Department of Psychology - Faculty of Health Sciences

Dexterity and Cognition in Mild Cognitive Impairment

A Pilot Study

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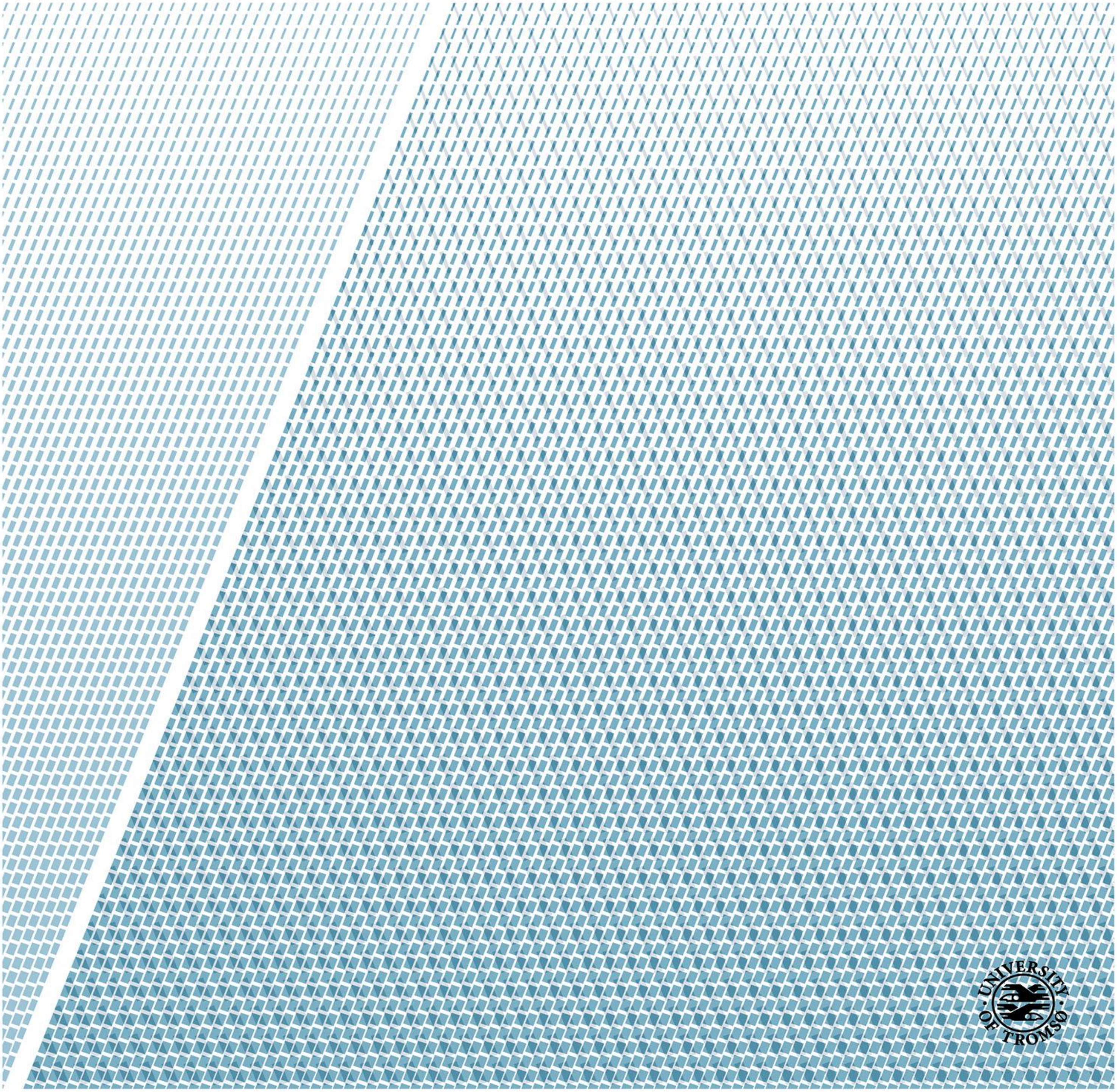
Ingvild Johansen and Heidi Almhaug

Thesis for the Cand. Psychol. Degree - May 2017



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Dexterity and Cognition in Mild Cognitive Impairment: A Pilot Study

Ingvild Johansen and Heidi Almhaug

Supervisor: Claudia Rodríguez-Aranda, Uit

PSY 2901 - Thesis for the Cand. Psychol. Degree

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Forord

Denne studien er en del av et større forskningsprosjekt ved Universitetet i Tromsø, som omhandler aldersrelaterte endringer i motorikk og kognitive funksjoner i normal aldring. Det ble i 2016 publisert en artikkel basert på prosjektet, hvor det ble funnet en forskjell i sammenhengen mellom kognitive funksjoner og hånddyktighet hos friske eldre og voksne. Vår interesse for gerontologi, nevropsykiatri og geriatri inspirerte oss til å fordype oss i temaet, og denne hovedoppgaven er en pilotstudie for videreutvikling av nevnte funn. Prosjektet er opprinnelig utformet av førsteamanuensis Claudia Rodríguez-Aranda, og gjennomført av stipendiat Marta Gorecka og stipendiat Olena Vasylenko, m.fl.. Gjennom prosjektet har vi hatt gleden av et lærerikt og positivt samarbeid med disse.

Kandidatene har begge bidratt med innhenting av nevropsykologiske data gjennom testing, og innhentet all kinematisk data i pasientgruppen. Data for kontrollgruppen er hentet fra tidligere innhentet data i samme prosjekt. Heidi Almhaug har utført dataprosessering av kinematisk analyse. Litteraturen i oppgaven har i hovedsak blitt innhentet av kandidatene. Ingvild Johansen har formulert innledning, mens Heidi Almhaug har formulert metodedel og store deler av resultatdelen. Metodedelen er basert på en tidligere publisert artikkel og utkast fra Olena Vasylenko (Rodríguez-Aranda, Mittner & Vasylenko, 2016). Claudia Rodríguez-Aranda har hjulpet til å formulere delene som omhandler assosiasjoner mellom kinematiske og kognitive skårer i både resultat- og diskusjonsdelen. Kandidatene har samarbeidet om å utforme diskusjonsdelen, med god hjelp fra veileder.

I forbindelse med hovedoppgaven er det mange som fortjener en stor takk. Claudia Rodríguez-Aranda foreslo først ideen til prosjektet, og har vært behjelpelig med koordinering av opplæring, gjennomføring av statistiske analyser, tekstgjennomgang og moralsk støtte gjennom prosessen. Vi ønsker å takke for god veiledning. Videre ønsker vi å takke Marta Gorecka, som har vært behjelpelig med opplæring i nevropsykologiske tester, og Olena Vasylenko, som har bidratt med opplæring og veiledning i forbindelse med dataprogrammer for prosessering av kinematiske og temporale data. En stor takk rettes til deltakerne som har bidratt til denne studien, som til tross for sviktende helse bidro med sin tid og innsats. Dette studiet hadde ikke vært mulig uten de.

Til slutt ønsker vi å takke familie, venner og medstudenter for støtte og inspirasjon gjennom arbeidet med hovedoppgaven.

Abstract

Previous research has demonstrated that age-related decline in cognitive and sensorimotor functions are related to dexterity and activities of daily living (IADL). Few studies have closely investigated the association between dexterity and cognitive functions. The purpose of this study was to explore possible differences in dexterity, cognition and IADL function across a group of mild cognitive impaired elders and a group of healthy elders. 11 MCI participants and 12 healthy participants were subjected to a neuropsychological and psychomotor test battery. IADL assessment was collected by the Lawton & Brody semi-structured IADL interview. The results confirms a difference in dexterity task performance between MCI individuals and healthy elderly. Correlational analysis showed that global mental status, memory and lexical knowledge were significantly associated with dexterity performance. The IADL assessment showed no difficulties in IADL function in the MCI group. Implications are discussed and recommendations for further research suggested.

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Introduction

A decline in cognitive and sensorimotor functions is a normal part of the human aging process. Some of these declines will affect different abilities required for “Activities of Daily Living” (ADL). ADL is a clinical concept defined as basic and instrumental self-maintenance activities that people tend to do every day without need of assistance (Wiener, Hanley, Clark & Van Nostrand, 1990; Erber, 2013). The ability to perform these tasks are important for older people to maintain independent life in the community (Erber, 2013). Basic ADL (BADL) involve activities like dressing, eating, bathing, toileting and walking, while instrumental ADL (IADL) refer to abilities required to reside in a community, like managing personal economy, shopping for groceries, driving a car or using public transportation, housekeeping etc. (Spector & Fleischman, 1998). A body of research has demonstrated that a decline in cognitive and sensorimotor abilities is accompanied by a decrease in IADL function (Cahn-Wiener, Boyle & Malloy, 2002; McGuire, Ford & Ajani, 2006; Scherder, Dekker & Eggermont, 2008; Perneczky, Pohl, Sorg, Hartmann, Tosic, et al., 2006). Several studies indicate that IADL screening can be used to determine the severity of cognitive deterioration in older individuals (Perneczky, Pohl, Sorg, Harmann, Komossa, et al., 2006; Folquitto et al., 2007; Nygård, 2003; Farias et al., 2006).

IADL is, among other factors, dependent on manual dexterity (Scherder et al., 2008; Shiffman, 1992; Incel, Sezgin, As, Cimen & Sahin, 2009). Dexterity is defined as the ability to manipulate objects rapidly and efficiently using different prehensile patterns (Shumway-Cook & Woollacott, 2007). Moreover, manual dexterity is significantly associated with executive functions (Rodríguez-Aranda, Mittner & Vasylenko, 2016). Dexterity can be assessed by the Purdue Pegboard Test or Grooved Pegboard Test, which measure precise movements of the dominant and non-dominant hand; as well as uni- and bimanual movements for manipulation of small objects (Kluger et al., 1997). A gradual decline in dexterity is related to a reduced level of ability to perform everyday tasks, such as pouring milk from a carton, eating, writing or getting dressed, thus increasing functional dependency (Scherder et al., 2008; Shiffman, 1992; Spector & Fleishman, 1998). Dexterity decline has been attributed to factors like loss of finger strength, changes in joints or manual speed, but also, as mentioned earlier, cognitive deterioration (Scherder et al., 2008).

Rodríguez-Aranda with colleagues (2016) investigated whether normal, age-related cognitive decline affects dexterity performance in healthy older adults. In this study, the authors addressed the relationship between executive functions, working memory and dexterity in younger adults and healthy elders. The findings were that dexterity, as measured by kinematic analyses of performance on The Purdue Pegboard Test, was less efficient in the elderly group, as compared to the younger participants. Also, the elderly's overall cognitive test performance was lower. Increased variability in dexterity, i.e. higher movement variations in different actions, was associated with executive functions in the elderly group, suggesting that there are different patterns of cognition-dexterity associations in younger and older adults. Although the direction of the association found in this study was not clarified, the data showed a clear involvement of executive functions in dexterity (older adults inserted fewer pins, completed less assemblies and were slower in grasping and inserting objects).

The above study has several implications not only for healthy elderly, but most importantly for older adults developing pathological cognitive decline. In fact, the above-mentioned study brings up the question of whether a similar relationship between appropriate dexterity function and executive functions can be found in older adults with cognitive dysfunction. The issue is of importance for the early detection of dementia. According to the

ICD-10 (WHO, 1992) the criteria for a diagnosis of dementia includes a decline in memory and cognitive function that leads to difficulties in registering, storing and retrieving recent or old information, reduced ability of cognition, reasoning and information processing, and *impaired ADL function*. Hence, whether or not an individual retain his/her ADL functions makes a difference for receiving a diagnosis and understanding the possible progression into a dementia state.

One of the proposed categories of pre-dementia states is mild cognitive impairment (MCI), which is a condition that lies between normal cognitive function and dementia, and is considered a prodromal phase of dementia (Petersen, 2004; Morris, Storandt & Miller, 2001). Reviews have concluded that these individuals have a heightened risk of developing Alzheimer's Disease (AD), with numbers ranging from 1 to 25 % per year (Golomb, Kluger & Ferris, 2004; Petersen et al., 1999). This relatively new classification in age-related research consists of individuals that score lower on a variety of neuropsychological and motor tests compared to cognitively normal older people, but do not meet the criteria of dementia or Alzheimer's disease. (Kluger, Golomb & Ferris, 2002; Golomb et al., 2004). People with MCI present independence in functional abilities and intact global cognitive function, but in many cases they report subjective memory complaints (Langa & Levine, 2014; Golomb et al., 2004). However, the exact onset of a patient's cognitive impairment that may classify as MCI is often difficult to pinpoint, and the progression from the debut of subjective memory difficulties to measurable symptoms of cognitive impairment or dementia occurs over several years. Many suggestions of categorizing different preclinical stages has been made, but current research has yet to present clear cut diagnostic categories on the MCI condition (Golomb et al., 2004; Roberts & Knopman, 2013). Suggested guidelines in the research body include: cognitive complaint, decline or impairment, objective memory impairment beyond age, objective impairment in cognitive domains; essentially normal functional activities; not demented (Roberts & Knopman, 2013; Langa & Levine, 2014; Bahureksa et al., 2017; Winblad et al., 2004)

In spite that it is customary to believe that IADL function remains adequate in MCI individuals (Langa & Levine, 2014), some studies have demonstrated that MCI subjects experience difficulties in IADL function, while BADL is unimpaired (Golomb et al., 2004; Folquitto et al., 2007; Nygård, 2003; Farias et al., 2006). Furthermore, other studies conclude that impairment of IADL function is present in MCI, particularly in complex IADL tasks involving memory and complex reasoning, and that evaluation of IADL can contribute to clinical diagnostics (Perneczky, Pohl, Sorg, Hartmann, Komossa, et al., 2006; Perneczky, Pohl, Sorg, Hartmann, Tosic, et al., 2006; Jekel et al., 2015; Teng, Becker, Woo, Cummings & Lu, 2010). A different study gives support to this finding. Farias with colleagues (2006) found that in a sample of 96 diagnosed MCI subjects, there was more functional impairment among these patients than in healthy controls, in areas of everyday tasks such as planning, organization, memory, language, visuoperceptual skills and divided attention.

