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„The International Neurocognitive Test Profile (INCP): A tablet-based neurocognitive assessment battery - Assessing potential education effects within a pilot study”

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"The vision of the global action plan on the public health response to dementia *[2017-2025]* is a world in which **dementia is prevented** and people with dementia and their carers live well and receive the care and support they need to fulfil their potential with dignity, respect, autonomy and equality."

(World Health Organisation [WHO], 2017, p. 4)

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The International Neurocognitive Test Profile (INCP): A tablet-based neurocognitive assessment battery - Assessing potential education effects within a pilot study

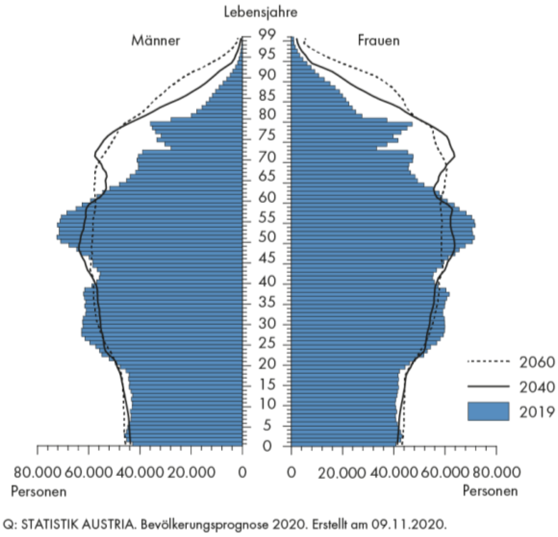
Dementia poses a major public health challenge all over the world, impacting individuals and societies physically, mentally, socially, and economically. As one of the major causes of disability and dependency among older people it poses a big burden for those affected, their carers and families, as well as health and welfare systems. According to statistics published by the WHO in 2020, about 50 million people were living with the diagnosis dementia, while each year there are almost ten million further diagnoses. Nearly 60% of them are living in low- and middle-income countries. The estimated proportion of affected people from the age of 60 at a given time is between 5 and 8%. Internationally, the total number of cases is estimated to reach 82 million by 2030 and 152 million by 2050. Its direct impact on medical and social care costs and costs of informal care was estimated to be US$ 818 billion in 2015, equalling 1.1% of the global gross domestic product (GDP) (WHO, 2020).

In Austria there are currently approximately 115 to 130 thousand people living with the diagnosis. Estimates are predicting more than twice as many cases until 2050 due to the increasing life expectancy, leading to a rising demand for support and care (ÖBIG, 2020). At the same time, less workforce in the care sector will be available due to decreasing birth rates (Oswald et al., 2012). This changing population distribution towards a majority of elderlies (see Figure 1) emphasizes the urgency of the development of proper preventative detection and intervention methods for dementia.

Although a certain amount of cognitive decline comes naturally with ageing, dementia is not a normal part of ageing and has to be prevented (WHO, 2020). Dementia is estimated to start before the age of 65 in between 2 and 10% of all cases and the prevalence doubles every additional five years after that age (WHO, 2012). As a result of higher life expectancy and higher risk of disease, women make up two third of the affected persons according to German statistics (Weyerer, 2005). Overall, some estimates of 2011 even suggested that globally 50 to 80% of all cases of dementia were either not properly diagnosed or never detected at all (Alzheimer's Disease International, 2011).

Figure 1

Development of Austria's Population Distribution in 2019, 2040 and 2060 (Statistik Austria, 2020)



During the past 15 years the conception of Alzheimer's disease has shifted to considering the disease as a continuum (Dubois et al., 2016). Substantial findings and evolving biomarker research have enabled the identification of the disease years or even decades before the onset of first clinical symptoms. The focus on the preclinical stage in dementia research offers potential, as early interventions are expected to lead to the greatest therapeutic success (Dubois et al., 2016). However, the biomarkers still need scientific evaluation (Rostamzadeh & Jessen, 2021) and it is challenging to distinguish normal from pathological processes in neuropsychological practise (Lehrner et al., 2011).

To sum up, with the large number of people affected worldwide, proceeding demographic change, unclear aetiology, and no existing effective treatment or cure, dementia is to be faced as a central concern of public health. Prevention or delay of the onset of cognitive decline are expected to be possible by minimising the exposure to common risk factors, and performing early detection and interventions (Rasmussen & Langerman, 2019). Physical, emotional, and financial pressures pose great stressors to the families and carers, and additional support from health, social, legal and financial systems is needed (WHO, 2020). Thus, patients as well as their carers, and healthcare and welfare systems, can benefit from the development of early detection methods. Neuropsychological test batteries have shown to be able to distinguish between subtle cognitive impairment and healthy individuals (e.g. Tierney et al., 2014). Furthermore, over the past decades computerized cognitive assessment tools have grown in popularity and are now a substantial part of managing dementia. In addition to that, there has been a growing general interest within society for monitoring one's own cognitive state (Lehrner, 2021).

As response to these issues, one of the leading clinical research institutions in Austria, the Medical University of Vienna, has conceptualized a neurocognitive assessment battery under the lead of Dr. Johann Lehrner – the International Neurocognitive Test Profile (INCP). The tablet-based neurocognitive assessment tool has been developed for regular self-monitoring of the cognitive status in order to efficiently identify early cognitive changes in individuals. The aim of this study is to contribute to the current evaluation and development of the third version of the INCP by assessing potential effects of education on the test performance.

Theoretical & Empirical Background

Dementia & Cognitive Decline

ICD-10 Definition

The ICD-10 (International Statistical Classification of Diseases and Related Health Problems) developed by the WHO defines dementia as follows:

> Dementia is a syndrome due to disease of the brain, usually of chronic or progressive nature, in which there is disturbance of multiple higher cortical functions, including memory, thinking, orientation, calculation, learning capacity, language and judgement. Consciousness is not clouded. Impairments of cognitive function are commonly accompanied, and occasionally preceded, by deterioration in emotional control, social behaviour or motivation. This syndrome occurs in Alzheimer's disease, in cerebrovascular disease, and in other conditions primarily or secondarily affecting the brain. (WHO, 1992, p. 42)

According to the ICD-10 the diagnosis dementia with the code F00-F03 consists of four subcategories: Dementia due to Alzheimer's disease (F00), vascular dementia (F01), dementia with elsewhere classified diseases (F02), such as primary Parkinson syndrome, Chorea Huntington, HIV-disease and not closer described dementia (F03) (Deutsches Institut für Medizinische Dokumentation und Information [DIMDI], 2019). Alzheimer's disease (AD) is the cause for around 60-80% of the dementia cases, followed by vascular dementia (15-20%), and dementia with Lewy-Bodies (7-20%). Other forms of dementia are rare (under 10%), however, boundaries are indistinct and mixed forms are common (Österreichische Alzheimer

Gesellschaft [ÖAG], n.d.). Other causes for organic brain diseases such as alcoholism, endocrine decompensation, medications, drugs, traumatic brain injury or hypoxic encephalopathy after cardio-pulmonal reanimation have to be excluded (Lehrner et al., 2011).

DSM-5 Definition

The Diagnostic and Statistical Manual of Mental Disorders 5 (DSM-5) (American Psychiatric Association [APA], 2013) rather focusses on the observation of the development of multiple cognitive deficits which have to be included in memory dysfunctions. Those deficits must be severe enough to limit social and work skills and remain for at least six months. The manual states the following criteria for the diagnosis of AD:

1) Memory impairment (impaired ability to learn new information or to recall previously learned information)
2) Aphasia and/or apraxia, agnosia or an impairment in executive functioning
3) Deficits must include a significant impairment in social or occupational functioning and represent a decline from a previous level of performance (e.g. not able to take a shower on your own)
4) The course of the disease is characterized by gradual onset and continuing cognitive decline
5) The cognitive impairments in 1) and 2) exclude other psychiatric disorders or neurological explanations for the decline of function
6) The cognitive impairments do not only occur during the course of a delirium

Differentiation from Pseudo-Dementia & Delirium

There are syndromes involving similar symptoms as dementia: Around 10% of patients with suspected dementia in fact suffer from so called *pseudo-dementia,* a cognitive impairment due to a mental, non-organic disorder (Fischer et al., 2002). Depressive pseudo-dementia is the most common form which often comes with memory deficits due to dysfunctional attention and concentration caused by the depression. With older age and milder symptoms, the differential diagnosis becomes even harder. The standard international procedure is anti-depressive treatment with further observation for at least three months. This therapy is supposed to improve the cognitive symptoms as well (Lehrner et al., 2011).

Furthermore, the consciousness of patients with dementia is ordinary as they are alert and react adequately to environmental stimuli in contrast to delirious patients. The differentiation between dementia and delirium can be challenging, especially in patients with only mild pre-delirious disorders. Patients with decreased attention are distractable but still alert. An efficient method to measure attention is the repetition of numbers or letters. With an average baseline intelligence, patients with mild dementia should still be able to repeat letters and numbers in correct order. Immediate and fluctuating confusion (especially when getting stronger at night-time), hallucinations, tremor, psychomotor hyperactivity or apathy are further clinical symptoms of delirium. Patients with AD and somatic comorbidity and/or intake of psychotropic drugs, anticholinergic or anti-Parkinson medications are especially vulnerable for delirium (Lehrner et al., 2011).

Comorbidities of Dementia

The most common comorbid diseases and symptoms with dementia are delirium (35-82%), limited vision (40-65%), limited hearing ability (55-80%), pain (49-83%), depression (15-55%), malnutrition and dysphagia (10-60%), hyponatraemia (5-30%), diabetes (16-21%), cardiovascular diseases and anaemia (15-70%), polypharmacy with anticholinergic acting medication (18-45%), and polypharmacy with benzodiazepine (16-21%) (Gebhard & Mir, 2019). Due to limited cognitive and verbal abilities, these additional physical symptoms often remain undiscovered, however, detecting and understanding them is crucial to understand possible early signs of dementia and certain behaviours in dementia, such as aggressivity, hallucinations, or refusal to eat (Kratz, 2017).

Stages of Dementia

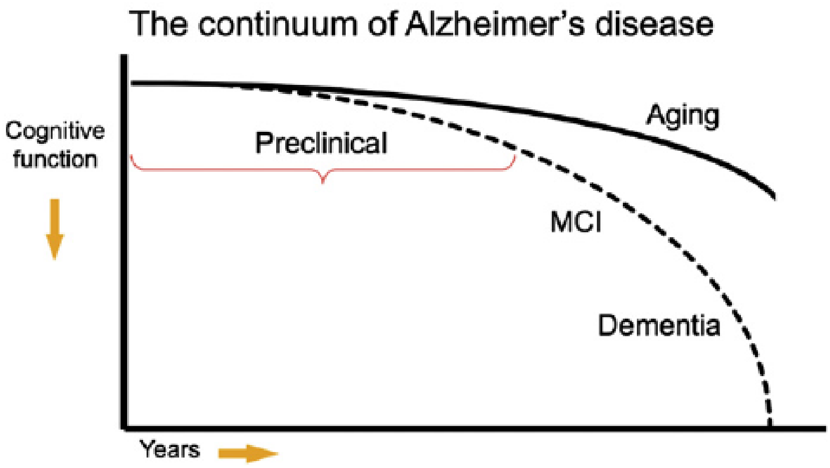
Detection of subtle cognitive decline in early stages can be very challenging because distinct clinical symptoms are not yet observable (F. Jessen et al., 2014). However, it would be crucial for the future to enable sensitive early detection as findings suggest that there is already progressed brain damage at the time of the diagnosis (Rostamzadeh & Jessen, 2021). The advancement in the research of biomarker-based early detection supports the hypothesis that AD is an insidious, progressive disease with an onset years or even decades before the actual dementia (Hall et al., 2000). Thus, within the past 15 years the conception of AD has shifted to considering its development on a continuum from cognitive health to dementia (Dubois et al., 2016)

AD is defined by neuropathological changes involving extracellular Beta-amyloid (Aβ) plaques and intracellular neurofibrillary tangles consisting of the Tau-protein, which are detected by autoptic-histological tests. According to the amyloid cascade hypothesis Aβ-plaques are toxic and lead to changes in tau causing entanglement, synaptic damage and neuronal cell death (Dubois et al., 2016). However, due to Rostamzadeh and Jessen (2021) these biomarkers still need scientific evaluation.

Jessen and colleagues (2014) have suggested a three-stage model for the development of AD (see fig. 2), which involves symptoms and biomarker evidence and can be generalised to all types of dementia:

Figure 2

The clinical Trajectory of Dementia/Alzheimer's disease (AD) (Sperling et al., 2011).



1. The Pre-Clinical Stage of AD. In the pre-clinical stage *Subjective cognitive decline* (SCD) can be present, which means that the individuals themselves perceive a constant decline of their cognitive abilities in any domain. At the same time no objective symptoms are observable yet and performance in standardised assessments is usually intact as this stage is associated with at least partly successful compensation (Frank Jessen et al., 2020). SCD alone, however, is not sufficient for a diagnosis of preclinical AD, as the preclinical stage is by definition a biomarker diagnosis. SCD is neither required for the diagnosis nor does it necessarily have to be present in all cases of preclinical AD (F. Jessen et al., 2014). The results of a meta-analysis by Mitchell and colleagues (2014) show that 14% of the individuals with SCD proceeded to dementia and the probability of developing dementia is twice as high with SCD than without SCD.

Jessen and colleagues (2020), however, claim that SCD is unspecific in cognition and cannot be adduced as an indicator for future cognitive impairment in the majority of persons.

They further state that there can be various medical causes for SCD other than AD. It can be related to conditions such as normal aging, psychiatric disorders, neurological and medical disorders, personality traits, substance use, medication, and possibly cultural background as well. Due to Jessen and colleagues (2014) effective treatment at this stage would maintain cognitive function at a high level, emphasising that further research with focus on the preclinical stage of AD is needed. They have addressed the issue of heterogenous definitions and high variations in conception and assessment of SCD by proposing criteria for consistent usage of SCD in research and practice.

2. The Prodromal Stage of AD: Mild Cognitive Impairment. In the prodromal stage *Mild cognitive impairment* (MCI) with objective cognitive impairment in at least one of the six cognitive domains (memory and learning, language, executive function, perceptual-motor function, social cognition, complex attention) is observable. Thus, patients show divergent performance in standardised neuropsychological tests while activities of everyday life, like bathing or dressing, are fundamentally intact (Dubois et al., 2016). Additionally, on the physiological level biomarker evidence for AD and pathological neuronal changes in brain imaging methods are already observable. Nevertheless, the impairments are not yet severe enough for a dementia diagnosis (Rostamzadeh & Jessen, 2021). With MCI the improvement of cognitive functions with complete remission as well as progression to dementia is possible (R. C. Petersen, 2004). Biomaker-based evidence enables to differentiate between MCI-patients according to their risk of developing dementia. In contrast, the use of biomarker-determination is not yet recommended in SCD due to the unclear data situation (Rostamzadeh & Jessen, 2021).

