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„Visuo-constructional functions in patients with subjective cognitive decline (SCD), mild cognitive impairment (MCI), Alzheimer's disease (AD) and Parkinson's disease (PD) "

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Master's Thesis

Visuo-constructional functions in patients with subjective cognitive decline(SCD), mild cognitive impairment(MCI), Alzheimer's disease(AD) and Parkinson's disease(PD)

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Abstract

Background: Visuo-constructional impairment may be one of the first symptoms of degenerative disorders and therefore its examination is important for early disease detection. **Objectives**: The aims of the present study were to determine the reliability, objectivity and validity of the VVT 3.0 and VVT 3.0 Screening and to examine differences in visuo-constructional abilities in clinical samples of patients with subjective cognitive decline(SCD), mild cognitive impairment(MCI), Alzheimer's disease(AD) and Parkinson's disease(PD). **Methods**: The study included 185 patients who were referred to the Department of Neurology, Medical University of Vienna for neurocognitive assessment. We tested the psychometric criteria of VVT 3.0/ VVT 3.0 Screening. Additionally, a ROC analysis was carried out. To further examine differences between groups statistical analysis included Kruskal-Wallis-Tests and Mann Whitney U Tests. Spearman r was used for correlation analysis testing for links between test scores and other variables. **Results**: Psychometric criteria of VVT 3.0/VVT 3.0 Screening were found to be satisfactory. Significant group differences were found in both measures. Significant correlations between scores in VVT 3.0/VVT 3.0 Screening and IQ measured with the WST, age and years of education were found. **Conclusion**: VVT 3.0 and VVT 3.0 Screening showed satisfactory psychometric criteria and can be administered in clinical practice. Visuo-constructional functions differed significantly in the tested groups and correlate with variables that play an important role in context of dementia.

Keywords: Subjective cognitive decline, Mild cognitive impairment, Alzheimer's disease, Parkinson's disease, visuo-constructional functions, visuoconstructive impairment.

Zusammenfassung

Hintergrund: Visuokonstruktive Beeinträchtigungen zählen zu den ersten Symptomen von degenerativen Störungen und ihre Untersuchung stellt damit eine Möglichkeit zur frühen Krankheitserkennung dar. **Ziele**: Die Ziele der vorliegenden Studie waren die Bestimmung der psychometrischen Qualität des VVT 3.0 und des VVT 3.0 Screenings, sowie die Untersuchung, ob sich die damit gemessenen visuokonstruktiven Fähigkeiten bei Patienten mit subjektiver kognitiver Beeinträchtigung(SCD), leichter kognitiver Beeinträchtigung(MCI), Alzheimer Krankheit(AD) und Parkinson Krankheit(PD) voneinander unterscheiden. **Design**: Die Studie wurde mit 185 Personen ausgeführt, die zur Abklärung ihres kognitiven Status in die Abteilung für Neurologie an der Medizinischen Universität in Wien kamen. Der VVT 3.0 und das VVT 3.0 Screening wurden auf statistische Gütekriterien hin getestet. Zudem wurde eine ROC Analyse durchgeführt zur Bestimmung der prognostischen Validität. Kruskal Wallis Tests und anschließende Mann Whitney U Tests wurden genutzt, um Gruppenunterschiede festzustellen. Spearman r sollte Korrelationen zwischen Testergebnissen und Variablen wie Alter, Bildung und WST-IQ messen. **Ergebnisse:** Die Gütekriterien wurden erfüllt. Es wurden sowohl signifikante Gruppenunterschiede, als auch signifikante Korrelationen zwischen Ergebnissen in VVT 3.0 und VVT 3.0 Screening und den getesteten Variablen gefunden. **Schlussfolgerung**: Der VVT 3.0 und VVT 3.0 Screening erfüllen die psychometrischen Qualitätsansprüche und beide können im klinischen Alltag eingesetzt werden. Visuokonstruktive Fähigkeiten unterscheiden sich in den getesteten Gruppen und korrelieren mit Variablen, die im Kontext von Demenz eine wichtige Rolle spielen.

Schlüsselwörter: Subjektive kognitive Verschlechterung, Leichte kognitive Beeinträchtigung, Alzheimer Krankheit, Parkinson Krankheit, visuokonstruktive Fähigkeiten, visuokonstruktive Beeinträchtigung.

1. Introduction.

The discussion on differential diagnosis across different variants of degenerative diseases originates from a society constantly getting older and in which neurocognitive disorders, especially dementia, are common diseases among older adults. New diagnostic criteria for dementia have recently been published, reflecting the current state of investigation in context of this disorder, technological advances, knowledge gained and the need of improving diagnosis and research in future. In 2013, the Diagnostic and Statistical Manual of Mental Disorders, Version V (DSM-V; American Psychiatric Association, APA, 2013) got published, renaming the term "dementia" into "major neurocognitive disorder"(major NCD). It details six cognitive domains. A decline in one or more of these domains and, as a key criteria, the loss of independence in activities of daily living are needed for diagnosis of dementia: complex attention, executive function, learning and memory, language, social cognition and perceptual-motor function, the latter including visuoconstructional reasoning. (APA, 2013) The lexical change is more than that, as the term dementia is often used synonymous to aging, memory loss and Alzheimer's disease. The term NCD encompasses cognitive impairment across all ages, different causative factors and clinical pictures. The International Classification of Diseases (ICD) published by the World Health Organisation(WHO) still sticks with the term dementia: According to ICD-10 criteria (Dilling, Mombour & Schmidt, 2011) higher cortical functions including memory, reasoning, calculating, language, orientation, adaptive learning capacity and judgement are common d omains probably being impaired when suffering from dementia. Additionally deterioration of emotional control, motivation and social behavior next to interference of activities of daily living are mentioned (Luck et al., 2012; Tabert et al., 2002). Due to mentioned demographic developments, dementia, encompassing a great number of underlying conditions, constitutes a medical and socioeconomic challenge (Fiedler, Wiltfang, Peters, & Benninghoff, 2012; Petersen, 2004). In the first Austrian Dementia Report (Gleichweit& Rossa, 2009) is stated that around 100.000 persons in Austria suffer from dementia, constituting a prevalence rate of 1.2%. Studies suggest that incidence rates of dementia will increase (Gleichweit& Rossa, 2009), from nowadays 28.100 persons to 59.500 persons in 2050 in Austria falling ill per year. The Delphi Study (Ferri et al., 2006) estimated 24.3 million people with dementia worldwide in 2001, with predictions of 4.6 million new cases arising per year, which constitutes a doubled prevalence rate every

20 years. The regions with the largest number of affected persons are North America (prevalence rate: 6.4%), Western Europe (5.4%), Latin America (4.9%), developing Western Pacific (4.0%) and Eastern Europe (3.8%). Due to these facts, it's inevitable to expand early detection of dementia to secure facilitating support for affected persons, caregivers and medical and socioeconomic systems, considering that dementia is not only an emotional but a financial burden to the private person as to public health care system.
Etiology is still unknown and pathological alterations are still mostly unclear due to the variety of conditions leading to dementia. In the present study Alzheimer's Disease has been used as proxy for the disease's issues. One approach of previous research points to a model in which subjective cognitive decline (SCD) via mild cognitive impairment (MCI) may be leading to Alzheimer's disease (AD) or dementia in context of Parkinson's disease(PD) (Jessen et al., 2010, 2014a).

1.1 Alzheimer's Disease

Alzheimer's Disease (AD) represents the most common cause of dementia (Fiedler et al., 2012; Krstic et al., 2012): 60-80% of cases can be referred to AD(McKhann et al., 2011).

AD is a progressive disorder, which means symptoms, a constellation of behavioral and cognitive changes, gradually worsen over time and are serious enough to interfere with activities of daily life. Degenerative processes in AD involve degradation in posterior cortical regions and in frontal cortical regions causing impairment of executive functioning (Rozzini et al., 2007). In the course of AD two typical neuropathological alterations leading to cerebral cell death take place: on one side the formation of extracellular amyloid plaques of abnormal modified Aß42-protein and on the other side the production of abnormal Tau-protein, and subsequently the devolution of neurofibrills (Thal & Braak, 2004, cited by Lehrner, Bodner, Dal-Bianco & Schmidt, 2006). Both processes probably begin years before the occurrence of clinical symptoms of AD(Lehrner et al., 2006) which leads to the question of the diagnostic determination of AD.
Criteria of the Diagnostic and Statistical Manual of Mental Disorders(DSM-V; APA, 2013) and the National Institute of Neurologic and Communicative Disorders and Stroke – Alzheimer Disease and Related Disorders Association(NINCDS-ADRDA; McKhann et al., 1984) are widely used for diagnosis of AD and specify memory, language, perceptual skills, attention, constructive abilities, orientation, problem solving and functional abilities as

cognitive domains to be possibly(definite) impaired in persons suffering from AD, mentioning also the evaluation of visuospatial abilities(McKhann et al., 2011) and visuoconstructional reasoning(APA, 2013). For definite diagnosis (definite AD) there's need of histopathologic confirmation (McKhann et al., 1984). The NINCDS-ADRDA criteria have been proven to be valid and reliable (Knopman et al., 2006; Blacker et al., 1994) for the diagnosis of probable AD, the form to be progressive and present in two or more areas of cognition, and have been used in clinical trials and clinical research(McKhann et al., 2011). The onset of impairment is between the ages of 40 and 90 years. There must be an absence of other diseases possibly producing dementia and symptoms must interfere with abilities to function in daily life. The two other forms of AD are possible (atypical syndromes, no alternative diagnosis) and unlikely (sudden onset of syndromes) AD, considering criteria of McKhann et al.(1984). Although etiological factors are still mostly unknown, risk factors such as genetic and vascular disorders are being considered of having impact on the disease(Povova et al., 2012). According to current literature, potential risk factors have already been detected concerning AD, the following being important for the present study: increasing age (Lindsay & Anderson, 2004; Hatcher, 1999) fewer years of education(Mcdowell, Xi, Lindsay & Tierney, 2007; Qiu, Bäckman, Winblad, Agüero-Torres & Fratiglioni, 2001; Ngnandu et al., 2007), subjective cognitive decline(SCD)(Jessen et al., 2010, Jessen et al., 2013, Jonker et al., 2000, Luck et al., 2014, Schofield, 1997) and mild cognitive impairment(MCI)(Forlenza, Diniz, Stella, Teixeira & Gattaz, 2013; Jessen et al., 2014; Mitchell et al., 2009; Yarnall, Rochester & Burn, 2013).