The challenge in this regard is how to determine the initial decline of IADL among MCI subjects. As a rule, evaluation of IADL occurs by the administration of an interview or a self-report questionnaire, with or without supplement from close family members, such as the Lawton Instrumental Activities of Daily Life Scale (Lawton & Brody, 1969). This instrument includes 8 items involving IADL tasks like using the telephone, shopping for groceries, preparing meals, housekeeping, etc. Limitations of assessing the IADL questionnaire by subjective report includes the risk of either over- or underestimating IADL function, as the performance of the task is not physically demonstrated. The instrument may also not be sensitive to subtle, cumulative changes of function (Graf, 2006, 2008; Katz, 1983). A more specific evaluation of IADL among MCI subjects could be obtained through a detailed and objective analysis of dexterity and hand function, as dexterity is practically related to IADL. A clear example where dexterity decline might be affecting IADL is for instance the case of older adults trying to pay at the cashier, using a long time to get the money because they are unable of grasping coins, bills etc., and they get stressed and feel embarrassed to make payments due to their difficulties.

A limited amount of studies have investigated dexterity in relation to cognitive functions in the MCI population. In two studies assessing motor function in older individuals with MCI, it was demonstrated that the MCI subjects perform more poorly on tasks involving fine and complex motor function than those with normal cognitive functioning (Kluger et al., 1997, 2008). In a study performed by Kluger with colleagues (1997), fine and complex motor task performance was able to effectively differentiate healthy elders from MCI, and MCI from AD dementia, comparably to differentiation based on cognitive tasks on memory and language. Results also showed that an important point of evaluating dexterity in the diagnosis of dementia is that psychomotor tests are relatively independent of educational level, which may allow for the diagnosis across different people with different levels of cognitive reserve. The concept of cognitive reserve has emerged from epidemiological observations that suggest that a pattern of life exposures such as educational level, occupational status, cognitively stimulating behaviors or lifestyle factors, seem to be associated with a reserve against age- or AD-related pathology (Stern, 2002). Several studies demonstrate that older individuals with high levels of cognitive reserve will not show clinical symptoms as early as those with low cognitive reserve, so that standard cognitive neuropsychological testing is less sensitive to identify pathology in high cognitive reserve subjects (Stern, 2002; Richard & Sacker, 2003). The rate of cognitive decline after diagnosis is more rapid in individuals with high reserve as compared to those of low reserve (Stern, 2002; Hall et al., 2007; Scarmeas, Albert, Manly & Stern, 2006). For these reasons, evaluation of dexterity may have a direct relevance in the early detection of dementia across heterogeneous groups.

Schröter and colleagues (2003) used kinematic analysis of handwriting in healthy elderly, MCI, AD, and depressed patients, to demonstrate that MCI subjects show a loss of fine motor performance compared to healthy subjects. MCI subjects performed worse on fine and complex tasks, where differentiation between MCI and healthy subjects increased with increased complexity. For AD subjects, peak velocity, which indicates the coordination and regularity of hand movements, was slightly elevated as compared to healthy controls, demonstrating an increased irregularity in movements. The study concludes that quantitative fine motor skill assessment can be used as a tool in the differential diagnosis of AD, MCI and depression. This indicates that early detection of fine and complex motor deficiencies in normal and MCI elders can identify individuals with higher risk of developing a pathological condition and IADL dysfunction.

The above-mentioned studies suggest a close relationship between dexterity and cognitive function. Nevertheless, the association is still poorly understood and the role of cognitive functions in hand motor skill should be further explored, as proposed by various authors (e.g., Rodríguez -Aranda et al., 2016). All in all, the evidence suggest an important link that is yet to be adequately addressed in normal aging and dementia states. This gives rise to the aim of this pilot study, which was to further investigate dexterity and cognition in groups of healthy controls and elders with mild cognitive impairment. Since an estimated 1.5 % of the

Norwegian population suffers from dementia, and more people will get the illness in the close future (Folkehelseinstituttet, 2014), understanding the relationship between dexterity, cognitive function and declined IADL could be of great importance for the amelioration of the early diagnosis of the disease.

The present pilot study

Based on the literature mentioned above, this pilot study aimed to investigate whether MCI subjects perform differently than controls on fine dexterity measures, whether the possible differences in dexterity were associated with level of cognitive function, and explore IADL function in the patient group. To this end, we conducted:

a) A detailed analysis on dexterity by means of collecting kinematic and temporal data from performance on the Purdue Pegboard Test, which is a psychomotor test of fine and complex motor control.
b) Assessment of cognitive functions using neuropsychological tests on memory, attention, working memory and executive functions.
c) Assessment of IADL function of the MCI group by a self-report questionnaire of IADL, where all items involved activities related to hand motor control. The IADL questionnaire was not administered to the healthy control group, given the assumption that these individuals do not have difficulties with IADL and that the existent instruments to evaluate these functions are not designed to assess IADL in healthy controls.

We formulated the following hypothesis: MCI subjects would, according to previous findings, perform more poorly on dexterity tasks, but also show different patterns of movement than the control group. The kinematic analysis of dexterity would identify specific movements or patterns of movement that significantly differ from healthy controls. In particular, we expected the MCI group to show more variability in dexterity as compared to the healthy group, and that they would also show slower movements, taking significantly longer time to perform the tasks. We also hypothesized that dexterity and cognition would show significant correlations in the whole sample. Level of IADL function was expected to be well preserved in the MCI group.

Method

Participants

23 community-dwelling older adults participated in the pilot study, of which 11 were in the MCI-group and 12 healthy, older adults were in the control group. Participants in the MCI-group (7 women, M_{age}= 67.09 years, range: 57-80 years) were recruited from the Geriatric department and the Neurological department at the University Hospital of North Norway. The healthy participants (5 women, M_{age}= 72.83 years, range: 64-88 years) were recruited at activity centers for older seniors by sharing flyers and by getting participants in the study to recruit friends and family. Before participating in the pilot study, all participants were briefed about the purpose of the pilot study and signed informed consent sheets. Demographic and health information were gathered through a short interview, as well as with the Norwegian version of the SF-36 (Loge, Kaasa, Hjermstad & Kvien, 1998). None of the participants had any illnesses or injuries that could affect cognition or dexterity, such as osteoarthritis, head trauma, stroke, or injuries of the hands. Mental status was assessed with the Mini-Mental State Examination (MMSE; Folstein,

Folstein & McHugh, 1975). For the MCI-group, a MMSE-score of 19 was set as lower cutoff for inclusion, and a MMSE-score of 28 was set as lower cutoff for inclusion in the control group. Participants were assigned to either the MCI- or the control group after a global assessment of cognitive function. It is important to mention that three of the participants in the MCI-group had a MMSE-score between 28-30. Nevertheless, since these individuals were patients recruited from the University Hospital they were placed in the MCI-group, due to their scores on the neuropsychological test battery and their subjective complaint of cognitive impairment. Because this pilot study is part of a larger project which also includes young adults, the Beck Depression Inventory (BDI), 2nd edition (Beck, Steer & Brown, 1996) was used to screen for depression. As proposed by Rodríguez-Aranda (2003), scores between 14 and 18 were accepted, because sleep and appetite naturally decline in healthy aging, and the BDI includes items that are sensitive to changes in sleep and appetite. Visual acuity was assessed with Snellen charts (Snellen, 1862). Only right-handed participants were included in the study, as performance on the Purdue Pegboard Test is affected by handedness (Judge & Stirling, 2003). The Handedness Inventory was used to ensure that all participants were right-handed (Briggs & Nebes, 1975). The Lawton Instrumental Activities of Daily Living (IADL) Scale (Lawton & Brody, 1969) was used to assess functional skills in the MCI-group (see appendix A). The pilot study was approved by the Regional Research Ethics Committee and carried out in accordance with the Helsinki guidelines.

Measures

Neuropsychological test battery. The Trail Making Test (TMT; Reitan & Wolfson, 1993) and the Stroop Color and Word Test (Golden, 1978) were used to assess executive function. The Block Design Test and the Digit Span Test from the Wechsler Adult Intelligence Scale, 4th edition (Wechsler, 2014) were used to measure attention and working memory. The Logical Memory Test from the Wechsler Memory Scale, 3rd edition (Wechsler, 1997) was used to assess memory. The Grip Strength Test and the Finger Tapping Test from the Halstead-Reitan neuropsychological battery, 2nd edition (Reitan & Wolfson, 1993) were used to evaluate physical hand function. The Verbal Fluency Test from the Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan & Kramer, 2001), the Controlled Oral Word Association Test (COWAT; Benton, Hamsher & Sivan, 1983), traditional semantic fluency (Newcombe, 1969), and the Vocabulary Test from the Wechsler Adult Intelligence Scale, 4th edition (Wechsler, 2014) were used to assess crystallized intelligence/premorbid function.

Purdue Pegboard Test and video recording. The Purdue Pegboard Test (PPT; Lafayette Instrument Model 32020) is made up of a board which measures 22.7 × 44.9 cm, with two parallel ranks of holes running down the centre of the board, and four cups at the top end of the board (Figure 1). The top end cups hold pins, washers, collars, and pins, from left to right. The PPT is a standardized test of manual dexterity, and includes four subtests. The first subtest measures dexterity in the dominant right hand, as participants are instructed to pick up a pin from the cup on the right-hand side of the board, and insert the pin into the topmost hole in the right-hand rank, solely by the use of their right hand. The participants are instructed to continue picking up one pin at the time, and work their way down the rank of holes, until they are asked to stop. The second subtest is uniform to the first subtask, except that participants are instructed to use their left hand and the left-hand cup and rank, thus measuring dexterity in the non-dominant hand. The third subtest is a composite of the previously described subtests, and requires that the participant engage both hands simultaneously to pick up and insert pins. In the fourth subtest participants are instructed to use both hands to assemble pins, washers and collars in a specified sequence in the right-hand rank. Participants are asked to stop after 30 seconds in the first three subtests, and after one minute in the last subtest. Performance measure is determined by the amount of pegs inserted within the given time.

As previously mentioned, the PPT consists of four subtest, but for this pilot study it was considered sufficient to only use the first two subtests, as they allow evaluation of manual dexterity in both the dominant and non-dominant hand by the use of the exact same small objects (pins). To conduct the kinematic analysis, two modifications were done to the original Pegboard. First, in order to obtain good videorecordings of the markers attached to the hand, the board was painted in black and the pegs in red (see Figure 1). Second, to get sufficient movement data for kinematic analysis, participants inserted 10 pins (with no time limit) in each test, instead of allowing subjects to execute the task within 30 seconds. In other words, there were no time constraint even though participants were instructed to insert as fast as possible the 10 units on each subtask. In the standardized version of the PPT, healthy older adults averagely complete ten trials in the 30 s given (Desrosiers, Hebert, Bravo & Dutil, 1995), and thus the modification of inserting 10 pins were considered to be sufficient. A Panasonic HC-X920 video camera at 50 Hz, attached to a rack above the table containing the Pegboard, was used to record movement from the dorsal view. The setup of the camera and Pegboard is shown in Figure 1.