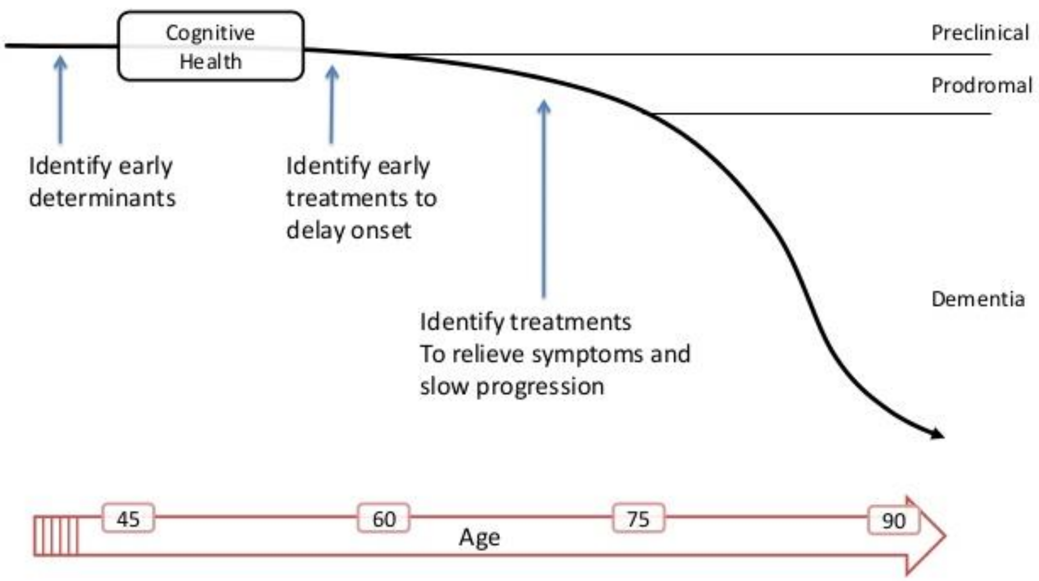
The observed annual conversion rate from MCI to dementia is approximately between 5 and 10% and the majority of cases will not proceed to dementia even after 10 years of follow-up, while the overall risk of developing dementia after MCI within 3 years after a MCI-diagnosis is around 33% (Mitchell & Shiri-Feshki, 2009). In the meta-analysis of Mitchell and colleagues (2014) 24.4% of individuals with SCD developed MCI within about 5 years.

However, MCI is a heterogenous syndrome with various possible causes (Rostamzadeh & Jessen, 2021). It can be divided in an *amnestic* (aMCI) and *non-amnestic* (naMCI) form. The amnestic subtype comes with a deficit in episodic memory functions. The non-amnestic form comes with language-related, visuospatial or executive impairments. In both subtypes either a single or multiple cognitive domains can be impacted (Rostamzadeh & Jessen, 2021). aMCI has been the focus of AD research and is more frequently reported (C. Petersen, 2011). Petersen (2004) mentioned the following criteria for the diagnosis of aMCI: Memory complaint usually corroborated by an informant, objective memory impairment for age, essentially preserved general cognitive function, largely intact functional activities and not demented. MCI can further be divided into *single-domain MCI* with deficits in one cognitive domain (memory in aMCI or one domain within naMCI) and *multiple-domain MCI* where various mild cognitive deficits including memory functions are present (Dubois et al., 2016).

3. Dementia due to AD. The third and last stage of the model is marked by biomarker evidence as well as symptoms of dementia due to AD for example. In this phase patients show clear restrictions in everyday life and are generally no longer able to live independently. The neurodegenerative disease comes with a progredient restriction of memory, cognition, orientation, language, attention, perception and reasoning (Rostamzadeh & Jessen, 2021).

Figure 3

The Challenge of the Progression of Dementia (Gallacher, 2015)



To sum up, the findings on the preclinical phase of AD emphasise the need for subjective reports of affected individuals in early stages especially. Figure 3 again emphasises the general importance of early detection and early interventions in the progression of pathological cognitive decline in contrast to normal aging processes. Early detection and following interventions can slow the progression and relieve the symptoms of dementia in the preclinical phase. Thus, the challenge of the subtle distinction between normal ageing and early pathological states which is supposed to be harder than distinguishing MCI from dementia (R. C. Petersen, 2004) has to be addressed in neuropsychological research an practice.

Treatment of Dementia

Early therapeutic interventions can improve cognitive function, treat depression, improve caregiver mood and eventually delay institutionalisation (Alzheimer's Disease International, 2011). However, treatment at later stages of incurable neurodegenerative diseases, such as AD, has found to be extensively unsuccessful to date (Rostamzadeh & Jessen, 2021). Restoring of lost cognitive functions is mostly not possible anymore, but there are still improvements in sub-areas possible. The main focus of clinical-psychological therapy lies then on compensation mechanisms, application of aids and increased usage of existing cognitive resources (remote memory, automatisms) and specifically developed combined programs for dementia. In the case of severe advanced dementia these methods become replaced by creative therapies, such as music therapy or arts therapy, and emotionally oriented therapies (with children, plants, or animals) with the purpose of improving the patients’ and carers’ wellbeing and quality of life (Lehrner et al., 2011).

Medical treatment of cognitive disability in dementia is currently available. As the effects are very individual, careful discussion and assessment of cognitive and non-cognitive changes with the patients and their dependents after at least three months is necessary. Possible medications are cholinesterase inhibitors which significantly improve cognitive function in patients with mild or moderate dementia. Furthermore, Memantin, a Glutamate receptor antagonist, has shown to significantly improve the global clinical status, cognition, and daily activities in progressed dementia. In general, due to the variation of symptoms in every single patient individual, multi-modal oriented therapy is crucial. Those medications, however, only treat the symptoms, not the cause neither decelerate the progression (Lehrner et al., 2011). According to the WHO (2019) pharmacological interventions should not be routinely considered and psychosocial interventions should be the frontline therapy in demented patients.

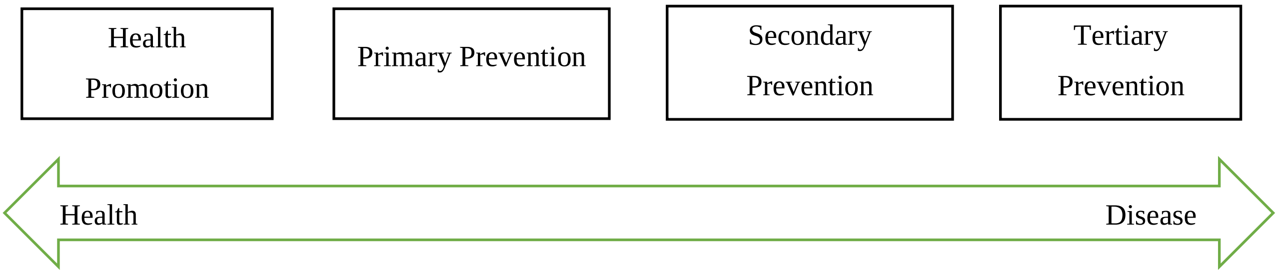
Thus, the insufficiency of efficient treatment methods further emphasises the importance of preventative approaches in assessment and interventions. In order to address the early onset, it is necessary to integrate preventative measures, such as psychoeducation and regular monitoring, in different stages and areas of health care.

Prevention of Cognitive Decline & Dementia

The aim of prevention is to avoid diseases and their negative effects, focussing on specific diseases. Prevention is divided in *primary*, *secondary* and *tertiary* preventative implementations (Caplan, 1964).

Figure 4

Alignment of Health Promotion and Prevention on the Health-Disease Continuum (own German-English translation out of Brinkmann (2014))



Primary Prevention. Primary preventive measures aim to reduce the incidence of diseases throughout the population. This involves measures such as laws for environmental standards for the industry, vaccinations and free preventive check-ups through a legal health insurance. Health psychology involves preventative measures targeting behaviour-related strategies to reduce disease-related risk factors. This involves, for instance, programs aiming to educate about risks of smoking or protective factors of a healthy diet (Knoll et al., 2013).

Protective and Risk Factors of Cognitive Decline. In the case of cognitive decline and dementia primary prevention mainly involves the reduction of possible risk factors and encouragement of protective factors. Due to the findings regarding the prolonged preclinical period of AD/dementia, research has increasingly focused on preclinical forms and risk factors for the development and progression of the disease (Clouston et al., 2020). In order to set proper preventative measures at any stage, it is essential to define specific factors which affect the development of the dementia.

As the origination of the disease has not been researched sufficiently, interventions broadly target the change in lifestyle, such as a low-fat, high-vitamin and high-fibre diet, regular physical activity, avoidance of smoking, alcohol consume, and over-weight (Kurz, 2013). Overall, Hussenoeder and Riedel-Heller (2018) suggested in their meta-review, which was based on systematic reviews and meta-analyses of many longitudinal observational studies, that protective factors such as physical activity, social interactions, a cognitively active lifestyle, a Mediterranean Diet, non-smoking and mental demands at work should be addressed in primary prevention. Risk factors such as heavy drinking, associated chronic conditions such as hypertension, type 2 diabetes, obesity, hearing loss, traumatic brain injury (TBI) and depression should be targets of public brain health agendas. The WHO (2020) released guidelines on risk reduction of cognitive decline and dementia which provide evidence-based recommendations on interventions to decrease those risk factors. They recommend regular medical check-ups to control conditions such as hypertension and diabetes which are linked to dementia illness.

Social contacts play a crucial role in compensating cognitive deficits of dementia as they offer proper social support and stimulate cognitions and emotions (Laske, 2007). Furthermore, education has already long been associated with a smaller risk of dementia (Stern et al., 2020) and increased cognitive function in general (Ceci, 1996). Clouston and colleagues (2020) concluded that the onset of severe symptoms of dementia is expected to be delayed by 2.30 years with an additional four years of a university degree at age 60, equalling 0.575 years per year of formal education. These results raise the expectation that higher educated persons globally have more compensation and adaption techniques in order to adjust to the early symptoms. As soon as the symptoms are stronger and visible, the progression of the disease then occurs faster though. According to these findings the detection of preclinical cognitive decline might be harder in higher educated persons because there are less objectively observable early symptoms. Thus, on one side education is expected to delay the onset of severe symptoms, giving the person more time without early symptoms, nevertheless earlier detection and thus early interventions are harder to implement.

Therefore, it is questionable whether education is to be seen as a direct protective factor for dementia. However, other protective factors such as a better health-related behaviour (Schrotter, Rieder & Dorner, 2013 cited in Müllegger, 2015; Mirowsky & Ross, 2003), better overall health status (Statistik Austria, 2009; Statistik Austria/BMGFJ – Bundeministerium für Gesundheit, Familie und Jugend, 2008) and increased life expectancy up to seven additional years (Mackenbach et al., 2008) are often associated with higher education. This education-caused health divergence in fact was found to increase with age (Leopold & Engelhardt, 2011 cited in Müllegger, 2015), emphasizing the need for lifelong education across all classes of population.

Preventative Interventions. For the purpose of avoiding or delaying the onset of cognitive dysfunction in older age specific, mostly verbally oriented trainings for vulnerable functions, such as speed functions, memory and flexibility of cognitive processes in daily life are available. Cognitive training programs in combination with physical training have been shown to effectively prevent dementia (Oswald et al., 2012). Additionally, specific consultation concerning the aging process and training of cognitive, physical and social functions is essential in order to avoid cognitive decline and maintain cognitive competences. Examples for neuropsychological approaches are training programs like memory training within the SIMA-project or computer-based training programs such as REHACOM or COGPACK (Lehrner et al., 2011). Studies have shown that improvement of the overall quality of life in old age affects the cognitive and physical process of ageing by addressing unspecific cognitively stimulating activities (e.g. Oswald et al., 2012; Wilson et al., 2002).

All in all, preventative measures can be summarized under the slogan “Use it or lose it!” (Lehrner et al., 2011). The known preventive possibilities should already be fostered in middle age. Synergic effects between the single measures are expected and many of the measures such as physical activity and a healthy diet contribute to healthy aging in general and are associated with higher life expectancy. Prevention relies on the individual’s personal responsibility and the motivation for healthy aging itself constitutes an important resource in this context (Laske, 2007). Because the INCP is designed to monitor the cognitive status of healthy individuals, it is a primary preventative instrument. It aims to detect cognitive variations or decline in the preclinical phase of possible dementia in order to set preventative measures and keep observing the development of cognitive functions.

Secondary Prevention. Secondary prevention, however, starts in the early stages of a disease aiming to decelerate the progression, reduce the duration, or avoid worse secondary diseases. A popular secondary preventative measure are screening-tests, for example for detection of cancer (Knoll et al., 2013). Early detection and treatment of behavioural and psychological symptoms must be considered to improve the patients’ and carers’ overall wellbeing. Additionally, information about the disease and long-term support for carers should be provided (WHO, 2020).

Tertiary Prevention. Tertiary prevention includes rehabilitative measurers to avoid complications in severe illnesses and minimise handicaps in everyday life. This involves, for instance, physiotherapy and psychological support for chronically ill people, such as stress management and psychoeducation (Knoll et al., 2013).

WHO Dementia Prevention Initiatives. Beyond research it is the responsibility of public health institutions worldwide to raise awareness for the disease itself and to address its possible protective and risk factors. In 2017, the WHO has recognized dementia as a public health priority by publishing the *Global action plan on the public health response to dementia 2017-2025* (WHO, 2017) with certain goals for policy makers internationally, nationally and regionally. Its overall vision is the following:

> The vision of the global action plan on the public health response to dementia is a world in which dementia is prevented and people with dementia and their carers live well and receive the care and support they need to fulfil their potential with dignity, respect, autonomy and equality." (WHO, 2017, p. 4)

Thus, the main points are enhancing the awareness of dementia, establishing dementia-friendly initiatives as well as reducing the risk of dementia. In specific, these aspects include diagnosis, treatment and care, support for carers, the development of information systems for dementia, and research and innovation in this field. The development of the INCP as primary preventative assessment tool addresses the points of diagnosis, research, innovation and eventually also reducing the risk of dementia. Up to date, the common case is a clinical diagnostical process when severe symptoms are observed. Thorough clinical diagnostics by different occupational groups plays a crucial role in the case of cognitive decline.

Dementia Diagnostics

The development of brain imaging techniques, like magnetic resonance (MR), computerized tomography (CT), and positron emission tomography (PET) in the past 30 years has enabled the detection of preclinical brain variations. Adequate diagnosis and treatment of individuals at-risk require biomarkers which reveal preclinical changes of the brain (Dubois et al., 2016). Neuropsychology in addition enables the detection of cognitive-behavioural changes by assessing cognitive performance and the mental state (Lehrner et al., 2011). At present, three common approaches are used for the diagnosis of Alzheimer's disease (Oedekoven & Dodel, 2019): the NINCDS-ADRDA (McKhann et al., 1984), ICD-10 (WHO, 1992), and DSM-5 (APA, 2013). In the present study, the assessment of cognitive decline is based on the DSM-5 criteria with focus on the six neurocognitive domains.