1.2 Parkinson Disease

Parkinson Disease(PD) as neurodegenerative disorder of the central nervous system affects around 3.3% of the elderly population and incidence increases with aging(Barbosa et al., 2006, cited by Tanaka et al., 2009). It is neuropathologically characterized by the reduction of dopamin as a consequence of the degeneration of the substance nigra. This leads to an impairment in nigro-striatal functioning, and subsequently its connections to the brain's prefrontal area(Dujardin et al., 2003, cited by Tanaka et al., 2009). A final diagnosis of PD requires post mortem analysis and confirmation. PD mainly affects the motor system and as dopaminergic therapy influences bradykinesia, tremor and rigidity, the majority of PD patients experience non-motor problems like sleep disturbances, autonomic dysfunction and neuropsychiatric problems like cognitive

impairment, the latter is present even in the early stages (Alves Forsaa, Pedersen, Gjerstad, & Larsen, 2008; Muzerengi, Contrafatto & Chaudhuri, 2007). Early cognitive impairment in PD is characterized by executive impairment and visuospatial dysfunction (Alves et al., 2008; Dubois et al., 2007). Also the risk of dementia, studies suggest, is six times higher in PD compared to healthy controls (Aarsland et al., 2001). Prevalence rates of dementia in PD (Parkinson's disease dementia (PDD)) range from 18 to 41% (Alves et al., 2008; Rippon & Marder, 2005; Emre, 2004). Aarsland, Andersen, Larsen, and Lolk (2003) showed in a prospective study that, at baseline, prevalence of dementia in PD patients was 26%, emerging to 78.2% in a 8-year study period(cited by Tanaka et al., 2009). Hely, Reid, Adena, Halliday, and Morris (2008) showed that after 20 years, 83% of surviving PD patients suffered from dementia.

1.3 Prodromal stages

Neurocognitive impairments may probably occur a long time before a final diagnosis of Alzheimer's or Parkinson's disease. Prodromal stages are an important examination factor to focus on, as early diagnosis and therapeutic interventions can be established and thus, there might be a chance of possible delay from transition to AD (Wee et al., 2012).

1.3.1 Subjective cognitive decline

Jessen et al.(2014b) divides the first symptomatic manifestation of AD into objective decline in test performance and subjective experience of cognitive decline, the latter as only being recently discussed and moving research on dementia to a preclinical stage. A subjectively experienced decline at a normal test performance level can be seen as an indicator of the first effects on cognition (Jessen et al., 2014b). The Subjective Cognitive Decline Initiative (SCD-I) working group, which was founded in 2012, agreed on a SCD criteria framework with self-experienced persistent cognitive decline, compared to a former "normal" status, and a clear demarcation to MCI, prodromal AD or dementia as main criteria to SCD. The given framework could be seen as a reaction to the recognized need of investigation of dementia's preclinical states and bases on research that points to subjective memory complaints as predictors for cognitive impairment and/or dementia (Geerlings, Jonker, Bouter, Ader, & Schmand, 1999; Jessen et al., 2010; Jessen et al., 2013; Jessen et al., 2014a; Jonker, Geerlings & Schmand, 2000; Koppara et al., 2015; Luck et al., 2014; Reisberg, Shulman, Torossian, Leng & Zhu, 2010; Schofield, 1997; Treves, Verchovsky, Klimovitzky & Korczyn, 2005; van Oijen, de Jong, Hofman, Koudstaal &

Breteler, 2007). Results of the German Study on Ageing, Cognition and Dementia in primary care patients (AgeCoDe; Luck et al., 2015) found a three times higher risk of developing AD within three years in persons who affirmed questions to SCD. Also neuroimaging studies found reduced volume in brain areas of SCD patients that are also affected in AD patients (Jessen et al., 2006; Saykin et al., 2006; Stripens et al., 2010, cited by Jessen et al., 2014b). Van Harten et al.(2013) showed in a longitudinal study that patients complaining about SCD and having biomarker evidence for amyloid pathology were at higher risk of prospective AD (cited by Jessen et al., 2014b). But, possibly due to definition processing and differences, various results concerning prognostic value of SCD were found. While some large-scale longitudinal studies showed that worries or concern for memory performance are risk factors for subsequent MCI or AD(Jessen et al., 2010; Jessen et al., 2013; Jonker et al., 2000; Schofield, 1997), other studies have not(Blazer, Hays, Fillenbaum & Gold, 1997; Jorm et al., 1997; Minett, Dean, Firbank, English & O'Brien, 2005).

1.3.2 Mild cognitive impairment

MCI as a concept and its diagnostic criteria originally got introduced by Petersen et al.(1999, 2004, 2011). The recently published DSM-V introduced the term "mild neurocognitive disorder"(mild NCD), which is an equivalent to MCI and to prodromal dementia. Thus, it emphasizes the important role of prodromal stages to dementia (or referring to DSM-V terminology "major NCD"), incorporating scientific research and changing clinical practice in which patients seek help and treatment earlier in the cognitive decline process. According to Ward et al.(2012) prevalence rates range between 3 and 42% - depending on the different criteria of definition applied. Changes in cognition compared to a previous level of performance in one or more cognitive domains, that were mentioned above in context of major NCD, with concurrent preservation of independence in functional abilities in daily life, are core criteria for mild NCD(APA, 2013). There should not be an evidence of a significant impairment in social or occupational functioning (Albert et al., 2011). There are four subtypes according to Petersen(2004): amnestic MCI single or multiple domain, and non-amnestic MCI single or multiple domain, with amnestic MCI being related more strongly to conversion to AD than single- or multi-domain non-amnestic MCI(Jessen et al., 2014b). Recent studies showed that MCI - patients show conversion rates to probable AD of 10% to 15% per year (Grundman et al., 2004; Petersen et al., 2001). Patients diagnosed with MCI have a 31–44% higher

risk of developing dementia (Busse, Hensel, Guhne, Angermeyer & Riedel-Heller, 2006; Zanetti et al., 2006). Still, diagnosis doesn't guarantee future decline, as impairments may be static or even improve, considering causative factors like traumatic brain injury.

1.4 Visuo-constructional functions

In identifying patients with SCD, MCI, AD or PD, neuropsychological assessment plays a key role (Samrah et al., 2016) and especially early diagnosis is vitally important. Visuo-construction, as integrating ability of many neurocognitive functions such as coordinating fine motor skills, understanding visuospatial relationships, planning and performing executive function skills (Samrah et al., 2016), has been longer known as being impaired in early stages of AD or MCI (Freeman et al., 2000; Mendez, Mendez, Martin, Smyth & Whitehouse, 1990, De Jager, Hogervorst, Combrenck and Budge, 2003, cited by Samrah et al., 2016). A disorder of visuo-constructional ability is commonly known as *constructional apraxia*, a term introduced by Kleist(1934) as malfunctioning in tasks such as assembling, building and drawing of objects, as failure in constructing the spatial form without a motoric apraxia for single movements. As a complex task *constructional praxis* meets different requirements (for example identification of characteristics of a figure) and thus can be easily influenced by a disturbed communication or coordination between processes: Attention, spatial integration and motor response integration are required, summarized as visual and tactile abilities (Lehrner et al., 2015). Constructional apraxia can be found in patients with cortical damage, especially lesions in prefrontal cortex (Benton, 1968). It also may occur with lesions in either left or right parietal lobe and recent neuroimaging studies showed early temporoparietal involvement in early AD, the parietal lobe as being considered as having an impact on assembling and drawing objects (Critchley, 1953; Mosconi et al., 2004; Whitwell et al., 2008, cited by Samrah et al, 2016). Examples of testing visuo-constructional impairments or abilities in clinical neurology are the presentation of tasks requiring the reproduction of easy or complex figures and by observing abnormalities in those tasks with free drawing or copying that can not be explained by low visual performance or motor disorders (Benton & Fogel, 1962): Subjects suffering from constructional apraxia have difficulties reproducing visual figures or copying a visual model (Benton, 1962). For example visuo-constructional abilities can be tested as draw-to-command task with the clock drawing test(CDT; Shon et al., 2013), in which the subject is presented with a white

paper with the instructions to draw a clock with hands at a fixed time("ten minutes past eleven") without a time limit. Clock drawing was shown to differentiate between healthy controls, MCI and AD patients (Thomann, Toro, Dos Santos, Essig & Schröder, 2008). The Clock drawing test is also an example for a copy-to-command task, next to the Mini-Mental State Examination (MMSE) pentagon task, the cube task from the Montreal Cognitive Assessment(MoCa; Nasreddine et al., 2005) and the Rey-Osterrieth Figure test(Rey, 1941; Osterrieth, 1944). Studies showed that those measures of constructional functions are able to discriminate between healthy controls and patients with moderate-to-severe dementia. (Lehrner et al., 2015) A significant decline in constructional functions and an impairment in copying in patients with AD was found. This impairment in copying was also found in patients with PDD, whereas PD patients were shown to be relatively unimpaired in constructional praxis. (Lehrner et al., 2015) The sensitivity of those measures varies according to the level of cognitive impairment, for example the CDT can be normal in cases of mild AD. Studies found that the CDT as single screening instrument for dementia was questionable. (Agrell & Dehlin, 1998) Such findings suggest to expand the range of screening measures and tests that are sufficiently sensitive and valid and thus offer an opportunity for early detection of impairment in this domain.

2. Aims of the study

The object of this study was twofold: Firstly, the diagnostical value of visuo-constructional funtions and secondly the identification of differences in visuo-constructional functions using the Vienna Visuoconstructional Test 3.0 (VVT 3.0; Lehrner et al., 2015) and VVT 3.0 Screening in terms of early detection of dementiaits role, more precisely the ability to differentiate between patient groups with SCD, MCI and AD and PD. Therefore, both the VVT 3.0 and the VVT 3.0 Screening have undergone a psychometric criteria investigation and the diagnostic groups SCD, MCI, AD and PD were tested for differences in VVT 3.0 – and VVT 3.0 Screening – scores. Different VVT 3.0 and VVT 3.0 Screening ratings were anticipated to be statistically significant in the groups. The correlation of the VVT 3.0, VVT 3.0 Screening and interesting variables were investigated including depressive symptoms examined with the Beck's Depression Inventory(BDI II; Hautzinger, Keller & Kühner, 2006) and the Geriatric Depression Scale(GDS; Sheikh & Yesavage, 1986), IQ measured with the WST(Schmidt & Metzler, 1992), age and years of education.