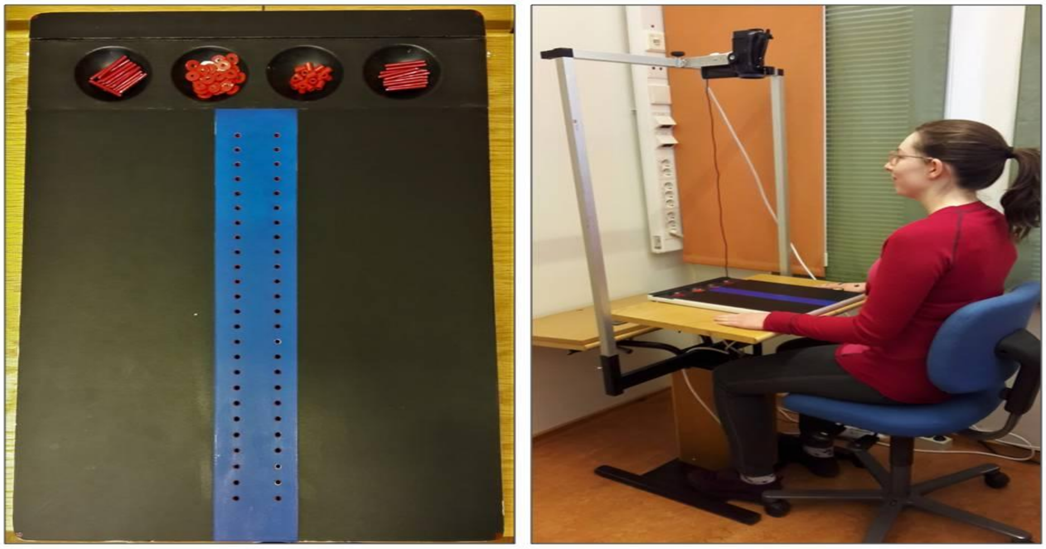
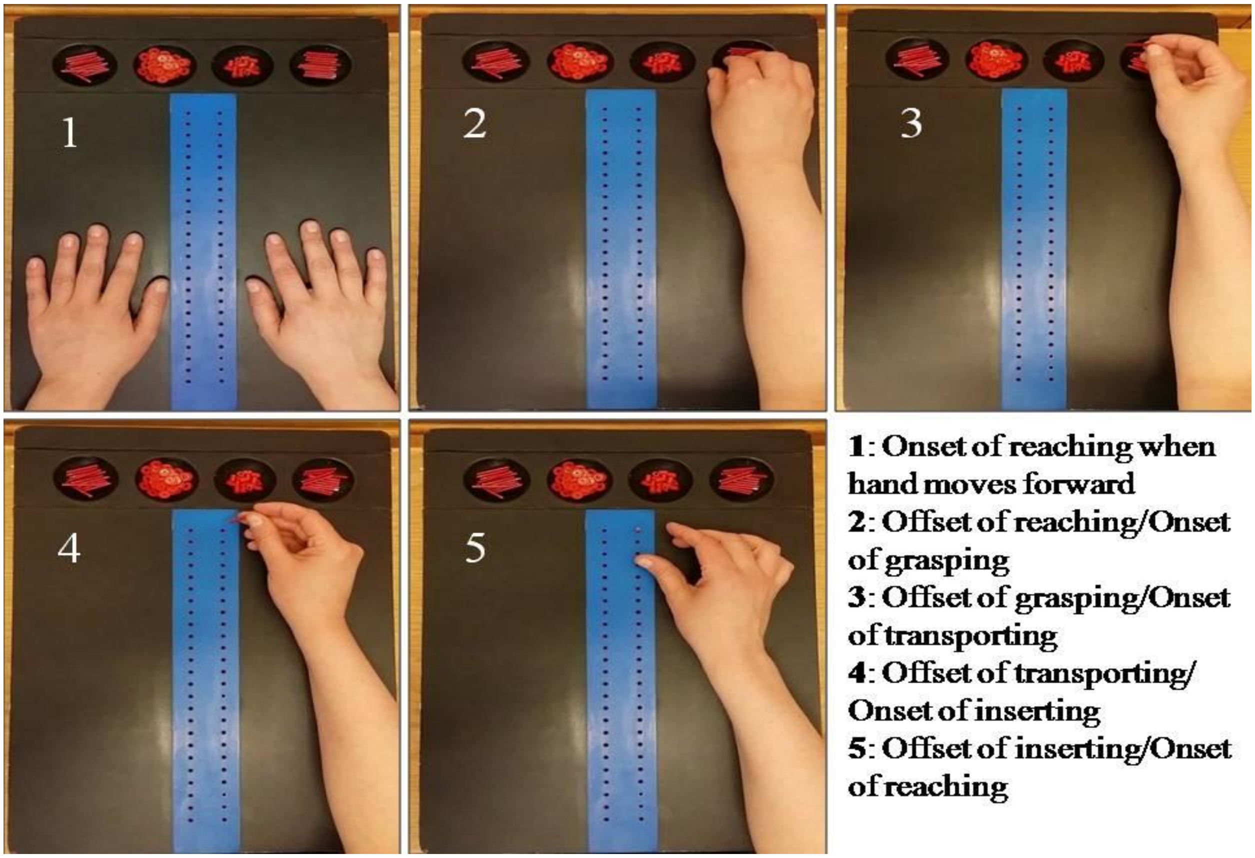


Figure 1. The modified Purdue Pegboard (left picture) and the setup of the camera and Pegboard (right picture).

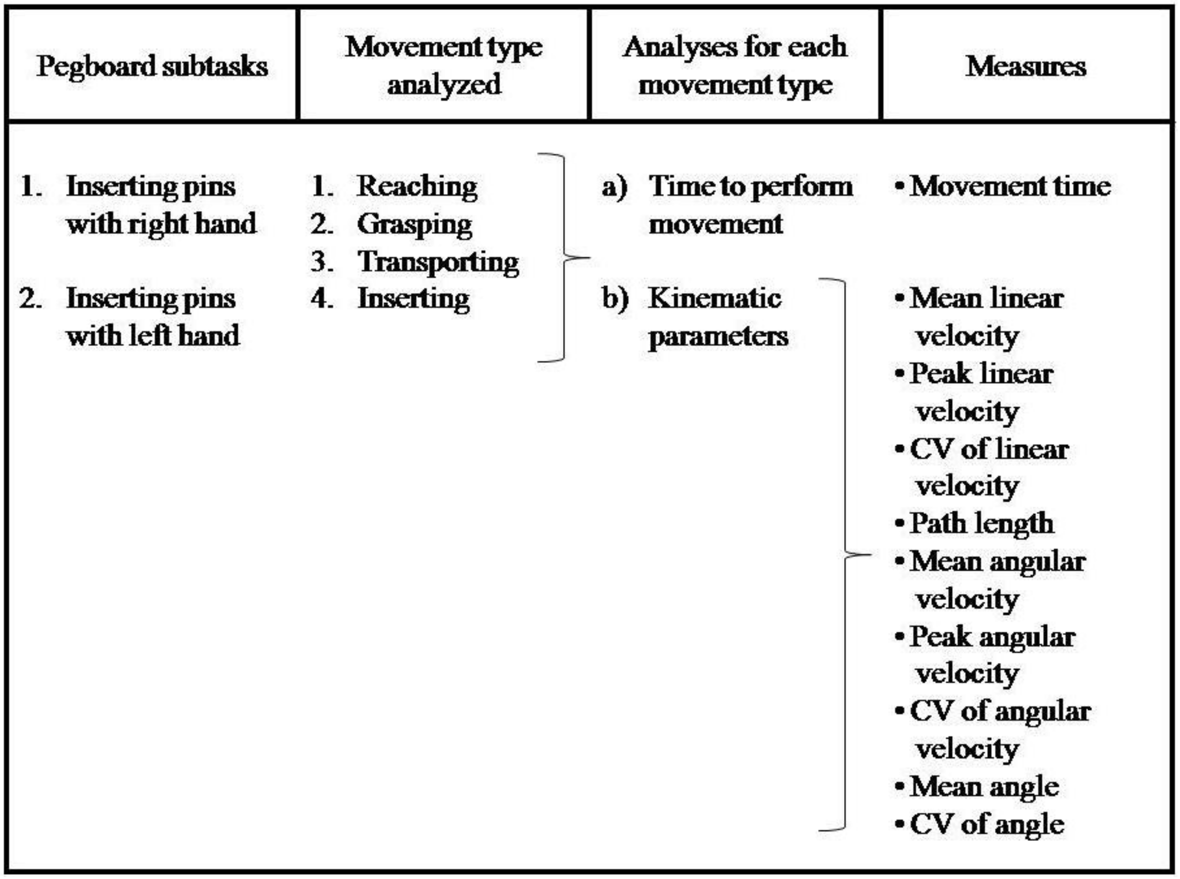
Temporal measures. In this pilot-study two subtasks of the PPT were used: inserting pins unimanually first with the right hand and then with the left hand, with 10 trials for each hand. For each task, four types of movement were analyzed in the video recordings: reaching, grasping, transporting, and inserting. Onset and offset of each movement were manually identified (see Figure 2). For reaching, onset was defined as the frame where the hand started to move towards the cup, and the offset was defined as the frame where the fingers reached the cup. The first frame after offset of reaching was defined as the onset of grasping, and offset of grasping was defined as the frame in which the pin was lifted out of the cup. Onset of transporting was defined as the first frame after end of grasping, and offset was defined as the frame where the fingers reached the hole. Onset of inserting was defined as the first frame after end of transport, and offset was defined as the frame where the fingers release the pin. For each trial of each task, movement times (MT), i.e., total time for each action were obtained. Mean MTs for each type of movement were used in the statistical analysis, and were obtained through averaging separately MTs for reaching, grasping, transporting, and inserting across the 10 trials. See Table 1 for an overview of tasks, temporal, and kinematic measures.



1: Onset of reaching when hand moves forward
2: Offset of reaching/Onset of grasping
3: Offset of grasping/Onset of transporting
4: Offset of transporting/ Onset of inserting
5: Offset of inserting/Onset of reaching

Figure 2. Manual identification of onset and offset of movement types.

Table 1. Overview of tasks, movement types, and temporal and kinematic measures analysed.



Pegboard subtasks	Movement type analyzed	Analyses for each movement type	Measures
1. Inserting pins with right hand 2. Inserting pins with left hand	1. Reaching 2. Grasping 3. Transporting 4. Inserting	a) Time to perform movement	• Movement time
		b) Kinematic parameters	• Mean linear velocity • Peak linear velocity • CV of linear velocity • Path length • Mean angular velocity • Peak angular velocity • CV of angular velocity • Mean angle • CV of angle

Note. Adaptation of the Table presented in Rodríguez-Aranda et al., 2016.

Kinematic measures. For kinematic analysis, the Vicon Motus 2D system (*Vicon Motion Systems, Inc.*, CO. USA) was used. Double-sided tape was used to place six round reflective markers, with a diameter of 6 mm, on each hand (for marker arrangement see Figure 3). After recording, each marker was tracked to obtain 2D coordinates. A low-pass Butterworth filter at the frequency of 7 Hz was used to filter raw coordinates of each marker. The filtered coordinates were used to compute nine kinematic measures for each movement: mean and peak linear velocity, path length, mean and peak angular velocity, mean angle, and coefficients of variability (CV) in linear velocity, angular velocity, and angle. See Figure 3 for marker numbers and angles used for analysis. Coordinates of marker 1 was used to compute mean and peak linear velocity, which gives information about the average speed of hand trajectory, and the highest speed of hand trajectory, respectively. Path length, which gives information about the total distance the hand travels during each movement, was also computed from coordinates of marker 1. Mean angle, which gives information about the average angular displacement of the hand, was computed between markers 2-1-5 for the right hand and 5-1-2 for the left hand. The same angles were used to compute angular velocity, which gives information about the rotational speed of the hand during each movement. The ratios of the standard deviation (*SD*) to the mean (*M*) were used to compute all within-trial CVs. CVs are typically calculated in kinematic analyses to understand the amount of variability on each movement (Steinberg & Bock, 2013) and thus, this outcome illustrates how variable the repetitive movements are on each subject. To obtain mean values of all parameters for statistical analysis, each parameter was averaged across the 10 trials of each type of movement.

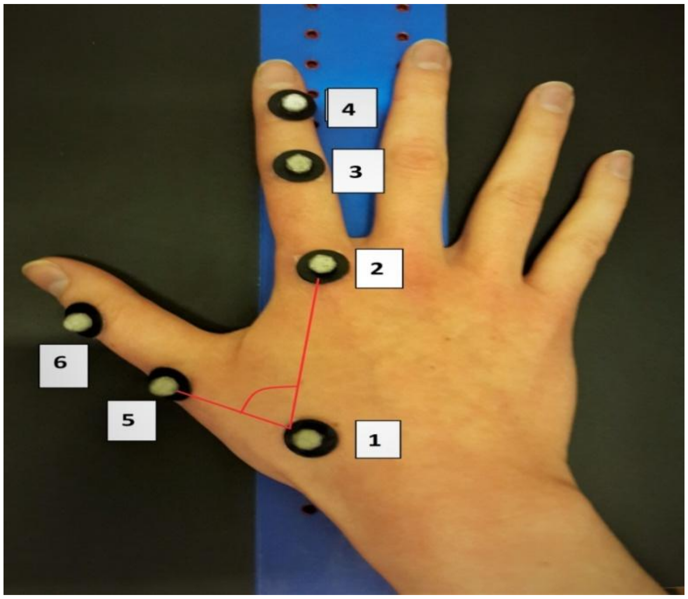


Figure 3. Marker arrangement with marker numbers and angle used for analysis.