The general diagnostical process of dementia involves the following steps (Hartje & Poeck, 2006):

1) Personal history of the patient + external anamnesis
2) Neurological and psychiatric status
3) Blood tests
4) Cerebrospinal fluid testing (CFU)
5) Neuroimaging, like MRI or CT
6) Neuropsychological evaluation

Neuropsychological Diagnostics. The core of neuropsychological diagnostics is to qualitatively and quantitatively assess and objectively describe the cognitive and affective functions due to acquired brain damage or brain dysfunction (Willmes & 2003). For this psychological diagnostics and specific neuropsychological methods are used in addition to medical information (including neurology, neuroradiology, psychiatry or internal medicine). Since the development of imaging procedures, such as EEG, CT, PET, and MRI, the tasks of neuropsychological diagnostics have changed from differentiating between persons with and without brain diseases to precise assessment of cognitive and affective functions, objectification of functional disabilities, follow-up examination and evaluation of rehabilitative measures (Sturm et al., 2009). The diagnostical process is goal-oriented, hypothesis-based, individually and flexibly adapted to the situation of the patient. All dimensions of functional health of the WHO-classification of ICF (DIMDI, 2005) and interactions between them are considered: health problems (health dysfunction, disease), body functions and structures, participation in activities, environmental and personal factors (Lehrner et al., 2011).

Possible neuropsychological screening tools used in Austria are for example the Mini-Mental-Status-Test (MMSE), the clock test („Uhrentest“), the DemTec, the Montreal Cognitive Assessment (MOCA), Vienna Visuo-Constructive Test (VVT 3.0) or the Parkinson Neuropsychometric Dementia Assessment (PANDA). The next steps are elaborated clinical scales, cognitive test batteries, psychopathological questionnaires (such as GDS or BDI) and questionnaires to assess behaviour and daily functions (such as B-ADL, FAST) (Lehrner et al., 2011). The neurocognitive assessment is the basis for further treatment choices and should:

- quantify the cognitive profile
- differentiate between normal and pathological changes
- exclude various differential diagnoses (especially depression)

- assess daily living skills, independence and judgement
- evaluate therapy efficiency

The aim is then to further determine possible pathological levels and to differentiate the symptoms from depression or pseudo-dementia (Hartje & Poeck, 2006).

Early Detection of Cognitive Decline. With the progression of dementia and increasing cognitive impairments, the ability to cope with more complex tasks in everyday life is decreasing (Rostamzadeh & Jessen, 2021). To reduce the negative impact on both the individuum and the society early diagnosis and following earlier interventions are of utmost importance to diminish the ‘treatment gap’ the disease onset and received support. In order to enable diagnosis at earlier stages, assessment tools should be sensitive enough to distinguish between normal cognitive status and pre-clinical cognitive impairment. The increase of affected patients and simultaneous restricted health care resources emphasize the need of the development of efficient and easy-to-use tools.

Another issue of concern in this field is the requirement for cognitive assessment over time. Frequent neurocognitive check-ups allow the monitoring of the progression of cognitive functions. They enable the detection and determination of progression of impairment, efficacy of treatment and evaluation of therapeutic research interventions. Additionally, frequent check-ups for cognitively still healthy people are essential to sensitively monitor the development of their overall cognitive functions and reveal possible areas which require further observation or training. Thus, this repetitive assessment design may help to better understand the transition from cognitive fitness to SCD, MCI and ultimately dementia.

Tablet-based Testing. To address the issues of efficiency, easy operability and sensitivity of testing Sabbagh et al. (2020a, 2020c) suggested the development of a tablet-based self-administered neurocognitive test battery. Online testing, in particular, provides a quick generation and analysis of data and immediate feedback to the participants, clinicians, and researchers (Possin et al., 2018). Computerized cognitive testing has already been available for years and associated with precise standardization of administration, presentation of stimuli, and reliability concerning the measurement of response latency (Gates & Kochan, 2015; Wild et al., 2008). Some computerized, self-administered tools have already been found to successfully distinguish between MCI and healthy individuals demonstrating potential for implementation in a primary setting with completion times of 30 minutes at the maximum (Tierney et al., 2014): The NIH toolbox Cognitive battery (Kahsay et al., 2019) is a self-administered 30-minute battery measuring memory, language, attention and executive functions. Additionally, the

Philadephia Cognitive Exam (P-Cog; (Weisman et al., 2015), a short screening test with less than 4 minutes completion time, is supposed to sensitively and specifically classify healthy cognition, MCI and dementia. The Cognitive Assessment for Dementia I-Pad (CADi; (Onoda et al., 2013) is another tablet-based cognitive test battery assessing memory, visuo-spatial abilities, attention and executive functions, which has been found to be reliable and valid for dementia screening in a Japanese sample.

In comparison to a standard computer with a mouse and keyboard, tablets may be better to use as touchscreens have been argued to be more intuitive for seniors aged 60 or older, allow more mobility in testing and thus lead to increased patient compliance (Werner et al., 2012). Further benefits of a home-based testing situation would be less travel times and nervousness due to unpleasant testing situations. This leads to the conclusion that a home-based self-monitoring testing tool would be the most efficient way of screening a large number of people for possible early cognitive decline.

Furthermore, Tsoy et al. (2020) have found the implementation of three tablet-based self-administered measures for the assessment of cognitive decline to be feasible and reliable, even in participants without prior experience with technology. As response to this paradigm shift, an international working group, the Global Advisory Group on Future MCI Care Pathways, convoked to discuss the optimal integration of digital tools in diagnostic pathways of AD. It argues for an implementation of large-scale cognitive evaluation within primary medical care (Sabbagh, Boada, Borson, Chilukuri, Dubois, et al., 2020).

To sum up, new cognitive assessment tools should be computerized even better tablet-based to meet the needs for efficiency, easy operability, frequency of application, and sensitivity. The test batteries should be developed on the basis of an unlimited source of comparable tests which are ideally not limited by language or culture. In addition to that, they should be highly accurate, precise, and reliable with progressive improvement (Possin et al., 2018).

The International Neurocognitive Test Profile (INCP) 3.0

In response to these issues, the *International Neurocognitive Test Profile (INCP)*, a tablet-based self-administered neurocognitive test battery, has been developed at the Medical University of Vienna, under the lead of Dr. Johann Lehrner (neuropsychological department). The software development for the tablet-application has been carried out by *Psimistri – Global Psychometric Test and Intervention Systems* (www.psimistri.com). At present, the test battery is in its third version and under interim evaluation in German language.

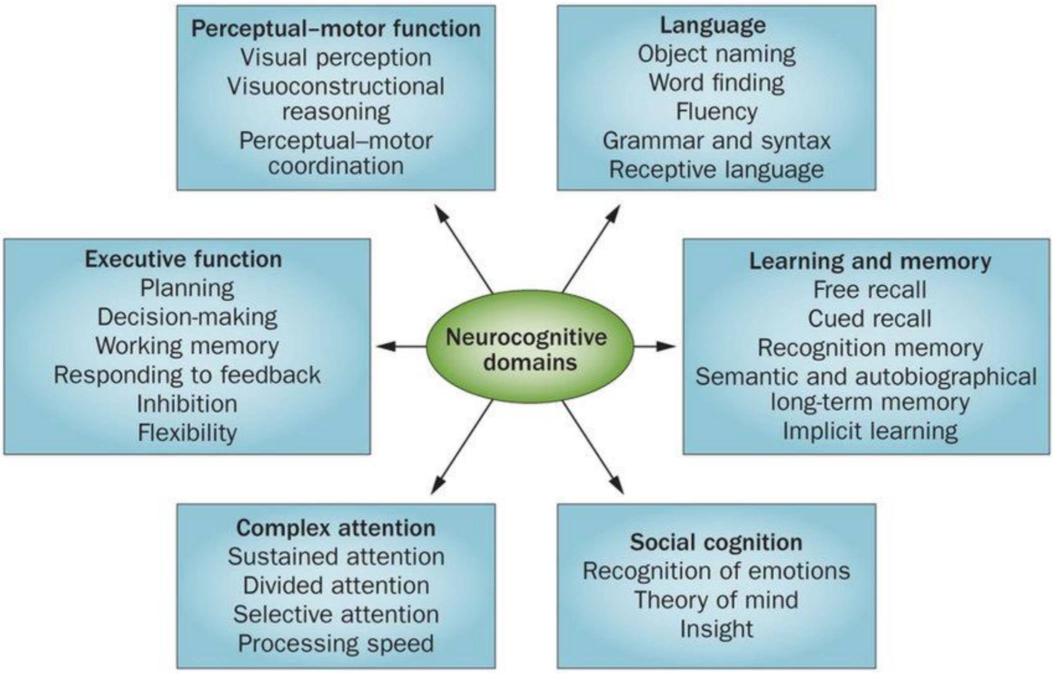
The INCP currently consists of 17 subtests which aim to assess cognitive impairment and be sensitive enough to detect the stages of SCD and MCI. The subtests have been newly developed for the tablet-format. The goal is to implement a self-monitoring instrument which is used to observe the development of the cognitive status autonomously over time at home. The target group are cognitively healthy individuals who are keen on regularly monitoring their cognitive functions. The intention is to perform a detailed baseline assessment of the cognitive status and a follow-up assessment after one year in a primary health care setting (either at a general practitioner or psychologist). In the meantime, a shorter cognitive test battery is supposed to be carried out ideally monthly at home. In addition to that, the aim is to implement a traffic-light system to give immediate feedback concerning the cognitive development based on specific cut-off values. This kind of self-monitoring is comparable with preventative monitoring of blood pressure with the purpose of detecting abnormalities early enough.

Assessed Six Cognitive Domains

The fifth and current edition of the Diagnostics and Statistics Manual of Mental Disorders (DSM-5; (APA, 2013) offers a framework for a standardised diagnosis of neurocognitive disorders. It is based on three syndromes: delirium, mild neurocognitive disorder and major neurocognitive disorder. Major neurocognitive disorder is mostly synonymous with dementia, yet impairments in learning and memory are not required for the diagnosis. In the broad range of neurocognitive disorders people show a clear decline from a previous level of functioning at least one of the key cognitive domains. The DSM-5 defines six main cognitive domains with several subdomains each: perceptual-motor function, language, learning and memory, social cognition, complex attention, and executive function (see fig. 5). In order to deduce the causes of the symptoms and severity of a neurocognitive disorder, it is essential to identify the affected domains and subdomains. Thus, the structure for diagnosing mild and major neurocognitive disorder is the same with a difference in severity of deficits and impairment (Sachdev et al., 2014). This domain concept should enable testing of individuals with more varied patterns of impairment leading to information about preclinical states of other types of dementia besides the common AD. Furthermore, in the INCP many parallel versions of subtests are supposed to minimize learning effects and decrease the attrition of patients.

Figure 5

Six neurocognitive domains & subdomains according to DSM-5 (Sachdev et al., 2014)



Cognitive screening tools and depression questionnaires are used to exclude cases of cognitive impairment and pseudo-dementia. In general, the test performance in mild neurocognitive impairment should be between 1-2 standard deviations below the normative mean or between the third and 16th percentiles in standardised tests. However, the DSM-5 does not regulate which kind and number of tests are supposed to be performed per cognitive domain. Yet the requirement is an objective demonstration of cognitive deficits in some form. As mild neurocognitive disorder must be distinguished from normal cognitive ageing as well as major neurocognitive it is more strongly reliant on neuropsychological assessment than major neurocognitive disorder. In order to assess decline, serial assessments might be required while it is important to consider practise effects, the lack of normative data on cognitive decline and variable test-retest reliability (Ganguli, 2013).

Evaluation & Pilot Study Design

Due to the fact that the INCP is still in further development and under interim evaluation, the current study represents the character of a pilot study. The process involves constant content-related and formal adaptions due to additional subtests, errors or to simply improve the operability of the screening tool. All participants were asked to give feedback after completing the study for the purpose of involving first-hand experience and opinions in the development process. A pilot study character usually implies a small feasibility study which is conceptualised in order to test various aspects of a new method or treatment designed for a larger, more detailed, or confirmatory investigation in the future (Arain et al., 2010). Instead of answering specific research questions right away, the main purpose is to prevent research from running a large-scale study without adequate knowledge of the methods proposed. Generally, the aim is to evaluate the quality and appropriateness of planned methods and procedures (Polit & Beck, 2017). This means to answer questions like: *Is a psychometric instrument appropriate (valid and reliable) for use in the target population under certain proposed circumstances?* An adaptive trial design allows prospective, concurrent or retrospective modifications in the study design or statistical procedure. This enables the efficient identification of clinical benefits to enhance the likelihood of successful clinical development (Chow & Chang, 2008).

The pilot study design may also support the identification of potential previously unknown confounding variables and the evaluation of the strength of relationships among key variables in order to facilitate the calculation of the required sample size (Polit & Beck, 2017). In general, well-planned and -executed pilot and feasibility studies are supposed to generate lessons to inform subsequent studies, instead of leaving more question (Lowe, 2019). As the subtests of the International Neurocognitive Test Profile have been newly developed and not yet been evaluated, a first explorative evaluation is needed in order to set further steps until its eventual implementation in practise. In this first analysis the impacts of factors such as age, gender, and education are further investigated to evaluate the validity of the assessment tool. The present study focusses on the impact of years of formal education on the performance in each subtest of the neurocognitive test profile.

Education as a potential Factor of Influence

Education is a common variable to show an impact on the achieved results in psychological testing. The level of education has shown to be significantly negatively related with general completion time in a psychological tablet assessment, which may be related to less familiarity and comfort with tablet computer among older adults with lower education (King et al., 2017). Results from a Diploma thesis (Garcia, 2020) suggest that IQ and duration of education are positively correlated with the performance in the subtests of the Neuropsychological Test Battery Vienna (NTBV). Heidinger & Lehrner (2020) have investigated the effect of education on the INCP's subtests Flag Knowlegde (FK) using visual input, and Capital Knowledge (CK) using semantic input. They found a significant effect of duration of education on semantic memory measures, while there was no significant effect on incidental memory measures. However, due to the small and well-educated sample the explanatory power of this study is limited. Additionally, years of education were found to be correlated with the performance in the CITY test, while such association was not found with the FACE test (Lehrner et al., 2017). Furthermore, education was found to be a significant estimator for the CITY test results with 0.28 points more per additional school year, however, this was not the case in the FACE test (Holzer, 2021).

In a sample of younger HIV+ Zambians, higher education was found to show protective effects on overall neurocognitive functioning, and for the specific domains of learning, information processing speed and executive functions (Kabuba et al., 2018). Schneeweis et al. (2014) have found a positive impact of years of schooling on memory performance (memory, fluency, numeracy, and orientation-to-date) in a European longitudinal study, with an increased score by 0.2 per additional year of education. A systematic review lead to the conclusion that education shows a robust positive association with the level of cognitive performance, however, this association could not have been confirmed yet with changes in cognitive performance over time (Seblova et al., 2020).

In a study by Elias et al. (1997) a decreasing education level was associated with lower performance in every neurocognitive assessment of a neuropsychological test battery (Kaplan-Albert), consisting of subtests from the original Wechsler Adult Intelligence and Memory Scales and the Benton and Hamsher Aphasia Examination. They also found that education was the cause for a larger percentage of variances than age or gender in various tasks (Logical Memory, Similarities, Word Fluency, Logical Memory-Delayed, Digit Span Forward, Digit Span Backward, the Learning and Immediate Recall composite, and the Attention and Concentration composite), emphasizing the need for the assessment of education effects. Furthermore, Berggren et al. (2018) have found a significant impact of education on most neuropsychological functions, and in specific on high-attention-demanding measures. According to this study, education is supposed to enhance two specific cognitive components: controlled processes and conceptualization ability, which may delay the clinical expression of neurodegenerative diseases.