3. Methods

3.1 Background

Data of the present study has been collected in ongoing research projects called „The Vienna Conversion to Dementia Study" (VCD Study) and the „Vienna Mild Cognitive Impairment and Cognitive Decline in Parkinson's Disease Study" (VMCI-CD-PD Study)(Lehrner et al., 2015). The Ethics Committee of the Medical University of Vienna approved the studies as they comply with the ethical principles of Helsinki´s Declaration. The ultimate ambition of the VCD Study was investigating conversion rates from patients with SCD and patients with MCI to dementia(Lehrner et al., 2016). The VMCI-CD-PD Study represents a prospective cohort study including PD patients who visit the movement disorder clinic of the Medical University of Vienna to assess their parkinsonism's status(Lehrner et al., 2014 b).

3.2 Subjects

The present study's sample consisted of persons, who attended the neurological outpatient clinic of the Medical University of Vienna due to (subjective or objective) memory declines. Patients either showed up via self-referral or got referred by the Department of Neurology for further examination of their cognitive status or were invited to follow up investigations. All patients underwent a complete neurological examination, standard laboratory blood tests and psychometric tests. Additionally, neuroimaging procedures like a magnetic resonance imaging (MRI) scan or a computer tomography (CT) scan of the brain were applied(Bodendorfer, 2015). Anamnesis for both studies contained the following criteria that would lead to exclusion: 1. Neurological disorders like cortical stroke or traumatic brain injuries in the past, which were determined by neuroradiologic and clinical examination. 2. Medical conditions possibly interfering with normal cognitive abilities including renal, respiratory, cardiac and hepatic disease. 3. Current major psychiatric disorder according to ICD-10 (Dilling et al., 2008) other than depressive symptoms. 4. Significant auditory, visual, language or motor deficits. (Stephan, Brayne, Savva & Matthews, 2011, cited by Bodendorfer, 2015) It was assumed that the above- mentioned diseases and deficits might interfere with the conduction of investigation due to possible cognitive deterioration and disturbance of the subject's cognitive performance

A detailed history of PD obtained by a standardized interview and a neurological examination were part of the clinical assessment for the VMCI-CD-PD Study. All PD patients were assessed on their regular medication and had to fulfill UK Parkinson's

Disease Society Brain Bank criteria for probable PD, plus were required to have a Mini-Mental State Examination (MMSE) score of ≥ 26.
(cited by Lehrner et al., 2014b)

3.3 Assessment procedures

The assessment of all participants started with semistructured interviews, using the brief cognitive rating scale (Reisberg, Ferris, De Leon & Crook, 1988, cited by Bodendorfer, 2015).

VVT 3.0 Screening

For the VVT 3.0 Screening the copying patterns(clock copying, pentagon copying and cube copying) of the VVT 3.0 are being scored: Scoring includes correctly drawn contour, correctly placed digits, and correctly placed pointers. Subjects score a point when one uses Roman numerals or places the digits outside the contour. The Screening is scored in dichotomous yes/no(1/0) answer format. For each parameter a score is assigned where zero indicates the worst performance. Thus, a total score for the screening in the present study ranges from 0 to 10. Tremor will be ignored. No limit is placed on response time.

VVT 3.0

The VVT 3.0(Lehrner et al., 2015) consists of three copying tasks or patterns: clock, pentagon and cube. The first task, the clock copying pattern, requires to copy a given clock with 12 digits and the hands' position "ten minutes after eleven" as accurately as possible, thus, resembling the clock task of the MoCa(Nasreddine et al., 2005). Scoring includes correctly drawing a contour, correctly placed digits, and correctly placed hands. The second pattern requires the copying of overlapping pentagons similar to the two pentagons of the Mini Mental State Test(Folstein, Folstein, & McHugh, 1975; MMSE). (Lehrner et al., 2015) The correct representation of the two pentagons and the intersection of the figures are scored. The third item is a three-dimensional cube. The correct representation of the three-dimensional figure is evaluated. The VVT 3.0 has an administration time of approximately 2–3 minutes. The maximum score of the VVT 3.0 is 98, (32 for the clock, 26 for the overlapping pentagons, and 40 for the cube)(Lehrner et al., 2015). When participants execute more than one copy of patterns, the best copy will be graded. Scoring of the VVT 3.0 Screening takes approximately 30 seconds, whereas scoring of the VVT 3.0 takes approximately 3– 5 minutes, whereby an evaluation sheet and transparent foil are used, and includes criteria of judgment as follows: 1. Right amount of lines and digits (clock, pentagon, cube), 2. Lengths of lines and hands (clock, pentagon, cube), 3. Size,

contour, drawn hands and their correct position (clock), 4. Right angle(45°) in lines (pentagon), 5. Parallelism of lines and right orientated front side (cube). In comparison to the former version of the VVT 3.0 the copying patterns got framed with a black line.

NTBV

All participants were afterwards subjected to the Neuropsychological Test Battery Vienna (NTBV) (Lehrner, Maly, Gleiß, Auff & Dal - Bianco, 2007). Participants achieving a MMSE score < 24 from 30 points were given the short version of the NTBV. The standardized, validated and normed NTBV was specifically designed for dementia diagnosis in a clinical setting and is administered to assess the cognitive status of the patient(Pusswald et al., 2013). It evaluates multiple cognitive domains: *concentration/attention, language, memory and executive functioning*(Lehrner et al., 2007). The classification of the subtests to these cognitive domains was made by cluster analysis based on test results of healthy subjects (Pusswald et al., 2013). Sensitivity of this test battery allows to diagnose prodromal phases of dementia(Lehrner et al., 2007). The implementation of neuropsychological testing based on the NTBV takes approximately 60 minutes, whereas the short version takes approximately 45 minutes. The NTBV consists of several tasks(cited by Bodendorfer, 2015) assessing attention performance with the Alters-Konzentrations-Test (AKT) (Gatterer, 2008), the Symbol Counting task from the inventory of cerebral insufficiency (C.I.) (Lehrl & Fischer, 1997), the second part of the Trail Making Test, Part B (TMTB), the score difference of the Trail Making Test A and B (Reitan, 1979) and the digit-symbol-subtest of the german WAIS-R (Tewes, 1994). Executive functioning was investigated by Trail Making Test A (TMTA) (Reitan, 1979), the Five-Point Test (Regard, Strauss & Knapp, 1982), the Maze test and the Stroop test of the Nürnberger Aging Inventory (NAI) (Oswald & Fleischmann, 1997) and the Interference subtest from the C.I. (Lehrl & Fischer, 1997). (Bodendorfer, 2015) Naming as many words beginning with the letters b, f and l and the Phonematic verbal fluency test (Goodglass & Kaplan, 1983) were used for the assessment of lexical verbal fluency. The modified Boston Naming Test (BNT) (Morris et al., 1989) and the Semantic Verbal Fluency test (Goodglass & Kaplan, 1983) were applied for testing of verbal fluency. The Verbal Selective Reminding Test (VSRT) (Lehrner, Gleiß, Maly, Auff, & Dal – Bianco, 2006) with several subtests (immediate, total and delayed recall and recognition of presented foods before) was applied for the assessment of memory (Boden-

dorfer, 2015). The NTBV has a good discriminating power in detecting AD dementia(Lehrner et al., 2007) and parts, in particular the VSRT, Alters-Konzentrations-Test (AKT) (Gatterer, 2008), Trail Making Test(TMT A and TMT B, Reitan, 1979) and digit-symbol-subtest of the German WAIS-R (Tewes, 1994), have shown to possess prognostic value in predicting whether a patient reporting memory problems converts to AD dementia within two years(Lehrner et al., 2005, cited by Lehrner et al., 2016). If subjects are being presented with the long testing procedure due to their MMSE score they are afterwards presented with the "Wortschatztest" (WST; Schmidt and Metzler, 1992), a standardized vocabulary test, to estimate the verbal intelligence levels and providing an estimation of premorbid IQ, the Beck's Depression Inventory (BDI – II; Hautzinger et al., 2009) and the Geriatric Depression Scale(GDS; Sheikh & Yesavage, 1986) to collect the ratings of depression.

3.4 Classification procedure

Diagnosis based on neuropsychological test results and was set by neuropsychologists, neurologists and other study personnel involved in the evaluation of the patient's cognitive status. Patients got classified into the diagnostic groups SCD, MCI, AD and patients with PD. For better comparison of individual test performance the raw scores of the tests were transformed into z-values. Relative position of the individual test performance is described by the standard value with respect to the corresponding reference population.

3.4.1 Diagnostic groups

SCD was diagnosed according to the framework given by SCD-I(Jessen et al., 2014) and defined as subjective decline in memory or non - memory domains. Additionally the objective test performance with an age, sex - and education-adjusted mean z-score of each domain was greater than -1.5 standard deviation (SD) on NTBV. MCI criteria were set out as follows(Petersen, 2011, cited by Bodendorfer, 2015): 1. patients or/and their partners, friends or families report subjective memory complaints, 2. functional activities don't seem to be significantly impaired, 3. decline in at least one cognitive domain by – 1.5 SD below age related norm, 4. no diagnosis of dementia according to the Diagnostic and Statistical Manual of Mental Disorders, version IV (DSM-IV) (Saß, Wittchen, Zaudig & Houben, 2003). Diagnosis of AD based on the NINCDS-ADRDA(McKhann et al., 1984) criteria and the criteria set of DSM-IV (Saß et al., 2003). Criteria in this paper for PD are also based on the lines of Petersen (2011).