Procedure

Evaluation of the whole test battery for cognitive functions and assessment of dexterity was conducted at the Department of Psychology, University of Tromsø. All participants signed informed consent sheets before the procedure was carried out. A short interview about demographic and health information was administered at the start of the procedure. The interview was followed by the screening instruments and the tests for assessing physical hand function, as well as the original PPT. Then the neuropsychological test battery was administered, before dexterity was assessed with the modified PPT. After each task on the PPT had been demonstrated, the participants got to practice until they had correctly inserted three pins. They were then asked to perform the task as quickly and accurately as they could when the experimenter gave the starting signal. The procedure took approximately 1.5 hours.

Statistical analyses

Independent *t*-tests were used to assess group differences in demographics and background variables. For the neuropsychological test scores a MANOVA was conducted due to the multiple evaluations in this domain. Two-way repeated measures MANOVAs for each type of movement (reaching, grasping, transporting, inserting) with Hand (right, left) as within-subject factor and Group (MCI, control) as between-subject factor, were used to analyze movement times (MT). Due to the small sample size in this pilot-study, it was not possible to perform MANOVAs with all four movements under one “movement factor”. For this reason, we decided to enter in the statistical analyses similar types of movements. For instance, reaching and transporting, which need both arm and hand displacement, were put together in one MANOVA, while grasping and inserting, which require the finest movements of the hand and fingers, were put together in another MANOVA. Thus, two-way repeated measures MANOVAs for the similar types of movement (reaching/transporting and grasping/inserting) with Hand (right, left) and Group (MCI, control) as the between-subjects factor, were used to analyze kinematics. The nine kinematic measures worked as dependent variables. Afterwards, univariate ANOVAs were explored for each kinematic measure. The Bonferroni correction was used to adjust significance levels in the univariate analyses, so a significant result was accounted if alpha value was below .001. Because of a small sample size, the sphericity assumption was not met, and therefore Greenhouse-Geisser corrections were used. All statistical analyses were performed with IBM SPSS Statistics Version 23 (IBM Corp., 2015).

Results

Demographics and Neuropsychological Results

Both independent t-tests and one-way ANOVAs were used to examine differences between the MCI- and the control group. In case of a significant Levene test ($p < .05$), the Mann-Whitney U test was applied.

Demographics and background variables: Descriptive statistics for demographic results are listed in Table 2. Although, participants in the MCI-group were younger than the healthy older adults, the difference (*MD* = -5.53, 95% CI [-12.19, 1.12]), was not significant ($t(20) = -1.74$, $p = .098$). In contrast, there was a significant difference in years of education between groups (*MD* = -3.85, 95% CI [-7.76, -.54], $t(20) = -2.42$, $p = .025$), where the healthy older adults had more years of education than participants in the MCI-group. The control group was, on average, slightly more right handed than the MCI-group, but this difference was not significant (*MD* = -2.98, 95% CI [-11.01, 5.04], $t(20) = -.78$, $p = .447$). There were furthermore no significant differences in terms of physical health, as conveyed by the SF-36, (*MD* = -2.18, 95% CI [-10.91, 6.54], *t*(20) = -.52, *p* = .607), or depression (*F*(1, 20) = .002, *p* = .964).

Table 2. Descriptive statistics for demographic results

	MCI (n=11)	Control (n=12)	*p*
	M (SD)	M (SD)	
Age	67.3 (7.39)	72.0 (7.49)	.098
Years of education	10.9 (3.60)	14.7 (3.79)	**.025***
BDI	5.1 (4.95)	5.0 (5.25)	.964
Handedness	18.1 (12.91)	21.08 (3.20)	.447
SF-36	103.4 (9.21)	105.6 (10.20)	.607

Note. *$p \leq .05$

Neuropsychological battery: The control group had, on average, slightly better scores on the neuropsychological test-battery than the MCI-group (see Table 3 for an overview of results). Not surprisingly, the MCI-group showed a significant lower score on the MMSE as compared to controls (*U* = 102.0, *p* = .004). Additionally, the MANOVA showed statistically significant differences for Digits Forward (*F*(1, 21) = 8.87, *p* = .007), Digits Backward (*F*(1, 21) = 9.57, *p* = .006), Vocabulary (*F*(1, 21) = 12.75, *p* = .002), Logical Memory I (*F*(1, 21) = 9.10, *p* = .007), and Logical Memory II (*U* = 116.5, *p*< .001). The rest of the cognitive tests (Stroop Color and Word (*F*(1, 21) = .82, *p* = .375), FAS mean (*F*(1, 20) = 3.17, *p* = .090), FAS errors (*F*(1, 20) = 1.97, *p* = .176), FAS repetitions (*F*(1, 20) = .02, *p* = .898), SEM mean (*U* = 73.5, *p* = .381), SEM errors (*F*(1, 20) = .31, *p* = .584), SEM repetitions (*F*(1, 20) = .00, *p* = .972), TMT-A (*U* = 52.0, *p*

= .628), TMT-B (*U* = 45.5, *p* = .346), and Block Design (*U* = 69.0, *p* = .880)) did not show significant group differences.

Table 3. Descriptive statistics for neuropsychological results

	MCI	Control	
Variable	*M (SD)*	*M (SD)*	*p*
MMSE	26.40 (3.24)	30.00 (0.00)	**.001*****
TMT A	41.90 (23.10)	33.01 (9.83)	.239
TMT B	142.50 (92.90)	89.36 (28.16)	.074
Stroop Color/Word	36.82 (12.82)	32.75 (8.43)	.375
Digits forward	7.73 (1.49)	9.92 (1.98)	**.007****
Digits backward	6.09 (2.12)	8.67 (1.88)	**.006****
Vocabulary	27.91 (7.02)	37.08 (5.25)	**.002****
Block design	37.91 (13.64)	42.17 (7.67)	.361
Logical memory I	7.20 (5.07)	12.50 (3.09)	**.007****
Logical memory II	5.30 (5.56)	16.75 (2.45)	**.000*****
FAS mean	12.17 (3.90)	14.89 (3.27)	.090
FAS errors	0.63 (0.84)	0.25 (0.41)	.176
FAS repetitions	0.37 (0.71)	0.33 (0.49)	.898
SEM mean	14.23 (5.07)	16.58 (2.55)	.174
SEM errors	0.07 (0.14)	0.11 (0.22)	.584
SEM repetitions	0.37 (0.37)	0.36 (0.41)	.972

Note. TMT = Trail Making Test, FAS = phonemic fluency, SEM = semantic fluency, *$p \leq .05$, **$p \leq .01$, ***$p \leq .001$

Concerning physical and psychomotor function, the two groups did not significantly differ on any of the measures (see Table 4 for an overview of results). None of the participants in the MCI-group had a total score higher than 8 on the IADL Scale, which indicates that they had no impairment of IADL function as assessed by the Lawton & Brody Instrumental Activities of Daily Living Scale.

Table 4. Psychomotor group differences

	MCI M (SD)	Control M (SD)	*p*
Grip strength			
Right hand	38.38 (13.76)	38.50 (12.04)	.983
Left hand	34.95 (11.25)	36.03 (10.96)	.827
Sight (Both eyes)	52.78 (61.7)	79.17 (62.01)	.346
Finger tapping			
Right hand	43.66 (11.61)	42.37 (89.34)	.782
Left hand	40.02 (10.52)	42.37 (9.34)	.865
Purdue Pegboard			
Right hand	11.60 (2.37)	12.17 (2.79)	.617
Left hand	11.00 (2.36)	11.33 (1.72)	.706
Both hands	9.10 (2.38)	9.50 (1.62)	.645
Assembly task	5.60 (2.37)	5.67 (1.37)	.935
PTA Best	23.81 (12.04)	20.31 (11.45)	.483

Note. PTA = Pure tone audiometry

Dexterity analysis

Movement Times (MT)

The time that participants employed on each action, or movement times (MT), was analysed through two-way repeated measures MANOVAs by hand. In this analysis we entered the type of movement (reaching, grasping, transporting, inserting) as the within subjects factor and the group (MCI, control) as the between subjects factor. For an overview of results, see Table 5 and 6.

Right hand results. Using Pillai's Trace, a main effect was found for action ($V = .85$, $F(6, 16) = 14.50$, $p < .001$), while no main effect was found for group ($V = .19$, $F(2, 20) = 2.32$, $p = .124$) or their interaction ($V = .46$, $F(6, 16) = 2.26$, $p = .090$). Univariate ANOVAs with Greenhouse-Geisser correction showed a statistically significant effect of action on both total movement time ($F(1.7, 35.9) = 54.29$, $p < .001$) and mean movement time ($F(1.7, 36.5) = 56.49$, $p < .001$). Post hoc tests using the Bonferroni correction showed a significant difference in both total and mean movement time between reaching and grasping, reaching and inserting, grasping and transporting, and transporting and inserting (all $p < .001$). No significant difference was found between reaching and transporting for either total ($p = .157$) or mean movement time ($p = .085$), and also between grasping and inserting (both $p = 1.000$).

Left hand results. This time a main effect was found for action ($V = .90$, $F(6, 16) = 23.54$, $p < .001$), group ($V = .29$, $F(2, 20) = 4.12$, $p = .032$) and their interaction ($V = .58$, $F(6, 16) = 3.64$, $p = .018$). Univariate ANOVAs with Greenhouse-Geisser correction showed a statistically significant effect of action on both total movement time ($F(2.3, 47.3) = 45.43$, $p < .001$) and mean movement time ($F(2.2, 46.2) = 47.86$, $p < .001$). Post hoc tests using the Bonferroni correction showed a significant difference in both total and mean movement time between reaching and grasping (both $p < .001$), reaching and transporting ($p = .003$ for total MT; $p = .001$ for mean MT), reaching and inserting (both $p < .001$), grasping and transporting (both $p < .001$), and transporting and inserting (both $p < .001$). No significant difference was found between grasping and inserting ($p = .481$ for total MT; $p = .390$ for mean MT). The significant interaction was further explored with simple main effects and it was found that the total time ($p < .05$) and the mean movement time ($p < .05$) for reaching showed a significant interaction with the group where controls used longer times to reach the pins.

Table 5. Movement times for right hand

	MCI	Control	
Measure	M (SD)	M (SD)	*p*
Total movement time			
Reaching	3.79 (.73)	3.16 (.36)	NS
Grasping	9.11 (3.51)	10.01 (4.18)	NS
Transporting	4.49 (1.21)	3.13 (.38)	NS
Inserting	8.14 (3.84)	9.46 (2.35)	NS
Mean movement time			
Reaching	.40 (.06)	.32 (.04)	NS
Grasping	.96 (.33)	1.00 (.42)	NS
Transporting	.50 (.13)	.31 (.04)	NS
Inserting	.86 (.36)	.95 (.23)	NS

Note. NS = non significant

Table 6. Movement times for left hand

Measure	MCI M (SD)	Control M (SD)	*p*
Total movement time			
Reaching	3.62 (.82)	4.37 (.60)	**.020***
Grasping	8.96 (1.80)	8.34 (3.86)	NS
Transporting	5.67 (2.30)	4.72 (.63)	NS
Inserting	9.67 (4.12)	10.09 (1.50)	NS
Mean movement time			
Reaching	.36 (.08)	.44 (.06)	**.019***
Grasping	.90 (.18)	.83 (.39)	NS
Transporting	.60 (.23)	.47 (.06)	NS
Inserting	1.00 (.40)	1.01 (.15)	NS

Note. NS = non significant, *$p < .05$

Kinematic Results

Kinematic variables were: mean linear velocity, peak linear velocity, CV of linear velocity, mean angular velocity, peak angular velocity, CV of angular velocity, mean angle, CV of angle, and path length. Two-way MANOVAs with repeated measures in one factor were executed for reaching and transporting in one analysis, and for grasping and inserting in another analysis. Both analyses were conducted for each hand separately, with group (MCI, Control) as between subjects factor. Due to the considerable amount of data, only significant results for simple main effects are illustrated in Figure 4 and 5, and Table 7. All *p*-values < .001 unless otherwise specified. An overview of univariate statistics are shown in Appendix B and C.

Right hand, reaching and transporting: This analysis showed a main effect of group ($V = .90$, $F(10, 12) = 10.96$), and action ($V = .97$, $F(10, 12) = 35.03$). A significant interaction effect was also obtained ($V = .77$, $F(10, 12) = 4.06$, $p = .012$). Univariate ANOVAs with Greenhouse-Geisser and Bonferroni correction showed a statistically significant effect of action on mean linear velocity, peak linear velocity, path length, CV of angular velocity, mean angle, and a near significant effect on CV of angle ($p = .002$). For group, a statistically significant effect was found on mean linear velocity, and CV of linear velocity. For the interaction effect, a statistically significant effect was found on CV of linear velocity ($p = .001$), and a near significant effect on path length ($p = .002$). An analysis of simple main effects showed a significant group difference in CV of linear velocity in both reaching and transporting (see Table 7), and, as depicted in Figure 4, in path length for reaching ($p = .021$), but not for transporting ($p = .577$).

