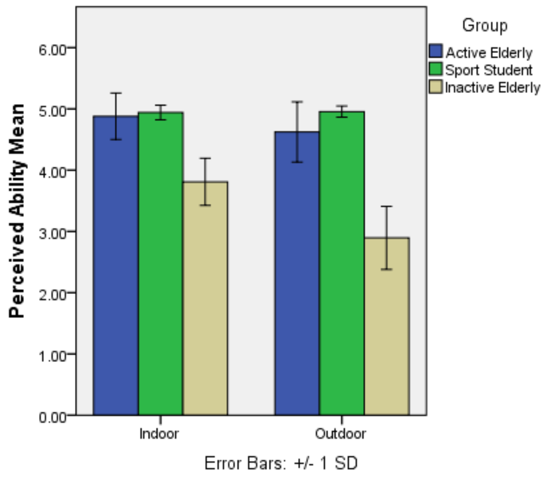


**Figure 15.** Perceived the ability to cope with indoor and outdoor tasks in the different groups

# 5. LONGITUDINAL STUDY

Aside for the above cross-sectional studies, a longitudinal study was conducted, as well, to investigate the effects of three types of resistance training in three subject groups of physically active but non-trained older adults on their distance estimation capabilities as dependent variable. Through this training study, the correspondence between physical activity in older adults and their distance estimation capabilities as indicate in chapter 4.1 should be further investigated with a special focus on strength training effects.

# 5. 1 Weight and Distance Estimation

### 5.1.1 Methods

Participants

A total of 82 older adults, aged 65 to 80 years, were recruited via advertisement through a local newspaper. Inclusion criteria for this experiment were the ability to walk independently and normal or corrected- to- normal vision. Their cognitive and mental health was assessed by the Mini-Mental-State-Examination (MMSE, <24 points). Based on the exclusion criteria in the pre-test results, 68 participants were included in the training study. The physical activity level was assessed through the Freiburg Questionnaire of Physical Activity. Participants were assigned (1: 1: 1) to one of three strength training groups balanced out by age and gender. Next, all groups were randomly stratified into one of three exercising modalities: machine-based stable resistance training (M-SRT), free-weigh resistance unstable training (F-URT), and machine-based adductor/abductor (M-ART). We used www.randomizer.org for the randomization of the training groups.

Design and procedures

A registered three-arm, single-blinded, randomized-control trial (Clinical Trials.gov: NCT03017365 on 01/04/2017) was conducted. The goal of the study was to examine the effects of three resistance training modalities on distance estimation in older adults. Participants were randomly assigned to one of the three resistance training groups. Participants were not informed about the research goals. Written consent was provided by all participants. The study was approved by the local ethics committee of the University of Kassel (E052016058) and all ethical standards of the latest Declaration of Helsinki (WMA, Oct. 2013) were considered. The pre- and post-test procedures were conducted in the biomechanics laboratory of the University of Kassel, Germany.

Distance Estimation

The distance estimations for an even and an uneven surface were examined for all participants by one single assessor. We marked the target distances using a cone and tape at the base line where participants were standing during their estimation task. Small plastic cones were placed at 3.80m, at 4.00 m, at 4.20 m, and at 4.40 m for the distance estimation. The sequence of distances was randomized with www.randomized.org. The participants underwent this procedure prior to their entrance to the laboratory. Participants estimated distances on both an even and an uneven surface. Moreover, they were asked to estimate the time they would need to walk theses distances (on even and uneven surfaces). For the first task, participants stood at the base line while holding a one-meter ruler as a scale reference and judged distances from their starting point to the cone placed at the given distance (3.80 m, 4 m, 4.20 m, or 4.40 m). Subjects verbally reported their distance and time estimates. Then, the actual walking time was assessed.

Weight Estimation

The same apparatus and the same stimuli were used as previously outlined in Chap. 4.2. Stimuli were presented on a laptop (Fujitsu Lifebook, windows 7 SPI). E Prime 2.0 (Psychology Software Tools (PST), Inc., and Sharpsburg, USA) was used to create the stimuli and record the responses. A male actor (180 cm, 82 kg, and 27 years) performed two different whole-body actions (lifting and pushing) with three different weights (12 kg, 24 kg, and 36 kg). Twelve-point-lights were generated by attaching markers on his body: toe, heel, ankle, knee, hip, shoulder, elbow, wrist and head. Point-light displays were produced by entering the 3-D coordinates of all markers. The participants were able to observe the movements from a lateral perspective, using a camera position of 1.7 meters in vertical height and five meters apart from the actor. All markers were a small white point presented in a black background. The actor was shown in the first frame standing upright while the box was in front of him (the box was invisible). The second frame showed the beginning of the acceleration downwards of the object.

The experiment was conducted in the experiment room of the University of Kassel, Germany. For the computer-based experiment, participants were seated at approximately 50 cm in front of the monitor. They received an instructed guide about the processes of making the point-light videos at the beginning of the experiment by showing them the real person (prepared with markers), who acted lifting and lowering a box and a corresponding point-light figure acting the same actions at the same time. One experimental block with 3 × 24 trails in a random order was presented to the participants. Two anchor videos of lifting and lowering tasks (middleweight) were shown at the beginning of the block as a reference. Participants were informed about the weight presenting in the reference videos. Then, they were asked to judge the weight of the box in the next eight trials before showing the two anchor videos again. Participants used the keys (5 = light; 3= middle; & 1= heavy) from the numeric keypad on the response box (Psychology Software Tools, Mode: 200 A) to enter their responses. Their response time was not limited. The experiment contained two breaks so that participants were able to continue as soon as they were ready.

## Training intervention

For all three groups, the exercise intervention began one week after the distance estimation in the pre-test. Two expert trainers supervised the training process at all time.

The participant-to-trainer ratio was 5:1. The exercise intervention lasted for 10 weeks. Subjects trained twice a week for one hour on non-consecutive days. The intervention included a one-week introductory phase and three major training blocks each lasting for three weeks in total. Training load was individually settled and progressively increased for every three-week block. The increase in the training load was based on a 15-repetition maximum (15-RM) measurement. Then, the resulting load was converted to the 1-repetion maximum load (1-RM) based on the prediction equation by Epley (Reynolds, Gordon, & Robergs, 2006) to calculate the required training load to be settled for each training block starting after week one and in weeks four and seven. The 15-RM measurement was conducted under stable conditions in every group. Three different rsistance training modalities were examined as intervention training including: machine-based stable resistance training (M-SRT), free-weight resistance unstable training (F-URT), and machine-based adductor/abductor resistance training (M-ART).

M-SRT: Primary exercises: squats exercises on a Smith machine with barbell fixed at hip level, leg-press exercise as main exercise routine; Secondary exercises: core performance exercises and walking with weights across an even surface.

F-URT: Primary exercises: squats on unstable surfaces with free dumbbell weights;, Secondary exercises: front lunges on unstable surfaces, core performance exercises incorporating an instability devices and carrying dumbbells while walking on an even surface (terrasensa classic; Huebner, Kassel, Germany).

M-ART: Primary exercises: thigh/hip adductor- and abductor resistance machine, Secondary exercises: adduction and abduction exercises using elastic rubber straps, lateral core exercises with participants walked on a motorized treadmill (robowalk, h/p/cosmos, Nussdorf-Traunstein, Germany) while applying a lateral pull to the ankles/ kness by elastic straps.

**The detailed intervention program, equipment, and progression are outlined in**

Table 10 for all groups and phases.

### 5.1.2 Results

Table 28 provides a summary of the mean pre-test and post-test distance estimate errors in the three resistance training groups. Version 23 of IBM statistical package for social science (SPSS) statistics was used for the statistical data analysis.

Variable 1: Distance Estimation

**Table 27.** Descriptive statistics for the distance estimation in the three training groups

| Distance Estimation | Group | N | M | SD |
|---|---|---|---|---|
| Pre-Test | M-SRT | 23 | 0.94 | 0.80 |
| | F-URT | 20 | 0.92 | 1.24 |
| | M-ART | 21 | 0.77 | 0.56 |
| | Total | 64 | 0.88 | 0.89 |
| Post-Test | M-SRT | 23 | 0.96 | 0.90 |
| | F-URT | 20 | 0.71 | 0.60 |
| | M-ART | 21 | 0.61 | 0.47 |
| | Total | 64 | 0.77 | 0.70 |

**Note. M-SRT =** Machine-based stable resistance training; F-URT = Free-weight unstable resistance training; M-ART = machine-based adductor/ abductor resistance training; N= number of samples; M; Mean; SD= Standard deviation

**Table 28.** Intervention program for the resistance trainng all groups across the intervention period

| | | Intro-phase (1week)<br>~2×12 reps (with low weights) | Block Ⅰ (3 weeks)<br>3×15 reps (%50 of the 1-RM) | Block Ⅱ (3 weeks)<br>3-4×15 reps (%60 of the 1-RM) | Block Ⅲ (3 weeks)<br>4×15 reps (%60 of the 1-RM) |
|---|---|---|---|---|---|
| M-SRT | Cross-Trainer | 10 min | 10 min | 10 min | 10 min |
| | Smith-Machine | 150° knee flex/ext angle | 120° knee flex/ext angle | 100° knee flex/ext angle | 100° knee flex/ext angle |
| | Leg-Press | 90° knee flex/ext angle | 90° knee flex/ext angle | 90° knee flex/ext angle | 90° knee flex/ext angle |
| | Core Exercise | Bridge exercise (2×15 reps) | Bridge exercise (3×20 reps) | Crunches (4×20 reps) | Air Bike Crunches (4×20 reps) |
| | Walking with dumbbells | 2 min without dumbbells | 3 min with 5% of BW | 4 min with 10% of BW | 5 min with 15% of BW |
| F-URT | Cross-Trainer | 10 min | 10 min | 10 min | 10 min |
| | Squats | 150° knee flex/ext angle on AIREX coordination rocker board round | 120° knee flex/ext angle on Thera-Band balance pads placed on AIREX coordination rocker board angled | 100° knee flex/ext angle on AIREX balance pad placed on AIREX coordination rocker board angled | 100° knee flex/ext angle on BOSU ball or Variosensa board |
| | Front Lunges | Thera-Band Balance Pads (front foot) | AIREX coordination rocker board round (front foot) and Thera-Band Balance Pads (rear foot) | AIREX balance pad (front foot) and Thera- Band Balance Pads (rear foot) | AIREX balance pad (front foot) and AIREX balance spinner soft (rear foot) |
| | Core Exercise (Bridge Exercise) | No additional device<br>No additional device | TOGU DYNAIR (under feet) | TOGU DYNAIR (under shoulder) & BOSU (under feet) | Swiss ball (under feet) |
| | Walking with dumbbells | 2 min without dumbbells on terrasensa flats | 3 min with 5% of BW on terrasensa flats | 4 min with 10% of BW on terrasensa classics | 5 min with 15% of BW on terrasensa |
| M-ART | Cross-Trainer | 10 min | 10 min | 10 min | 10 min |
| | Adductor | Habituation | Full ROM | Full ROM | Full ROM |
| | Abductor | Habituation | Full ROM | Full ROM | Full ROM |
| | Adductor Thera-Band | Habituation | Full ROM | Full ROM | Full ROM |
| | Adductor Thera-Band | Habituation | Full ROM | Full ROM | Full ROM |
| | Core Exercise | Side plank on knees | Side Crunches | Standing Oblique Crunch | Russian Twist Sitting with dumbbell %5 bw |
| | Treadmill walking on robot walk | 2 min habituation | 3 min with MLpull above knee joint with 5% of BW | 4 min with ML pull at ankles with 5% of BW | 5 min with ML pull above the knee joint and at ankles with 5% of BW, respectively |

Note: M-SRT = Machine-based stable Resistance training, F-URT = Free weight unstable resistance training, M-ART = Machine-based Adductor/ Abductor resistance training, reps = repetitions, RM = repetition maximum, BW = body weight, ML = medio-lateral, flex = flexion, ext = extension

The following variables were examined using ANOVA with repeated measures. All in all, the results showed that resistance training intervention had no significant effect on distance estimation (Table 29).