4. Statistical Analysis

Statistical analyses of the clinical data were conducted using SPSS (version 23 SPSS Inc., Chicago, IL, USA) for Mac. For a clearer overview, results for VVT 3.0 Screening and VVT 3.0 will be presented separately. Demographic variables and neuropsychological data are described by means and standard deviations. Descriptive statistics were used to characterize the study sample. Psychometric criteria of the VVT 3.0 Screening and VVT 3.0 got evaluated through internal reliability analysis with Cronbach alpha for total sample and for the diagnosed groups, as well as for the three copy tasks solely. Discriminatory power and selectivity was tested via item-total-correlation. Additionally difficulty indices, interrater reliability and test-retest-reliability got evaluated. Validity of the VVT 3.0 Screening and the VVT 3.0 got evaluated through correlation analysis with NTBV domains. Receiver Operator Characteristic (ROC) curves were calculated for total group and subgroups to check the prognostic value of the VVT 3.0 Screening and VVT 3.0 and to obtain the optimal cut-off scores for testing sensitivity and specificity using the Youden index. According to Bortz & Döring(2006), the Area under the curve (AUC) represents an indicator of the prognostic significance of the VVT 3.0. Positive predicted value (PPV) and negative predicted value (NPV), positive likelihood ratio (LR+) and negative likelihood ratio (LR-) were calculated(Bodendorfer, 2015). According to Jaescke, Guyatt, and Sackett (1994) a LR+ > 10 and a LR–< 0.1 show convincingly diagnostic evidence; a LR+ 5 –10 and a LR–0.1–0.2 show highly diagnostic evidence; a LR+ 2–5 and a LR – 0.2 – 0.5 show weak diagnostic evidence; and a LR+1–2 and LR – 0.5 – 1 show scarcely diagnostic evidence, respectively. By finding the point on the ROC curve that demonstrates the highest sensitivity and specificity the optimal cut-off score got evaluated. Sensitivity indicates the proportion of subjects who have the target condition and have positive test results(for example the likelihood that patients with AD are correctly classified as demented), specificity is the proportion of subjects without the target condition(for example the probability that non-demented individuals are correctly identified as healthy, SCD or MCI)(Weiß, 2013). Afterwards the main data analysis was conducted in subsequent steps, explained in more detail below. The assumptions of normal distribution, linearity and homoscedasticity were not fulfilled. Therefore nonparametric statistical methods were used. Test score differences between CG and patients with SCD, MCI, AD and PD in VVT 3.0 Screening were investigated. For VVT 3.0 test score differences between patients with SCD, MCI, AD and PD were investigated. ANOVAs were not performed since viola-

tion of the conditions for parametric approach existed(Field, 2009; Bortz & Döring, 2006). Instead Kruskal Wallis analysis was conducted for a between-group analysis with diagnosis group as the independent variable and scores as the dependent variables. Pairwise post-hoc comparisons were adjusted using Mann Whitney U test(Field, 2009). Spearman r(r_s) correlations were calculated to discover correlates of VVT 3.0 Screening/VVT 3.0 and interesting variables(BDI II, GDS, WST IQ, age, sex, education). According to Cohen (1988) $r_S < 0.30$ represents a small effect size, $r_S > 0.30$ represents a medium effect size and a $r_S > 0.50$ represents a large effect size.

5. Results

This study consists of different parts with different population. Parts 1-3 present the results for VVT 3.0 Screening, as parts 4-6 show results for VVT 3.0.

Part 1 – Psychometric criteria – VVT 3.0 Screening

The first part of reliability and validity testing used a population of 130 adults for the VVT 3.0 Screening. Due to missing data, considering that the VVT 3.0 including VVT 3.0 Screening are new versions of the former version TEVK test-retest reliability and validity testing via correlation analysis with NTBV domains got tested with smaller populations.

Of the 130 subjects included in the testing of psychometric criteria of the VVT 3.0 Screening, 32(24.6%) were in the control group, 17(13.1%) had SCD, 30 (23.1%) suffered from MCI, 31(23.8%) from AD and 20(15.4%) from PD. Reliability testing of the screening with total sample(N = 130) showed high internal consistency with Cronbach alpha of 0.84. Split up into diagnostic groups, results for the screening were the following: $\alpha_{CG} = 0.68$, $\alpha_{SCD} = 0.47$, $\alpha_{MCI} = 0.79$, $\alpha_{AD} = 0.84$, $\alpha_{PD} = 0.66$(see table 1). Item means ranged between 0.69 and 0.96. Discriminatory power that was tested via item-total-correlation showed overall positive correlations of each item with screening score, ranging from 0.30 to 0.80. Reliabilities when item left out showed Cronbach alpha ranging from 0.79 to 0.85.(table 2) Spearman's r was run to determine if there was agreement between raters. There was high agreement between the two raters' judgements, $r_s = 0.84$ for total group, split up into diagnostic groups results were the following: $r_{CG} = 0.99$, $r_{SCD} = 0.64$, $r_{MCI} = 0.75$, $r_{AD} = 0.87$, $r_{PD} = 0.52$($p < .01$)(table 3). Additionally test-retest(N = 70) reliability, with a time interval of M = 19.8 months, got evaluated with a result of $r_s = 0.54$(table 4). Validity of the VVT 3.0 Screening got evaluated through correla-

tion analysis with NTBV domains(table 5). Since violation of the conditions for parametric approach existed, Spearman correlation was used, resulting in r_s = -0.54 to 0.58. The result of the ROC-analysis for total group, with AD as a positive condition, revealed an AUC of 0.85, 95% CI [0.76 to 0.94] with a standard error of 0.04 ($p < .01$) for the VVT 3.0 Screening. The optimal screening cut-off score was 8.5 with a Youden – Index of 0.61, thus, scores lower than 8.5 in the VVT 3.0 Screening presume that patients might suffer from AD, with a maximum of sensitivity and specificity: A sensitivity of 0.68 and specificity of 0.93 was attained. For the cut-off of 8.5, a PPV of 0.76 and a NPV of 0.89 was found. A LR+ with 9.71 and a LR- with 0.34 was found for the screening. Results for subgroups, in which every subgroup(negative condition on the left) is confronted with each other in regard to AUC, cut-off scores, sensitivity and specificity, PPV, NPV, LR+ and LR- can be found in table 6.

Part 2 - group differences - VVT 3.0 Screening

The second part used a population of 109 adults due to missing data. The sample consisted of 44 men (40.4%) and 65 women (59.6%) between 21 and 90 years of age (M = 64.7, SD = 14). Mean years of formal education were 12.6 ± 3.9. Mean premorbid WST-IQ was 111.1 (SD = 14.2). Table 7 shows characteristics of the total sample. Of the 109 subjects included in this study 32(29.4%) were healthy controls, 12(11%) suffered from SCD, 30 (27.5%) suffered from MCI, 28(25.7%) suffered from AD and 7 subjects (6.4%) had PD and were presented with the VVT 3.0 Screening. In the second analysis differences between the split diagnostic groups CG, SCD, MCI, AD and PD were examined. A non- parametric calculation with Kruskal Wallis test was used(table 8), with additional pairwise post hoc comparisons using Mann Whitney U test. Significant($p < .01$) differences in split diagnostic groups were detected in the VVT 3.0 Screening, but not all groups differed significantly from each other (see table 9).

Part 3 - correlation analysis - VVT 3.0 Screening

All Spearman correlations (r_S) between VVT 3.0 Screening scores and variables of interest are listed in table 10. Due to the small sample size(n = 7), the calculation for the PD group was not possible. Visuo-constructional abilities tested with the VVT 3.0 Screening were not significantly associated with cognitive performance in WST/premorbid IQ(r_{sTG} = 0.140, p = 0.216). Split up into groups, there were no significant results found. Non-cognitive correlates of visuo-constructional impair-

ment were increased levels of depression, higher age and lower educational level. There were significant positive correlations between VVT 3.0 Screening scores and years of education(r_{sTG} = 0.32, p < .01), but not when data got split up into groups. Age correlated significantly (r_s = -0.30, p < .01) negative with the VVT 3.0 Screening scores, split up in diagnostic subgroups, there were again no significant negative correlations between VVT 3.0 Screening scores and age. Depression scales(BDI - II, GDS) did not correlate significantly negative with the VVT 3.0 Screening scores for total group and subgroups. Men and women did not differ significantly in their results in the screening.

Part 4 – Psychometric criteria - VVT 3.0

The first part of reliability and validity testing used a population of 98 adults for the VVT 3.0, as a control group is missing in the VVT 3.0. Test-retest reliability was again tested with a smaller population(N = 7), due to missing data.

Of the 98 subjects included in the testing of psychometric citeria of the VVT 3.0, 17 had SCD(17.3%), 30(30.6%%) suffered from MCI, 31(31.6) from AD and 20(20.4%) from PD. Reliability testing of the VVT 3.0 with total sample(N = 98) showed high internal consistency with Cronbach alpha of 0.94. Split up into diagnostic groups, results for the VVT 3.0 were the following:. α_{SCD} = 0.87, α_{MCI} = 0.94, α_{AD} = 0.98, α_{PD} = 0.95(table 11). Split up in different tasks, results of reliability testing were the following: α_{cube} = 0.89, $\alpha_{pentagon}$ = 0.81, α_{clock} = 0.89(table 12). Spearman's r was run to determine if there was agreement between raters and correlated highly with r_s = 0.90, split up into diagnostic groups r_{SCD} = 0.7 r_{MCI} = 0.92, r_{AD} = 0.93, r_{PD} = 0.88. Split up in the different tasks, interrater reliability was r_s = 0.90 for the clock copy task, r_s = 0.90 for the pentagon task, r_s = 0.82 for the cube task(table 13). Item means for the clock task ranged between 0.15 and 0.94(table 14). Item means for the pentagon task ranged between 0.35 and 0.97(table 15). Item means for the cube task ranged between 0.39 and 0.98(table 16). Discriminatory power which was tested via item-total-correlation showed overall positive correlations of each item with VVT 3.0 score, ranging from 0.2 to 0.66 for the cube items, 0.2 to 0.62 for the pentagon items, 0.18 to to 0.75 for clock items. Reliabilities when items were left out showed Cronbach alpha ranging from 0.88 to 0.89 for cube, 0.80 to 0.81 for pentagon, 0.88 to 0.89 for clock(table 14-16). Additionally test-retest reliability, with a time interval of M = 14.7 months, got evaluated with a result of 0.52(N =7, p = 0.23), was not statistically significant(table 17). Validity of the VVT 3.0

was evaluated through correlation analysis with NTBV domains. Since violation of the conditions for parametric approach existed, Spearman correlation was used, resulting in r_s= -0.48 to 0.49(table 18). The result of the ROC-analysis for the VVT 3.0 for total group, with AD as a positive condition, revealed an AUC of 0.79, 95% CI [0.70 to 0.80] with a standard error of .05 ($p < .01$). The optimal cut-off score was 69.5 with a Youden – Index of 0.45, thus, scores lower than 69.5 in the VVT 3.0 presume that patients might suffer from AD, with a maximum of sensitivity and specificity: A sensitivity of 0.84 and specificity of 0.61 was attained. For the cut-off of 69.5, a PPV of 0.50 and a NPV of 0.89 was found. A LR+ with 2.15 and a LR- with 0.26 were found for the VVT 3.0. Results for subgroups, in which every subgroup(negative condition on the left) is confronted with each other in regard to AUC, cut-off scores, sensitivity and specificity, PPV, NPV, LR+ and LR- can be found in table 19.