Right hand, grasping and inserting: Results showed a main effect of group ($V = .87$, $F(10, 12) = 7.83$, $p = .001$), and action ($V = .90$, $F(10, 12) = 11.14$). There was also a significant interaction effect ($V = .78$, $F(10, 12) = 4.24$, $p = .011$). Univariate ANOVAs with Greenhouse-Geisser and Bonferroni correction showed a statistically significant effect of action on CV of linear velocity, and mean angular velocity ($p = .001$). A near significant effect was found for action on peak angular velocity ($p = .006$), CV of angle ($p = .003$), and CV of angular velocity ($p = .007$). For group, a near significant effect was found on CV of angular velocity ($p = .002$), and mean angle ($p = .002$). For the interaction effect, a near significant effect was found on CV of linear velocity ($p = .008$). As depicted in Table 7, an analysis of simple main effects showed a significant group difference in CV of linear velocity for inserting ($p = .018$), but not for grasping ($p = .307$).

Left hand, reaching and transporting: Results showed a main effect of group ($V = .89$, $F(10, 12) = 10.16$), and for action ($V = .91$, $F(10, 12) = 12.33$). There was also a significant interaction effect ($V = .73$, $F(10, 12) = 3.20$, $p = .030$). Univariate ANOVAs with Greenhouse-Geisser and Bonferroni correction showed a statistically significant effect of action on mean linear velocity, peak linear velocity, path length, mean angular velocity, CV of angular velocity, mean angle (*p* = .001), and a near significant effect on CV of linear velocity (*p* = .003) and CV of angle (*p* = .002). For group, a significant effect was found on path length (*p* = .001), and a near significant effect on CV of angle (*p* = .005). For the interaction effect, a significant effect was found on CV of linear velocity, and path length (*p* = .001). As depicted in Table 7, an analysis of simple main effects showed a significant group difference in CV of linear velocity in both reaching (*p* = .043) and transporting, and in path length for reaching (see Figure 4), but not for transporting (*p* = .055).

Left hand, grasping and inserting: The analysis showed a main effect of group (*V* = .96, *F*(10, 12) = 25.53), and of action (*V* = .91, *F*(10, 12) = 12.25). There was also a significant interaction effect (*V* = .76, *F*(10, 12) = 3.73, *p* = .017). Univariate ANOVAs with Greenhouse-Geisser and Bonferroni correction showed a statistically significant effect of action on CV of linear velocity and CV of angular velocity, and a near significant effect on peak linear velocity (*p* = .004) and mean angular velocity (*p* = .002). For group, a significant effect was found on peak linear velocity, CV of linear velocity, and mean angular velocity (*p* = .001). A near significant effect was found for group on mean angle (*p* = .006). For the interaction effect, a significant effect was found on peak angular velocity, and CV of angular velocity (*p* = .001). A near significant effect was found on mean angular velocity (*p* = .008) for the interaction effect. An analysis of simple main effects (see Figure 5) showed a significant group difference in mean angular velocity for grasping (*p* = .001), but not for inserting (*p* = .111), and in peak angular velocity for grasping (*p* = .001), but not for inserting (*p* = .893). Table 7 illustrates significant differences in CV of angular velocity for inserting (*p* = .001), but not for grasping (*p* = .470).

A summary of all significant findings in kinematic variables, by hand, is presented in Table 8.

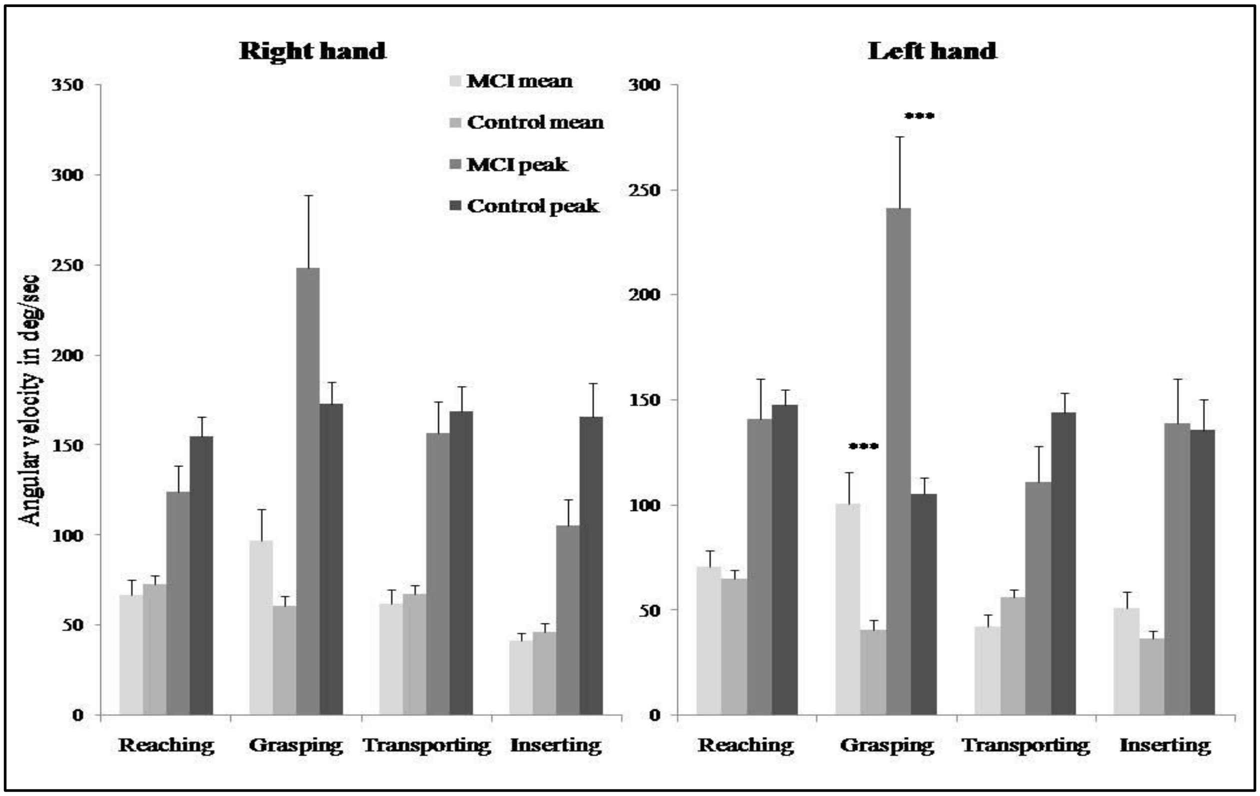


Figure 4. Group differences in angular velocity with SE-bars.

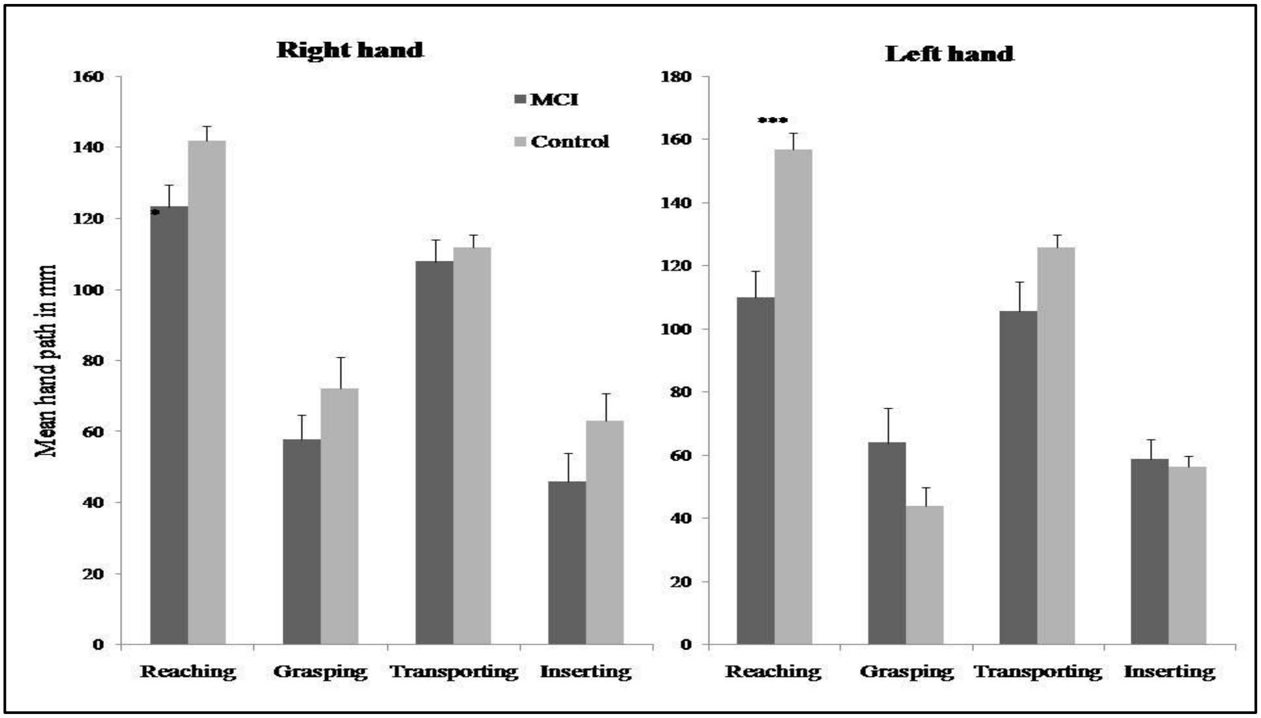


Figure 5. Group differences in path length with SE-bars.

Table 7. Group differences in coefficient of variability

	CV of linear velocity			CV of angular velocity		
	MCI		Control	MCI		Control
Right hand	M (SD)		M (SD)	M (SD)		M (SD)
Reaching	.46 (.02)	**	.34 (.02)	.57 (.17)		.64 (.03)
Grasping	.63 (.03)		.67 (.02)	.73 (.02)		.75 (.04)
Transporting	.51 (.02)	**	.29 (.02)	.76 (.04)		.82 (.03)
Inserting	.84 (.03)	*	.73 (.03)	.74 (.04)		.96 (.03)
Left hand						
Reaching	.44 (.03)	*	.50 (.01)	.57 (.03)		.66 (.03)
Grasping	.70 (.04)		.54 (.02)	.74 (.03)		.71 (.03)
Transporting	.61 (.03)	**	.46 (.01)	.75 (.05)		.83 (.03)
Inserting	.88 (.03)		.65 (.02)	.79 (.06)	**	1.02 (.02)

*Note.***p* < .05, ***p* < .001

Table 8. Summary of main significant group differences for kinematic variables

Movement	RIGHT HAND	LEFT HAND
Reaching	CV linear velocity (higher in patients) Path length (higher in controls)	CV linear velocity (higher in controls) Path length (higher in controls)
Grasping		Mean angular velocity (higher in patients) Peak angular velocity (higher in patients)
Transporting	CV linear velocity (higher in patients)	CV linear velocity (higher in patients)
Inserting	CV linear velocity (higher in patients)	CV angular velocity (higher in controls)

Note. Interpretation of the kinematic variables is: CV linear velocity = *variability in speed*; Path length = *extension of movements;* Angular velocity = *rotational speed;* Peak angular velocity = *highest value of rotational speed.*

Association between kinematics and cognitive scores

In order to evaluate the relationship between dexterity outcomes and cognitive function, kinematics together with the neuropsychological results were subjected to two separate Pearson Product Moment correlation analyses. Because no group differences were observed in movement times, correlations with these dexterity outcomes were not further explored. Each correlational analysis tested the relationship cognition-dexterity for dominant and non-dominant hand. Results of these analyses are presented in Table 9 and 10.

Associations for right hand: These results showed mainly two groups of moderate associations between different cognitive test scores and CV of linear velocity for the actions of reaching and transporting. First, scores on the MMSE were significantly correlated to same degree and negatively with both CV of linear velocity for reaching (r = -.47,) and for transporting (r = -0.48). These results indicate that higher MMSE scores were associated with lower variability in linear velocity. Furthermore, two additional cognitive scores were also associated with CV of linear velocity: Logical memory II and Vocabulary. This time associations were not equivalent, though they were negative. Vocabulary showed same degree of association between CV of linear velocity and reaching (r = -0.45) and CV of linear velocity and transporting (r = -0.46). As for Logical memory II, degree of association was different between CV of linear velocity and reaching (r = -0.47) and the respective correlation for transporting (r= -0.62). These data showed that a stronger relationship exist for the action of transporting and delayed memory. In addition to the mentioned scores, Logical Memory I was also associated negatively with CV of linear velocity in reaching (r = -0.46), but not with transporting. In turn, Stroop Color-Word subtest was significantly correlated with CV of linear velocity for transporting (r = 0,44), as well as Digits forward (r = -0,50). These results showed that for transporting a) higher scores for Stroop test, that is less proficient performance, there was higher variability in linear velocity and b) at lower scores of Digits forward the variability increased. The last significant correlation that was observed in this analysis was between CV of linear velocity and again Digits forward during inserting (r = -0.46).