**Table 29.** Between and within subjects' effects of groups and pre- post-tests using ANOVA (Walking distance estimation error)

| | Sum of Squares | F | Sig. | Mean Square | df |
|---|---|---|---|---|---|
| Pre-Test - Post Test | 0.42 | 0.76 | 0.38 | 0.42 | 1, 61 |
| Pre-Test - Post Test* Group | 0.31 | 0.28 | 0.75 | 0.15 | 2, 61 |
| Group | 1.49 | 0.99 | 0.37 | 0.74 | 2, 61 |

Variable 2: Walking Time Estimation Error on Even Surface

**Table 30**. Walking time estimation error on an even surface

| Walking Time Estimation | Group | N | Mean | SD |
|---|---|---|---|---|
| Pre-Test Error | M-SRT | 21 | 5.72 | 8.09 |
| | F-URT | 17 | 5.89 | 10.36 |
| | M-ART | 19 | 3.68 | 4.93 |
| | Total | 57 | 5.09 | 7.93 |
| Post-Test Error | M-SRT | 21 | 5.07 | 7.54 |
| | F-URT | 17 | 1.64 | 1.42 |
| | M-ART | 19 | 2.72 | 6.11 |
| | Total | 57 | 3.26 | 5.92 |

**Note:** N: Number of Subjects, SD: Standard Deviation

According to the results in Table 31, there are no significant main effects or interactions effects for the walking time estimation error on the even surface.

**Table 31.** Main effects and interaction effects for walking time error measurements on an even surface

| | Sum of Squares | F | Sig. | Mean Square | df |
|---|---|---|---|---|---|
| Pre-Test vs. Post Test | 0.42 | 0.76 | 0.38 | 0.42 | 1, 61 |
| Pre-Test vs. Post Test* Group | 0.31 | 0.28 | 0.75 | 0.15 | 2, 61 |
| Group | 1.49 | 0.99 | 0.37 | 0.74 | 2, 61 |

Variable 3: Walking Time Estimation Error on Uneven surface

There is a significant effect on walking time estimation error on the uneven surface between pre and posttests so that, walking time estimation error on the uneven surface has decreased after the intervention. This reduction showed no significant difference between the three groups. However, a tendency was detected showing largely decrease in the walking time error estimation for F-URT (Eckardt & Rosenblatt, 2018).

Table 32. Descriptive statistics data of walking time estimation error on an uneven surface

| Walking Time Estimation Error | Group | N | M | SD |
|---|---|---|---|---|
| Pre-Test | M-SRT | 20 | 10.28 | 9.50 |
| | F-URT | 17 | 14.69 | 18.43 |
| | M-ART | 18 | 11.66 | 15.39 |
| | Total | 55 | 12.09 | 14.50 |
| Post-Test | M-SRT | 20 | 6.85 | 10.54 |
| | F-URT | 17 | 2.56 | 1.74 |
| | M-ART | 18 | 4.63 | 7.22 |
| | Total | 55 | 4.80 | 7.72 |

**Note: N: Number of samples, M: Mean, SD: Standard Deviation**

**Table 33**. Walking time estimation error on an uneven surface

| Variable | Sum of Squares | F | Sig. | Mean Square | df |
|---|---|---|---|---|---|
| Pre-Test- Post Test | 1551.63 | 15.48 | 0.00 | 1551.63 | 1, 52 |
| Pre-Test- Post Test* Group | 348.88 | 1.74 | 0.18 | 174.44 | 2, 52 |
| Group | 4.93 | 0.01 | 0.98 | 2.46 | 2, 52 |

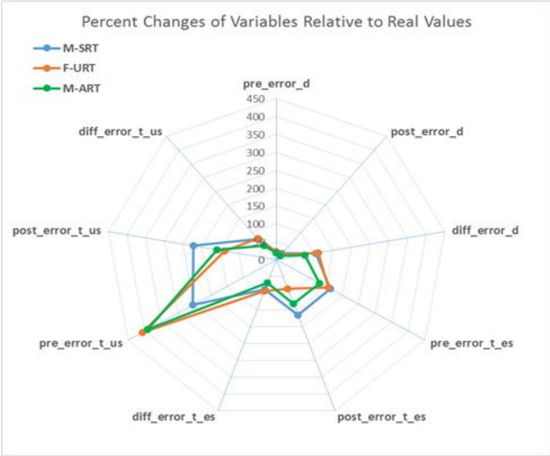


Figure 16. Percent changes of variables relative to the real values

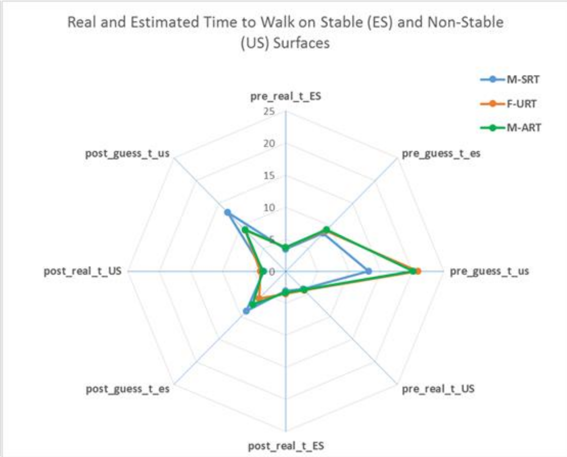


**Figure 17.** Real and estimated walking time on even and uneven surfaces

### 5.2.2 Results

We examined the effects of time, task, weight and group variables on the weight estimation error using the ANOVA test. (Time (2) × Task (2) × Weight (3) × Group (3)). The main effect results for each variable and their interaction effect presented in the following table.

**Table 34.** Within- and between-subjects effects using ANOVA with repeated measure

| Variable | F | df | Sig. |
|---|---|---|---|
| Time | 0.04 | 1 | 0.83 |
| Time x Group | 1.66 | 2 | 0.19 |
| Weight | 14.41 | 2 | 0.00 |
| Time x Weight | 2.01 | 2 | 0.13 |
| Time x Weight x Group | 2.34 | 4 | 0.05 |
| Group | 0.36 | 2 | 0.69 |

**Note:** df: degree of freedom, Sig: Significant

As indicated in Table 34, significant main effects for the weight, the task, and an interaction effect between task and weight were found. However, there was no significant difference between the three types of resistance training (main effect:

group). For a more detailed investigation on the relationships between tasks and weights an ANOVA with repeated measures and Bonferroni post-hoc tests were conducted regardless of the type of exercise for pre- and post-testing separately.

**Table 35.** Means and standard deviations of weight estimation error in pre- and post-test across training groups

| | Means | | | Standard Deviations | | |
|---|---|---|---|---|---|---|
| Variables | M-SRT | F-URT | M-ART | M-SRT | F-URT | M-ART |
| Height | 1.70 | 1.71 | 1.69 | 0.07 | 0.10 | 0.09 |
| Age | 69.4 | 71.4 | 69.6 | 3.6 | 4.1 | 3.8 |
| Pre-LLW | 0.64 | 0.73 | 0.59 | 0.20 | 0.18 | 0.28 |
| Pre-LMW | 0.45 | 0.45 | 0.38 | 0.24 | 0.26 | 0.19 |
| Pre-LHW | 0.06 | 0.05 | 0.09 | 0.08 | 0.11 | 0.19 |
| Pre-PLW | 0.47 | 0.52 | 0.52 | 0.31 | 0.30 | 0.32 |
| Pre-PMW | 0.55 | 0.60 | 0.61 | 0.21 | 0.23 | 0.21 |
| Pre-PHW | 0.95 | 0.95 | 0.89 | 0.07 | 0.07 | 0.16 |
| Post-LLW | 0.73 | 0.77 | 0.60 | 0.24 | 0.18 | 0.24 |
| Post-LMW | 0.32 | 0.33 | 0.43 | 0.17 | 0.23 | 0.23 |
| Post-LHW | 0.06 | 0.03 | 0.06 | 0.11 | 0.10 | 0.12 |
| Post-PLW | 0.53 | 0.44 | 0.53 | 0.31 | 0.36 | 0.32 |
| Post-PMW | 0.65 | 0.66 | 0.70 | 0.17 | 0.26 | 0.22 |
| Post-PHW | 0.92 | 0.95 | 0.86 | 0.13 | 0.07 | 0.16 |

**Note:** M-SRT = machine based stable resistance training; F-URT = free-weight resistance unstable training; M-ART = machine-based adductor/ abductor resistance training; N= number of subjects; LLW= lifting light weight; LMW= Lifting Middle Weight; LHW= Lifting Heavy Weight; PLW= Push Light Weight; PMW= Push Middle Weight; PHW= Push Heavy Weight; M= mean; SD= standard deviation

**Table 36.** Within-subjects' effects of task and weight in the pre-test

| Variable | F | Sig. |
|---|---|---|
| Task | 267.39 | 0.00 |
| Weight | 7.88 | 0.00 |
| Task * Weight | 131.79 | 0.00 |

**Note:** df: degree of freedom, Sig: Significant

**Table 37.** Bonferroni post-hoc tests between weights

| Weight | Weight | Mean Difference | Std.Error | Sig. |
|---|---|---|---|---|
| Light | Middle | 0.07 | 0.02 | 0.00 |
| | Heavy | 0.08 | 0.02 | 0.00 |

**Table 38.** Main effects for task and weight and their in post-testing

| Variable | F | Sig. |
|---|---|---|
| Task | 246.98 | 0.00 |
| Weight | 15.65 | 0.00 |
| Task * Weight | 134.87 | 0.00 |

**Note:** Sig: Significant

The results of the above table show that the weight estimation error in different tasks has a significant difference so that the estimated error rate in push is greater than lift. Also, the rate of weight estimation error in different weights is different, which are shown in pairwise comparison in the table below. The difference was only significant between lightweight and middleweight, and lightweight with a heavyweight so that the weight estimation error in the lightweight was more than two other weights. However, there was no significant difference between the middle and heavyweight.

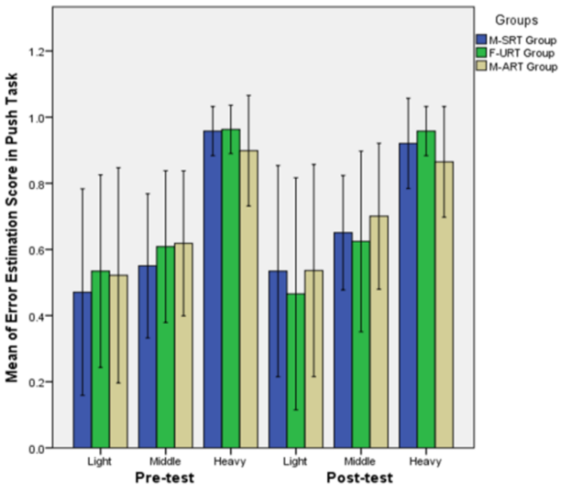


**Figure 18**. The intervention of weight-on-weight estimation error in lifting task

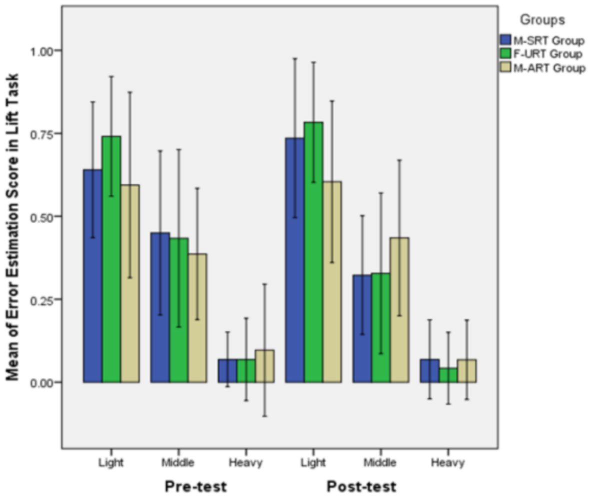


**Figure 19.** The intervention of weight-on-weight estimation error in pushing task

Also, the results of pre- and post- tests were compared using the t-Correlated Test which has been shown in Table 40 the results show a significant difference for only in two comparisons.