Part 5 – group differences – VVT 3.0

For the main analysis of the VVT 3.0 there was again a different population with N =185. The sample included 95 men (51.4%) and 90 women (48.6%) between 37 and 92 years of age (M = 68.4, SD = 10.7). Mean years of formal education (Bodendorfer, 2015) were 12.5 ± 5.2(n=2 were excluded due to missing data). Mean premorbid WST-IQ was 110.5 (SD = 14.6). Table 20 shows characteristics of the total sample. Of the 185 subjects included in this study, 23(12.4%) suffered from SCD, 95 (51.4%) suffered from MCI, 44(23.8%) suffered from AD and 23 subjects (12.4%) had PD and were presented with the VVT 3.0. In the second analysis differences between the split diagnostic groups SCD, MCI, AD and PD were examined. Non-parametric calculation with Kruskal Wallis test was used(table 21), with additional pairwise post hoc comparisons using Mann Whitney U test(table 22). Significant($p < .01$) differences in split diagnostic groups were detected in the VVT 3.0. With SCD scoring highest, followed by MCI, PD and AD, groups differed from another(see figure 1), but not all significantly: between SCD subjects and MCI subjects and between the AD and PD diagnostic group, there were no significant results found.

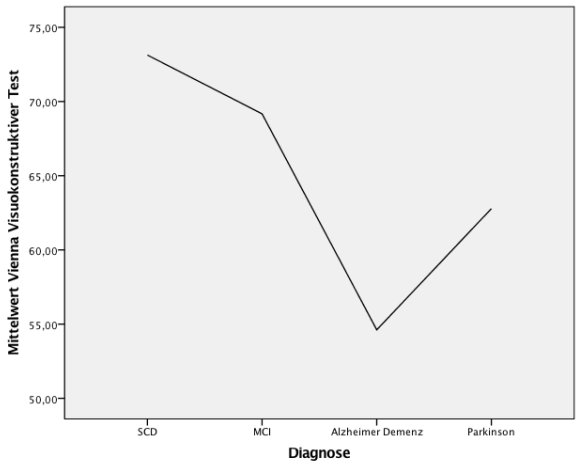

Figure 1.

Part 6 – correlation analysis – VVT 3.0

All Spearman correlations (r_S) between VVT 3.0 and variables of interest are listed in table 23. Visuo-constructional abilities tested with the VVT 3.0 were associated with increased cognitive performance in WST/premorbid IQ(r_{sTG} = 0.19, p < .05) but split up into diagnostic groups only the MCI group(r_{sMCI} = 0.24, p < .05) was significant. Non-cognitive correlates of visuo-constructional impairment were increased levels of depression, higher age and lower educational level. There were significant positive correlations between VVT 3.0 scores and years of education, but not in the AD group(r_{sAD} = -0.23, p = .128) and PD group (r_{sPD} = 0.37, p = .086). There were also significant positive correlations between VVT 3.0 scores and years of education (r_{sTG} = 0.22, p < .01) for total group. Age correlated significantly (rs = -0.29, p < .01) negative with the VVT 3.0 scores, split up in diagnostic subgroups, there were significant negative correlations in MCI and PD group(r_{sMCI} = -0.28, p < .01; r_{sPD} = -0.50, p < .05). Men and women did not differ significantly in their results in the VVT 3.0, neither a significant correlation was found between scores in depression scales(BDI - II, GDS) and the VVT 3.0 scores for total group(BDI r_{sTG} = -0.09, p = .319, GDS r_{sTG} =-0.10, p = .196). Split up in diagnostic groups there were significant negative results in the SCD group for BDI(r_{sSCD} = -0.53, p < .05).

6. Discussion

Summary of Results

This study investigated if visuo-constructional functions are valuable for differentiating between CG, SCD, MCI, AD and PD patients in a sample of elderly participants. For this purpose the VVT 3.0 and VVT 3.0 Screening, developed to measure visuo-constructional skills, underwent a psychometric criteria check based on data from the Vienna Conversion to Dementia Study and Vienna Mild Cognitive Impairment and Cognitive Decline in Parkinson's Disease Study. After criteria check, differences in VVT 3.0 Screening and VVT 3.0 scores between the mentioned groups were examined to further assess the value of VVT 3.0 Screening and VVT 3.0. The last step was an investigation of correlation between variables of interest and the scores of visuoconstructive testing.

Psychometric criteria

VVT 3.0 Screening

Reliability testing showed high internal consistencies of VVT 3.0 Screening and also the accordance between raters was highly satisfying. Test-retest reliability

showed an average Cronbach alpha. This average reliability could actually be a sign of appropriateness of the method, as between baseline and follow up investigations, for example patients with SCD might have converted to MCI, thus indicating a lower score in the second investigation due to conversion rates. Thus, it might be an average reliability caused by processes linked to the disease's nature. Item difficulties, in this study equal to item means due to true-false format, ranged from difficult to easy items. We then had a look at the reliabilities when items were left out: Reliabilities didn't rise significantly, and the mix between easy and difficult items spoke for a broad difficulty distribution. When the predictive validity of the VVT 3.0 Screening was investigated, measured by means of receiver operating curves (ROC), it showed an AUC of 0.85, when using a cut-off of 8.5, a sensitivity of 0.68; a specifity of 0.93, a PPV of 0.76, a NPV of 0.89, a LR+ of 9.71 and a LR- of 0.34. Thus, 68% of persons who previously received the diagnosis of AD were correctly classified as affected in this study, whereas 93 % of the persons were correctly classified as not affected in terms of AD. The AUC of 0.85 demonstrates a very good accuracy of the screening in terms of how well the VVT 3.0 Screening separates the group being tested into those with and without AD. Additionally, using LR+/LR- we found highly diagnostic evidence for the VVT 3.0 Screening for total group according to Jaeschke et al.(1994). The results of the ROC analyses regarding the subgroups, respectively, support the usability of the VVT 3.0 Screening: Results of upto LR+ = 8.50 and LR- = 0.35(SCD – AD) for the VVT 3.0 Screening support the convincingly diagnostical value of the method differentiating between patients suffering from AD and adults concerning about subjective cognitive decline and/or rather mild symptoms.

VVT 3.0

Again, reliability testing showed high internal consistencies and also the accordance between raters was highly satisfying in the VVT 3.0. Test-retest reliability was again average and not significant in the VVT 3.0, probably due to a small n. Item difficulties ranged from difficult to easy items. Reliabilities when items were left out didn't rise significantly. The VVT 3.0 showed an AUC of 0.79, when using a cut-off of 69.5, a sensitivity of 0.84; a specifity of 0.61, a PPV of 0.50, a NPV of 0.89, a LR+ of 2.15 and a LR- of 0.26. Thus, 84% of patients diagnosed with AD were correctly classified in our clinical sample and 61 % of the patients were classified correctly as not affected. Again, the AUC of 0.79 shows a good accuracy of separating between AD patients and non-

affected persons, but using LR+/LR- we found weak diagnostic evidence for the VVT 3.0. It's important to mention that test properties are likely to change dependent on the disease severity and distribution of competing conditions(Jaeschke et al., 1994). Sensitivity will increase(and with it LR+ will increase) when patients with the target disorder are severely ill and vice versa: If patients without AD have medical conditions that mimic conditions of AD patients, LR+ will decrease, LR- will increase and the test will appear less useful. Thus, as a conclusion to the present study, it might be that patients with SCD, MCI or PD have very similar conditions and test results compared to AD patients in the VVT 3.0 Screening. This theory is also supported by the fact, that when a control group was added like in the VVT 3.0 Screening, LR+ and LR- showed highly diagnostic evidence. Nonetheless, it was necessary to calculate ROCs with the subgroups, respectively. Results of upto LR+ = 9.17/LR- = 0.48 (SCD – PD) for the VVT 3.0 support the convincingly diagnostical value and the usability of the VVT 3.0 differentiating between patient groups.

Additionally, the very good performance of the VVT 3.0 and VVT 3.0 Screening in terms of Negative Predicted Value may suggest that the two measures may have clinical utility in terms of investigating if patients who are not diagnosed with AD are sought. This has to be investigated more thoroughly in a specific setting. Summarized, the VVT 3.0 and VVT 3.0 Screening are able to discriminate diseased from nondiseased subjects.

As conclusion, we decided to work with the present VVT 3.0 and VVT 3.0 Screening and found both methods satisfactory concerning psychometric criteria.

Group differences

We investigated the discriminant power of the VVT 3.0 and VVT 3.0 Screening. To test, if the VVT 3.0 and VVT 3.0 Screening might be able to differentiate between several patient groups, differences in scores between control group, patients with subjective cognitive decline, mild cognitive impairment, Alzheimer's disease and Parkinson's disease got examined in the main analysis. The results suggest that visuoconstructive abilities measured with the VVT 3.0 and VVT 3.0 Screening worsen from SCD to MCI and subsequently to AD or PD. In AD patients visuo-constructional abilities have been described to differ significantly compared to healthy controls and visuoconstructive impairment has long been seen as an early feature of AD. (Freeman et al., 2000; Mendez, Mendez, Martin, Smyth, & Whitehouse, 1990, cited by Samrah et al.) Our data supported this.

VVT 3.0 Screening

Lower scores in VVT 3.0 Screening have been found for AD patients than for patients with SCD, MCI, PD and healthy controls, but there were no significant results between CG and SCD, SCD and MCI and MCI and PD, which also might be related to a small n, and, again, to mentioned similar medical conditions in the groups.

VVT 3.0

Lower scores in VVT 3.0 have been found for AD patients than for patients with SCD, MCI, PD, but there was no significant difference between the AD and PD group in the VVT 3.0, and between the SCD and MCI group.

Still, these findings do not support the data examining superiority of visuo-constructional abilities in AD patients compared to subjects with PD(Freeman et al., 2000) but the opposite. Although there has been considerably less research examining visuo-constructional deficits associated with MCI than with AD, patients with MCI were found to be significantly more impaired compared with controls and less impaired than AD patients in the Clock Drawing Test (De Jager, Hogervorst, Combrenck, and Budge ,2003, Thomann, Toro, DosSantos, Essig, and Schroder, 2008). But, there were also studies that found the CDT not being specific or sensitive enough to be a useful screening method for detection of very mild dementia(Powlishta et al., 2002; Kirby, Denihan, Bruce, Coakley & Lawlor, 2001). It should be emphasized that, in the present study, we were able to show that visuo-constructional functions measured via the VVT 3.0 and VVT 3.0 Screening are also impaired in patients with SCD and MCI: The present study found significant results between healthy controls and MCI patients in visuo-constructional abilities, with MCI scoring significantly lower than healthy controls in the VVT 3.0 and VVT 3.0 Screening. Although there were no significant differences found in the VVT 3.0 and VVT 3.0 Screening scores between SCD and MCI group, SCD in both methods scored higher than MCI. This is very important in context of the SCD framework by Jessen et al.(2014), as these findings demonstrate that there are signs of visuo-constructional impairment in very mild stages of cognitive deterioration, that can be detected and differentiated from CG and/or MCI with appropriate tests and – for future studies – with a larger population.