Associations for left hand: The analysis conducted for the non-dominant hand demonstrated stronger correlations than for the dominant hand in a different set of dexterity measures and cognitive scores, mainly related to grasping and inserting. As a whole it is possible to identify (see Table 10) three groups of moderate to strong correlations. The first two groups with strong significant correlations involve associations between Mean angular velocity and Peak angular velocity during grasping and MMSE (r = -0,61; *r* = -0,69, respectively), TMT B (r = 0.44; r = 0.49, respectively), Digits forward (*r* = -0.58; r = -0.57, respectively), Logical memory II (r = -0.61; r = -0.66, respectively) and Vocabulary (*r* = -0.47; r = -0.51, respectively). The second populated group of correlations was found between CV of linear velocity in inserting and MMSE (r = -0.52), Digits forward (r = -0.46), Logical Memory I (r = -0.53), Logical memory II (r = -0.77) and Vocabulary (r = -0.56). Finally, a smaller group of correlations was observed between CV of angular velocity during inserting and Digits forward (r = 0.47), Digits backwards (r =0.55) and Logical memory II (r = 0.57). Two additional significant correlations were found, but these were sporadic for the action of reaching between Path length and Logical Memory II (r = 0.55) and between CV of linear velocity and Digits forward (r = 0.42).

Table 9. Correlation coefficients for right hand

	Path Length (reaching)	CV LinV (reaching)	CV LinV (transporting)	CV LinV (inserting)
MMSE	.040	**-.468***	**-.476***	−.283
TMT A	−.195	.041	.029	−.094
TMT B	−.236	.209	.152	−.177
Stroop CW	−.248	.296	**.436***	.216
Digits Forward	.229	−.245	**-.497***	**-.464***
Digits Backward	.223	−.199	−.401	−.182
Logical Memory I	.134	**-.455***	−.413	.006
Logical Memory II	.232	**-.472***	**-.616****	−.360
Vocabulary	.015	**-.445***	**-.460***	−.361
Block Design	.385	−.083	−.043	.057
FAS mean	.254	−.121	−.178	−.229
FAS errors	−.114	.137	.140	−.019
FAS repetitions	.091	.082	−.053	.185
SEM mean	.008	−.179	−.087	−.046
SEM errors	−.021	−.234	−.251	−.274
SEM repetitions	.021	.165	.048	−.084

Note. TMT = Trail Making Test, Stroop CW = Stroop Color and Word, FAS = phonemic fluency, SEM = semantic fluency, CV = coefficient of variability, LinV = linear velocity, AngV = angular velocity, *$p \leq .05$, **$p \leq .01$

Table 10. Correlation coefficients for left hand

	Path Length (reaching)	CV LinV (reaching)	Mean AngV (grasping)	Peak AngV (grasping)	CV AngV (inserting)	CV LinV (inserting)
MMSE	.259	.202	**-.606****	**-.686****	.270	**-.523***
TMT A	−.072	.334	.139	.193	−.122	.223
TMT B	−.242	.133	**.438***	**.487***	−.167	.407
Stroop CW	−.292	−.207	.268	.203	−.080	.096
DF	.363	**.420***	**-.575****	**-.565****	**.472***	**-.459***
DB	.297	.383	−.408	−.408	**.552****	−.409
LM-I	.329	−.016	−.409	**-.467***	**.423***	**-.527***
LM-II	**.547****	.365	**-.606****	**-.661****	**.569****	**-.769****
Vocabulary	.265	.097	**-.470***	**-.512***	.176	**-.557****
Block Design	.105	−.087	−.288	−.327	.053	−.255
FAS mean	.047	.043	−.074	−.118	.237	−.337
FAS errors	.003	.010	.003	.030	−.366	.257
FAS repetitions	−.249	.332	.020	.027	−.048	.009
SEM mean	.130	−.346	−.137	−.237	−.038	−.346
SEMerrors	.125	.252	−.222	−.214	−.090	−.145
SEM repetitions	−.125	.208	.098	.042	−.006	.094

Note. TMT = Trail Making Test, Stroop CW = Stroop Color and Word, DF = Digits Forward, DB = Digits Backward, LM = Logical Memory, FAS = phonemic fluency, SEM = semantic fluency, CV = coefficient of variability, LinV = linear velocity, AngV = angular velocity, **p* ≤ .05, ***p* ≤ .01

Discussion

The main purpose of the present pilot study was to investigate whether MCI subjects differ in respect to task performance on fine dexterity measures compared to healthy controls; whether these differences were associated with cognitive function, and to investigate whether IADL function, as measured with a regular questionnaire for this purpose, identified weaknesses in IADL among patients. The results of this study confirms a difference in dexterity task performance between MCI individuals and healthy elderly. The study further confirms associations between dexterity performance and cognitive functions. As hypothesized, the IADL assessment showed no difficulties in IADL function in the MCI group.

Dexterity Results

To begin with, results of the present study disclosed significant differences in dexterity task performance between MCI individuals and healthy elderly. In accordance with previous research (Kluger et al., 1997; Kluger et al., 2008; Schröter et al., 2003) we confirmed that MCI individuals differs in execution of hand dexterity from healthy elderly when a detailed kinematic analysis is employed. Mainly, differences were observed for reaching, transporting and inserting in both hands. Variability in linear velocity seemed to be of particular importance across actions, as this variable significantly differed between patients and controls. For instance, the MCI-group showed greater variability in speed of hand trajectory in both transporting and inserting than the control group, for both left and right hand. This indicates that MCI patients experience more irregularity in performing dexterity tasks, as compared to healthy elderly, possibly due to irregularity of movement, hesitance, or less adjustment in linear movement of the hand. This could explain the difficulties reported for MCI patients in earlier studies (Kluger et al., 1997; Kluger et al., 2008; Schröter et al., 2003). The same was true for reaching in the left hand condition, where healthy elderly showed even more increased variability on speed of hand trajectory in transporting and inserting, which indicates that healthy elderly focus more on control of movement when using the non-dominant hand compared to MCI patients.

For both right and left hand, the control group covered more distance in reaching (i.e., path length) than the MCI-group. An interpretation of this result could be that healthy elderly exhibits a more controlled and accurate fine hand motor function in reaching for small objects. In the left hand condition, the control group had a greater mean and peak rotational speed in grasping than the MCI-group, which indicates better control of rotation in healthy elderly. However, the healthy elderly showed greater variability in rotational speed for inserting than patients, which is difficult to interpret.

Of importance is that contrary to our initial hypothesis, the data did not demonstrate significant differences in regards to movement times. A general slowing of movement and longer movement times in normal aging has been demonstrated through numerous studies (Welford, 1988; Shiffman, 1992; Warabi, Noda & Kato, 1986). However, in our study we could not find that MCI individuals had a more pronounced slowing than healthy subjects. The outcome of the present study could reflect that the natural age-related slowing in hand movement affects healthy elderly and MCI elderly equally. In this regard, it is interesting that no difference between the two groups was found on the standard scoring of PPT, while kinematic measures on the modified PPT revealed differences between healthy participants and patients. This indicates that even though outcomes based on the PPT has proven useful in earlier studies, by differentiating MCI from AD (Kluger et al., 1997), the PPT might not be useful in detecting the subtle changes in dexterity that accompanies the MCI condition when compared to normal aging. This vouches for the use of kinematic measures to obtain a genuine evaluation of dexterity function in diagnostic assessment.

Cognitive Results

As expected, the control group had on average slightly better scores on the neuropsychological test battery than the MCI-group. The greatest difference was found in tests sensitive to attention and memory; Digits Forwards and Backwards, Vocabulary, and Logical Memory I and II. The difference between groups that were found on tests that measure attention and memory, and the average MMSE score of 26.40 in the MCI group, indicates that the MCI-group had more impaired memory and attention than healthy participants, which is consistent with current diagnostic guidelines of MCI (Roberts & Knopman, 2013; Langa & Levine, 2014, Bahureksa et al, 2017). Based on these results, it seems evident that on average participants in the MCI-group had amnestic MCI rather than non-amnestic MCI. The Vocabulary subtest is sensitive to years of education (Kaufman, McLean & Reynolds, 1988), and since the control group had more years of education than the MCI-group, this can explain some of the difference found here.

Association between Dexterity and Cognitive Results

The obtained results for the correlational analyses show moderate to strong associations between kinematics and some cognitive tests. In the right hand condition, MMSE, Logical Memory I and Vocabulary were the cognitive tests more associated with variability in linear speed during reaching and transporting. These findings suggest that global mental status, delayed memory and lexical knowledge are cognitive processes involved in the control of speed regulation during dexterity. The rest of the significant associations encountered for the right hand might be coincidental as these do not show strong associations and they were associated with single dexterity values. However, it is not impossible that the two correlations observed for Digits forward and variability during transporting and inserting, actually point to an interesting matter, as attentional control similar to the one assessed by this test has been reported in the past to be of relevance in motor control (Baldauf & Deubel, 2010).

For the left hand, it was evident that the associations between cognitive tests and kinematics were far more important than for the right hand. Specifically, higher scores correlations were found between kinematics of grasping and inserting and Logical Memory II and Digits forward. These results show particularly strong associations with delayed memory scores (Logical Memory II) ranging between r = 0.55 to r = -0.77. Most of these results were negative, which means that lower performance in memory implicated higher changes in kinematics. The exception was the relationship with variability in angular speed during inserting, which turned out to be a positive value. This results, together with the other correlations for this specific kinematic (CV angular velocity) suggest that variability in rotational hand movements, increase with higher cognitive scores. Maybe appropriate rotation of hands depends on fast and varied adjustments that require attention and memory capacities. The second group of cognitive variables that were moderately correlated also with kinematics of grasping and inserting were MMSE and Vocabulary. Performance on these tests was associated with mean and peak of rotational movements during grasping and speed variability during inserting. All in all, these data point to that preserved global mental status and semantic/lexical knowledge are important for appropriate dexterity execution.

In general, we interpret these data as signals that these latter capacities together with attention and memory declines are relevant for understanding group differences in dexterity of

MCI patients, since these patients demonstrated lower performances on these exact cognitive functions. The rest of the significant associations observed for the left hand did not show a regular involvement with kinematics and therefore, we believe that these results should be further explored in a larger group of patients and controls.

IADL Results

The IADL forms indicated no difficulties concerning IADL function, as none of the MCI participants obtained a higher total score than 8. This is in line with previous studies, that observe that MCI is not accompanied by IADL dysfunction (Langa & Levine, 2014). Nonetheless, dexterity measured by means of kinematic analyses demonstrate differences between MCI and healthy individuals in the present pilot study. This could reflect that dexterity changes involved in the MCI condition is not substantial enough to produce a functional decline. Previous findings indicate no clear association between IADL and MCI. However, several studies have demonstrated a real decline in IADL function (Golomb et al., 2004; Folquitto et al., 2007; Nygård, 2003; Farias et al., 2006). Thus, our results could also mean that the possible effect of dexterity changes does not produce changes in IADL that are easily observable through standard self-report measures. This is directly relevant for an adjustment of assessment in diagnosing and detection of future pathology, as it would imply that standard IADL screening might give limited success in determining a person’s true IADL function level, and that a more objective analysis of the use of hands would be beneficial. This statement is supported by Jekel and colleagues (2015), who suggests an intensification of performance-based assessment of IADL due to the subtleness of IADL dysfunction in MCI individuals.

Limitations of the study

A limitation of the study is the small sample size, which reduces generalizability of the results. However, being a pilot study the results are promising. Also, self-report of IADL function was used for assessment of IADL level in the patient group, which possibly gives an assessment based on subjective rather than objective information. A more objective assessment could be obtained by assessing IADL abilities in a more comprehensive manner, by including supplementary information from close family members, physicians or other health personnel familiar with the participant.