**Table 39.** Bonferroni post-hocs tests for differences between weights

| Weight | Weight | Mean Difference | Std.Error | Sig. |
|---|---|---|---|---|
| Light | Middle | 0.09* | 0.02 | 0.00 |
| | Heavy | 0.12* | 0.02 | 0.00 |
| Middle | Heavy | 0.02 | 0.02 | 0.87 |

**Table 40.** Paired comparison of tasks and weights between pre and post-test

| Group | Variable | t | df | Sig. (2-tailed) |
|---|---|---|---|---|
| M-SRT | Pre-LLW _ post-LLW | -1.91 | 20 | 0.07 |
| | Pre-LMW _ post-LMW | 2.35 | 20 | 0.02 |
| | Pre-LHW _ post-LHW | 0.00 | 20 | 1.00 |
| | Pre-PLW _ post-PLW | -0.79 | 20 | 0.43 |
| | Pre-PMW _ post-PMW | -1.68 | 20 | 0.10 |
| | Pre-PHW _ post-PHW | 1.43 | 20 | 0.16 |
| F-URT | Pre-LLW _ post-LLW | -1.40 | 20 | 0.17 |
| | Pre-LMW _ post-LMW | 2.46 | 20 | 0.02 |
| | Pre-LHW _ post-LHW | 0.75 | 20 | 0.45 |
| | Pre-PLW _ post-PLW | 1.12 | 20 | 0.27 |
| | Pre-PMW _ post-PMW | -0.23 | 20 | 0.81 |
| | Pre-PHW _post-PHW | 0.43 | 20 | 0.66 |
| M-ART | Pre-LLW _ post-LLW | -0.15 | 22 | 0.87 |
| | Pre-LMW _post-LMW | -0.84 | 22 | 0.40 |
| | Pre-LHW _ Post-LHW | 0.92 | 22 | 0.36 |
| | Pre-PLW _ post-PLW | -0.24 | 22 | 0.80 |
| | Pre-PMW _ post-PMW | -1.32 | 22 | 0.20 |
| | Pre-PHW _ post-PHW | 1.43 | 22 | 0.16 |

**Note**: LLW= Lifting Light Weight; LMW= Lifting Middle Weight; LHW= Lifting Heavy Weight; PLW= Push Light Weight; PMW= Push Middle Weight; PHW= Push Heavy Weight; M-SRT= machine-based stable resistance training; F-URT= free-weight unstable resistance training; M-ART= machine-based adductor/abductor training, dg: degree of freedom, Sig: Significant

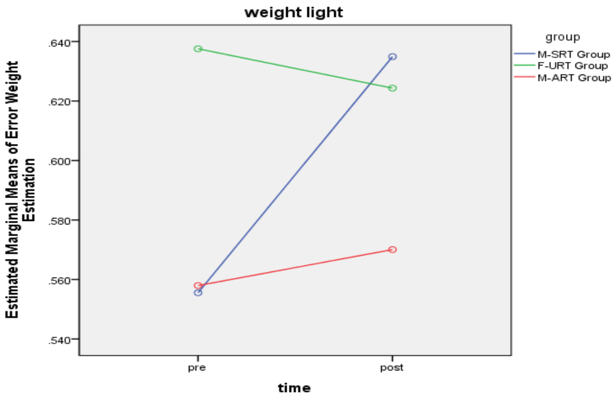


**Figure 20.** Light sight estimates in the three training groups

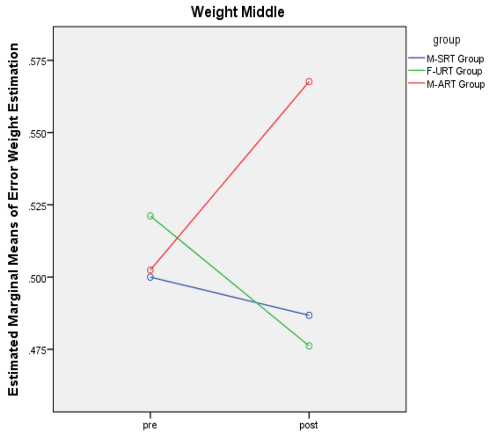


**Figure 21.** Middle weight estimates in the three training groups

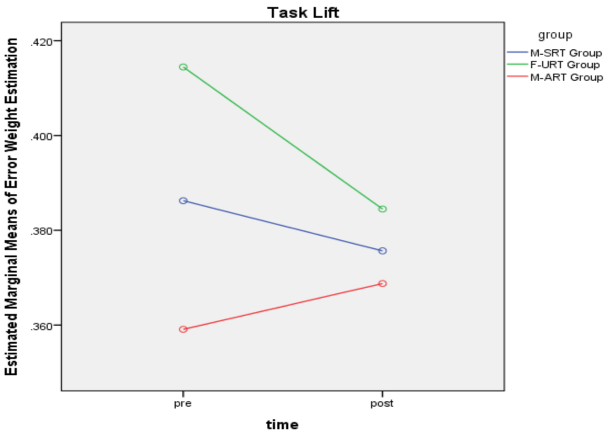


**Figure 22.** Pushing task weight estimates in the three training groups in the pre and post-test measurements

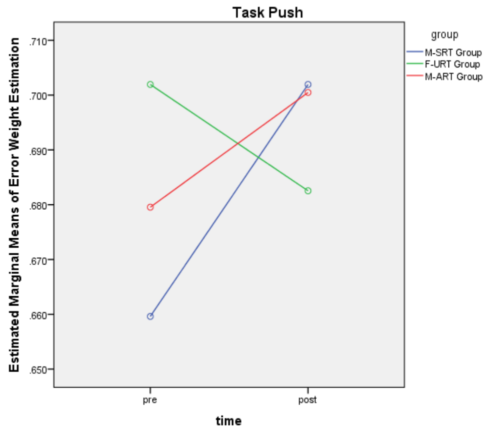


**Figure 23** Lifting task weight estimates in the three training groups in pre and post-test measurements

# 6. DISCUSSION

The presented PhD thesis includes a series of studies involving both cross-sectional and longitudinal investigations. The goal of these studies was, for a better understanding of the issue, to provide evidence that embodied perception differs in older adults depending on the amount and the quality of their physical activity. The results of these studies will be, now, discussed in the context of earlier evidence on the interaction of embodiment, aging, and physical activity (Seidler et al., 2010; Tinetti et al., 1986; Witt, 2011), executive function (Bielak et al., 2014; Kimura et al., 2010; Watson et al., 2010) and motor cognition (Kourtzi & Shiffrar, 1999).

In summary, our findings demonstrated:

1. Inactive seniors were found more likely to overestimate distances than active older adults and sports students (control group). Physical activity had a significant effect on the distance estimation error ($F(1, 57) = 36.39$, $p = 0.00$) and walking time estimation error ($F(1, 57) = 69.23$, $p = 0.00$).
2. Both active and inactive of older adults showed larger distance estimation errors in the load condition ($F(1, 57) = 21.68$, $p = 0.00$) as compared to the without load condition.
3. There was no significant difference in the walking time estimation error between with and without load conditions in the groups. However, load and distance had a significant effect on walking time estimation error.
4. In the longitudinal study, there were no significant differences in the distance estimation errors between the three types of resistance training ($F(2,61) = 0.99$, $p = 0.37$ between groups, pre- post-test $F(1,61) = 0.38$, $p = 0.38$). However, there was a significant effect of training on the walking time estimation error on uneven surface ($F(1, 52) = 15.48$, $p = 0.00$).
5. There were significant differences in walking time estimation error between pre and post-test for the free-weight unstable resistance training group (F-URT) ($t(16) = -2.84$, $p=0.01$) and for the machine-based adductor/abductor training group ($t(17) = -2.15$, $p = 0.04$).

6. A close to significance result was found for the walking time estimation on the uneven surface between pre and post-test in the three resistance training groups ($F_{(2,65)} = 2.38$, $p = 0.10$).

7. Physical activity had a significant effect on the weight estimation error ($F_{(4, 114)} = 5.20$, $p = 0.00$). However, there was no significant difference in weight estimation error between the three types of resistance training ($F_{(2, 62)} = 0.36$, $p = 0.69$). In turn, machine-based adductor/abductor training had a significant effect on weight estimation error in lifting middleweight task ($t_{(2)} = 2.35$, $p = 0.02$). In addition, free-weight resistance unstable training had a significant effect on weight estimation error in weight estimation for the lifting task in middle weights ($t_{(20)} =2.45$, $p = 0.02$).

8. In the cross sectional-study, active older adults showed a better score in executive functions standard tests than inactive older people.

9. The amount of physical activity had a significant effect on the ability to cope with daily indoor tasks ($F_{(2,55)} = 77.68$, $p = 0.00$) and outdoor tasks (($F_{(2,55)} =138.63$, $p = 0.00$) in older adults.

## 6.1 Distance Estimation (Cross-Sectional Study)

In this study, we investigated whether the physical activity status in seniors would affect their perception of distance, estimated walking time from a starting point to the given target, and the difference between estimated and real walking time. Moreover, the study examined the hypothesis that participants in a load condition would show significantly larger distance estimates, time estimates, and the real-walking time as compared to a without load condition. The predictions were supported by the findings.

Three groups of active older adults, inactive older adults, and sports students estimated distances from a starting point to a given target in two conditions with a loaded handbag and without a handbag. In the second part of the experiment, participants were asked to estimate the time necessary to walk from the starting point to the target. Then, they actually walked the given distance and their required time was recorded by the experimenter. Table 1presented the descriptive statistics of all 24 estimates for three groups. The data exhibited differences in the mean distance estimation errors between the three groups. More precisely, inactive older adults overestimated the distances in comparison to active seniors and sports students. Moreover, our findings showed a significant effect of physical activity on the estimated distance error between the three groups at the $p < 0.05$ level. This finding corresponded with a previous finding showing that people with a poor potential to act would overestimate surrounding spatial measures (Proffitt, 2006). This indicate that the perception of the environment may be associated with our abilities to act within it (Proffitt et al., 2003; Witt et al., 2004). For example, older adults overestimated egocentric distances when compared to younger observers (Bian & Andersen, 2013). In accordance these findings, another study showed that observers overestimated the distances as compared to a control group when previously being primed by the older adults stereotype (Chambon, 2009). Also, older adults reported that walking was physically difficult and exhausting (Bendall et al, 1989). Therefore, it appears plausible our distance estimations may have been influenced by the physical differences between inactive older adults, the active older adults, and the young subjects.

The most interesting result was the significant difference in the perceived distance between active and inactive older adults. Our inactive older adults showed significantly larger walking distance estimation errors than active older adults. These results can be explained from different perspectives. On one hand, there is a generalized decrease in cognitive functioning and physical ability evolving through the aging process. Inactive older adults shower lower scores on global tests of cognitive functioning (MMSE) than active older adults and sports students (Table 20). This decline may be associated with more functional impairments such as decrements in the judgment of events or activities (Lezak, 1982). On the other hand, there is evidence that motor activity and depth perception are internally related (Wexler & van Boxtel, 2005). As a result, physical activity in seniors may lead to a more accurate distance estimation by improving the cognitive performance such as depth perception (Wexler & van Boxtel, 2005). In turn, physical inactivity may lead to an opposite effect. As a possible consequence, inactive older adults have a more extensive history of falling than active older adults. In particular, the fear of falling is considered an important and influential factor for the step length during gait in older adults such that shorter step lengths are observed as compared to active older adults. In addition, it appears reasonable that inactive seniors may overestimate distances because they need a larger number of steps to walk a given distance as compared to active seniors (Chamberlin et al., 2005). Accordingly, observers who are able to reach out farther perceive goals as closer (Witt, 2011).