Correlates

Additionally, visuoconstructive abilities measured with the VVT 3.0 and VVT 3.0 Screening seem to significantly corre-

late with variables, like years of education, age and IQ measured with the WST. Low educational achievement (Gatz et al., 2001; Sando et al., 2008; Paradise, Cooper & Livingston, 2009; Schmand et al., 1997) and increasing age (Levy et al., 2002; Aarsland et al., 2007; Hatcher, 1999; Terry et al., 2011) are two of the few variables consistently being reported to be significant risk factors of dementia. Therefore it was important for the present study to investigate if there would be significant correlations between those factors and visuoconstructive abilities or impairments measured with the VVT 3.0 and VVT 3.0 Screening.

VVT 3.0 Screening

We determined the VVT 3.0 Screening's discriminant validity by correlating scores, WST, age, BDI, GDS and years of education and found low-to-moderate correlations. Significant negative correlations between VVT 3.0 Screening scores and age were found for total group, which supports the thesis of worsening performance in visuo-constructional functions and increasing age. Findings also support the hypothesis of higher educational achievements and less visuoconstructional impairments: Significant moderate correlations between years of education and scores in VVT 3.0 Screening were found. We did not find sex effects, indicating that women and men performed equally well and no significant results for WST and depression scores(BDI, GDS). We further found low-to-moderate correlation coefficients between VVT 3.0 Screening performance and performance in other cognitive domains including attention, language, memory, and executive function, measured with the NTBV.

VVT 3.0

We also found low-to-moderate correlations for the VVT 3.0, again significant negative correlations between age and VVT 3.0 scores and significant positive correlations between years of education and visuo-constructional functioning measured with the VVT 3.0. For the VVT 3.0 there were also significant positive correlations for scores of VVT 3.0 and WST, indicating that higher premorbid intelligence level might be related to better visuo-constructional functioning. Again, we did not find sex effects, indicating that women and men performed equally well. Low-to-moderate correlation coefficients were further found between VVT 3.0 performance and performance in other cognitive domains including attention, language, memory, and executive function, measured with the NTBV.

These findings indicate not only that visuo-constructional function is an independent cognitive domain, data also sug-

gests that measures as the VVT 3.0 and VVT 3.0 Screening are able to differentiate between the groups and may be useful for the detection of AD early in the process. Thus, testing of visuo-constructional impairment would state a useful addition in the process of diagnosing cognitive decline and its diagnosis would be highly important in the context of early interventions.

Strengths and Limitations

In every study, strengths and limitations need to be considered. A strength of the current study is the good design as a detailed medical and neuropsychological investigation of their cognitive status was given to the participants. Another important strength is the inclusion of the SCD group, with findings that support Jessen et al.'s framework. The used methods VVT 3.0 and VVT 3.0 Screening showed good discriminating power between groups and are methods that don't allow participants to cheat, for example to exaggerate their results, as it would be with self-report questionnaires. Due to easy and fast application the methods constitute a needed addition to the present state of research in the field of dementia. Despite the strengths described above, this study shows also some limitations that need to be considered. First of all, the sample of the present study is specific and thus, results may not be generalizable to the general population. Also, due to small sample sizes (for example in the test-retest-reliability testing for the VVT 3.0, or PD group in VVT 3.0 Screening(ROC analysis, group differences) results were partly not significant and in future, balanced group sizes should guarantee the statistical power. Another point is that it's important to state that procedures with older participants have to be applied and interpreted with care due to fatigue and subsequently less concentration. Also, since current mood at investigation time is linked to performance, current mood should be taken into consideration for further studies(Marino et al., 2009). Additionally, patients with frontotemporal lobar degeneration, Lewy body disease, vascular disease, traumatic brain injury, substance/medication abuse, human immunodeficiency virus infection, prion disease, Huntington's disease, etc. have not been investigated in this study and should be investigated in upcoming studies (Lehrner et al., 2015).

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Part 1 – Psychometric criteria – VVT 3.0 Screening

Table 1. Internal consistencies VVT 3.0 Screening(N = 130)

Group	Cronbach alpha Screening
TG	0.84
CG	0.68
SCD	0.47
MCI	0.79
AD	0.84
PD	0.66

Note: TG, total group, N = 130, CG, control group, n = 32, SCD, subjective dognitive decline, n = 17, MCI, mild cognitive impairment, n = 30, AD, Alzheimer's disease, n = 31, PD, Parkinson disease, n = 20.

Table 2. Item means VVT 3.0 Screening

Item	Means	SD	Item-total-correlation	Cronbach alpha when item left out
Uhr_Kontur_Copy	0.96	0.19	0.38	0.83
Uhr_Zahlen_Copy	0.90	0.30	0.55	0.81
Uhr_Zeiger_Copy	0.70	0.46	0.31	0.85
Fünfeck_A	0.92	0.28	0.64	0.81
Fünfeck_B	0.95	0.21	0.63	0.82
Fünfeck_C	0.91	0.29	0.59	0.81
Würfel_A	0.86	0.35	0.80	0.79
Würfel_B	0.91	0.29	0.70	0.80
Würfel_C	0.79	0.41	0.71	0.80
Würfel_D	0.69	0.46	0.30	0.85

Table 3. Spearman correlation(r_s) between two raters – VVT 3.0 Screening(N=130)

	r_s
CG	0.99
SCD	0.64
MCI	0.75
AD	0.87
PD	0.52
total	0.84

Note: CG, control group, SCD, subjective dognitive decline, MCI, mild cognitive impairment, AD, Alzheimer's disease, PD, Parkinson disease, $r_S < 0.30$ small, $r_S > 0.30$ medium, $r_S > 0.50$ large effect size; $p < .01$(uncorrected p).

Table 4. Spearman correlation(r_s) between test and retest – VVT 3.0 Screening (N = 70)

	r_s
TG	0.54

Note: TG, total group, * $p < .01$ (uncorrected p)

Table 5. Spearman correlation(r_s) between VVT 3.0 Screening and NTBV(N=109)

	r_s
Concentration/attention	
AKT I	-0.54**
AKT II	0.55**
Digit-symbol(WAIS-R)	0.34**
Symbol counting(C.I.)	-0.47**
TMTB	-0.36**
TMTB-TMTA	-0.05
Executive functioning	
TMTA	-0.12**
5-Point-Test_right	0.19
5-Point-Test_perserveration	-0.26*
Maze – Test I(NAI)	-0.43**
Maze – Test II(NAI)	-0.32**
Maze – Test III(NAI)	0.32**
Maze – Test IV(NAI)	0.37**
Stroop I(NAI)	-0.24*
Stroop II(NAI)	-0.23*
Stroop III(NAI)	-0.06
Stroop IV(NAI)	0.06
Stroop V(NAI)	0.19
Stroop VI (NAI)	-0.07
Interference I(C.I.)	-0.51**
Interference II(C.I.)	-0.19
Language	
SVT	0.35**
PVT_b	0.08
PVT-f	0.22*
PVT_l	-0.09
BNT	0.58**
Memory	
VSRT_IR	0.51**
VSRT_TR	0.54**
VSRT_DR	0.41**

Note: AKT I, Alters-Konzentrations-Test, time, AKT II, Alters-Konzentrations-Test, total/time, WAIS - R, Wechsler Adult Intelligence Scale – Revised, C.I., Inventory of cerebral insufficiency, TMTA,TMTB, Trail Making Test, Maze Test I, time, Maze Test II, mistakes, Maze Test III, total, Maze Test IV, total/time, Stroop I, time(colour), Stroop II, time(words), Stroop III, total/time, Stroop IV, interference, NAI, Nürnberger Aging Inventory, SVT, Semantic Verbal Fluency Test, PVT, Phonematic verbal fluency test, BNT, Boston Naming Test, VSRT, Verbal Selective Reminding Test, VSRT_IR, immediate recall, VSRT_TR, total recall, VSRT_DR, delayed recall, VSRT_REC, recognition; *p < .05, **p < .01 (uncorrected p).

Table 6. ROC Analyses with AUC [95 % Confidence Interval] at optimal Cut-off using highest Youden Index of VVT 3.0 Screening, N =109

		Cut off	AUC[95% CI]	SE	SP	PPV	NPV	LR+	LR-
TG[1]	AD	8.5	0.85[0.76 – 0.94]	0.68	0.93	0.76	0.89	9.71	0.34
CG	SCD	9.5	0.56[0.39 – 0.74]	0.29	0.84	0.44	0.77	1.81	0.85
	MCI	9.5	0.70[0.56 – 0.83]	0.57	0.84	0.77	0.68	3.56	0.51
	AD	9.5	0.89[0.80 – 0.97]	0.87	0.84	0.83	0.90	5.44	0.15
	PD	9.5	0.89[0.79 – 0.99]	1.00	0.84	0.58	1.00	6.25	0
SCD	MCI	9.5	0.61[0.42 – 0.80]	0.57	0.67	0.81	0.38	1.73	0.64
	AD	8.5	0.86[0.73 – 0.98]	0.68	0.92	0.95	0.55	8.5	0.35
	PD	9.5	0.79[0.58 – 1.00]	1.00	0.67	0.64	1.00	3.03	0
MCI	AD	8.5	0.80[0.69 – 0.92]	0.68	0.90	0.88	0.79	6.8	0.36
	PD	9.5	0.67[0.50 – 0.84]	1.00	0.43	0.28	1.00	1.75	0
PD	AD	8.5	0.79[0.64 – 0.93]	0.89	0	0	0.78	0.89	0

Note: VVT 3.0 Screening, Vienna Visuoconstructional Test Screening, TG[1](N = 109), Control group(n=32), Subjective cognitive decline(n=12), Mild cognitive impairment(30) and Parkinson group(n=7) as negative condition, Alzheimer's disease(n=28) as positive condition, AUC, Area under curve; SE, Sensitivity, SP, Specificity; PPV, Positive Predicted Value; NPV, Negative Predicted Value; LR+, Positive likelihood ratio; LR-, Negative likelihood ratio.