The current study aims to further investigate the potential effect of education on the performance in the INCP to ensure validity for future implementation. The variable is assessed through years of formal education. Even though years of education might be the most inclusive and comparable metric available in studies, the arrangement in clean categories of different levels of education may be more comparable (Clouston et al., 2020). Therefore, in this study education groups are formed by the division in 1-9, 10-13, 14-18 and 19+ years of formal education. Formal education includes primary and secondary education from primary school to high school graduation, and tertiary education including university and university of applied sciences (in German: "Fachhochschule").

Study Aim

To sum up, recent literature emphasizes the importance of the development of efficient, easy-to-use, sensitive and regularly applicable diagnosis tools with the purpose of facilitating preventative measures and decelerating the progression of the disease. Thus, the aim of this pilot study project is to fill this research gap by contributing to the test evaluation in order to ensure a valid testing tool for early detection of cognitive decline. The main concern of the present research is the assessment of potential differences between the education groups regarding the performance in each subtest of the International Neurocognitive Test Profile.

Question of Research

The main research question reads as follows: *Does the duration of education have an impact on the psychometric data gathered through the INCP?*

- $H1_1$**:** There is a difference between the education groups regarding the performance in the World Capital Knowledge.
- $H1_2$**:** There is a difference between the education groups regarding the performance in the Auditory Vocabulary Test.
- $H1_3$**:** There is a difference between the education groups regarding the performance in the Verbal Vocabulary Test.
- $H1_4$**:** There is a difference between the education groups regarding the performance in the Digital Symbol Test.
- $H1_5$**:** There is a difference between the education groups regarding the performance in the Figure Fluency Test.
- $H1_6$**:** There is a difference between the education groups regarding the performance in the Traffic Light Test-short.
- $H1_7$**:** There is a difference between the education groups regarding the performance in the Word Scramble-s.

- $H1_8$**:** There is a difference between the education groups regarding the performance in the World Flag Knowledge.
- $H1_9$**:** There is a difference between the education groups regarding the performance in the Equation Solving Test.
- $H1_{10}$**:** There is a difference between the education groups regarding the performance in the Time-Duration-Test.
- $H1_{11}$**:** There is a difference between the education groups regarding the performance in the CITY test.
- $H1_{12}$**:** There is a difference between the education groups regarding the performance in the Pattern Cancel Test.
- $H1_{13}$**:** There is a difference between the education groups regarding the performance in the Image Naming Test.
- $H1_{14}$**:** There is a difference between the education groups regarding the performance in the Dice-2-n-back test.
- $H1_{15}$**:** There is a difference between the education groups regarding the performance in the Emotion Face Test-short.
- $H1_{16}$: There is a difference between the education groups regarding the performance in the Faces-Couples-Test.
- $H1_{17}$**:** There is a difference between the education groups regarding the performance in the Story Comprehension Test.

Methods

The study has received final approval by the Ethics committee of the Medial University of Vienna on December 23rd, 2020. It was performed in accordance with the Good Scientific Practice and the Good Clinical Practice (GCP) of the Medical University of Vienna. The participation in the present study did not bring any direct benefit or compensation for the participants, except for feedback on their cognitive performance in the task. There were no direct risks related to the participation in this study. The only risk, which is the disclosure of sensitive data, was minimized with the aid of date pseudonymization and strict data security policies.

Sample Characteristics & Recruitment

The sample included 279 neurologically healthy participants of both genders (female: 176, male: 92, missing information: 11). People aged between 18 and 88 years within Austria were recruited. A flyer with a call for participants was used to gain voluntary participants from the public by posting it on social media and in the General Hospital Vienna (AKH). Additionally, healthy companions of patients of the Department for Neurology of the Medical University of Vienna were asked to participate. Prior to inclusion in the study each participant had to give written consent of participation. They were also informed of their right to terminate the study at any given time.

Inclusion & Exclusion Criteria

All participants first went through an interview answering questions regarding their known mental status and medical condition. Furthermore, they were required to be able to read and hear properly in order to handle the tablet autonomously. They were preliminarily excluded from the study if any of the following conditions applied:

1) known neurological disease such as stroke, severe head trauma, epilepsy, Parkinson disease,
2) known current mental diagnosis according to the International Classification of Disease (ICD-10) (Dilling, Mombour & Schmidt, 2000),
3) known diagnosis of dementia illness according to DSM-5 (APA, 2013),
4) any known medical condition that leads to severe cognitive deterioration including renal, respiratory, cardiac or hepatic disease.

Assessment Procedure

The study consisted of a cross-sectional design with the participants completing the test battery at one point. Overall, the completion of the informed consent, the screening and the INCP took approximately 1.5 to 2 hours. The assessments were either performed at the Neurology outpatient clinic (AKH Vienna), at the psychological institute of the University of Vienna or in private settings. All participants have received the same instructions in the same order. Variations between examiners (Psychology or Medical degree candidates, Psychology interns or Dr. Lehrner) should have been minimised by standardized instructions and the tablet-setting. Depending on the setting, noise and other distractions could have differed, but were kept down by providing headphones. Participants were allowed to take breaks and ask questions whenever needed.

Instruments

Demographic Data

For the data analysis demographic data concerning the individual's age, gender and education were collected. Age and education were generated using the total number of years as indicator. Gender was assessed by self-closure.

Screening

In addition to the clinical screening interview for prior exclusion, screening tests and questionnaires were added to the test battery in order to detect progressed cognitive impairment and pseudo-dementia for retrospective exclusion.

Cognitive Screening. All participants first went through an interview regarding their mental status and medical condition. Afterwards they were subjected to the paper-pencil Vienna Visuo-Constructive Test (VVT 3.0; Lehrner, 2015) measuring visuo-constructional abilities to ensure the absence of cognitive impairment. The patients were instructed to draw three figures (a clock, two five-sided figures, and a cube) as accurately as possible. In the delayed recall at the end of the whole assessment they had to draw those figures from memory. A higher test score indicates a higher visuo-constructional performance. A VVT-3.0 score of 9 or 10 was required for inclusion in the study (Valencia & Lehrner, 2018). The screening tool shows an internal consistency (Cronbach's alpha) of $\alpha = .84$ (Numrich, 2017).

Furthermore, the so-called *Wortschatztest* (WST) which assesses the verbal level of intelligence and speech comprehension was directly administered on the tablet. It contains 40 items which are made of one target word and five fictional distractor words. As standardized vocabulary test it allows an estimation of the premorbid intelligence level before mild or medium organic brain decay. The more correct words the person recognises, the higher is the WST-score. A WST-IQ of at least 85 is required for inclusion. The split-half reliability is $r = .95$ and the internal consistency (Cronbach's alpha) $\alpha = .94$ (Schmidt & Metzler, 1992).

Screening for Depression. To measure the factor depression the German version of the *Beck Depression Inventory* (BDI-II) (Hautzinger, Keller, & Kühner, 2006) was presented. It includes 21 questions about the person's feelings during the past two weeks on a four-point Likert-scale. As scores above 13 indicate clinically relevant symptoms of depression, a score of 13 or lower is required for inclusion, (Hautzinger et al., 2006). Evaluations of the BDI-II including clinical and non-clinical samples suggest an internal consistency (Cronbach's alpha) of $\alpha \geq .84$ and a test-retest reliability of $r \geq .75$ (Hautzinger et al., 2006; Kühner et al., 2007).

The International Neurocognitive Profile (INCP) - Version 3.0

The International Neurocognitive Profile (INCP) was used to assess overall cognitive functioning based on the six DSM-5 cognitive domains (APA, 2013; see Fig. 6). The tasks have been newly developed for the tablet-based format. Therefore, the subtests are still under evaluation and there are no psychometric values available yet. Relevant previously collected data for some subtests of the former first and second versions have been included in the analysis as well. The latest third version currently involves 17 subtests which are described more closely in the following (Lehrner, 2021). Firstly, language functions were assessed by the following first three subtests:

Image Naming Test (INT). In the INT pictures of things are presented and the participant has to choose the correct name regarding the item out of two options. A total of 100 items is presented and there is no time limit. The task is supposed to assess memory skills.

Auditory Vocabulary Test (AVT). The task in the AVT is to listen to a voice saying words which are either real or made up and to then identify the real words. The participant can choose between “Yes” or “No” concerning the decision whether it is a real German word or not. Half of the words are listed in the Duden dictionary, while the other half is invented but similar in terms of word-sound as well as pronunciation. The task consists of 100 items and takes approximately 3 minutes to complete.

Verbal Vocabulary Test (VVT). In the VVT the participant has to decide whether written words are either real or made up by selecting “Yes” or “No”. Like in the AVT, one half of the words are listed in the Duden dictionary, while the other half is invented but similar in terms of typeface as well as pronunciation. The task consists of 100 items and takes approximately 3 minutes to complete.

World Capital Knowledge (WCK). The WCK task consists of 20 items within three rounds in total. It is supposed to measure the episodic memory containing verbal inputs. The participant has to identify the matching country to a given capital out of two options. The score is the sum of all correct scores over the three rounds. Additionally, after a delay of 15 minutes, the participant is asked to list all the capitals shown in the previous rounds by the test conductor *(World Capital Free Recall).* Thus, this is the only task of the INCP where an interaction with a test conductor and speech production are required. In another round, the participant has to decide whether the capitals were presented in the first rounds by indicating “Yes” or “No” (*World Capital Recognition).*

World Flag Knowledge (WFK). The WFK task consists of 20 items showing flags of different countries within three rounds in total. It is supposed to assess episodic memory with visual inputs. The participant has to identify the matching country to a given flag out of two options. After approximately 15 minutes he/she has to recognize the capitals as well as flags in a recognition task *(World Flag Recognition).* The participant has to decide whether the capitals were presented in the first rounds by indicating “Yes” or “No”.

Digit Symbol-Test (DST). The task in the DST is to pair a symbol and a number according to a given template as quickly as possible during a time period of 60 seconds. The sum score consists of all pairings over three rounds in total. The test takes around 3 minutes and is supposed to measure attention skills. It is a neuropsychological test with high sensitivity for brain damage and dementia (Lezak et al., 2004).

Figure Fluency Test (FFT). In the FFT participants are instructed to connect dots to form as many unique patterns as possible within 180 seconds. A figure can be created by touching the lines. The test is used for the neuropsychological assessment of executive function.

Traffic Light Test-short (TLT-s). In the TLT-s a traffic light with either a green or red light is shown for a short amount of time. In the first turn a "Go"-button has to be pressed when the green light is on, and a "Stop"-button has to be pressed when the red light is on. In the second turn the conditions are switched. This task should assess executive function.

Word Scramble short (WS-s). In the short version of the scramble test a certain number of letters is given to form a German word out of them. The participant has to correctly combine the letters to a noun, verb, pronoun, adverb, or numeral listed in the Duden dictionary. The score is the sum of correctly formed words within 5 minutes. This task is supposed to assess language skills.

Equation Solving Test (EST). In the EST the participant must solve mathematical equations and choose the solution out of two given answers. Four basic operations (addition, subtraction, multiplication, and division) in the range from 10 to 10.000 are presented with no time limit. The equations rank from easy to complex and are included to assess executive function.

Time-Duration-Test (TDT). In the TDT geometric figures are presented for a certain amount of time. Afterwards the same figure appears again, and the participant has to press the figure for the same amount of time as it was previously shown. There is no time limit. The score is the sum of absolute difference between the time units presented and the time units given by the participant in seconds. Thus, the lower the value the more accurate the time estimate. The task is supposed to assess executive function.

Dice 2-n Back (DICE). In the Dice Test a row of moving (to the left) dices is presented. Each round a new one is covered, and the participant has to decide if the dice in the middle is the same one as the covered one on the left. By either choosing "equal" or "not equal" the participant chooses whether the two dices are matching or not. The score is the sum of all correct decisions minus the incorrect answers. The task is supposed to assess executive function.

Pattern Cancel Test (PCT). In the PCT a certain figure is given and all identical figures have to be marked as fast as possible. The score is the sum of all correct patterns expressed. The task is used to measure attention skills.

Emotion Face Test-short (EFT-s). A smiley-face is shown either with a mouth pointing upwards (happy) or downwards (sad). The task is to choose the right word ("happy" or "sad" in German) regarding the face as fast as possible. In a second trial the condition is switched. The score consists of the sum of all correct, incorrect as well as "not responding" answers. The task is supposed to measure emotional ability.

Faces-Couples-Test (FCT). In the FCT photos of faces have to be matched according to given rules to form couples. First there is a forced choice two-alternative immediate recognition condition (FCT-FCTAIR): The face of a woman and of a man, who are a couple, are shown. The participant then has to remember the combinations within two rounds. Then the participant will be asked about the pairs and has to choose which woman belongs to which man or vice versa. A green frame around the photo indicates if the correct face is chosen and a red frame indicated an incorrect answer. In the delayed recognition condition (FCT-FCSADR) the participants will have to select the corresponding face out of six faces again. In the Recognition condition (FCT-REC) half of the faces are the ones shown in the previous rounds and the other half have not been shown before. The participant has to indicate "Yes" or "No" depending on whether the face has been shown before or not. The total score is obtained by adding the scores of all four conditions. The tasks are supposed to assess memory skills.

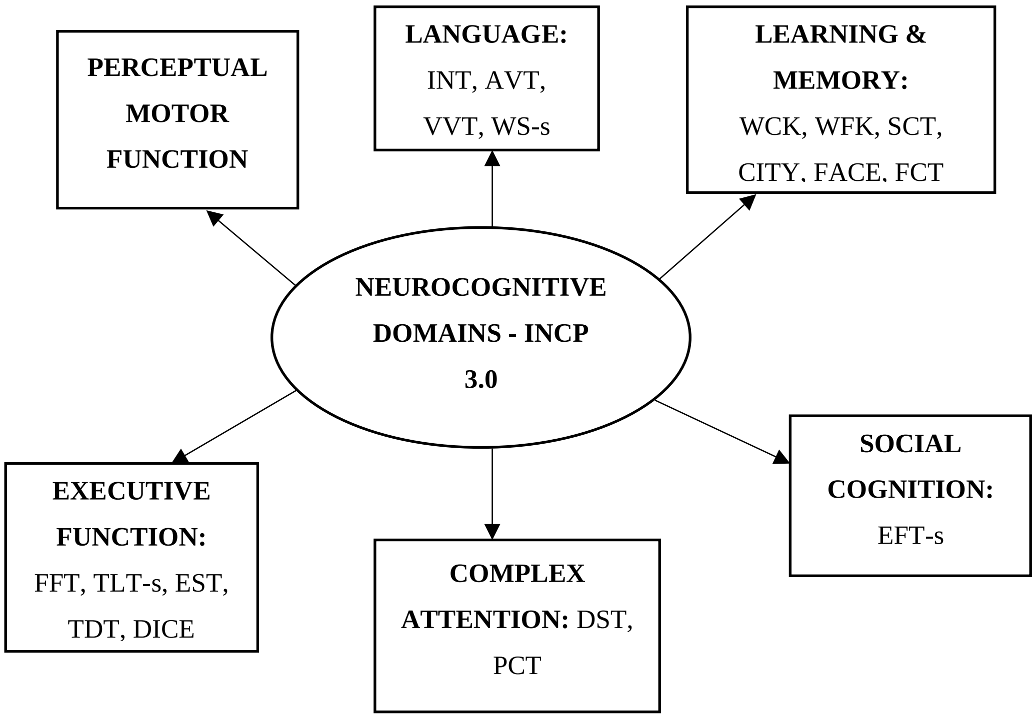
Story Comprehension Test (SCT). The SCT consists of the presentation of different stories which have to be read carefully and remembered. Afterwards, questions about these stories must be answered in a forced-choice format. In total 30 texts are included and the score is the sum of all correct answers. The task is supposed to assess memory functions.