As a further finding of our study, a significant difference between the actual walking time and estimated time required for walking the given distance to the target between the three groups could not be detected. A possible explanation for this missing effect concern the familiarity of the participants with the environment when conducting the second and the third experiment. However, other reesearchers suggested that there is no evidence that familiarity effects may bias perception (Epstein et al., 2007). Obviously, all three groups showed larger distance and walking time estimation errors at longer distances (10, 12, and 14 m) as compared to the short distances (4, 6, and 8m) (Figure 1,Figure 2). This observation corresponds to a previous finding showing a difference between age-related distance estimation and physical activity at a middle and long distance (6m and beyond) only, but not at a short distance (4m) (Bian & Andersen, 2013). In contrast, inactive older adults needed more time to walk (with and without load) at different distances in compare with active older adults and sport students respectively. This finding is consistent with the results of a study by Buchner and colleagues showing that the resistance and endurance activities in older adults improved physical performance, such as walking speed, stair-climbing speed, balance, and chair stand (Buchner et al., 1993). As final evidence to support our finding, older adults were found to overestimate the slope of the hills when compared to younger adults (Bhalla & Proffitt, 1999).

Further, our study showed that an additional load significantly modified the distance estimations ($F(1, 57) = 21.68$, $p = 0.00$). Subjects in all three groups, at all distances and, with an additional load in hands, overestimated the distances to the target as opposed to the without load condition (Figure 3, Figure 4). Here, the effect of load on the distance estimation error was found to be similar across all three groups. However, the load seems to having had a larger effect on the estimations of longer distances (Figure 3, Figure 4). Moreover, load had a significant effect on the time estimated to walk the given distance to the target ($F(1, 57) = 11.47$, $p = 0.00$). This effect was even more pronounced for the longer distances (Figure 3Figure 4). This result is supported by the findings of other studies concerning the effects of activity on perception. For example, the incline of a mountain slope is rated to be larger when standing on top as opposed to standing at the foot of the mountain (Bhalla & Proffitt, 1999). Larger estimates for steeper mountain slopes were also found in fatigued and in older subjects (Bhalla & Proffitt, 1999). Moreover, velocities of runners and walkers were estimated differently when subjects were running or walking on their own (Jacobs & Shiffrar, 2005). Less physically active observers estimated walking velocities as higher when compared to physically fit observers (Jacobs & Shiffrar, 2005). Hence, overestimating distances within a load condition is consistent with such effort hypothesis. Other studies have supported the effort hypothesis by manipulating efforts in tasks such as asking participants to throw a heavy ball or carrying a heavy backpack to a target. Similarly, participants within a load condition exerted more energy in comparison to participants without load (Bhalla & Proffitt, 1999; Proffitt et al., 2003; Witt et al., 2004). All these results are consistent with previous research outcomes having revealed that a distance perception may be overestimated according to by age, poor health or when an observer is loaded with a heavy backpack (Bhalla & Proffitt, 1999).

An open question in our study was whether verbal estimates issued by the participants would provide a valid indicator to their perception when derived during an experimental manipulation. There is evidence showing that both verbal estimates as well as blind walking are valid measurements for the perception of egocentric distances (Philbeck & Loomis, 1997). One critical limitation regarding distance estimates within a load condition concerns the issue whether participants may infer that carrying a handbag would relate to an anticipated expectation towards their estimation results. It cannot be ruled out completely that subjects may have anticipated our expectation for longer distance etsimates in a load condition as compared to a no-load condition. Hence, our findings may provide a new viewpoint for further investigations to find out possible interrelations between different kinds of physical activity and distance estimates. In addition, our findings may be useful for clinicians given that physical activity plays an essential role in older adult's everyday life to prevent for falls based on the amount of error in distance estimates.

## 6.2 Distance Estimation (Longitudinal Study)

Our experiment aimed to evaluate the different effects evolving from three types of resistance training in the error when estimating distances, walking time estimates, and real walking time on two even and uneven surfaces in older adults. In this respect, distance estimation remained uninfluenced by the three training types based on the pre and post-testing results (Table 29). The disagreement towards the results in our cross-sectional study could be related to the short duration of intervention training across a time period of 10 weeks with two weekly training sessions. For a comparison, strength training program to promote muscle hypertrophy typically consist of three times per week for 8 to 12 weeks (Petrella & Chudyk, 2008). Our most important finding concerned a significant effect of resistance training on walking time estimation error between pre and post-testing on uneven surfaces ($F(1, 52) = 15.48$, $p = 0.00$ (Table 33). This result showed that older adults made fewer errors in the walking time estimation after 10 weeks of intervention training on uneven surfaces compared to before intervention training. As a possible cause, the intervention may have decreased the subjects' anxiety when facing new challenges. Another explanation for this improvement through resistance training in lower legs may be related to stronger legs leading to better walking capacity (Norgren et al., 2007).

A reduction in walking time estimation error on uneven surfaces after the intervention duration is supported by earlier findings illustrating an association between resistance training and improved balance (Lord et al. 1995). This positive correlation between improved balance ability on one side and its interaction with the environment (walking time estimation) on the other side corresponds to the embodied perception effect when estimating the velocity of runners and walkers when running or walking on your own. This finding translates to physically less active observers may estimate walking velocities as higher when compared with physically fit observers (Jacobs & Shiffrar, 2005). Also, seniors, who are more active, need less time to walk the distances to the targets. This result is consistent with the findings by Proffitt et al. (2005) showing that effort for walking influences distance perception. As a last point of note, large standard deviations for the time estimates (Table 30) must be considered despite the normal distribution of the individual values. In this respect, large interindivual differences were observed across the study sample with some subjects estimating the time significantly higher than others.

In summary, our study confirmed that resistance training may be beneficial for the improvement of motor cognition in older adults. In addition, we assume that a longer intervention duration may be an important issue in the context of every day spatial perception in older adults. In this respect, we consider accurate distance and time estimates in everyday taks to be vital to avoidance accidents and to prevent from falling based on faster responses to surrounding health hazards in the environment. Moreover, moderate- to high-intensity resistance training may be better tolerated by the older adults than moderate- to high intensity aerobic exercises (Kortianou et al., 2010). However, such training recommendation may not be properly applicable for older adults with cognitive impairment specifically. Nevertheless, findings in the literature discussed above suggest that resistance training may reduce the frequency of falls through the improvement of balance ability in older adults. Further studies are required to provide more conclusive evidence on the effects on the specificity in resistance training to positively influence the prevention of falls.

## 6.3 Weight Estimation (Cross-Sectional Study)

Previously, we had hypothesized that ratings of perceived effort, shown in point-light video displays on lifting, lowering, pushing and pulling tasks should differ depending on the level of physical activity. In this respect, aging was considered to be associated with various physical and perceptual changes impairing seniors' ability to judge other people's actions. However, there is only little scientific knowledge about the overall effects of aging on action perception. Therefore, our study aimed to provide more evidence on the effects of physical activity in older adult's weight perception through observing the point-light displays. This study was a replication of Grierson (2013), however, using older adults as subjects instead of younger adults. We manipulated the boxes' weights and the tasks performed by an actor. In this respect, we assumed that physically active older adults would issue more accurate weight estimates when judging weights to be lifted, lowered, pushed, or pulled in point-light video displays. As a results, we found a significant difference in weight estimation error between the three groups ($F(4,114) = 5.20$, $p = 0.00$) in supported for our hypotheses. In addition, our findings showed that active seniors issued more accurate weight estimates for lighter weights whereas inactive seniors estimated heavy weights more accurately (Figure 17). This finding corresponds with the results of Wilson (2001) showing that the understanding of other's actions to rely on the ability to perform the same movements. Researchers showed that basketball players exhibit better performance and higher activation in the premotor cortex when observing occluded video displays of free throws in basketball as opposed to coaches or commentators (Aglioti et al., 2008). In other words, elite basketball players can predict the outcomes of free throws in basketball displayed in vidoeclips better than coaches and commentators as these actions belonging to their domain of motor experiences and not on their perceptual experiences only. As a consequence, for interpersonal coordination achievements a strong link between the action system and the visual system concerning other people's actions was suggested in the literature (Knoblich & Flach, 2001; Shiffrar & Pinto, 2002; Viviani & Stucchi, 1992). Correspondingly, substancial neural activity above baseline was observed in the motor areas of expert badminton players' brain when aksed to predict a stroke direction in badminton (Wright et al., 2010). In a similar experiment, Knoblich et al. (2001) showed that the detection of hit accuracy in visually observed dart throws in occluded video displays was significantly better for throws performed by the observer as compared to throws performed by other players.

The above observation relate to our result showing that inactive seniors were most accurate in detecting heavy weights rather than light weights. As the inactive seniors had less ability to lift the weights, thus they overestimated the weight of weights.. Correspondingly, the results of a study by Hamilton and colleagues showed that the estimations of the weight lifted by an actor were related to the observers ability to lift that weight himself/ herself (Hamilton, Wolpert, & Frith, 2004). There is another result from a behavioral study to support our hypotheses on the functional interrelation between the motor experience and visual perception of human movement (Viviani & Stucchi, 1992). Scientific evidence suggests that the interaction between perceptual learning (Grossman & Blake, 2001) and motor system input (Decety, 1997; Rizzolatti et al., 2001; Stevens et al, 2000) to fundamentally shape people's visual perceptions of the world. Accordingly, the observer's action system is thought to contribute to the visual analysis of another person' movement. Our finding expanded this previous research demonstrating the influence of kinematic cues to contribute to the perceptual weight judgment. In this respect, observers might use statistical information about their movement behavior to identify the observed cues (Hamilton et al., 2007). Our findings provide additional evidence for an influence of physical activity on weight perception corresponding with other studies on embodied perception in domains such as language perception, distance perception, time perception, and motion perception (Klatzky et al., 2008; Proffitt et al., 1995; Wachsmuth et al., 2008).

Given that the sports students issued more accurate weight estimates than the active older adults and the inactive seniors respectively we assume that, as an individuals' capabilities to act are high, their abilities to understand and discriminate an action will be increased as well (Viviani & Stucchi, 1992). Accordingly, the weights that were handled by some actors within point-light displays in our study were perceived to be lighter by active older adults than by inactive older adults.

## 6.4 Weight Estimation (Longitudinal Study)

Aside from the cross-sectional study, the effects of three different types of resistance in older adults on their weight estimation abilities were investigated in the course of a longitudinal intervention, as well. However, our findings did not confirm our hypotheses. Although the results of strength training intervention did not show any significant improvement in the weight estimation error between the groups ($F(2, 62) = 0.367$, $p = 0.69$) and between pre- and post-measurements ($F(1, 62) = 0.04$, $p = 0.83$) the findings, nevertheless, indicate that resistance training may improve cognitive performance in older adults. There were significant differences between the weight estimates after the machine-based stable resistance training (M-SRT) ($t(20) = 2.35$, p

= 0.02) (Table 35) and for the free-weight resistance training on unstable supports (F-URT) (t (20) = 2.46, p = 0.02) (Table 38) for the lifting task with moderate size weights. Overall , we observed a reduction in the weight estimation error in all three groups after the 10 week training intervention for in the heavy weights. Both the M-SRT and F-URT group showed more accurate weight estimates for the middle weights and all three groups in the heavy weights. These results confirmed our hypothesis showing that the seniors exhibited a more accurate weight estimation through the training intervention when observing an actor lifting, lowering, pulling, or pushing weights in point-light video displays. Indirectly, these findings correspond to the results of Hamilton et al. (2004) who argued that the weight carried by another person is rated larger by an observer when lifting heavy weights himself. Furthermore, our results supported the assumption that visual sensitivity and physical activity is associated to one's own motor system (Knoblich & Flach, 2001; Prinz, 1997; Stevens et al., 2000; Viviani & Stucchi, 1992). As shown in Figure 18 and Figure 19 weight estimation errors decreased as weight increased. However, this was true for the lifting task, only. which is consistent with previous studies showing that observers overestimated the lighter weights more than the heavier ones (Bingham et al., 1994; Runeson & Frykholm, 1981). Although we did not significant difference between the three types of resistance training on their weight estimations, overall, participants of the free weight unstable resistance training (F-URT) and the stable-based stable resistance training (M-SRT) produced a smaller post-intervention weight estimation errors in the lifting and pushing tasks and for three weights (light, middle, and heavy).