Part 2 – group differences, VVT 3.0 Screening

Table 7. Demographic and screening sample characteristics VVT 3.0 Screening (N = 109)

	TG (N=109)	CG (n=32)	SCD (n=12)	MCI (n=30)	AD (n=28)	PD (n=7)
Female(n/%)	65/53.8	22/68.8	2/16.7	22/73.3	15/53.6	4/57.1
Age	64.7/14	59/19.2	64.3/11.6	64.7/10.3	71.5/9.7	64.7/8.1
Education	12.6/3.9	13.2/4.1	13.3/4	13.3/4.2	11.3/3.3	11.1/3.7
VVT 3.0 Screening	8.7/2.1	9.7/0.8	9.5/0.9	9/1.7	6.7/2.9	9/0
WST	111/14.2	111.2/12.7	112.5/11.3	112.3/17.3	104.5/16.4	105.6/9.8
BDI II	9.7/14.6	4.8/5.1	7.7/8.8	16.5/21.7	9.7/7.6	6.8/3
GDS	3.6/3.6	2.3/3.2	4 .1/3.5	5/3.8	4.1/3.5	1.7/0.8

Note: all variables are presented as means & standard deviation; TG, total group, CG, control group, SCD, subjective cognitive decline, MCI, mild cognitive impairment, AD, Alzheimer's disease, PD, Parkinson disease, education measured in school years, WST, Wortschatztest, BDI, Beck's Depression Inventory, GDS, Geriatric Depression Scale.

Table 8. Kruskal Wallis H Test VVT 3.0 Screening

	Mean rank
	Screening H(4) = 45.2 (p < .01)
CG	75.8
SCD	67.7
MCI	57
AD	26.9
PD	42

Note: CG, control group, SCD, subjective cognitive decline, MCI, mild cognitive impairment, AD, Alzheimer's disease, PD, Parkinson disease

Table 9. Mann- Whitney U Test VVT 3.0 Screening

	Midrange		Midrange	U
CG	23.5	SCD	19.8	159.5
	37.4	MCI	25.2	290.5**
	41.7	AD	17.7	90.5**
	22.7	PD	7.5	24.5**
SCD	24.9	MCI	20.2	139.5
	30.5	AD	16.2	48**
	12	PD	6.5	17.5*
MCI	38	AD	20.5	166.5**
	20.2	PD	14	70
AD	16	PD	26	42*

Note: CG, control group, SCD, subjective cognitive decline, MCI, mild cognitive impairment, AD, Alzheimer's disease, PD, Parkinson disease; *p < .05, ** p < .01(uncorrected p)

Part 3 - correlation analysis - VVT 3.0 Screening

Table 10. Spearman Correlations (r_S) between VVT 3.0 Screening – Scores and variables of interest

	WST	Education	Age	BDI II	GDS
CG	0.19	0.19	-0.30	-0.21	-0.16
SCD	0.49	0.13	-0.02	0.10	-0.04
MCI	0.10	0.23	-0.02	0.09	-0.01
AD	-0.89	0.27	0.15	-0.87	-0.40
PD	-	-	-	-	-
total	0.14	0.32**	-0.30**	-0.20	-0.17

Note: CG, control group, SCD, subjective cognitive decline, MCI, mild cognitive impairment, AD, Alzheimer's disease, PD, Parkinson disease, WST, Wortschatztest, BDI, Beck's Depression Inventory, GDS, Geriatric Depression Scale, 0.10 small, 0.30 moderate, 0.50 large effect size, ** $p < .01$. (uncorrected p).

Part 4 – Psychometric criteria – VVT 3.0

Table 11. Internal consistencies VVT 3.0

Group	Cronbach alpha
TG	0.94
SCD	0.87
MCI	0.94
AD	0.98
PD	0.95

Note: TG, total group, N = 98, CG, control group, n = 32, SCD, subjective dognitive decline, n = 32, MCI, mild cognitive impairment, n = 30, AD, Alzheimer's disease, n = 31, PD, Parkinson disease, n = 20.

Table 12. Internal consistencies VVT 3.0

	Cronbach alpha
cube	0.89
pentagon	0.81
clock	0.89

Table 13. Spearman correlation(r_s) between two raters VVT 3.0

	r_s
SCD	0.70
MCI	0.92
AD	0.93
PD	0.88
TG	0.90
Clock	0.90
Pentagon	0.90
Cube	0.82

Note: SCD, subjective dognitive decline, n = 32, MCI, mild cognitive impairment, n = 30, AD, Alzheimer's disease, n = 31, PD, Parkinson disease, n = 20, TG, total group, N = 98.

Table 14. Item means – VVT 3.0 – clock

	means	SD	Item-total correlation	Cronbach alpha when item left out
Uhr_copy_Kontur_a1	0.94	0.24	0.18	0.89
Uhr_copy_Kontur_a2	0.52	0.50	0.19	0.89
Uhr_copy_b1_Zahl1	0.91	0.29	0.82	0.88
Uhr_copy_b1_Zahl2	0.94	0.24	0.70	0.88
Uhr_copy_b1_Zahl3	0.92	0.28	0.81	0.88
Uhr_copy_b1_Zahl4	0.92	0.28	0.81	0.88
Uhr_copy_b1_Zahl5	0.92	0.28	0.81	0.88
Uhr_copy_b1_Zahl6	0.92	0.28	0.81	0.88
Uhr_copy_b1_Zahl7	0.91	0.29	0.80	0.88
Uhr_copy_b1_Zahl8	0.92	0.28	0.81	0.88
Uhr_copy_b1_Zahl9	0.92	0.28	0.81	0.88
Uhr_copy_b1_Zahl10	0.92	0.28	0.81	0.88
Uhr_copy_b1_Zahl11	0.91	0.29	0.71	0.88
Uhr_copy_b1_Zahl12	0.90	0.30	0.71	0.88
Uhr_copy_b2_Zahl1	0.42	0.50	0.28	0.89
Uhr_copy_b2_Zahl2	0.38	0.49	0.27	0.89
Uhr_copy_b2_Zahl3	0.37	0.49	0.32	0.89
Uhr_copy_b2_Zahl4	0.32	0.47	0.38	0.89
Uhr_copy_b2_Zahl5	0.22	0.42	0.26	0.89
Uhr_copy_b2_Zahl6	0.57	0.50	0.40	0.89
Uhr_copy_b2_Zahl7	0.46	0.50	0.37	0.89
Uhr_copy_b2_Zahl8	0.36	0.48	0.29	0.89
Uhr_copy_b2_Zahl9	0.25	0.43	0.30	0.89
Uhr_copy_b2_Zahl10	0.26	0.44	0.29	0.89
Uhr_copy_b2_Zahl11	0.15	0.36	0.32	0.89
Uhr_copy_b2_Zahl12	0.25	0.43	0.29	0.89
Uhr_copy_Zeiger_c1	0.91	0.29	0.44	0.88
Uhr_copy_Zeiger_c2	0.92	0.28	0.47	0.88
Uhr_copy_Zeiger_c3	0.85	0.36	0.42	0.88
Uhr_copy_Zeiger_c4	0.71	0.45	0.21	0.89
Uhr_copy_Zeiger_c5	0.31	0.46	0.19	0.89
Uhr_copy_Zeiger_c6	0.46	0.50	0.15	0.89

Table 15. Item means – VVT 3.0 – pentagon

	means	SD	Item-total correlation	Cronbach alpha when item left out
Fünfeck_Linie1	0.96	0.20	0.41	0.81
Fünfeck_Linie2	0.96	0.20	0.41	0.81
Fünfeck_Linie3	0.96	0.20	0.50	0.80
Fünfeck_Linie4	0.95	0.22	0.54	0.80
Fünfeck_Linie5	0.97	0.17	0.41	0.81
Fünfeck_Linie6	0.96	0.20	0.55	0.80
Fünfeck_Linie7	0.94	0.24	0.45	0.80
Fünfeck_Linie8	0.96	0.20	0.55	0.80
Fünfeck_Linie9	0.96	0.20	0.55	0.80
Fünfeck_Linie10	0.95	0.22	0.53	0.80
Fünfeck_Länge1	0.48	0.50	0.29	0.81
Fünfeck_Länge2	0.42	0.50	0.25	0.81
Fünfeck_Länge3	0.44	0.50	0.35	0.81
Fünfeck_Länge4	0.32	0.47	0.22	0.81
Fünfeck_Länge5	0.50	0.50	0.34	0.81
Fünfeck_Länge6	0.49	0.50	0.42	0.80
Fünfeck_Länge7	0.35	0.48	0.26	0.81
Fünfeck_Länge8	0.49	0.50	0.38	0.80
Fünfeck_Länge9	0.40	0.49	0.44	0.80
Fünfeck_Länge10	0.49	0.50	0.44	0.80
Fünfeck_Q_Länge1	0.64	0.48	0.43	0.80
Fünfeck_Q_Länge2	0.61	0.49	0.33	0.81
Fünfeck_Q_Länge3	0.39	0.50	0.37	0.80
Fünfeck_Q_Länge4	0.53	0.50	0.36	0.80
Fünfeck_Q_Parallel1_3	0.53	0.50	0.18	0.81
Fünfeck_Q_Parallel2_4	0.55	0.49	0.18	0.81

Table 16. Item means – VVT 3.0 – cube

	means	SD	Item-total correlation	Cronbach alpha when item left out
Würfel_Linie 1	0.98	0.14	0.50	0.89
Würfel_Linie 2	0.96	0.20	0.45	0.89
Würfel_Linie 3	0.95	0.22	0.57	0.89
Würfel_Linie 4	0.92	0.28	0.51	0.89
Würfel_Linie 5	0.95	0.22	0.53	0.89
Würfel_Linie 6	0.93	0.26	0.48	0.89
Würfel_Linie 7	0.96	0.20	0.56	0.89
Würfel_Linie 8	0.97	0.17	0.40	0.89
Würfel_Linie 9	0.91	0.29	0.55	0.89
Würfel_Linie 10	0.93	0.26	0.63	0.88
Würfel_Linie 11	0.92	0.28	0.65	0.88
Würfel_Linie 12	0.92	0.28	0.60	0.88
Würfel_Länge 1	0.47	0.50	0.38	0.89
Würfel_Länge 2	0.42	0.50	0.37	0.89
Würfel_Länge 3	0.49	0.50	0.15	0.89
Würfel_Länge 4	0.46	0.50	0.33	0.89
Würfel_Länge 5	0.40	0.49	0.29	0.89
Würfel_Länge 6	0.42	0.50	0.37	0.89
Würfel_Länge 7	0.39	0.49	0.28	0.89
Würfel_Länge 8	0.41	0.49	0.43	0.89
Würfel_Länge 9	0.52	0.50	0.36	0.89
Würfel_Länge 10	0.53	0.50	0.31	0.89
Würfel_Länge 11	0.39	0.49	0.34	0.89
Würfel_Länge 12	0.50	0.50	0.37	0.89
Würfel_Parallel1	0.89	0.32	0.34	0.89
Würfel_Parallel2	0.85	0.36	0.37	0.89
Würfel_Parallel3	0.83	0.38	0.49	0.89
Würfel_Parallel4	0.80	0.41	0.46	0.89
Würfel_Parallel5	0.82	0.39	0.40	0.89
Würfel_Parallel6	0.74	0.44	0.48	0.89
Würfel_Parallel7	0.81	0.40	0.45	0.89
Würfel_Parallel8	0.81	0.40	0.28	0.89
Würfel_Grad1	0.69	0.46	0.40	0.89
Würfel_Grad2	0.65	0.48	0.46	0.89
Würfel_Grad3	0.61	0.49	0.30	0.89
Würfel_Grad4	0.69	0.47	0.42	0.89
Würfel_Front_Linie1	0.76	0.43	0.41	0.89
Würfel_Front_Linie2	0.75	0.44	0.38	0.89
Würfel_Front_Linie5	0.67	0.47	0.42	0.89
Würfel_Front_Linie8	0.70	0.46	0.39	0.89