City Identification Test (CITY). The CITY test (Lehrner, 2001) is a multiple-choice tool where a matching capital has to be found to its corresponding country. Participants are provided with 16 items and can choose between four city options each with no time limit. It is supposed to assess semantic memory skills and has a Cronbach's alpha of α=.80 and a retest reliability after four years of 0.82 in the paper pencil version (Doblinger, 2013).

Face Identification Test (FACE). The FACE test (Lehrner, 2001) is a multiple-choice tool where a matching name has to be found to its corresponding face of a former or current celebrity of the last century. Participants are provided with 16 items and can choose between four name options each with no time limit. The test is supposed to measure memory function. It has shown a Cronbach's alpha of α=.86 and a retest reliability after four years of 0.77 in the paper pencil version (Doblinger, 2013) .

Figure 6

Neurocognitive Domains and inherent INCP subtests



The clinical interview, screening tests, and INCP subtests were carried out in the same order by each participant (see Table 1).

Table 1

Clinical Trial Flow Chart

1.	**Informed Consent**	Informed consent form: reading, signing, clarify possible questions
2.	**Demographic Data**	Age, gender, years of education
3.	**Cognitive Screening**	VVT 3.0
		WST
		BDI-II
		GDS
		HADS-D
4.	**INCP**	INCP-WCK
		INCP-AVT
		INCP-FCT
		INCP-SCT
		INCP-DST
		INCP-FACE
		INCP-CITY
		INCP-PCT
		INCP-EFT-S
		INCP-FFT
		INCP-INT
		INCP-VVT
		INCP-TLT-S
		INCP-WS-s
		INCP-EST
		INCP-WFK
		INCP-DICE
		INCP-TDT
		Evaluation
5.	**Delayed Recall**	VVT-3.0 Delayed Recall
6.	**Time for Feedback**	Feedback Form

Materials

The letter of consent, the VVT-3.0 and feedback form were presented in paper and pencil form. The INCP and the other screening instruments were conducted using an Apple iPad (5^{th} generation (2017)) with a screen size of 9,7 inch. The application software is provided by www.psimistri.com. Headphones were provided for a listening comprehension task and to enable more concentration in the case of noise interference.

Statistical Analysis

Statistical analyses were performed using IBM SPSS (version 27) with a significance level of α = .05. Firstly, the collected data was arranged properly in an SPSS file and sum scores for each subtest and screening test were calculated for the conduction of the relevant analyses. In a second step, the data set was checked for plausibility. Missing data was added if available, implausible values were checked and corrected or excluded. Descriptive statistics were generated to visualize the distribution of the demographic variables (age, gender, and formal education) and main parameters (sum scores of the VVT 3.0, WST-IQ, BDI-II screenings and all subtests of the INCP).

Main Question of Research

To assess potential differences between the education groups regarding the performance in the INCP, education groups were formed: group 1 (below 10 years), group 2 (10-13 years), group 3 (14-18 years) and group 4 (above 18 years). For the investigation of the question an analysis of variances (ANOVA) and a post-hoc analysis were planned. Subtests with varying item presentation (INT, AVT; VVT, WCK, WFK, EST, SCT, WS-s, FCT) were only analysed descriptively due to small sample sizes per item. As the majority of the variables was not distributed normally across the education groups and the assumption of homogeneity of variances was violated, a non-parametric alternative method, the Kruskal-Wallis test (H-test), was used for the investigation of group differences. Another argument for using the H-test is the small sample size within the groups, especially group 1 and 2 with lower education levels. Additionally, F-statistics are supposed to be robust only in the case of equally distributed group sizes, especially in the case of unequal variances (Field, 2018). Effect sizes for the results of the Kruskal-Wallis test were calculated using the formula: $r = |\frac{z}{\sqrt{n}}|$ and interpreted based on Cohen's criteria (1988): $r \geq .10$ suggesting a small, $r \geq .30$ a medium and $r \geq .50$ a large effect.

Additional Exploratory Analyses

In order to further investigate the association between performance in the INCP subtests and years of formal education correlation coefficients were calculated. For this the non-parametric Spearman's correlation coefficient (*rS*) was used since the assumption of normal distribution was violated in several variables. Additionally, compared to the Pearson's correlation coefficient (*r*), it is supposed to be more robust to outliers and influential cases (Field, 2018). Effect sizes of the correlations were interpreted based on Cohen's criteria (1988): $r \geq .10$ suggesting a small, $r \geq .30$ a medium and $r \geq .50$ a large effect.

Results

Overall Sample

Eventually, the total sample consisted of 279 persons who have participated in the INCP-study since December 2019. The mean age was 47.54 years (*SD* = 20.34) with a range of 18 to 88 years. Altogether 176 participants were female (63.1%) and 92 were male (33.0%), while the gender data for 11 participants (3.9%) is missing. Years of formal education ranged from eight to 27, with a mean of 15.02 years (*SD* = 4.16*)*. In several cases demographic variables were missing (see Table 2).

Table 2

Mean Values, Standard Deviations and Range of the Demographic Variables

Variable	*N*	*M*	*SD*	Range
Gender	268	.66	.48	0 – 1
Age	256	47.54	20.34	18 - 88
Years of education	224	15.02	4.16	8 - 27

Note. *N* = sample size with relevant data, *M* = mean, *SD* = standard deviation, range = actual manifestations of the scale values (min. - max.)

Descripitives

Screenings

The screening tests included the Vienna Visuo-constructive Test 3.0 (VVT 3.0) and Wortschatztest (WST) for cognitive screening, and the Beck Depression Inventory (BDI-II) to exclude participants with symptoms of clinical depression. As shown in Table 3 there were different sample sizes for each screening test. This was caused by the pilot study character as the WST and BDI-II were added later throughout the assessment procedure as well as missing data on the three tests in various cases.

Table 3

Sample Sizes, Mean Values, Standard Deviations and Ranges of the Screening Tests

				Range	
Sum Score	*N*	*M*	*SD*	Possible	Actual
VVT 3.0	248	9.60	.82	0 - 10	5 - 10
WST-IQ	143	107.01	10.60	0 - 139	72 - 129
BDI-II	141	7.17	8.92	0 – 63	0 - 48

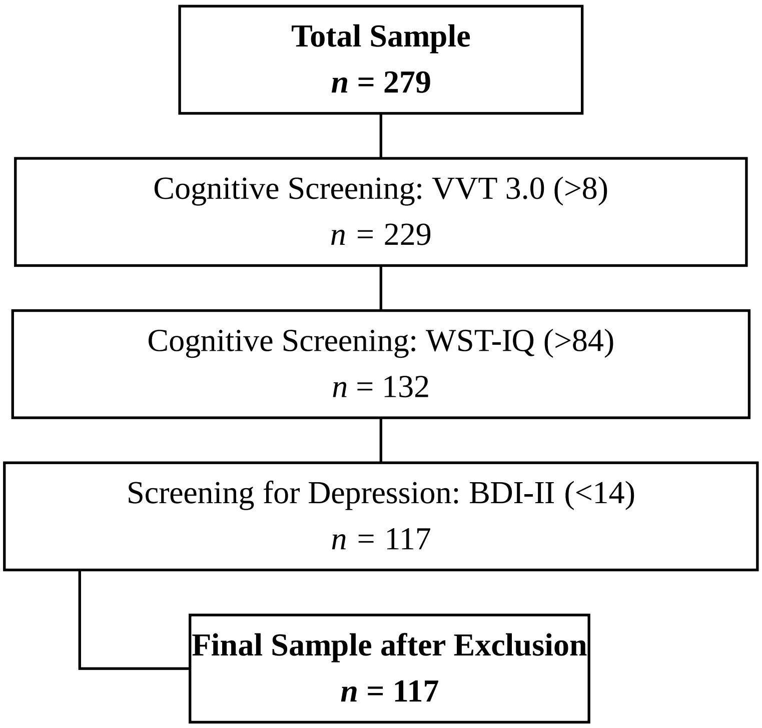
Note. N = sample size for the relevant variable, *M* = mean, *SD* = standard deviation, range = possible & actual manifestations of the scale values (min. - max.)

Exclusion Process

The data of 162 persons had to be fully excluded due to missing screening data or not meeting the screening criteria in the VVT 3.0, WST-IQ and/or BDS-II, resulting in a final sample size of 117 (see Fig. 7). Out of the initial 279 participants a total of 50 had to be excluded due to the VVT 3.0 cognitive screening, resulting in a sample size of 229. Nineteen cases have reached a score below nine which may indicate cognitive impairment. The data of 31 persons was missing. Additionally, the data for the WST-IQ was missing in 136 cases. Another six cases had to be excluded due to a WST-IQ score below 85, indicating insufficient verbal intelligence and speech comprehension. Altogether 142 participants were excluded due to the WST-IQ data. Furthermore, 138 participants did not complete the BDI-II for screening for depression and thus had to be excluded. Twenty-four out of the remained sample of 141 persons have reached a score above 13, indicating clinically relevant symptoms of depression. Thus, a total of 162 cases had to be excluded due to the BDI-II score.

Figure 7

Flow Chart: Sample Exclusion Process



INCP Subtests

Due to different versions as part of the pilot study character there are also different sample sizes for each subtest. Additionally, the FCT had to be excluded during the assessment period due to programming errors which lead to early test aborts. At this point, the PCT was added subsequently. The sample size, average performance, performance range, and possible range of each subtest sum score are presented in Table 4.

Due to random presentation of items in various subscales resulting in very small sample sizes per item, only the FACE, CITY, DST, TDT, DICE, EFT, FFT, TLT-s and PCT could be analysed concerning the postulated hypotheses. The scores of the INT, AVT, VVT, WCK, WFT, EST, SCT, WS-s and FCT are thus only described descriptively in the following. Hypotheses number 1, 2, 3, 7, 8, 9, 13, 16 and 17 could therefore not have been investigated in the present study.

Table 4

Sample Sizes, Mean Values, Standard Deviations and Ranges of the INCP Subtests (N = 117)

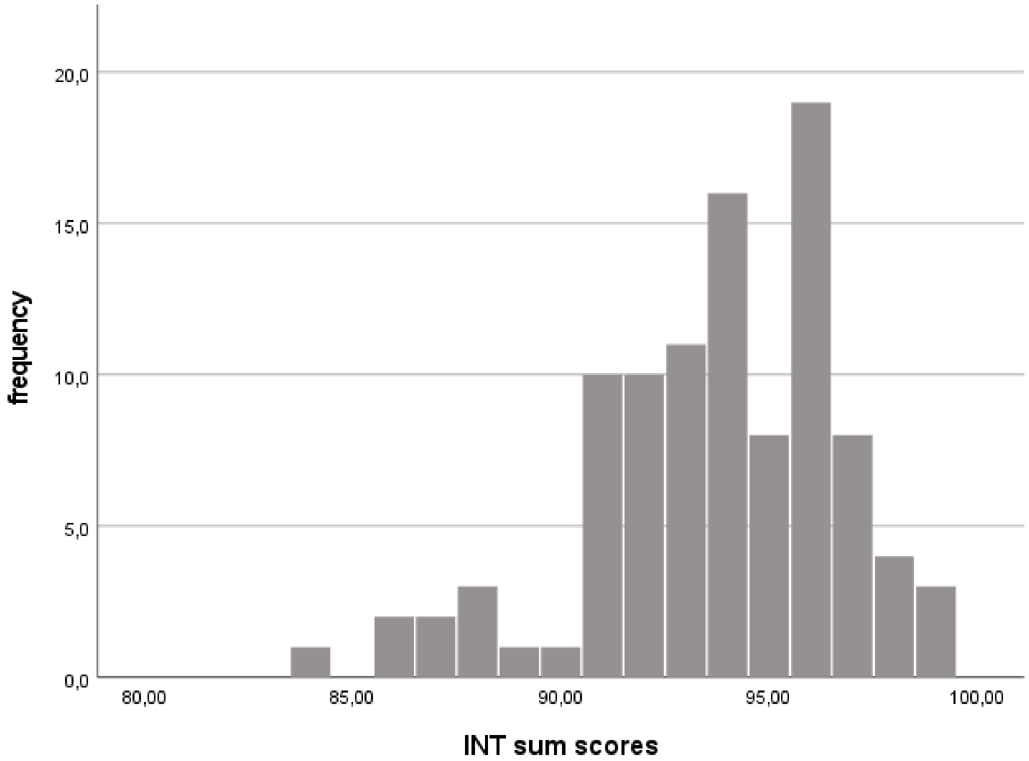
Subtest				Range	
Sum Score	*N*	*M*	*SD*	Possible	Actual
INT	99	93.73	3.04	0 – 100	84– 99
AVT	113	79.86	9.53	0 – 100	5 - 92
VVT	92	83.32	4.07	0 – 100	74 – 92
WCK	114	51.58	8.17	0 - 60	16 – 60
WFK	87	51.61	5.33	0 - 60	35 - 60
DST	75	67.61	13.89	0 - n.l.	28 - 92
FFT	85	23.74	20.74	0 – n.l.	1 – 101
TLT-s	104	55.94	9.00	0 – 60	0 - 60
WS-s	88	4.38	3.28	0 – 70	0 - 16
EST	105	30.68	1.85	0 – 100	20 - 32
TDT	99	37.16	9.13	0 – n.l.	18.85 – 78.67
DICE	96	41.42	13.59	- n.l.	-5 - 50
PCT	34	13.21	2.67	0 – 16	6 - 16
EFT-s	101	29.19	3.95	0 – 60	2 - 31
FCT	31	76.39	10.04	0 – 100	52 - 90
SCT	57	26.79	2.33	0 – 30	20 – 30
CITY	109	12.84	2.34	0 – 16	7 – 16
FACE	107	11.86	3.09	0 – 16	4 – 16

Note. N = sample size, *M* = mean sum score, *SD* = standard deviation, range = possible and actual manifestations of the scale values (min. - max.), n.l. = not listed

Image Naming Test (INT). For the analysis of the Image Naming Test (INT) the data of N = 99 cases could be included. This sample consisted of n = 59 female and n = 40 male participants. The mean age was 38.43 years (SD = 16.59) with a range from 18 to 79 years. The mean years of formal education were 16.53 (SD = 3.67), with a range from eight to 27 years. The average sum score in the present sample was 93.73 (SD = 3.04), ranging 84 to 99 (see Fig. 8). The possible range in this subtest reached from 0 to 100.