Already, previous studies had demonstrated that resistance training has a beneficial effect on the cognitive functioning in older adults (Liu-Ambrose et al., 2011; Nagamatsu et al, 2012). Moreover, we found that participants in the F-URT group showed improved weight estimations following their strength intervention as opposed to the M-SRT and M-ART group. This finding supports previous studies assuming that each kind of exercise may have a differential effect on cognitive functioning and their related neural substrates (Nagamatsu et al., 2013). Possibly, the beneficial effects of resistance training on cognition may be related to an increased cerebral blood flow (Rhyu et al., 2010) contributing to a reduction in neuro inflammation (Parachikova, Nichol, & Cotman, 2008). However, previous studies had, so far, not yet evaluated the effect of resistance training on weight estimation in seniors. Our findings indicated that resistance training may play an important role to improve the awareness and the prediction of events in the surrounding environment (Endsley & Bolstad, 1994).

In fact, spatial awareness and/ or the perceptibility of the surrounding environment are essential factors to cope with different dynamic situations in the everyday tasks of older adults. A decline in spatial awareness (Bolstad, 2001) and/ or a slowing of information processing speed (Salthouse & Meinz, 1995) pose severe challenge in the everyday tasks of older adults such as driving and carrying the objects. Also, the decline in visual perception is considered a major cause of falling in seniors (Akbarfahimi, 2013). Therefore, interventions that help to prevent such age-related decline and even improve the perception of the surrounding environment are beneficial for older adults. However, when compared to the literature, our 10-week resistance training intervention may been too short such that a need evolves for longer intervention periods to be investigated in the future.

## 6.5 Executive Functions

Aside from weight and distance estimation effects of physical activity in older adults, in our study, effects in executive function tests were assessed as well. For example, the results in our cross-sectional studies revealed a strong positive correspondence between physical activity and executive function scores. Here, the sports students (control group) had higher mean scores than active seniors and inactive older adults in all tests analyzed. This finding indicates that, regardless of its type and intensity, physical activity may modify age-related declines in specific executive function test such as Mini-Mental State Examination, Montreal Cognitive Assessment, and Verbal Digit Span. Although a manifold of studies had previously examined an impact of physical activity of older adults promoting their cognitive functioning only a limited of investigations specifically compared executive functions between active and inactive older adults. For example, a substantial association between physical activity and executive functioning in older adults was found by Carvalho and coworkers (Carvalho et al., 2014). During the past two decades, important studies on the effects of physical activity, as behavioral factor, in the prevention of cognitive decline in older adults were conducted. Some of these investigations revealed that physical activity is particularly beneficial at older age. In this respect, our results correspond with findings by Liu-Ambrose and Donaldson (2008) showing that a six months home-based strength and balance training (the Otago Exercise Program) was effective to promote executive function among seniors at the age of 70 years and older in individuals who had recently experienced falls. Further support is provided by a study by Brown and colleagues showing an improvement in fluid intelligence among seniors (living in retirement villages) following a 12 month strength and balanced training in a group-based setting (Brown et al., 2009). Significant effects on the verbal memory in seniors following a 6-month aerobic training were reported by Nagamatsu et al. (2013) showing that both resistance and aerobic training may improve executive functions. In fact, aside from aerobic and resistance training other types of physical exercises were shown to be effective for the improvement of executive functions (Colcombe & Kramer, 2003) and for seniors as well (Garcia et al., 2004). Other results of a cross-sectional study showed that women with poor executive function scores, regardless of impaired MMSE scores, had a widespread functional problem in comparison with women with normal cognitive function (Johnson et al., 2007). In addition, large and significant correlations were observed between executive functions and functional difficulty (Cahn-Weiner et al., 2000; Royall et al., 2004).

Our findings from three executive function tests related to changes in the executive functions in the longitudinal study were not related to the type of physical activity (Cahn-Weiner et al., 2000; Royall et al., 2004). This is consistent with the results of a study by Liu-Ambrose and colleagues showing an association between different types of physical activity and two different executive function tests. Their results also showed that people with higher levels of daily physical activity were associated with better functional cognitive abilities. Consequently, these abilities were found to improve through a wide variety of exercises (Cassilhas et al., 2012). In addition, physical activity was found to be associated with an exercise-related reduction in body fat mass promoting improvements in cognitive performance (Elias et al., 2003; Waldstein & Katzel, 2006), avoiding adverse effects on memory (Elias et al., 2003), and improving executive functions (Waldstein & Katzel, 2006) which are thought to be caused by obesity. However, the underlying processes related to the negative impact of obesity on cognitive functioning are still unclear. In specific, significantly reduced balance and coordination was observed in individuals with mild degrees of cognitive impairment (MCI) or mild Alzheimer disease (AD) compared to normal individuals (Franssen et al., 1999). Researchers consider impairments of physiological functioning to be associated with an increased risk of falling (Aggarwal et al., 2006). Other studies supported this argument by showing that seniors with impairments in executive functioning experienced more falls and injurious falls than seniors without such impairments (Lord et al, 1994). This close correspondence between executive functioning and the prevalent risk of falling in older adults was confirmed through the results of a study by Nagamatsu et al. (2013), as well, through results of Herman et al. (2010) for an association of poor executive function scores and an increased risk of falling regardless of any balance impairment. It is possible that individuals with executive function impairment lost their abilities of balance and coordination as compared to individuals without cognitive impairment (Liu-Ambrose & Donaldson, 2008).

For an indirect support of the above argument, we found lower scores in the Montreal- Cognitive- Assessment (MoCA) test for inactive seniors as compared to than normal older adults (Table 19).Although low MoCA scores are considerd to unrelated to dementia or mild cognitive impairment (MCI) they may use as indicators for a risk to suffer from mild cognitive impairment (MCI) in inactive older adults as compared to active older adults with larger MoCA scores.

Aside from MoCA, two more screening tools for cognitive functioning in older adults were used in our study. The different cognitive tests are ised to assess different domains of cognitive functioning. For example, MoCA and MMSE evaluate attention and visual-spatial ability. Previous studies argued that MoCA is more sensitive and more specific as compared to the MMSE when screening cognitive impairments (Luis et al., 2009). Low scores in the executive function tests are considered as a risk for mortality in inactive older adults. For example, Johnson et al. (2007) reported an increased risk of mortality after six years in women with poor scores on the Trail Making Test B (Trails B) regardless of their performance in the MMSE.

Our findings confirmed a significant effect of physical activity on executive functioning. However, in this respect, no significant difference was detected between the active older adults and sports students in the Mini-Mental-State-Examination (MMSE) or the digit verbal span (DVS) scores. This result did not correspond to previous studies suggesting that, overall, younger adults gained higher scores on all executive function tests and sub-tests (Chasseigne et al., 1997; Salthouse, 1992). In general, studies suggest that age poses a definitive and continuous impact on executive function tests such as decision-making skills and causing reductions in the older adults leaving it open whether active or inactive (Denburg et al., 2005; Fein et al., 2007). Aside from their physical activity level, cognitive differences in older adults may depend on their age category, as well (for example between subgroups of older adults between 75 and 84 and younger seniors between 60 and 67 years (Singer et al., 2003). Another explanation for differences in the xecutive function within older adults may relate to their level of high education (Ardila et al., 2000). However, further evidence is needed to substantiate this argument. Our results show that the present physical activity had a significant effect on executive functions in our older subjects possibly which, in turn, may contribute as a significant predictor of mortality (e.g. MMSE or other general cognition tests as reported by McGuire et al. (2006) and Ramos et al. (2001) or the Digit Symbol Substitution test as reported by Small and Bäckman (1997).

These above findings could be interesting for clinicians to consider physical activity not only for its physical benefits but owing to its benefits for the brain functioning, as well. As we were using standard executive function tests easy to administer and to evaluate regardless of physical impairments, our results can be easily compared to other studies. However, there are also some limitations in this study of note. As a first point, the participants may have either underestimated or overestimated their executive function abilities using the self-reported executive function questionnaires instead of performance-based measures. In addition, general differences among participants (e.g., educational status, health condition, nutrition, and personality traits) may have influenced their cognitive performance (Schaie & Willis, 2010). Several studies suggest that different kinds of activity may selectively influence the cognitive processes. Consequently, more research is needed to clarify the relationship between the specificity in the physical exercise program and the executive functioning. Moreover, while our study considered active and inactive older adults based on questionnaire data future studies should include older adults with prior falls experiences to analyze the effect of physical activity in this particular subgroup. Moreover, studies are needed to clarify a minimum duration for interventions in older adults considering at statement by Nagamatsu et al. (2013) who suggested a six month intervention training to confirm the changes in cognitive functioning.

## 6.6 Coping with Indoor and Outdoor Daily Tasks Study

To capture an activity based effect in older adults' self-confidence towards daily tasks we explored the differences between active and inactive older adults when asked to envision their efforts during selected indoor and daily outdoor tasks presented in images. The self-confidence to cope with such daily tasks were measured in three groups (active older adults, inactive older adults and sports students) during the presentations of photographic images of daily indoors and outdoors tasks. The results showed that physical activity had a significant effect on the self-confidence to cope with these tasks. However, no significant difference was detected between active seniors and sports students (acting as a control group) (

Table 36). So, overall higher degrees of physical activity in seniors was associated with higher self-confidence to cope with the given indoor and outdoor tasks. This finding is consistent with earlier studies (Painter et al 2000) showing a correspondence between the level of physical functioning in the subscale of the SF36 and the level of physical activity. In another words, physical activity is positively influencing the quality of life in older adults.

Other authors reported about seniors who were physically inactive showing a higher-level of perceived effort during physical activity (Wanderley et al., 2011). Similarly, Porto et al. (2012) found a significant correspondence between the level of physical activity in an older population and their perceived quality of life score (QOLs), as well. All in all, these results indicate that, although after the age of 60 years and while women appear to be less active than man, both genders show the same behavioral patterns in according to their physical activity levels. Available findings demonstrate that 76% of the women who overestimated the intensity of their physical activity were physically inactive (Skatrud-Mickelson et al., 2011). In comparison, younger people tend to underestimate the intensity of their physical activity (Skatrud-Mickelson et al., 2011). Hence, a higher level of perceived effort may be related to lower levels of physical activity and a lower quality of life. Overall, the rate of the perceived effort appears to indicate a level of physical fitness and quality of life a person (Skatrud-Mickelson et al., 2011). In another study, Andrea and colleagues assessed the influence of physical activity on seniors towards their stress coping capacity (Andréa et al., 2010). The results showed that physical activity had a significant effect on their ability to cope with stress. This effect remains as the intervention period continues.