Table 17. Spearman correlation(r_s) between test and retest, VVT 3.0

	r_s
TG	0.52

Note: TG, total group, N = 7

Table 18. Spearman correlation(r_s) between VVT 3.0 and NTBV

	r_s
Concentration/attention	
AKT I	-0.45**
AKT II	0.46**
Digit-symbol(WAIS-R)	0.32**
Symbol counting(C.I.)	-0.40**
TMTB	-0.30**
TMTA-TMTB	-0.24**
Executive functioning	
TMTA	-0.42**
5-Point-Test right	0.33**
5-Point-Test perserveration	-0.05
Maze – Test I(NAI)	-0.34**
Maze – Test II(NAI)	-0.30**
Maze – Test III(NAI)	0.30**
Maze – Test IV(NAI)	0.28**
Stroop I(NAI)	-0.25**
Stroop II(NAI)	-0.30**
Stroop III(NAI)	
Stroop IV(NAI)	
Stroop V(NAI)	0.33**
Stroop VI (NAI)	-0.34**
Interference I(C.I.)	-0.48**
Interference II(C.I.)	-0.33**
Language	
SVT	0.23**
PVT b	0.18*
PVT-f	0.15*
PVT l	0.07
BNT	0.34**
Memory	
VSRT IR	0.38**
VSRT TR	0.46**
VSRT DR	0.42**
VSRT_REC	0.41**

Note: AKT I, Alters-Konzentrations-Test, time, AKT II, Alters-Konzentrations-Test, total/time, WAIS - R, Wechsler Adult Intelligence Scale – Revised, C.I., Inventory of cerebral insufficiency, TMTA,TMTB, Trail Making Test, Maze Test I, time, Maze Test II, mistakes, Maze Test III, total, Maze Test IV, total/time, Stroop I, time(colour), Stroop II, time(words), Stroop III, total/time, Stroop IV, interference, NAI, Nürnberger Aging Inventory, SVT, Semantic Verbal Fluency Test, PVT, Phonematic verbal fluency test, BNT, Boston Naming Test, VSRT, Verbal Selective Reminding Test, VSRT_IR, immediate recall, VSRT_TR, total recall, VSRT_DR, delayed recall, VSRT_REC, recognition; *p < .05, **p <.01 (uncorrected p).

Table 19. ROC Analyses with AUC [95 % Confidence Interval] at optimal Cut-off using highest Youden Index of VVT 3.0

		Cut off	AUC[95% CI]	SE	SP	PPV	NPV	LR+	LR-
TG[1]	AD	69.5	0.79[0.70 – 0.80]	0.84	0.61	0.50	0.89	2.15	0.26
SCD	MCI	70.5	0.62[0.50 – 0.73]	0.55	0.70	0.93	0.50	1.83	0.64
	AD	69.5	0.86[0.77 – 0.95]	0.84	0.74	0.96	0.73	3.23	0.22
	PD	68.0	0.81[0.67 – 0.95]	0.55	0.94	0.92	0.64	9.17	0.48
MCI	AD	65.5	0.81[0.70 – 0.92]	0.65	0.87	0.83	0.70	5	0.40
	PD	65.5	0.70[0.55 – 0.85]	0.55	0.87	0.71	0.72	4.23	0.52
PD	AD	69.5	0.64[0.48 – 0.80]	0.84	0.45	0.70	0.64	1.53	0.36

Note: VVT 3.0, Vienna Visuoconstructional Test, TG[1](N=185), Subjective cognitive decline(n=23), Mild cognitive impairment(n=95) and Parkinson group(n=23) as negative condition, Alzheimer's disease(n=44) as positive condition, AUC, Area under curve; SE, Sensitivity, SP, Specificity; PPV, Positive Predicted Value; NPV, Negative Predicted Value; LR+, Positive likelihood ratio; LR-, Negative likelihood ratio.

Table 20. Demographic and sample characteristics VVT 3.0 (N = 185)

	TG (N=185)	SCD (n=23)	MCI (n=95)	AD (n=44)	PD (n=23)
Female(n/%)	90/48.6	9/39.1	50/52.6	23/52.3	8/34.8
Age	67.7/13.1	62.7/14.4	68.4/10.2	73.3/9	62.3/9.3
Education	12.5/5.2	11.9/3.6	13.6/6.2	11.3/3.5	11/4.2
VVT 3.0	65.4/15.1	73.1/8.1	69.2/11	54.6/19.4	62.8/14.6
WST	110.5/14.6	111.4/11.9	111.7/15.4	102.8/16.7	106.9/11.2
BDI II	10.9/8.9	8.2/8.2	11.6/9.2	13.3/13	9/4.7
GDS	4/3.5	3.4/3.2	4.2/3.7	4/3.2	3.5/3.2

Note: all variables are presented as means & standard deviation; TG, total group, CG, control group, SCD, subjective cognitive decline, MCI, mild cognitive impairment, AD, Alzheimer's disease, PD, Parkinson disease, education measured in school year, WST, Wortschatztest, BDI II, Beck's Depression Inventory, GDS, Geriatric Depression Scale.

Table 21. Kruskal Wallis H Test, VVT 3.0

	Mean rank
	VVT 3.0
	H(3) = 33.2 (p < .01)
SCD	126
MCI	104.4
AD	58.2
PD	79.5

Note: SCD, subjective cognitive decline, MCI, mild cognitive impairment, AD, Alzheimer's disease, PD, Parkinson disease

Table 22. Mann – Whitney U Test VVT 3.0

	Midrange		Midrange	U
SCD	70.7	MCI	56.8	835
	49.9	AD	25.7	139.5*
	29.4	PD	17.6	128.5*
MCI	80.9	AD	46.4	1051.5*
	62.7	PD	46.4	791**
AD	31.1	PD	39.5	378.5

Note: SCD, subjective cognitive decline, MCI, mild cognitive impairment, AD, Alzheimer's disease, PD, Parkinson disease; *p < .01, **p < .05(uncorrected p)

Table 23. Spearman Correlations (r_S) between VVT 3.0 – Scores and variables of interest

	WST	Education	Age	BDI II	GDS
SCD	0.04	0.47*	-0.20	-0.53*	0.36
MCI	0.24*	0.21*	-0.28**	-0.01	-0.01
AD	-0.22	-0.23	-0.01	0.29	-0.20
PD	0.11	0.37	-0.50*	0.11	-0.04
total	0.19*	0.22**	-0.29**	-0.09	-0.10

Note: Note: SCD, subjective cognitive decline, MCI, mild cognitive impairment, AD, Alzheimer's disease, PD, Parkinson disease, 0.10 small, 0.30 moderate, 0.50 large effect size, * $p < .05$. ** $p < .01$. (uncorrected p).

Vienna Visuokonstruktiver Test – 3.0 Screening

Uhr, Würfel und Fünfecke kopieren

Instruktion: **„Bitte kopieren Sie diese Zeichnungen so genau wie möglich. Der Mittelpunkt für die Uhr ist für Sie schon vorgegeben“**

Uhr-Copy

Auswertung (Maximum = 3 Punkte)

Je 1 Punkt für

- Kontur (kreisförmig mit geringer Verzerrung),
- Zahlen (alle Zahlen, in korrekter Reihenfolge und in den entsprechenden Quadranten),
- Zeiger (zwei Zeiger, der Uhrzeit 10 Minuten nach 11 entsprechend platziert, der Stundenzeiger deutlich kürzer als der Minutenzeiger, die Zeiger in der Nähe der Uhrmitte)

Fünfecke

Auswertung für die Fünfecke

Maximum = 3 Punkte, je 1 Punkt für

- 2 fünfseitige Figuren
- Überschneidung der Figuren
- der sich überschneidende Teil hat 4 Seiten

Würfel

Auswertung für Würfel

Maximum = 4 Punkte, je ein Punkt für

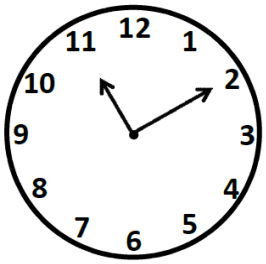
- Dreidimensionalität der Figur
- korrekt orientierte Frontseite
- korrekt gekennzeichnete innere Linien
- die gegenüberliegenden Seiten sind parallel (innerhalb 10°)

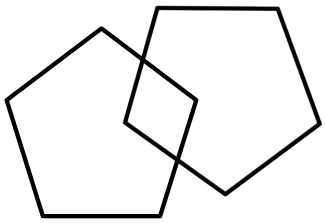
VVT-Screeningscore = Summe aus Uhr-Copy, Fünfecke-Copy und Würfel-Copy

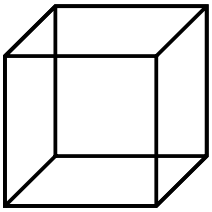
					Summe
Uhr-Copy	Kontur: Ja/Nein	Zahlen: Ja/Nein	Zeiger: Ja/Nein		
Fünfecke-Copy	A: Ja /Nein	B: Ja /Nein	C: Ja /Nein		
Würfel - Copy	A: Ja /Nein	B: Ja /Nein	C: Ja /Nein	D: Ja /Nein	
Total (max. 10)					

Vienna Visuokonstruktive Test (VVT 3.0)

„Bitte **kopieren** Sie diese Zeichnungen **so genau wie möglich**.
Der Mittelpunkt für die Uhr ist für Sie schon vorgegeben“







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