Figure 8

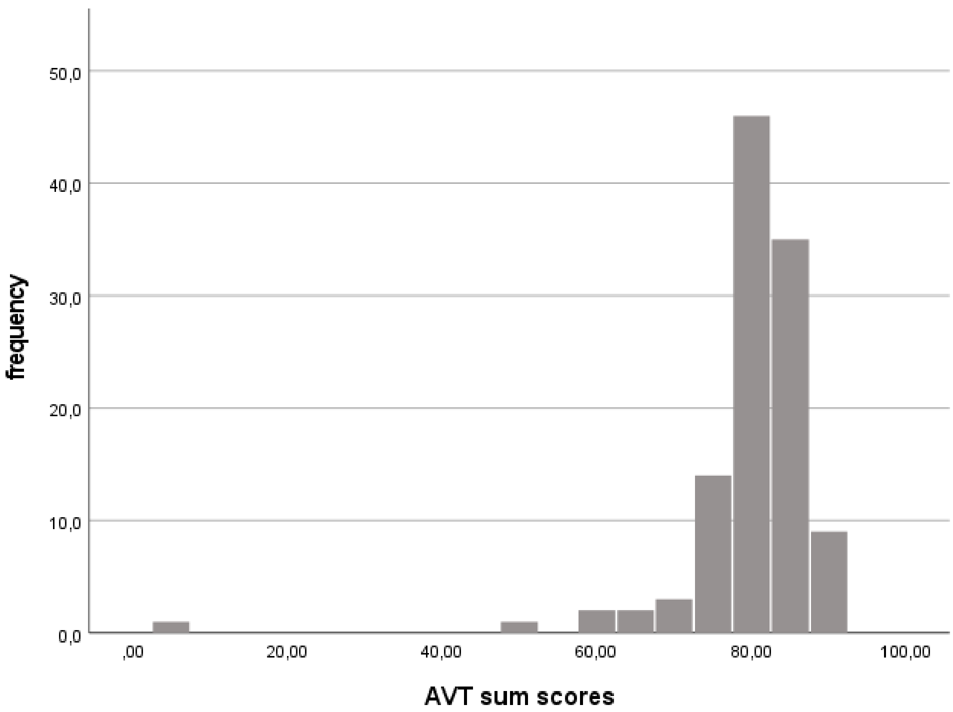
INT sum score distribution



Auditory Vocabulary Test (AVT). The final sample for the analysis of the Auditory Vocabulary Test (AVT) consisted of *N* = 113 participants. Out of them *n* = 69 were female and *n* = 44 were male. The average age was 40.88 years (*SD* = 18.10) with a range from 18 to 85. The mean years of formal education were 16.13 (*SD* = 3.96) with a range from eight to 27. The mean sum score reached by the present sample was 79.86 (*SD* = 9.53) in a possible range of 0 to 100 points. The actual scores reached from five to 92 (see Fig. 9).

Figure 9

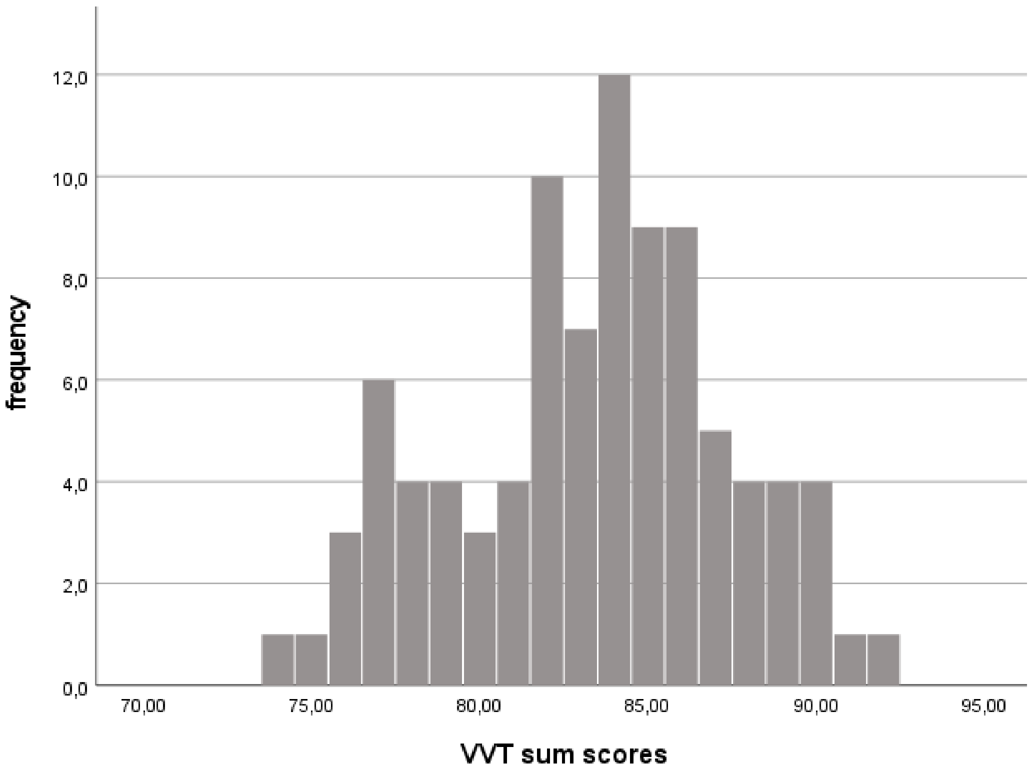
AVT Sum Score Distribution



Verbal Vocabulary Test (VVT*).* The final sample for the analysis of the Verbal Vocabulary Test (VVT) consisted of *N* = 92 participants. Out of them *n* = 60 were female and *n* = 32 were male. The mean age was 41.05 years (*SD* = 18.15) with a range from 18 to 85. The average years of formal education were 16.03 (*SD* = 3.90) with a range from eight to 27. The mean sum score reached by the present sample was 83.32 (*SD* = 4.07) in a possible range of 0 to 100 points. The actual scores reached from 74 to 92 (see Fig. 10).

Figure 10

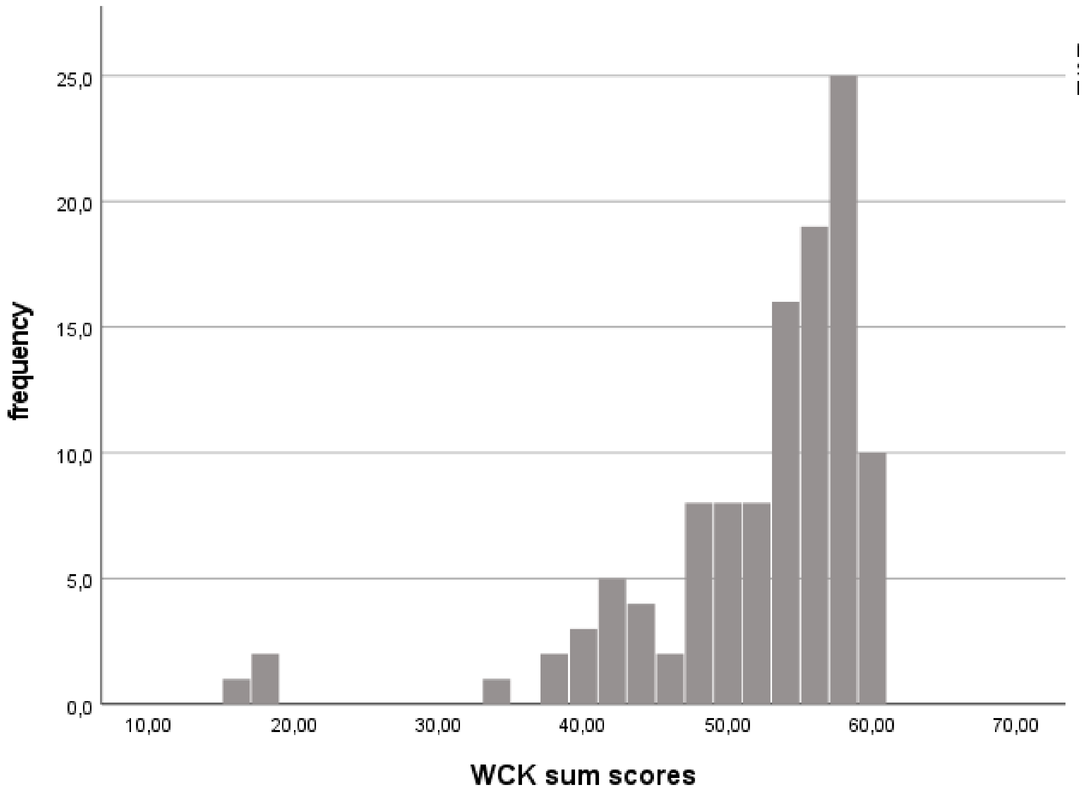
VVT Sum Score Distribution



World Capital Knowledge (WCK). For the analysis of the World Capital Knowledge (WCK) the data of *N* = 114 participants could be included. Out of them *n* = 69 were female and *n* = 45 were male with a mean age of 41.04 years (*SD* = 18.11). The average amount of years of formal education was 16.11 (*SD* = 3.95), with a range from eight to 27 years. The average sum score reached in the present sample was 51.58 (*SD* = 8.17) out of a possible range of 0 to 60. The actual range of sum scores reaches from 16 to 60 (see Fig. 11).

Figure 11

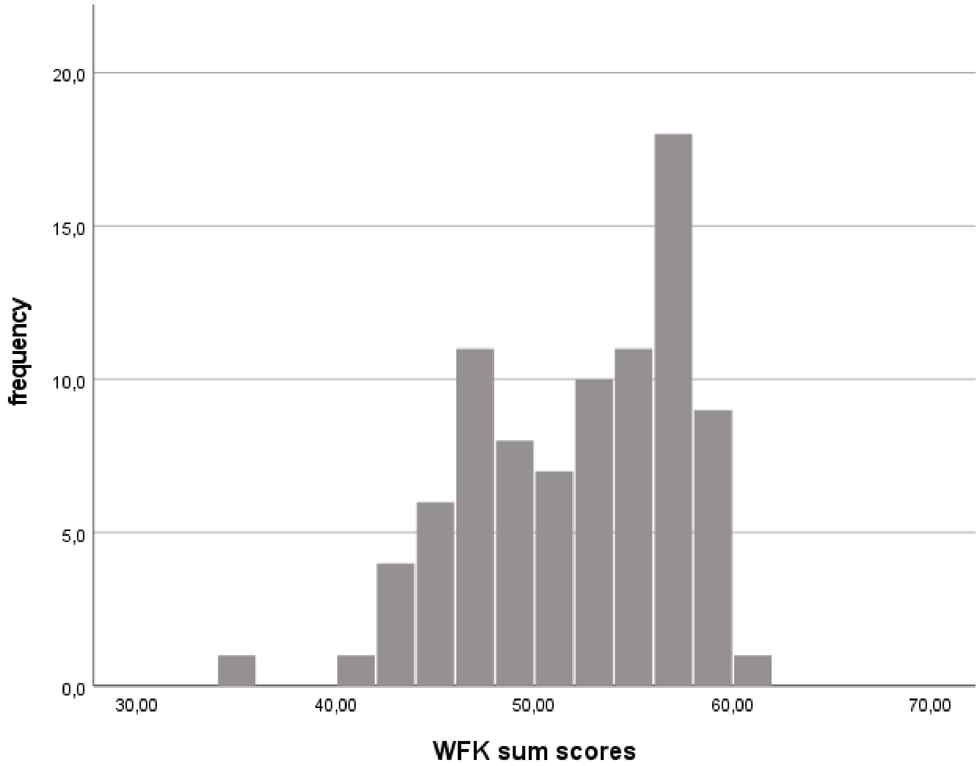
WCK Sum Score Distribution



World Flag Knowledge (WFK). For the analysis of the World Flag Knowledge (WFK) the data of N = 87 participants could be included. Out of them n = 69 were female and n = 45 were male with a mean age of 41.04 years (SD = 18.11). The average amount of years of formal education was 16.11 (SD = 3.95), with a range of eight to 27 years. The average sum score in the present sample was 51.61 (SD = 5.33) out of a possible range of 0 to 60. The actual range of sum scores reached from 35 to 60 (see Fig. 12).

Figure 12

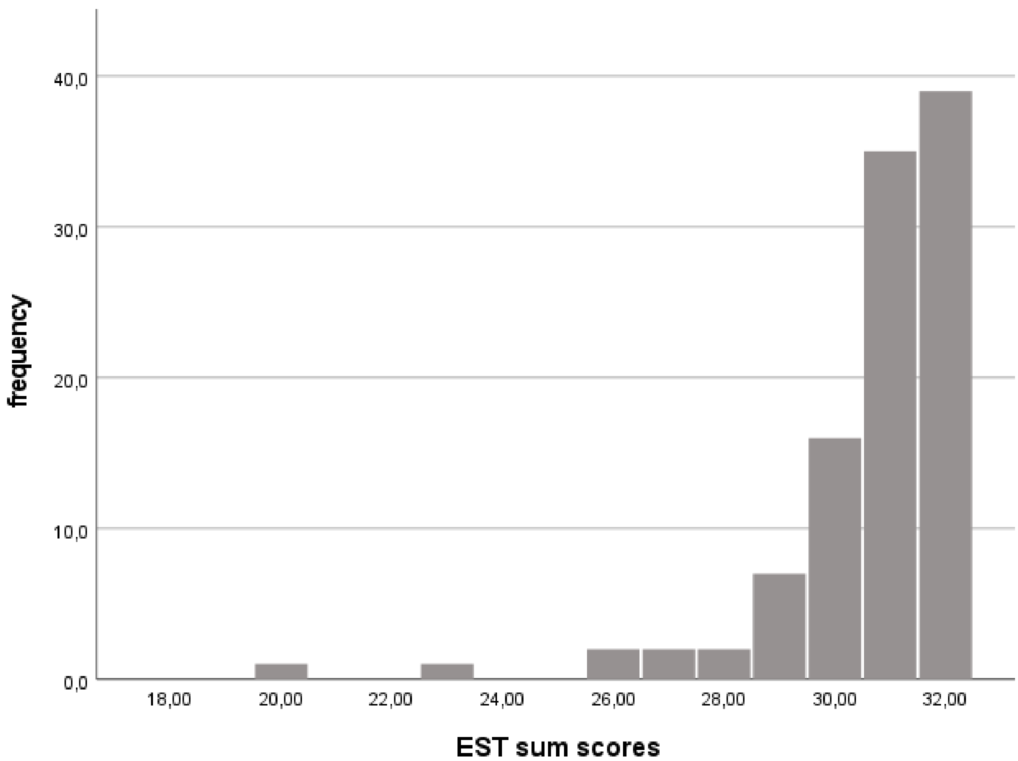
WFK Sum Score Distribution



Equation Solving Test (EST). The final sample for the analysis of the Equation Solving Test (EST) consisted of N = 105 participants. Out of them n = 67 were female and n = 38 were male. The average age was 39.33 years (SD = 17.30) with a range from 18 to 85. The mean years of formal education were 16.23 (SD = 3.80) with a range from eight to 27. The mean sum score reached by the present sample was 30.676 (SD = 1.85) within a possible range from 0 to 100. The actual scores reached from two to 32 (see Fig. 13).