However, a further interpretation of these result is available based on the interrelation of self-efficacy, reported physical activity, physical functioning, and functional difficulties. The fear of falling during everyday tasks in older adults may evolve from their expectations based on a previously experienced association of self-efficacy, fear of falling, and physical functioning (McAuley et al., 2007). In this respect, physical activity may have a moderating effect on the reduction of functional limitations (McAuley et al., 2007). However, this association between perceived effort of activity and the fear of falling is not thoroughly explaining the anxiety when executing everyday tasks. Studies indicate, as well, a relationship between perceived energy deficiency and a person's decision-making and risk-taking capacities (Symmonds et al., 2010). Conversely, older adults with a more pronounced walking activity were found to estimate their perceived effort more accurately than older adults with less walking activity (Brach et al., 2002). Taken together, our finding that physically active older adults feel more confident in coping with everyday indoor and outdoor tasks is consistent with the results from the literature. In contrast, there were no significant differences between indoor and outdoor daily living tasks for the sports student sample. This result indicates that inactive seniors may perceive certain taks in theire daily life as obstacles limiting their mobility. In fact, according to the results of a study by Le Morellec et al. (2013), more than 40% of the older adults beyond an age of 75 years had more difficulties to cope with their outdoor tasks outdoor as compared to indoor tasks.

All in all, these results provide a concept linking difficulties in daily tasks with sensory and physiological limitations (e.g., cardiac, respiratory, visual and auditory problems) as well as major physical problems (e.g., difficulties to carry heavy bags while they are moving around). Also, this concept indicates that older adults being able manage outdoor tasks will find more challenges as compared to indoor tasks. In this regard, they need a better health and physical status to deal with these outdoor challenges. Previous study outcomes suggested that indoor falls tend to occur rather for inactive older adults with indicators of poor health and an inactive lifestyle. In turn, the risk of outdoor falls in the older adults were related to a high level of physical activity (Li et al., 2006; Mänty et al., 2009). In fact, the most age-related falls were found to occur during outdoor walking (Bergland et al., 1998). Walking on roads and uneven surfaces increased the risk of falling such that a fear of falling may be associated with a decline in independence and mobility (Bergland et al., 1998). All in all, research on physical activities in daily living suggests that senior have most difficulties in managing mobility tasks (Bergland et al, 1998). In contrast, older adults appear to have less problems to cope with physical activities indoors (e.g. eating or toileting) (Bergland et al, 1998). Consequently, an increase in the ability to manage outdoor tasks, as compared to indoor task, may be promoted by a higher level of physical activity, as well as an improved health status overall. Differences in the confidence to cope with daily tasks between active and inactive older adults, as detected in our study, illustrate the importance of being active in daily life to enhance physical functioning and the feeling of confidence to cope with daily challenges.

For a proper understanding and interpretation of our findings, however, the limitations of this study must be considered as well. In the present study, we used a cross-sectional self-report design. By using this kind of research, participants may have estimated their perceived confidence to manage with daily tasks more positively or negatively than their true abilities and health conditions would suggest. The second limitation of this study concerns the mean age of our inactive older adults of roughly 78 years was slightly higher than for active older adults (average age: approximately 75 years).

# 7. CONCLUSION

In summary, the literature background of our study indicated that successful aging relates to different aspects of life. Physical activity and cognitive functioning are two important factors to achieve this success (Rowe & Kahn, 1997). Also, it has been shown that physical exercise is vital to enhance general health. As a result, physical activity can preserve or enhance physical and cognitive abilities in older adults.

In this project, we conducted a cross-sectional and a longitudinal study to investigate, overall, the impact of the physical activity status (in cross-sectional study) and specifically (longitudinal study) the impact of three types of resistance training on motor cognition in seniors. In the first study, four cross-sectional investigations were conducted to examine the effect of physical activity on motor cognition based on distance estimations, weight estimations, perceived confidence when observing images of daily indoor and outdoor tasks, and assessing some standard testing of executive functions in older adults.

In the longitudinal study, the effects of three different types of resistance training across a period of 10 weeks on weight and distance estimation measures and were investigated. These included machines based stable resistance training, free-weight resistance unstable training, and machine-based adductor/ abductor resistance training programs that were executed twice a week on non-consecutive days. Each session lasted one hour for each of the three older adults groups. The results showed a higher level of motor-cognition and less cognitive decline in the active older adults groups after the intervention training. The estimated walking time error decreased substantially in all groups after the intervention training. No difference in the estimated walking time error was observed between the three types of resistance training.

The specific mechanisms by which motor-cognition is improved though resistance training remain unclear. One possible explanation relates to the benefits of body movements and skeletal muscle utilization in physical exercises that provide physical fitness to prevent an. age-related cognitive decline. Further investigations are needed for a thorough understanding about the impact of the exercise type on motor cognition in seniors. In addition, as our findings were assessed after an intervention of 10 weeks only, future studies are needed across longer periods of to better understand and substantiate the underlying mechanisms. As resistance training proved to be beneficial of the cognitive functioning, clinicians should motivate their patients to engage in resistance training not only for physical benefits but also because of its prevailing effects of brain health. Also, more studies are needed to explore further assessment methods in order to detect more effects in other effects motor cognition based on different types of resistance training. We conclude that participation in different types of resistance training may provide a suitable intensity of physical activity to delay, prevent, and/ or improve age-related cognitive impairment and dementia in older adults.

**Limitations**

Several limitations have influenced the findings of our study.

1. The number of participants in these studies was in-homogeneous in terms of the gender in the analyzed samples.
2. The weather conditions, the temperature, the amount of sunlight during different day times may have influenced the croess-section distance and walking time estimation study.

3. Another limitation of the walking distance estimation was the lack of control in some health factors (e.g., cardio-vascular, nervous, or musculoskeletal issues in the subjects) that may have influenced the speed and length of the gait.
4. Learning through repetition of the videos in weight estimation study may have influenced the results.
5. The social desirability bias may have occurred in the participants through the collection data even despite being asked to answer the questions as honestly as possible.

**Summary**

For the presented doctoral thesis, four cross-sectional studies and a longitudinal study were conducted to examine the correspondence between physical activity and motor cognition in older adults. A total of six hypotheses were tested. Forty older adults between 65 and 80 years of age (subdivided into an active and an inactive subgroup based on Freiburg Physical Activity Questionnaire) and 20 sports students as a control group participated in the cross-sectional studies. Eighty-two seniors aged between 65 and 80 years of age all randomly subdivided into the three different resistance training groups participated in the longitudinal study. In the course of the training study, the correspondences between three types of strength exercises including different degrees of instability and the distance and weight estimation capabilities of older adults were investigated.

Prior to and following the strength training regimens, participants completed a series of experiments including distance and walking time estimations, weight estimations, perceived confidence to manage daily tasks, and executive function tests as dependent variables.

The results of the cross-sectional studies provide evidence for a statistically significant correspondence between physical activity and motor cognition effects. Moreover, some evidence was provided on how physical activity employed through three resistance training types may influence older adults' motor cognition.

In conclusion, the investigations showed that seniors with a higher level of physical activity showed higher degrees of motor cognition as opposed to inactive older adults. These findings could be beneficial for clinical settings to motivate seniors with motor cognition deficiencies in order to use specific exercise modes to improve their motor cognition abilities.

Key Words: physical activity, motor cognition, older adults.

**Zusammenfassung**

Für die vorliegende Doktorarbeit wurden vier Querschnittsstudien und eine Längsschnittstudie durchgeführt, um den Zusammenhang zwischen körperlicher Aktivität und motorischer Kognition bei älteren Erwachsenen zu untersuchen. Insgesamt wurden sechs Hypothesen getestet. An den Querschnittsstudien nahmen 40 ältere Erwachsene zwischen 65 und 80 Jahren (unterteilt in eine aktive und eine inaktive Untergruppe nach dem Freiburger Fragebogen für körperliche Aktivität) und 20 Sportstudenten als Kontrollgruppe teil. An der Längsschnittstudie nahmen 82 Senioren im Alter zwischen 65 und 80 Jahren teil, die alle nach dem Zufallsprinzip in die drei verschiedenen Krafttrainingsgruppen eingeteilt wurden. Im Rahmen der Trainingsstudie wurden die Übereinstimmungen zwischen drei Arten von Kraftübungen mit unterschiedlichem Instabilitätsgrad und der Distanz- und Gewichtseinschätzungsfähigkeit älterer Erwachsener untersucht.

Vor und nach den Krafttrainingsprogrammen absolvierten die Teilnehmer eine Reihe von Experimenten, darunter Entfernungs- und Gehzeitschätzungen, Gewichtsschätzungen, wahrgenommene Selbstwirksamkeit bei der Bewältigung von Alltagsaufgaben sowie Test der exekutiven Funktionen als abhängige Variable.

Die Ergebnisse der Querschnittsstudien belegen einen statistisch signifikanten Zusammenhang zwischen körperlicher Aktivität und motorischer Kognition. Darüber hinaus wurden einige Belege dafür gefunden, wie körperliche Aktivität, moderiert durch drei Arten von Krafttraining, die motorische Kognition älterer Erwachsener beeinflussen kann.

Zusammenfassend zeigten die Untersuchungen, dass körperlich aktive Senioren im Gegensatz zu körperlich inaktiven älteren Menschen eine höhere Ausprägung an motorischer Kognition aufweisen. Diese Ergebnisse könnten für klinische Einrichtungen von Vorteil sein, um Senioren mit Defiziten in der motorischen Kognition zu motivieren, spezifische Körperübungen zur Verbesserung ihrer motorischen Kognition zu verwenden.

Schlüsselbegriffe: Körperliche Aktivität, Motorische Kognition, Ältere Menschen

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# APPENDICES

## Questionnaires

## Appendix I. Mini-Mental-Status-Exam questionnaire

Der MMST erlaubt anhand eines einfachen Fragebogens eine Abschätzung der kognitiven Fähigkeiten eines älteren Menschen. Die Testdauer beträt ca. 10 Minuten. Ergebnisinterpretation: Bei weniger als 13 Punkten, werden globale kognitive Störungen angenommen und die Voraussetzungen für das Kompetenzzentrum können bejaht werden.

**Testperson :** ______________ **Geburtsdatum:** ______________

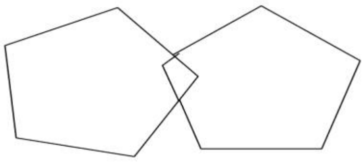
**Datum der Erhebung:** __________ **Erhebung wurde durchgeführt von** ______________

| | | Punkte | |
|---|---|---|---|
| **I. Orientierung** | (1) Datum | 1 | 0 |
| | (2) Jahr | 1 | 0 |
| **Zeit** (z.B. Welchen Tag haben wir heute?) | (3) Jahreszeit | 1 | 0 |
| | (4) Wochentag | 1 | 0 |
| | (5) Monat | 1 | 0 |
| | (6) Bundesland | 1 | 0 |
| **Ort** (z.B. Wo sind wir jetzt?) | (7) Landkreis/Stadt | 1 | 0 |
| | (8) Stadt/Stadtteil | 1 | 0 |
| | (9) Klinik/Praxis/Pflegeheim | 1 | 0 |
| | (10) Station/Stockwerk | 1 | 0 |
| | Summe (max. 10): | | |
| **II. Merkfähigkeit** (Der Untersucher nennt die Gegenstände und fordert auf, diese zu wiederholen) | (11) Apfel | 1 | 0 |
| | (12) Pfennig | 1 | 0 |
| | (13) Tisch | 1 | 0 |
| maximal 6 Wiederholungen | Summe (max. 3): | | |
| **III. Aufmerksamkeit und Rechenfertigkeit** | (14) >93 < L | 1 | 0 |
| | (15) >86< H | 1 | 0 |
| Ziehen Sie von 100 jeweils 7 ab oder buchstabieren Sie "STUHL" rückwärts | (16) >79 < oder U | 1 | 0 |
| | (17) >72 < T | 1 | 0 |
| | (18) >65 < S | 1 | 0 |
| | Summe (max. 5): | | |
| **IV. Erinnerungsfähigkeit** | (19) Apfel | 1 | 0 |
| Was waren die Dinge, die Sie sich vorher gemerkt haben? | (20) Pfennig | 1 | 0 |
| | (21) Tisch | 1 | 0 |
| | Summe (max. 3): | | |

| **V. Sprache** | | | |
|---|---|---|---|
| Was ist das?<br>(Der Untersucher zeigt zwei Gegenstände und fordert die Testperson auf diese zu benennen) | (22) Armbanduhr<br>(23) Bleistift | 1<br>1 | 0<br>0 |
| Sprechen Sie nach:<br>(Der Untersucher fordert die Testperson auf, nachzusprechen) | (24) „Sie leiht ihm kein Geld mehr“ (max. 3 Wdh.) | 1 | 0 |
| Kommandos befolgen | (25) Nehmen Sie bitte das Papier in die Hand. | 1 | 0 |
| | (26) Falten Sie es in der Mitte. | 1 | 0 |
| | (27) Lassen Sie es auf den Boden fallen. | 1 | 0 |
| | (28) Bitte schließen Sie die Augen! | 1 | 0 |
| | (29) Schreiben Sie einen vollständigen Satz | 1 | 0 |
| | (30) Fünfecke nachzeichnen (Alle 10 Ecken müssen wiedergegeben sein und 2 davon müssen sich überschneiden) | 1 | 0 |
| | Summe (max. 9): | | |