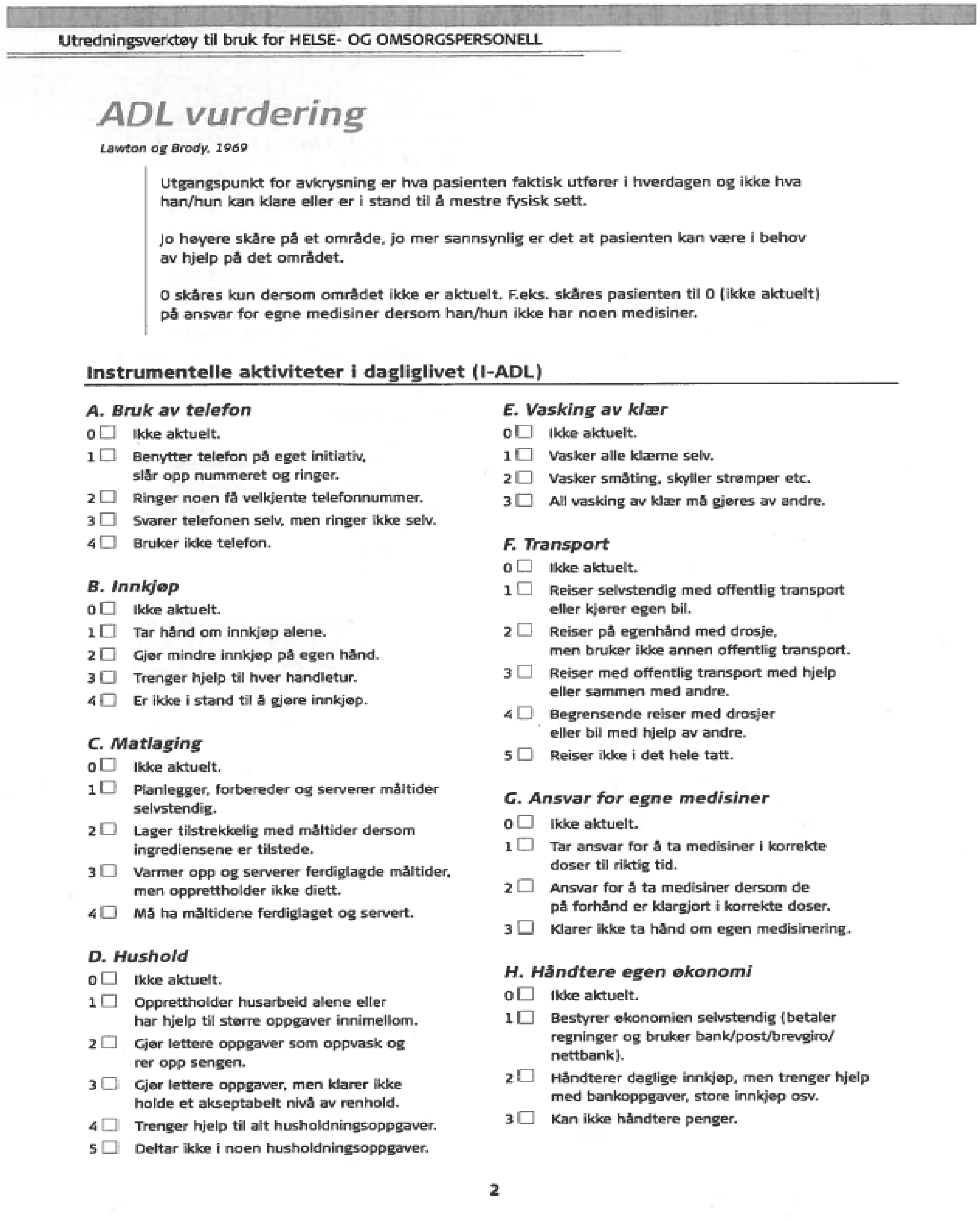
Further research

To our knowledge, scarce studies have investigated specific cognitive functions and how they relate to dexterity and IADL function in the MCI population. The results of this pilot study generates several interesting subjects for further studies to address. Further research is already being conducted at the Department of psychology to replicate this study with a larger sample size, to maximize statistical strength that enhances generalizability. The benefits of research on dementia states is relevant for individuals and at a socioeconomic basis. As many MCI subjects develop AD, a test-retest design could provide interesting knowledge on how dexterity performance develops between MCI individuals with and without pathological progression, where incremental decreases in dexterity function can be assessed. Interesting research questions to address is whether specific movements or patterns of movement evidently remain stable between groups of MCI individuals who do and do not develop dementia or AD, and whether there exists a predictive value of dexterity on cognitive functions.

Conclusion

The present pilot study investigated whether MCI elders and healthy elders differ in respect to dexterity task performance. Many elders suffer from MCI in a prodromal phase of dementia, which may affect their ADL function. Our results demonstrate that even though IADL function remains intact in MCI as examined with regular instruments, unambiguous differences in dexterity in terms of variability are present in the MCI population as compared to healthy elderly. Particularly hand rotation and speed of hand trajectory in reaching and transporting small objects differed between groups. These differences are connected to global mental status, memory capacity, lexical knowledge and attention, and are not revealed through standard IADL assessment and PPT testing. Although our results display significant associations between specific cognitive domains and dexterity, further research is needed to accomplish more robust and comprehensive knowledge on these associations. Hopefully, this pilot study contributes in gaining a fuller understanding of the nature of dexterity in age-related cognitive decline.

Appendix A. The Lawton & Brody Instrumental Activities of Daily Living Scale



Utredningsverktøy til bruk for HELSE- OG OMSORGSPERSONELL

ADL vurdering

Lawton og Brody, 1969

Utgangspunkt for avkrysning er hva pasienten faktisk utfører i hverdagen og ikke hva han/hun kan klare eller er i stand til å mestre fysisk sett.

Jo høyere skåre på et område, jo mer sannsynlig er det at pasienten kan være i behov av hjelp på det området.

0 skåres kun dersom området ikke er aktuelt. F.eks. skåres pasienten til 0 (ikke aktuelt) på ansvar for egne medisiner dersom han/hun ikke har noen medisiner.

Instrumentelle aktiviteter i dagliglivet (I-ADL)

A. Bruk av telefon

0 ☐ Ikke aktuelt.
1 ☐ Benytter telefon på eget initiativ, slår opp nummeret og ringer.
2 ☐ Ringer noen få velkjente telefonnummer.
3 ☐ Svarer telefonen selv, men ringer ikke selv.
4 ☐ Bruker ikke telefon.

B. Innkjøp

0 ☐ Ikke aktuelt.
1 ☐ Tar hånd om innkjøp alene.
2 ☐ Gjør mindre innkjøp på egen hånd.
3 ☐ Trenger hjelp til hver handletur.
4 ☐ Er ikke i stand til å gjøre innkjøp.

C. Matlaging

0 ☐ Ikke aktuelt.
1 ☐ Planlegger, forbereder og serverer måltider selvstendig.
2 ☐ Lager tilstrekkelig med måltider dersom ingrediensene er tilstede.
3 ☐ Varmer opp og serverer ferdiglagde måltider, men opprettholder ikke diett.
4 ☐ Må ha måltidene ferdiglaget og servert.

D. Hushold

0 ☐ Ikke aktuelt.
1 ☐ Opprettholder husarbeid alene eller har hjelp til større oppgaver innimellom.
2 ☐ Gjør lettere oppgaver som oppvask og rer opp sengen.
3 ☐ Gjør lettere oppgaver, men klarer ikke holde et akseptabelt nivå av renhold.
4 ☐ Trenger hjelp til alt husholdningsoppgaver.
5 ☐ Deltar ikke i noen husholdningsoppgaver.

E. Vasking av klær

0 ☐ Ikke aktuelt.
1 ☐ Vasker alle klærne selv.
2 ☐ Vasker småting, skyller strømper etc.
3 ☐ All vasking av klær må gjøres av andre.

F. Transport

0 ☐ Ikke aktuelt.
1 ☐ Reiser selvstendig med offentlig transport eller kjører egen bil.
2 ☐ Reiser på egenhånd med drosje, men bruker ikke annen offentlig transport.
3 ☐ Reiser med offentlig transport med hjelp eller sammen med andre.
4 ☐ Begrensende reiser med drosjer eller bil med hjelp av andre.
5 ☐ Reiser ikke i det hele tatt.

G. Ansvar for egne medisiner

0 ☐ Ikke aktuelt.
1 ☐ Tar ansvar for å ta medisiner i korrekte doser til riktig tid.
2 ☐ Ansvar for å ta medisiner dersom de på forhånd er klargjort i korrekte doser.
3 ☐ Klarer ikke ta hånd om egen medisinering.

H. Håndtere egen økonomi

0 ☐ Ikke aktuelt.
1 ☐ Bestyrer økonomien selvstendig (betaler regninger og bruker bank/post/brevgiro/nettbank).
2 ☐ Håndterer daglige innkjøp, men trenger hjelp med bankoppgaver, store innkjøp osv.
3 ☐ Kan ikke håndtere penger.

Appendix B. Univariate statistics for kinematic results (right hand)

	Reaching and Transporting			Grasping and Inserting		
	F	*p*	Partial η^2	F	*p*	Partial η^2
Action						
Mean LinV	67.58	**.000***	.76	5.24	.032	.20
Peak LinV	85.71	**.000***	.80	1.87	.186	.08
CV LinV	0.01	.920	.00	27.04	**.000***	.56
Path length	126.84	**.000***	.86	2.72	.114	.12
Mean AngV	0.84	.370	.04	14.75	**.001***	.41
Peak Ang V	5.54	.028	.21	9.42	.006	.31
CV Ang V	38.44	**.000***	.65	8.87	.007	.30
Mean Angle	89.12	**.000***	.81	2.12	.160	.09
CV Angle	11.98	.002	.36	11.12	.003	.35
Group						
Mean LinV	19.06	**.000***	.48	3.37	.081	.14
Peak LinV	3.20	.088	.13	0.34	.566	.02
CV LinV	50.57	**.000***	.71	1.52	.231	.07
Path length	2.61	.121	.11	2.88	.104	.12
Mean AngV	0.53	.474	.03	2.72	.114	.12
Peak AngV	1.53	.230	.07	0.11	.739	.01
CV AngV	3.97	.060	.16	12.85	.002	.38
Mean Angle	0.16	.692	.01	12.20	.002	.37
CV Angle	0.10	.752	.01	0.00	.997	.00
Action*Group						
Mean LinV	0.02	.880	.00	0.03	.865	.00
Peak LinV	2.61	.121	.11	0.94	.344	.04
CV LinV	15.43	**.001***	.42	8.57	.008	.29
Path length	12.91	.002	.38	0.05	.828	.00
Mean AngV	0.01	.932	.00	05.05	.036	.19
Peak AngV	0.90	.353	.04	7.78	.011	.27
CV AngV	0.07	.800	.00	6.87	.016	.25
Mean Angle	0.34	.566	.02	2.30	.144	.10
CV Angle	1.46	.241	.07	3.45	.077	.14

Note. CV = Coefficient of variability, LinV = linear velocity, AngV = angular velocity, Bonferroni correction: $*p \leq .001$

Appendix C. Univariate statistics for kinematic results (left hand)

	Reaching and Transporting			Grasping and Inserting		
	F	*p*	Partial η^2	F	*p*	Partial η^2
Action						
Mean LinV	126.82	**.000***	.86	0.10	.754	.01
Peak LinV	97.18	**.000***	.82	10.28	.004	.33
CV LinV	11.56	.003	.36	24.98	**.000***	.54
Path length	24.52	**.000***	.54	0.40	.532	.02
Mean AngV	21.29	**.000***	.50	12.01	.002	.36
Peak Ang V	2.98	.099	.12	05.04	.036	.19
CV Ang V	24.81	**.000***	.54	34.77	**.000***	.62
Mean Angle	15.92	**.001***	.43	7.26	.014	.26
CV Angle	12.96	.002	.38	1.82	.191	.08
Group						
Mean LinV	4.36	.049	.17	3.67	.069	.15
Peak LinV	5.14	.034	.20	24.54	**.000***	.54
CV LinV	04.06	.057	.16	56.06	**.000***	.73
Path length	13.50	**.001***	.39	1.87	.186	.08
Mean AngV	0.38	.543	.02	15.20	**.001***	.42
Peak AngV	1.39	.251	.06	7.73	.011	.27
CV AngV	5.10	.035	.20	6.12	.022	.23
Mean Angle	6.69	.017	.24	9.35	.006	.31
CV Angle	9.94	.005	.32	0.34	.567	.02
Action*Group						
Mean LinV	2.33	.142	.10	2.14	.158	.09
Peak LinV	5.55	.028	.21	0.83	.374	.04
CV LinV	29.44	**.000***	.58	1.61	.219	.07
Path length	14.05	**.001***	.40	2.30	.144	.10
Mean AngV	5.73	.026	.21	8.43	.008	.29
Peak AngV	1.84	.190	.08	17.16	**.000***	.45
CV AngV	0.05	.825	.00	16.79	**.001***	.44
Mean Angle	0.89	.357	.04	7.61	.012	.27
CV Angle	1.85	.188	.08	2.28	.146	.10

Note. CV = Coefficient of variability, LinV = linear velocity, AngV = angular velocity, Bonferroni correction: $*p \leq .001$

References

Bahureksa, L., Najafi, B., Saleh, A., Sabbagh, M., Coon, D., Mohler, M. J., & Schwenk, M. (2017). The Impact of Mild Cognitive Impairment on Gait and Balance: A Systematic Review and Meta-Analysis of Studies Using Instrumented Assessment. *Gerontology*, *63*, 67-83. doi: 10.1159/000445831

Baldauf, D., & Deubel, H. (2010). Attentional landscapes in reaching and grasping. *Vision research*, *50*(11), 999-1013. doi: 10.1016/j.visres.2010.02.008

Beck, A.T., Steer, R.A., & Brown, G.K. (1996). *Manual for the Beck Depression Inventory-II*. San Antonio, TX: Psychological Corporation.