Figure 13

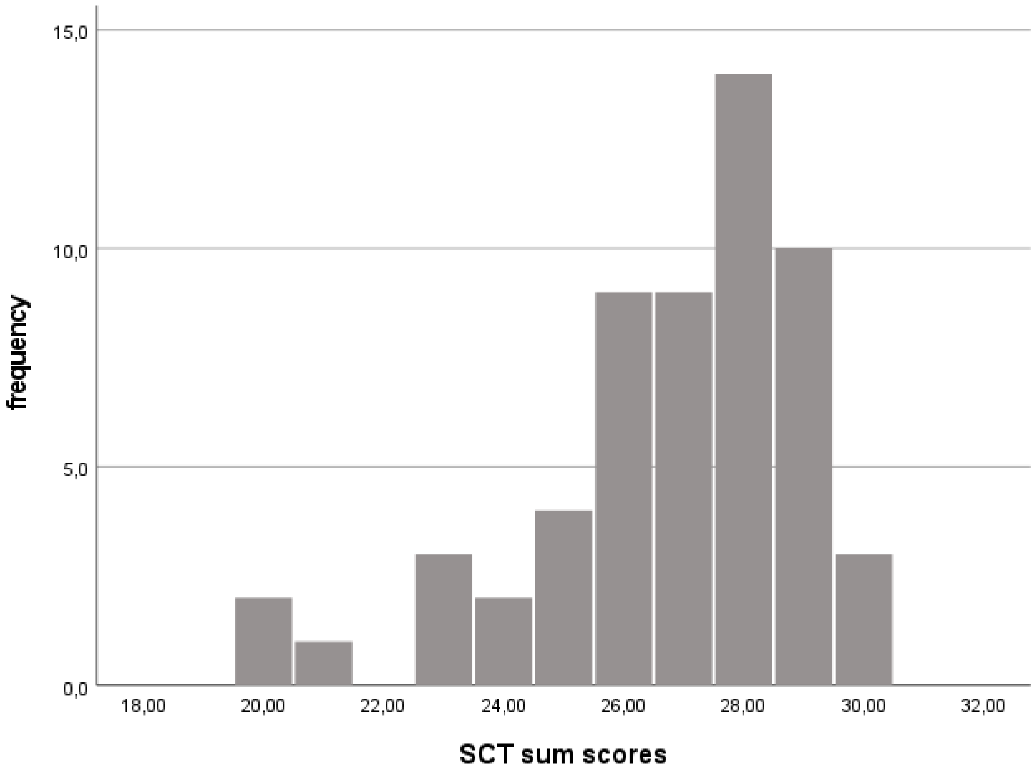
EST Sum Score Distribution



Story Comprehension Test (SCT). The final sample size for the analysis of the Story Comprehension Test (SCT) was *N* = 57. It consisted of *n* = 31 female and *n* = 26 male participants. The average age was 39.25 years (*SD* = 16.26) with a range from 18 to 79. The mean years of formal education were 16.70 (*SD* = 4.01) with a range from eight to 26. The mean sum score reached by the present sample was 26.790 (*SD* = 2.33) within a possible range of 0 to 30 points. The actual scores reached from 20 to 30 (see Fig 14).

Figure 14

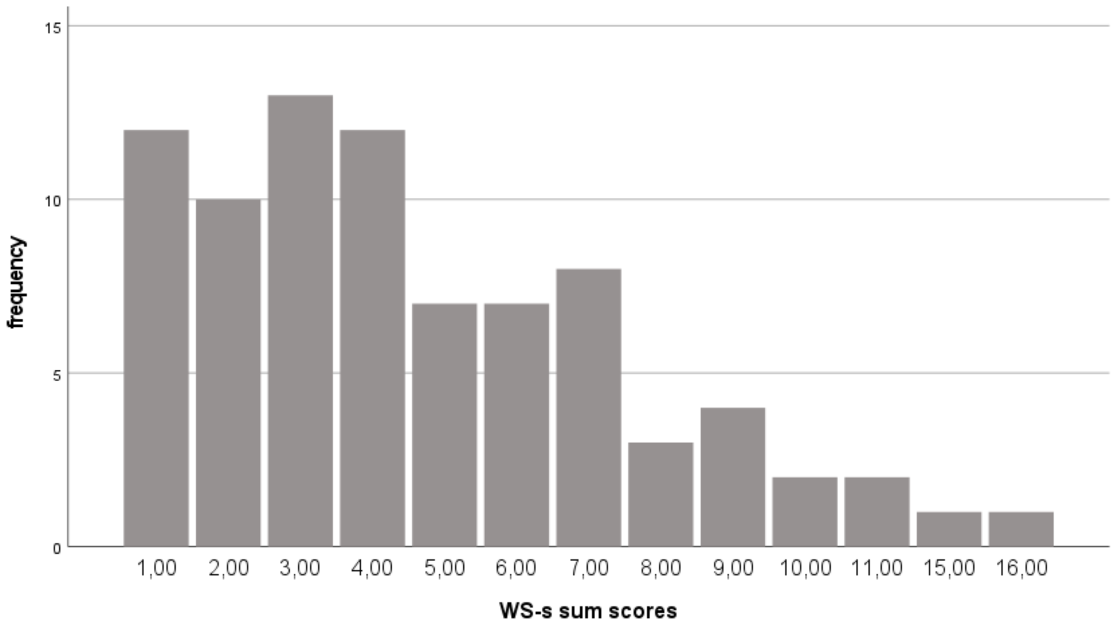
SCT Sum Score Distribution



Word Scramble-short (WS-s). The final sample for the analysis of the World Scramble-short (WS-s) test consisted of N = 88 participants. Out of them n = 51 were female and n = 31 were male. The average age was 38.71 years (SD = 17.11) with a range from 18 to 85. The mean years of formal education were 16.39 (SD = 3.69) with a range from eight to 26. The average sum score reached by the present sample was 4.38 (SD = 3.28) in a possible range of 0 to 70 points. The actual scores reached from 0 to 16 (see Fig. 15).

Figure 15

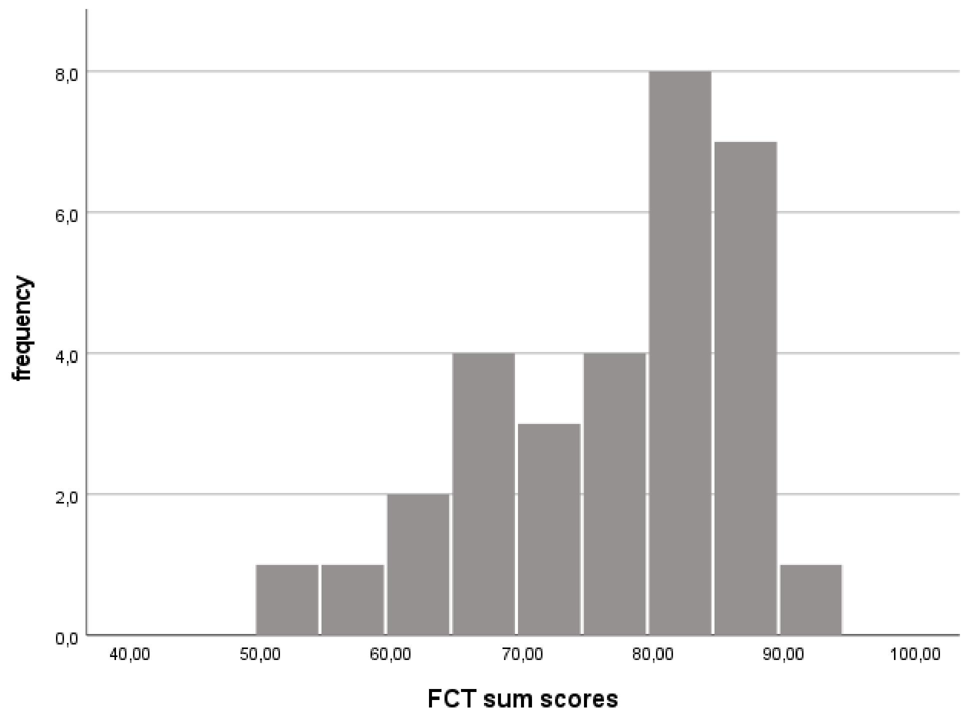
WS-s Sum Score Distribution



Faces Couples Test (FCT). The final sample for the analysis of the Faces Couples Test (FCT) consisted of *N* = 31 participants. Out of them *n* = 16 were female and *n* = 15 were male. The average age was 39.90 years (*SD* = 16.89) with a range from 21 to 79. The mean years of formal education were 15.90 (*SD* = 3.97) with a range from eight to 23. The mean sum score reached by the present sample was 76.39 (*SD* = 10.04) in a possible range of 0 to 100 points. The actual scores reached from 52 to 90 (see Fig. 16).

Figure 16

FCT Sum Scores Distribution

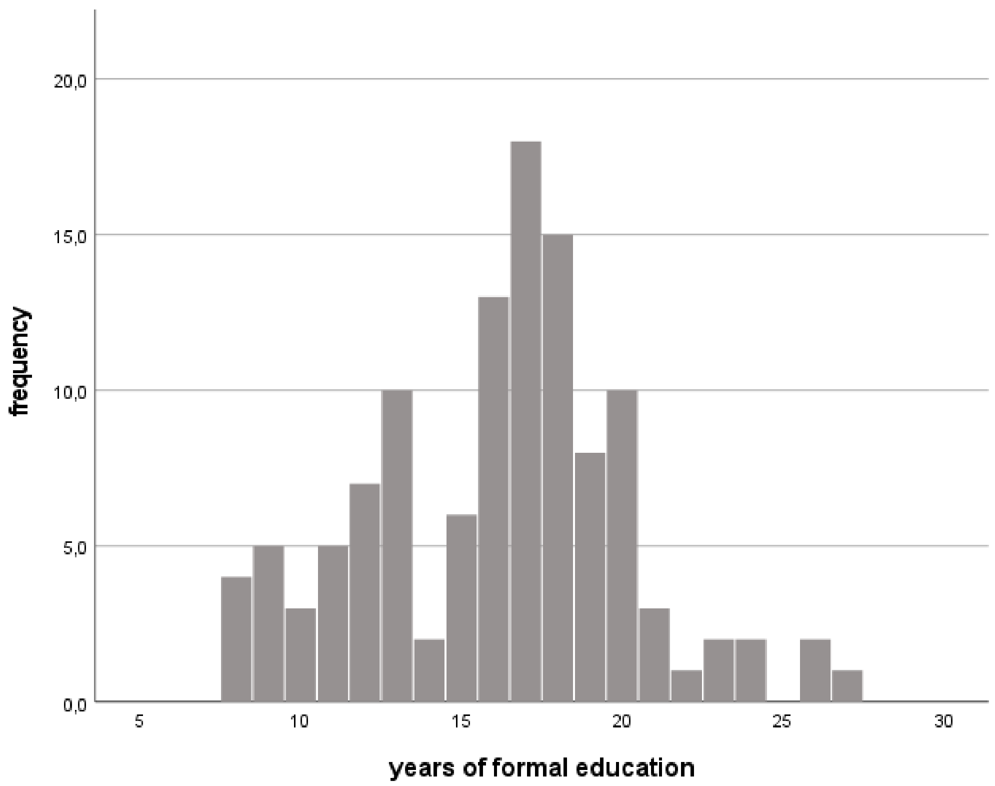


Question of Research: Education Effects

To determine whether performances differed significantly depending on the participants' level of education, a Kruskall-Wallis test was conducted for the following subtest variables: FACE, CITY, DST, TDT, DICE, EFT and PCT. The grouping variable were the four groups of formal years of education. As presented in Figure 17 the formal years of education were distributed in a range between eight and 27 years, with a mean of 16.14 years (*SD* = 4.06).

Figure 17

Distribution of Formal Years of Education (N = 117)



Education groups

Exclusion Process. The data of 20 persons of education group 1 (*N* = 29) had to be excluded due to the screening criteria, resulting in a smaller group with less than 10 years of education (*n* = 9). In addition to that, 36 cases from education group 2 (*N* = 61) were taken out in the exclusion process. Another 38 were excluded in education group 3 (*N* = 92) and 13 in education group 4 (*N* = 42). The data on years of education was missing in 55 cases. However, they were already excluded due to other criteria. Table 5 presents the resulting distribution of sample sizes, mean age and gender distribution of the four education groups. Figure 18 illustrates the age distribution across the education groups. Different sample sizes per subtest, however, lead to different exact distributions of education groups for each hypothesis.

Table 5

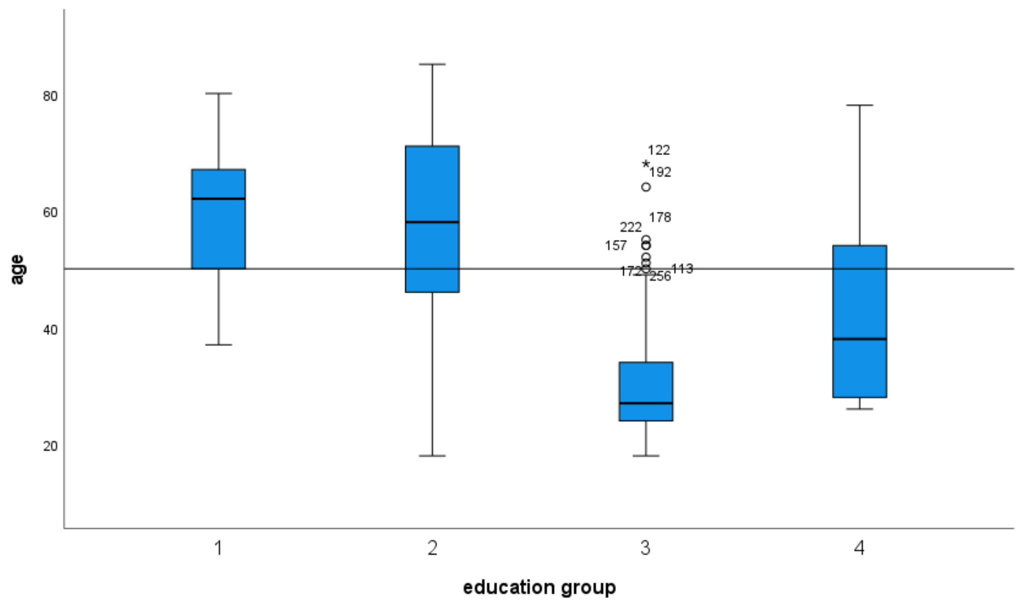
Absolute and Percentual Sample Sizes, Mean Age and Standard Deviations, and Gender Distribution in Education Groups

			age		gender	
	N	*%*	*M*	*SD*	female	male
group 1 (1-9 years)	9	7.7	59.22	14.93	4	5
group 2 (10-13 years)	25	21.4	54.00	20.23	18	7
group 3 (14-18 years)	54	46.2	31.98	11.95	34	20
group 4 (19+ years)	29	24.8	41.66	15.49	15	14

Note. *N* = sample size, % = percentual ratio compared to total sample, *Age: M* = average age within group, *SD* = standard deviation of age, *gender: female/male* = absolute number of females and males within group