Gesamtsumme:

Fünfeck



Abgezeichnetes Beispiel

# Appendix II. Freiburg questionnaire for physical activity

Bitte beantworten Sie die folgenden Fragen zur körperlichen Aktivität für den Zeitraum vor Beginn Ihrer Rehabilitation.

| | ja | nein |
|---|---|---|
| **1. Sind Sie berufstätig** (auch Hausfrau) **oder in Ausbildung?**.......... | ☐1 | ☐2 |

**Wenn ja, welche Tätigkeiten beinhaltet Ihr Beruf/ Ihre Ausbildung hauptsächlich?**

| **sitzende** Tätigkeiten (z.B. Büro, Student...) | **mäßige** Bewegung (z.B. Handwerker, Hausmeister, Hausfrau...) | **intensive** Bewegung (z.B. Postzusteller, Wald- und Bauarbeiter...) |
|---|---|---|
| ☐1 | ☐2 | ☐3 |

**2. Waren Sie in der Woche vor Beginn Ihrer Reha zu Fuß unterwegs,**

| | ja | nein |
|---|---|---|
| a) **...z.B. auf dem Weg zur Arbeit oder zum Einkaufen?**.................. | ☐1 | ☐2 |

**Wenn ja, wie lange** sind Sie dabei gegangen? insgesamt_______________Minuten

| | ja | nein |
|---|---|---|
| b) **...zum Spazierengehen?**.................................................................... | ☐1 | ☐2 |

**Wenn ja, wie lange** waren Sie in der Woche vor Beginn Ihrer Reha spazieren? insgesamt_______________Minuten

**3. Sind Sie in der Woche vor Beginn Ihrer Reha Fahrrad gefahren,**

| | ja | nein |
|---|---|---|
| a) **...zur Arbeit oder zum Einkaufen usw.?**......................................... | ☐1 | ☐2 |

**Wenn ja, wie lange** sind Sie dabei geradelt? insgesamt_______________Minuten

| | ja | nein |
|---|---|---|
| b) **...auf dem Heimtrainer bzw. auf Radtouren?**................................ | ☐1 | ☐2 |

**Wenn ja, wie lange** sind Sie dabei geradelt? insgesamt_______________Minuten

| | ja | nein |
|---|---|---|
| **4. Haben Sie einen Garten?**.................................................................. | ☐1 | ☐2 |

**Wenn ja, wie viele Stunden** haben Sie **in der Woche vor Beginn Ihrer Reha** dort verbracht? ____________**Stunden pro Woche**

Davon waren ____________Stunden Garten**arbeit**

und ____________Stunden **Ruhe** und **Erholung**

| | | ja | nein |
|---|---|---|---|
| 5. | **Steigen Sie im Alltag regelmäßig Treppen?**................................ | ☐1 | ☐2 |

**Wenn ja:** ____________Stockwerke, ___________mal am **Tag**

| | | ja | nein |
|---|---|---|---|
| 6. | **Sind Sie im letzten Monat vor Beginn Ihrer Reha geschwommen?**............................................................................ | ☐1 | ☐2 |

**Wenn ja:** ca. ____________Stunden im **Monat** (reine **Schwimmzeit**)

| | | ja | nein |
|---|---|---|---|
| 7. | **Haben Sie im letzten Monat vor Beginn Ihrer Reha Sport betrieben?**...................................................................................... (z. B. Jogging, Fußball, Handball, Federball, Squash, Gymnastik, Tennis,…) | ☐1 | ☐2 |

**Wenn ja, welchen Sport?**

Beispiel:
1. Dauerlauf ca. 30 Minuten pro Woche
2. Federball ca. 2 Minuten pro Woche

1. ________________________________ ca. ___________Minuten pro Woche
2. ________________________________ ca. ___________Minuten pro Woche
3. ________________________________ ca. ___________Minuten pro Woche
4. ________________________________ ca. ___________Minuten pro Woche

| | | ja | nein |
|---|---|---|---|
| 8. | **Gehen Sie zu Tanzveranstaltungen?**............................................ | ☐1 | ☐2 |

**Wenn ja:** ____________mal/ Monat, je:___________Stunden

| | | ja | nein |
|---|---|---|---|
| 9. | **Gehen Sie kegeln?**........................................................................ | ☐1 | ☐2 |

**Wenn ja:** ____________mal/ Monat, je:___________Stunden

**Auswertungsanleitung zum Freiburger Fragebogen Auswertung des "Freiburger Fragebogen zur körperlichen Aktivität"**

**Berechnung des Aktivitatsumfangs (h/Woche):**

Alle Aktivitäten werden in Stunden pro Woche umgerechnet.

Treppensteigen (h/Woche) = (Stockwerke * 10/3600) * (wie oft) * × 7.

(Für die Umsatzberechnung Treppensteigen: MET=6)

Wurde eine Aktivität nicht ausgeführt setze: h/Woche=0.

**Berechnung des Aktivitätsumsatz (Angaben in METs):**

Die Aktivitätszeiten (h/Woche) warden mit den zugehörigen "MET"werten (siehe Liste) multipliziert.

Bsp.: Wege zu fuß (Frage 2a):

0.7 h/Woche:0.7*3 (MET)=2,1 MET

Bsp: Sport (Frage 7)

1 h/ Woche-Fußball: 1*7 (MET)=7 MET

**Teilsummen bilden.**

Basisaktivitäten **=** Wege (zu fuß/ per Rad (Frage 2a+3a) + Gartenarbeit + Treppensteigen.

Freizeitaktivitäten = Spaziergänge (F2b) +" Radtouren" / Heimtrainer (F3b) + Tanzen+ Kegeln.

Sport=Schwimmen (F6) + Sport (F7).

Basis-+Freizeit-+ Sportaktivität = Gesamtaktivität Stunden pro Woche bzw. Met pro Woche

Eine ausführliche List emit diversen Aktivitäten und zugehörigen"MET" findet sich bei

Ainsworth BE et al: (Med Sci Sports Ex 1993, 25, 71-80)

Med Sci Sports Ex 2000 S498-S516

Fragen an:

Dr.I. Frey

UKL Freiburg

0761 270 7467E-mail: frey@msm1.ukI-Freiburg.de

Quelle: Effekte eines komplexen Golffitness auf die Golf-Performance von Freizeitgolfern [Elektronische Ressource]: Wirkung eines 8- wöchigen Golffitness-Trainings (5-Saulen- Übungssystem nach Dinse) auf ausgewählte Fitness- und Schwungparameter / vorgelegt von Christine Dinse, Hamburg, Univ., Diss., 2008

# Appendix III. Montreal Cognitive Assessment

Basis-+Freizeit-+ Sportaktivität = Gesamtaktivität Stunden pro Woche bzw. Met pro Woche

Eine ausführliche List emit diversen Aktivitäten und zugehörigen"MET" findet sich bei

Ainsworth BE et al: (Med Sci Sports Ex 1993, 25, 71-80)

Med Sci Sports Ex 2000 S498-S516

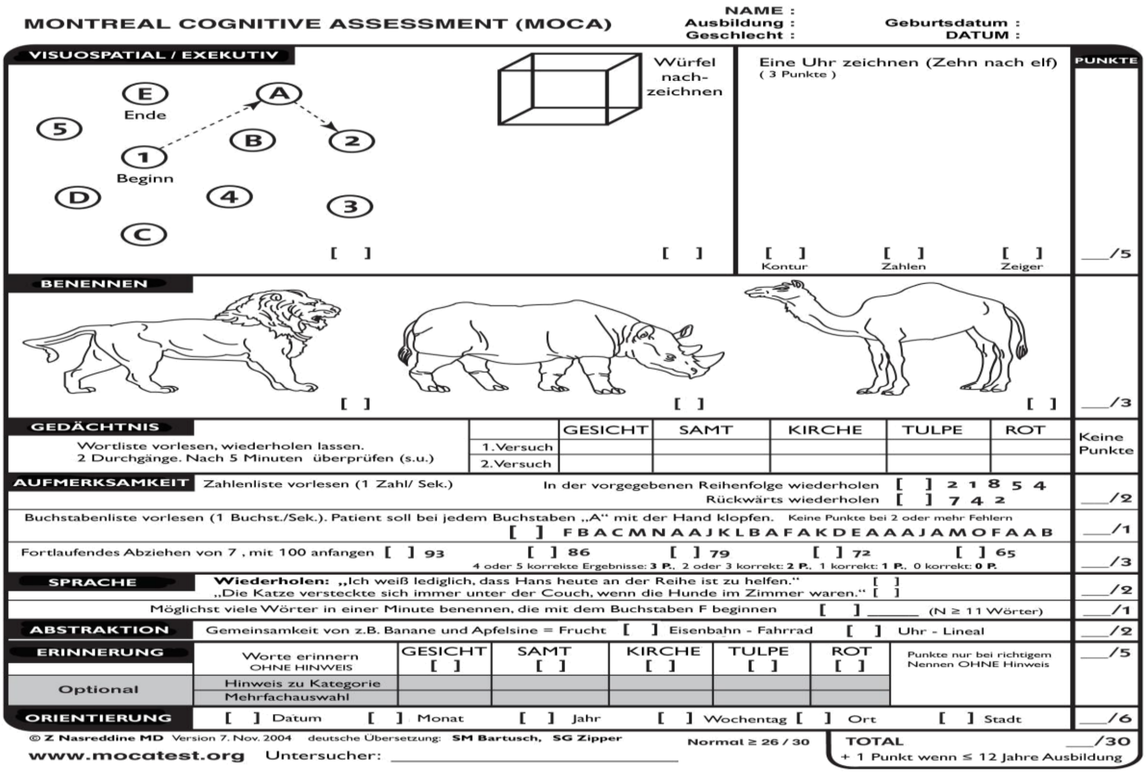
Fragen an:

Dr.I. Frey

UKL Freiburg

0761 270 7467E-mail: frey@msm1.ukI-Freiburg.de

Quelle: Effekte eines komplexen Golffitness auf die Golf-Performance von Freizeitgolfern [Elektronische Ressource]: Wirkung eines 8- wöchigen Golffitness-Trainings (5-Saulen- Übungssystem nach Dinse) auf ausgewählte Fitness- und Schwungparameter / vorgelegt von Christine Dinse, Hamburg, Univ., Diss., 2008