Benton, A.L., Hamsher, de S.K., & Sivan, A.B. (1983). *Multilingual aplasia examination* (2nded.). Iowa City, IA: AJA Associates.

Briggs, G. G., & Nebes, R. D. (1975). Patterns of hand preference in a student population. *Cortex, 11*(3), 230-238.

Cahn-Wiener D, A., Boyle, P. A., & Malloy, P. F. (2002). Tests of executive function predict instrumental activities of daily living in community-dwelling older individuals. *Applied Neuropsychology, 9,* 187-191. doi: 10.1207/S15324826AN0903_8

Delis, D.C., Kaplan, E., & Kramer, J.H. (2001). *Delis-Kaplan Executive Function System (D-KEFS).* San Antonio, TX: The Psychological Corporation.

Desrosiers, J., Hebert, R., Bravo, G., & Dutil, E. (1995). The Purdue Pegboard Test: normative data for people aged 60 and over. *Disability and Rehabilitation*, *17*(5), 217-224.

Erber, J. T. (2013). *Aging and Older Adulthood*. Chichester, West Sussex: Wiley-Blackwell.

Farias, S. T., Mungas, D., Reed, B. R., Harvey, D., Cahn-Weiner, D., & DeCarli, C. (2006). MCI is Associated With Deficits in Everyday Functioning. *Alzheimer Disease and Associated Disorders, 20*(4), 217–223. doi: 10.1097/01.wad.0000213849.51495.d9

Folkehelseinstituttet. (2014). *Folkehelserapporten - Helsetilstanden i Norge: Demens*. Retrieved from https://www.fhi.no/nettpub/hin/helse-og-sykdom/demens---folkehelserapporten-2014/

Folquitto, J. C., Bustamante, S., Barros, S. B, Azevedo, D., Lopes, M. A., Hototian, S. R., Filho, W., ... Bottino, C. M. (2007). The Bayer - Activities of Daily Living Scale (B-ADL) in the differentiation between mild to moderate dementia and normal aging. *Revista Brasileira Psiquiatria, 29*(4), 350-353. doi: 10.1590/S1516-44462006005000037

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

Golden, C.J. (1978). *Stroop Color and Word Test: a manual for clinical and experimental uses.* Chicago, IL: Stoelting.

Golomb, J., Kluger, A., & Ferris, S. F. (2004). Mild cognitive impairment: historical development and summary of research. *Dialogues in Clinical Neuroscience, 6*(4), 351-367.

Graf, C. (2006). Functional decline in hospitalized older adults. *American Journal of Nursing, 106*(1), 58-67.

Graf, C. (2008). The Lawton Instrumental Activities of Daily Living Scale. *American Journal of Nursing, 108*(4), 52-62. doi: 10.1097/01.NAJ.0000314810.46029.74

Hall, C. B., Derby, C., LeValley, A., Katz, M. J., Verghese, J., & Lipton, R. B. (2007). Education delays accelerated decline on a memory test in persons who develop dementia. *Neurology, 69*(17), 1657-64. doi: 10.1212/01.wnl.0000278163.82636.30

Incel, N. A., Sezgin, M., As, I., Cimen, O. B., &Sahin, G. (2009). The geriatric hand: correlation of hand-muscle function and activity restriction in elderly. *International Journal of Rehabilitation Research, 32*(3), 213-218. doi: 10.1097/MRR.0b013e3283298226

Jekel, K., Damian, M., Wattmo, C., Hausner, L., Bullock, R., Connelly, P., ... Frölich, L. (2015). Mild cognitive impairment and deficits in instrumental activities of daily living: a systematic review. *Alzheimer's Research & Therapy, 7*, 17.doi: 10.1186/s13195-015-0099-0

Judge, J., & Stirling, J. (2003). Fine motor skill performance in left- and right-handers: Evidence of an advantage for left-handers. *Laterality, 8*(4), 297-306. doi: 10.1080/13576500412331325342

Katz, S. (1983). Assessing Self-maintenance: Activities of Daily Living, Mobility, and Instrumental Activities of Daily Living. *Journal of the American Geriatrics Society, 31*, 721–727. doi: 10.1111/j.1532-5415.1983.tb03391.x

Kaufman, A. S., McLean, J. E., & Reynolds, C. R. (1988). Sex, race, residence, region, and education differences on the 11 WAIS-R subtests. *Journal of clinical psychology*, *44*(2), 231-248. doi: 10.1002/1097-4679(198803)44:2<231::AID-JCLP2270440224>3.0.CO;2-J

Kluger, A., Gianutsos, J. G., Golomb, J., Ferris, S. H., George, A. E., Franssen, E., & Reisberg, B. (1997). Patterns of motor impairment in normal aging, mild cognitive decline, and early Alzheimer's Disease. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *52*(1), 28-39. doi: 10.1093/geronb/52B.1.P28

Kluger, A., Gianutsos, J., Golomb, J., Wagner, A., Wagner, D., & Scheurich, S. (2008). Clinical features of MCI: Motor changes. *International Psychogeriatrics,20*(1), 32-39. doi: 10.1017/S1041610207006461

Kluger, A., Golomb, J., & Ferris, S. F. (2002). Mild cognitive impairment. In N. Qizilbash et al. (ed.), *Evidence-based Dementia* (pp. 341-354). Oxford: Blackwell.

Langa, K. M., & Levine, D. A. (2014). The Diagnosis and Management of Mild Cognitive Impairment. A Clinical Review. *Journal of the American Medical Association,312*(23), 2551-2561. doi: 10.1001/jama.2014.13806

Lawton, M.P., & Brody, E.M. (1969). Assessment of older people: Self-maintaining and instrumental activities of daily living. *The Gerontologist, 9*(3), 179-186.

Loge, J.H., Kaasa, S., Hjermstad, M.J., & Kvien, T.K. (1998). Translation and performance of the Norwegian SF-36 Health Survey in patients with rheumatoid arthritis. I. Data quality, scaling assumptions, reliability, and construct validity. *J Clin Epidemiol, 51*(11), 1069-1076.

McGuire, L. C., Ford, E. S., & Ajani, U. A. (2006). Cognitive Functioning as a Predictor of Functional Disability in Later Life. *The American Journal of Geriatric Psychiatry, 14*(1), 36-42. doi: 10.1097/01.JGP.0000192502.10692.d6

Morris, J. C., Storandt, M., & Miller, J. P. (2001). Mild cognitive impairment represents early Alzheimer’s disease. *Archives of Neurology, 58*(3), 397-405. doi: 10.1001/archneur.58.3.397

Newcombe, F. (1969). *Missile Wounds of the Brain. A Study of Psychological Deficits.* London: Oxford University Press.

Nygård, L. (2003). Instrumental activities of daily living: a stepping-stone towards Alzheimer's disease diagnosis in subjects with mild cognitive impairment? *Acta Neurologica Scandinavica, 107,* 42–46. doi: 10.1034/j.1600-0404.107.s179.8.x

Perneczky, R., Pohl, C., Sorg, C., Hartmann, J., Komossa, K., Alexopoulos, P., ... Kurz, A. (2006). Complex activities of daily living in mild cognitive impairment: conceptual and diagnostic issues. *Age and Aging, 35*(3), 240-245.doi: 10.1093/ageing/afj054

Perneczky, R., Pohl, C., Sorg, C., Hartmann, J., Tosic, N., Grimmer, T., ... Kurz, A. (2006). Impairments of activities of daily living requiring memory or complex reasoning as part of the MCI syndrome. *International Journal of Geriatric Psychiatry, 21*, 158-162. doi: 10.1002/gps.1444

Petersen, R. C. (2004). Mild cognitive impairment as a diagnostic entity. *Journal of Internal Medicine*, *256*(3), 183-194. doi: 10.1111/j.1365-2796.2004.01388.x

Petersen, R. C., Smith, G. E., Waring, S. C., Ivnik, R. J., Tangalos, E. G., & Kokmen, E. (1999). Mild Cognitive Impairment. Clinical Characterization and Outcome. *Archives of Neurology, 56*(3), 303-308. doi: 10.1001/archneur.56.3.303

Reitan, R.M., & Wolfson, D. (1993). *The Halstead-Reitan neuropsychological test battery: Theory and clinical interpretation* (2nd ed.). Tucson, AZ: Neuropsychology Press.

Richard, M., & Sacker, A. (2003). Lifetime Antecedents of Cognitive Reserve.*Journal Of Clinical And Experimental Neuropsychology, 25*(5), 614-624. doi: 10.1076/jcen.25.5.614.14581

Roberts, R., & Knopman, D. S. (2013). Classification and Epidemiology of MCI. *Clinics in Geriatric Medicine*, *29*(4), 753-772. doi: 10.1016/j.cger.2013.07.003.

Rodríguez-Aranda, C. (2003). Reduced writing and reading speed and age-related changes in verbal fluency tasks. *The Clinical Neuropsychologist, 17*(2), 203-215. doi: 10.1076/clin.17.2.203.16508

Rodríguez-Aranda, C., Mittner, M., & Vasylenko, O. (2016). Association between Executive Functions, Working Memory, and Manual Dexterity in Young and Healthy Older Adults:

An Exploratory Study. *Perceptual and Motor Skills, 122*(1), 165-192. doi: 10.1177/0031512516628370

Scarmeas, N., Albert S. M., Manly, J. J., & Stern, Y. (2006). Education and rates of cognitive decline in incident Alzheimer's disease. *Journal of Neurology, Neurosurgery & Psychiatry, 77*(3), 308-16. doi: 10.1136/jnnp.2005.072306

Scherder, E., Dekker, W., & Eggermont, L. (2008). Higher Level Hand Motor Function in aging and (preclinical) dementia: Its relationship with (instrumental) activities of daily life - A mini-review. *Gerontology, 54,* 333-341. doi: 10.1159/000168203

Schröter, A., Merger, R., Bürger, K., Hampel, H., Möller, H, J., & Heger, U. (2003). Kinematic Analysis of Handwriting Movements in Patients with Alzheimer’s Disease, Mild Cognitive Impairment, Depression and Healthy Subjects. *Dementia and Geriatric Cognitive Disorders, 15,* 132-142. doi: 10.1159/000068484

Shiffman, L. M. (1992). Effects of Aging on Adult Hand Function. *American Journal of occupational Therapy,46,* 785-792. doi: 10.5014/ajot.46.9.785

Shumway-Cook, A., & Woollacott, M. H. (2007). *Motor control: Translating research into clinical practice* (3rd ed.). Philadelphia, PA: Lippincott, Williams & Wilkins.

Snellen, H. (1862). *Probebuchstaben zur Bestimmung der Selschärfe [Sample Letters for the Determination of Visual Acuity]*. Utrecht.

Spector, W., & Fleishman, J. (1998). Combining Activities of Daily Living with Instrumental Activities of Daily Living to Measure Functional Disability. *Journal of Gerontology, 53*(1), 46-57.

Steinberg, F., & Bock, O. (2013). Influence of cognitive functions and behavioral context on grasping kinematics. *Exp Brain Res, 225,* 387-397. doi: 10.1007/s00221-012-3379-y

Stern, Y. (2002). What is cognitive reserve? Theory and research application of the reserve concept. *Journal of the International Neuropsychological Society, 8*, 448–460. doi: 10.1017.S1355617701020240

Teng, E., Becker, B. W., Woo, E., Cummings, J. L., & Lu, P. H. (2010). Subtle Deficits in Instrumental Activities of Daily Living in Subtypes of Mild Cognitive Impairment. *Dementia and Geriatric Cognitive Disorders, 30,* 189-197. doi: 10.1159/000313540

Warabi, T., Noda, H., & Kato, T. (1986). Effect of aging on sensorimotor functions of eye and hand movements. *Experimental Neurology, 92*(3), 686–697.

Wechsler, D. (1997). *WMS-III: Wechsler memory scale administration and scoring manual.* San Antonio, TX: Psychological Corporation.

Wechsler, D. (2014). *Wechsler Adult Intelligence Scale - Fourth Edition.* San Antonio, TX: Psychological Corporation.

Welford, A. T. (1988). Reaction Time, Speed of Performance, and Age. *Annals of the New York Academy of Sciences, 515*, 1–17. doi: 10.1111/j.1749-6632.1988.tb32958.x

Wiener, J., M., Hanley, R., J., Clark, R., &Van Nostrand, J., F. (1990). Measuring the Activities of Daily Living: Comparisons Across National Surveys. *Journal of Gerontology, 45*(6), s 229-237. doi: 10.1093/geronj/45.6.S229

Winblad, B., Palmer, K., Kivipelto, M., Jelic, V., Fratiglioni, L., Wahlund, L.O., … Petersen, R.C. (2004). Mild cognitive impairment - beyond controversies, towards a consensus: report of the International Working Group on Mild Cognitive Impairment. *Journal of Internal Medicine, 256*, 240-246.

World Health Organization. (1992). *The ICD-10 classification of mental and behavioural disorders: Clinical descriptions and diagnostic guidelines*. Geneva: World Health Organization.