MONTREAL COGNITIVE ASSESSMENT (MOCA)

NAME :
Ausbildung :
Geschlecht :
Geburtsdatum :
DATUM :

PUNKTE

VISUOSPATIAL / EXEKUTIV
E Ende
A
5
B
2
1 Beginn
D
4
3
C
[ ]
Würfel nachzeichnen [ ]
Eine Uhr zeichnen (Zehn nach elf) (3 Punkte)
[ ] Kontur [ ] Zahlen [ ] Zeiger
___/5

BENENNEN
[ ] [ ] [ ]
___/3

GEDÄCHTNIS
Wortliste vorlesen, wiederholen lassen.
2 Durchgänge. Nach 5 Minuten überprüfen (s.u.)

| | GESICHT | SAMT | KIRCHE | TULPE | ROT |
|---|---|---|---|---|---|
| 1.Versuch | | | | | |
| 2.Versuch | | | | | |

Keine Punkte

AUFMERKSAMKEIT
Zahlenliste vorlesen (1 Zahl/ Sek.)
In der vorgegebenen Reihenfolge wiederholen [ ] 2 1 8 5 4
Rückwärts wiederholen [ ] 7 4 2
___/2

Buchstabenliste vorlesen (1 Buchst./Sek.). Patient soll bei jedem Buchstaben „A" mit der Hand klopfen. Keine Punkte bei 2 oder mehr Fehlern
[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B
___/1

Fortlaufendes Abziehen von 7 , mit 100 anfangen [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
4 oder 5 korrekte Ergebnisse: **3 P.**, 2 oder 3 korrekt: **2 P.**, 1 korrekt: **1 P.**, 0 korrekt: **0 P.**
___/3

SPRACHE
**Wiederholen:** „Ich weiß lediglich, dass Hans heute an der Reihe ist zu helfen." [ ]
„Die Katze versteckte sich immer unter der Couch, wenn die Hunde im Zimmer waren." [ ]
___/2

Möglichst viele Wörter in einer Minute benennen, die mit dem Buchstaben F beginnen [ ] ______ (N ≥ 11 Wörter)
___/1

ABSTRAKTION
Gemeinsamkeit von z.B. Banane und Apfelsine = Frucht [ ] Eisenbahn - Fahrrad [ ] Uhr - Lineal
___/2

ERINNERUNG

| | | GESICHT | SAMT | KIRCHE | TULPE | ROT | |
|---|---|---|---|---|---|---|---|
| | Worte erinnern OHNE HINWEIS | [ ] | [ ] | [ ] | [ ] | [ ] | Punkte nur bei richtigem Nennen OHNE Hinweis |
| Optional | Hinweis zu Kategorie | | | | | | |
| | Mehrfachauswahl | | | | | | |

___/5

ORIENTIERUNG
[ ] Datum [ ] Monat [ ] Jahr [ ] Wochentag [ ] Ort [ ] Stadt
___/6

© Z Nasreddine MD Version 7. Nov. 2004 deutsche Übersetzung: **SM Bartusch, SG Zipper**
www.mocatest.org Untersucher: ____________
Normal ≥ 26 / 30
TOTAL ___/30
+ 1 Punkt wenn ≤ 12 Jahre Ausbildung

# Appendix IV. Verbal Digit Span forward and backwards questionnaire

An assessment procedure for specialist teachers to investigate verbal memory difficulties in children's learning. Both parts are administered.

**Digits forwards**

**Start** Item A

**Finish** Failure on both trials of a pair.

**Directions** "Listen carefully as I say some numbers. When I finish, you say them."

**Delivery** Digits should be given at the rate of one per second. Administer both trials of each item. Recite digits in an even monotone without any variation in pitch of voice.

**Scoring** The individual's score is the total number of items correctly repeated forwards.

**WORKED EXAMPLE**

| Item | First Trial | √ or X | Second Trial | √ or X |
|---|---|---|---|---|
| A | 43 | √ | 16 | √ |
| B | 792 | √ | 847 | √ |
| C | 5941 | X | 7253 | √ |
| D | 93872 | X | 75396 | X |

In this example, the total correct is 5.

**Digits Backwards**

**Directions** Administer as above but say, "Repeat these numbers after me but this time I want you to say them backwards." Give two practice trials of two digits first – any two numbers. If the child gets them wrong - correct her or him. If the child repeats the digits *forwards*, give a reminder that they should be reversed.

**Score** As for digits forwards.

**Final score** Total number managed (ticks) backwards and forwards *added together*. Consult Table 1 for standard score. This can also be expressed as a percentile equivalent: consult Table 2.

**Comparison** Most people can remember two more digits forwards than they can backwards. If the gap is larger than three, or smaller than one, this may be worthy of note.

**DIGITS FORWARDS**

| Item | First trial | √ or X | Second trial | √ or X | Total |
|---|---|---|---|---|---|
| A | 43 | | 16 | | |
| B | 792 | | 847 | | |
| C | 5941 | | 7253 | | |
| D | 93872 | | 75396 | | |
| E | 152649 | | 216748 | | |
| F | 3745261 | | 4925316 | | |
| G | 82973546 | | 69174253 | | |
| H | 246937185 | | 371625948 | | |
| | | | | Forwards score: | |

**DIGITS BACKWARDS**

| Item | Trial one | √ or X | Trial two | √ or X | Total |
|---|---|---|---|---|---|
| A | 83 | | 29 | | |
| B | 475 | | 615 | | |
| C | 2619 | | 3852 | | |
| D | 28736 | | 59413 | | |
| E | 624719 | | 276391 | | |
| F | 4183627 | | 1586937 | | |
| G | 52624197 | | 94617385 | | |
| | | | | Backwards score: | |

**FINAL SCORE:**

| | |
|---|---|
| Total forwards and backwards: | |
| Standard score: | |
| Percentile equivalent: | |

Martin Turner
Jacky Ridsdale
revised 6th October 2004

**TABLE 1**

Table 1: Estimated standard scores for digit memory performances from six years to adult

| Age | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Adult |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Raw score 4 | 74 | 57 | 60 | 56 | 54 | 55 | 50 | 48 | 52 | 52 | 51 | 50 |
| 5 | 79 | 63 | 65 | 61 | 59 | 59 | 55 | 53 | 56 | 56 | 55 | 54 |
| 6 | 85 | 69 | 70 | 66 | 64 | 64 | 59 | 57 | 60 | 60 | 59 | 57 |
| 7 | 90 | 75 | 75 | 71 | 69 | 68 | 64 | 61 | 64 | 64 | 63 | 61 |
| 8 | 96 | 81 | 80 | 76 | 74 | 73 | 68 | 66 | 68 | 68 | 66 | 64 |
| 9 | 101 | 87 | 85 | 81 | 79 | 77 | 73 | 70 | 72 | 72 | 70 | 68 |
| 10 | 106 | 93 | 90 | 86 | 85 | 82 | 77 | 74 | 76 | 75 | 74 | 71 |
| 11 | 112 | 99 | 95 | 91 | 90 | 86 | 81 | 78 | 80 | 79 | 78 | 75 |
| 12 | 117 | 105 | 100 | 96 | 95 | 91 | 86 | 83 | 84 | 83 | 82 | 79 |
| 13 | 123 | 111 | 105 | 101 | 100 | 95 | 90 | 87 | 88 | 87 | 86 | 82 |
| 14 | 128 | 117 | 110 | 106 | 105 | 100 | 95 | 91 | 92 | 91 | 89 | 86 |
| 15 | 134 | 123 | 115 | 111 | 110 | 105 | 99 | 96 | 96 | 95 | 93 | 89 |
| 16 | 139 | 129 | 120 | 116 | 115 | 109 | 104 | 100 | 100 | 98 | 97 | 93 |
| 17 | 144 | 135 | 125 | 121 | 121 | 114 | 108 | 104 | 104 | 102 | 101 | 96 |
| 18 | 150 | 141 | 130 | 126 | 126 | 118 | 112 | 109 | 108 | 106 | 105 | 100 |
| 19 | 155 | 147 | 135 | 131 | 131 | 123 | 117 | 113 | 112 | 110 | 108 | 104 |
| 20 | 161 | 153 | 140 | 136 | 136 | 127 | 121 | 117 | 116 | 114 | 112 | 107 |
| 21 | | | 145 | 141 | 141 | 132 | 126 | 122 | 120 | 118 | 116 | 111 |
| 22 | | | 150 | 146 | 146 | 136 | 130 | 126 | 124 | 121 | 120 | 114 |
| 23 | | | 155 | 151 | 152 | 141 | 134 | 130 | 128 | 125 | 124 | 118 |
| 24 | | | 159 | 156 | 157 | 145 | 139 | 134 | 132 | 129 | 127 | 121 |
| 25 | | | | | | 150 | 143 | 139 | 136 | 133 | 131 | 125 |
| 26 | | | | | | 154 | 148 | 143 | 140 | 137 | 135 | 129 |
| 27 | | | | | | 159 | 152 | 147 | 144 | 141 | 139 | 132 |
| 28 | | | | | | 163 | 157 | 152 | 148 | 144 | 143 | 136 |
| 29 | | | | | | | | 156 | 152 | 148 | 147 | 139 |
| 30 | | | | | | | | 160 | 156 | 152 | 150 | 143 |
| 31 | | | | | | | | | 160 | 156 | 154 | 146 |
| 32 | | | | | | | | | 164 | 160 | 158 | 150 |
| 33 | | | | | | | | | | | | 154 |
| 34 | | | | | | | | | | | | 157 |
| 35 | | | | | | | | | | | | 161 |
| 36 | | | | | | | | | | | | 164 |

**TABLE 2**

| Standard score | %ile equiv | Standard score | %ile equiv | Standard score | %ile equiv | Standard score | %ile equiv |
|---|---|---|---|---|---|---|---|
| 54 | 0.1 | 77 | 6 | 100 | 50 | 123 | 94 |
| 55 | 0.1 | 78 | 7 | 101 | 53 | 124 | 95 |
| 56 | 0.2 | 79 | 8 | 102 | 55 | 125 | 95 |
| 57 | 0.2 | 80 | 9 | 103 | 58 | 126 | 96 |
| 58 | 0.3 | 81 | 10 | 104 | 61 | 127 | 96 |
| 59 | 0.3 | 82 | 12 | 105 | 63 | 128 | 97 |
| 60 | 0.4 | 83 | 13 | 106 | 66 | 129 | 97 |
| 61 | 0.5 | 84 | 14 | 107 | 68 | 130 | 98 |
| 62 | 0.6 | 85 | 16 | 108 | 70 | 131 | 98 |
| 63 | 0.7 | 86 | 18 | 109 | 73 | 132 | 98 |
| 64 | 0.8 | 87 | 19 | 110 | 75 | 133 | 99 |
| 65 | 1 | 88 | 21 | 111 | 77 | 134 | 99 |
| 66 | 1 | 89 | 23 | 112 | 79 | 135 | 99 |
| 67 | 1 | 90 | 25 | 113 | 81 | 136 | 99.2 |
| 68 | 2 | 91 | 27 | 114 | 82 | 137 | 99.3 |
| 69 | 2 | 92 | 30 | 115 | 84 | 138 | 99.4 |
| 70 | 2 | 93 | 32 | 116 | 86 | 139 | 99.5 |
| 71 | 3 | 94 | 34 | 117 | 87 | 140 | 99.6 |
| 72 | 3 | 95 | 37 | 118 | 88 | 141 | 99.7 |
| 73 | 4 | 96 | 39 | 119 | 90 | 142 | 99.7 |
| 74 | 4 | 97 | 42 | 120 | 91 | 143 | 99.8 |
| 75 | 5 | 98 | 45 | 121 | 92 | 144 | 99.8 |
| 76 | 5 | 99 | 47 | 122 | 93 | 145 | 99.9 |