Figure 18

Age Distribution across Education Groups



Tests for Assumptions

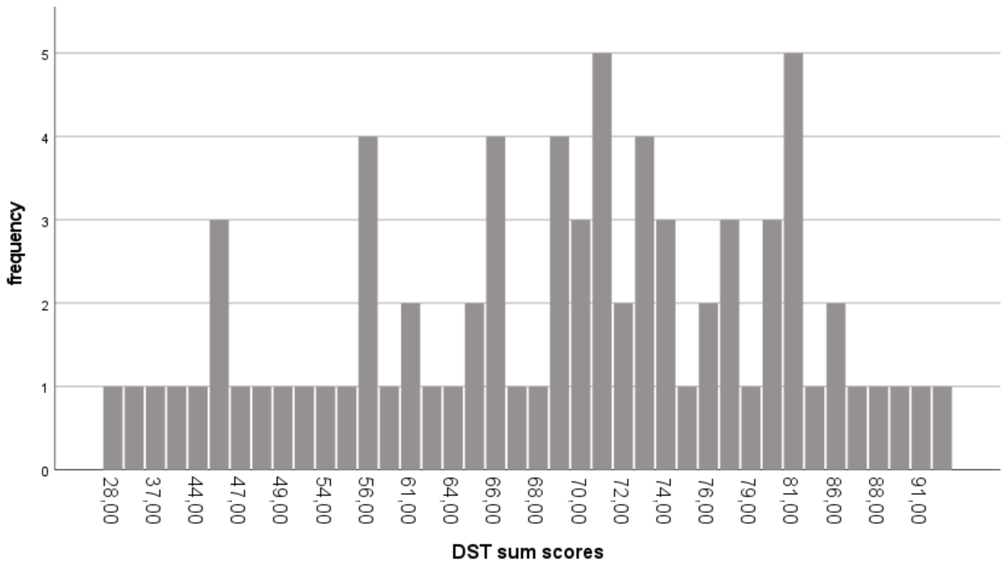
For the purpose of analysing the data regarding their distribution within the education groups, a Shapiro-Wilk test was used. It is supposed to have higher statistical power than the Kolmogorov-Smirnov test (Field, 2018). The assumption of normal distribution across the education groups was violated in the cases of the PCT, DICE, EFT-s and CITY scores, $p < .05$. Additionally, the assumption of equal variances across the groups was violated in the cases of PCT, DICE, CITY and TDT due to a significant Levene test-statistic, $p < .05$. As a result of the violation of the assumption of normal distribution and unequally distributed and small samples in general, the non-parametric Kruskall-Wallis test was conducted instead of the planned ANOVA. Due to small sample sizes, a control for multiple comparisons by means of a Bonferroni correction was performed (Field, 2018). Sum score distributions and boxplots for the mean score distribution across the four groups were used for better illustration of the results. Asterisks in the boxplot figures represent outliers.

Hypothesis 4: Digital Symbol Test (DST)

The final sample for the analysis of the Digital Symbol Test (DST) consisted of $N = 75$ participants. Out of them $n = 42$ were female and $n = 33$ were male. The average age was 39.73 years ($SD = 17.79$) with a range from 22 to 85. The mean years of formal education were 15.97 ($SD = 3.87$) with a range from eight to 26. The mean sum score reached by the present sample was 67.61 ($SD = 13.89$). The possible maximum of items completed within 2.4 seconds (0.8 seconds each round) depended on the speed of the participant. The actual scores reached from 28 to 92 (see Fig. 19).

Figure 19

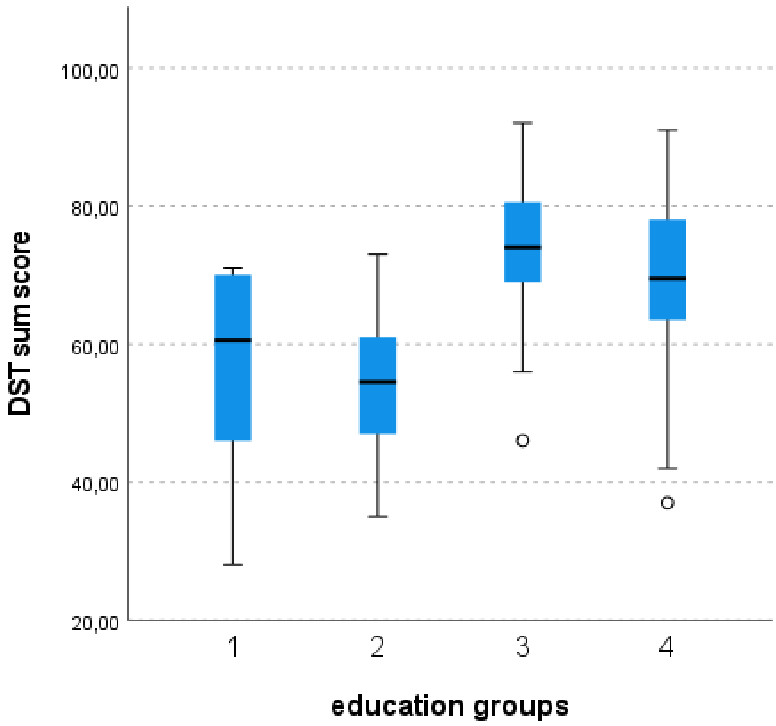
Distribution of Sum Scores in the Digital Symbol Test



Kruskall-Wallis Test. The results of the Kruskall-Wallis test showed a highly significant difference between the education groups in the performance in the Digital Symbol Test, $H(3) = 23.73$, $p < .001$. Post-hoc analyses have shown that scores significantly differed between group 1 and group 3 with a medium effect size, $H = -2.761$, $p < .05$, $r = .416$. The test also showed a highly significant difference between group 2 and 3 with a large effect size, $H(3) = -4.46$, $p < .001$, $r = .613$. Thus, group 3 has shown a significantly higher mean score than group 1 and group 2. The alternative hypothesis 4 can therefore be partly accepted. Figure 20 illustrates the DST mean sum score distribution across the four education groups.

Figure 20

Boxplots of DST Sum Scores across Education Groups

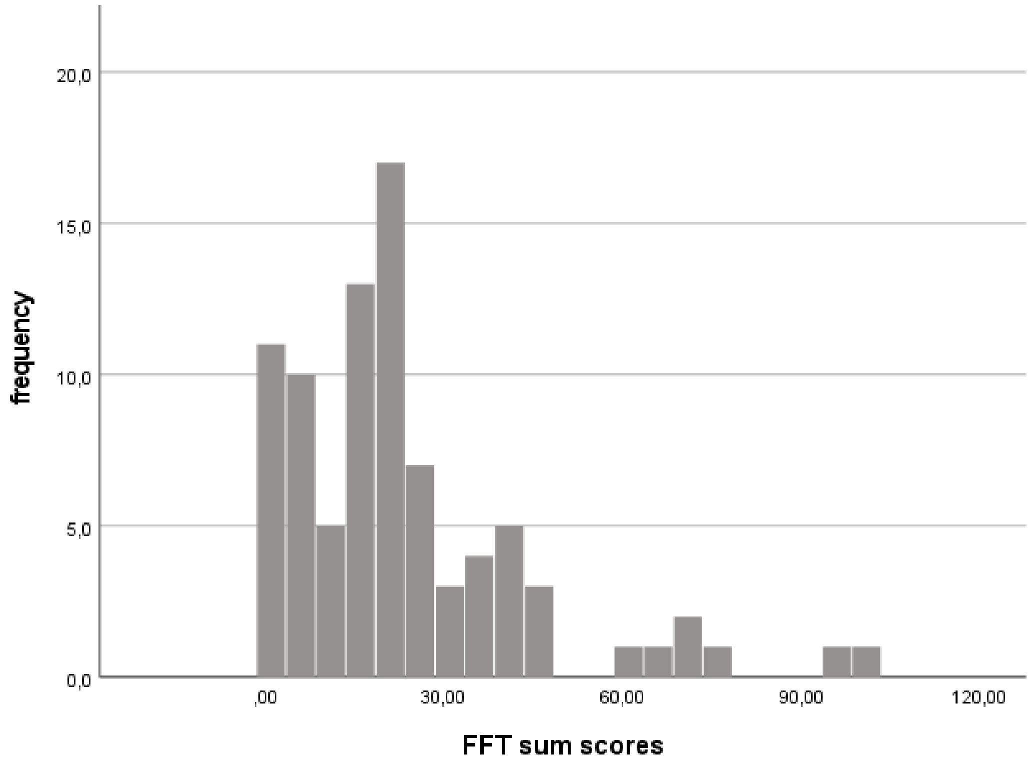


Hypothesis 5: Figure Fluency Test (FFT)

The final sample for the analysis of the Figure Fluency Test (FFT) involved of *N* = 85 participants. It consisted of *n* = 52 female and *n* = 33 male individuals. The average age was 39.42 years (*SD* = 17.79) with a range from 18 to 80. The mean years of formal education were 16.13 (*SD* = 3.84) with a range from eight to 27. The mean sum score reached by the present sample was 23.74 (*SD* = 20.74) with a range from one to 101. Figure 21 illustrates the distribution of the FFT sum score in steps of five per bar.

Figure 21

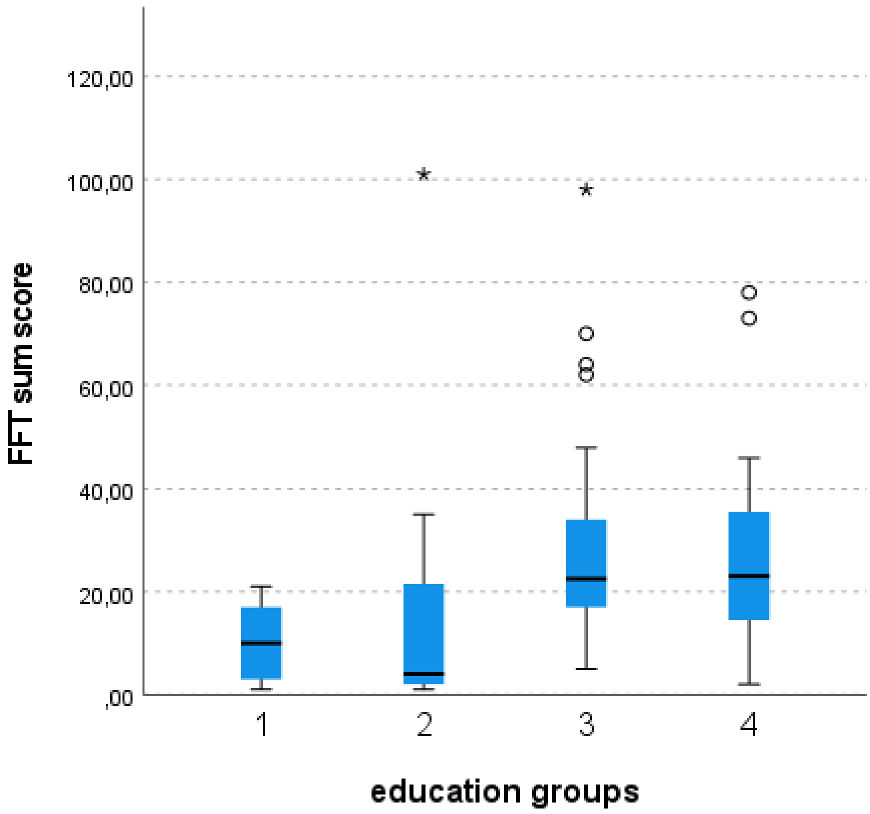
FFT Sum Score Distribution



Kruskall-Wallis Test. The Kruskall-Wallis test has shown that there were significant differences in the performance in the Figure Fluency Test between the education groups, $H(3) = 17.402$, $p = .001$. Group 2 and group 4 differed significantly with a medium effect, $p = .036$, $r = .424$. Additionally, group 2 and group 3 showed a significant difference with a medium effect, $p = .001$, $r = .273$. The other groups (group 1 and 2, group 1 and 4, group 1 and 3, group 3 and 4) showed no significant differences, $p > .05$. To sum up, group 2 showed significantly lower results than group 3 and 4. Therefore, the alternative hypothesis number 5 can be partly accepted. Figure 22 illustrates the FFT sum score distribution across the four education groups.

Figure 22

Boxplots of FFT Sum Scores across Education Groups

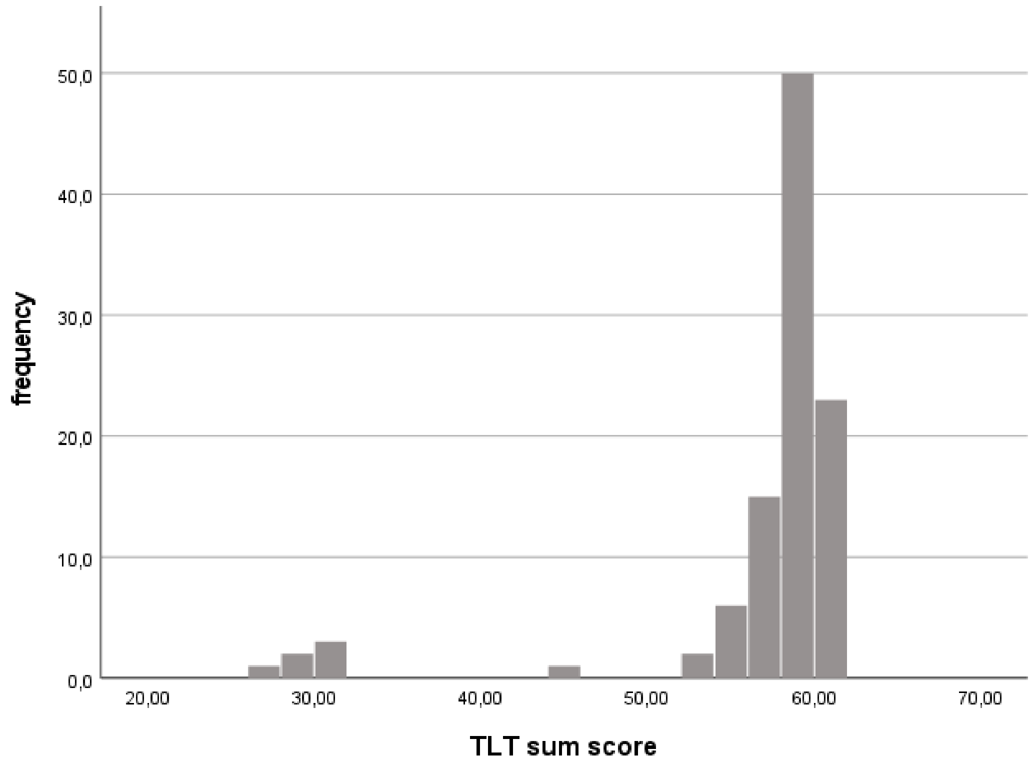


Hypothesis 6: Traffic Light Test-short (TLT-s)

The final sample for the analysis of the Traffic Light Test-short (TLT-s) consisted of *N* = 104 participants. Out of them *n* = 65 were female and *n* = 38 were male. The average age was 39.17 years (*SD* = 17.42) with a range from 18 to 85. The mean years of formal education were 16.29 (*SD* = 3.80) with a range from eight to 27. Demographic information of one participant was missing. The mean sum score reached by the present sample is 55.94 (*SD* = 9.00) in a possible range of 0 to 60. The range of the actual scores was 0 to 60 as well (see Fig. 23).

Figure 23

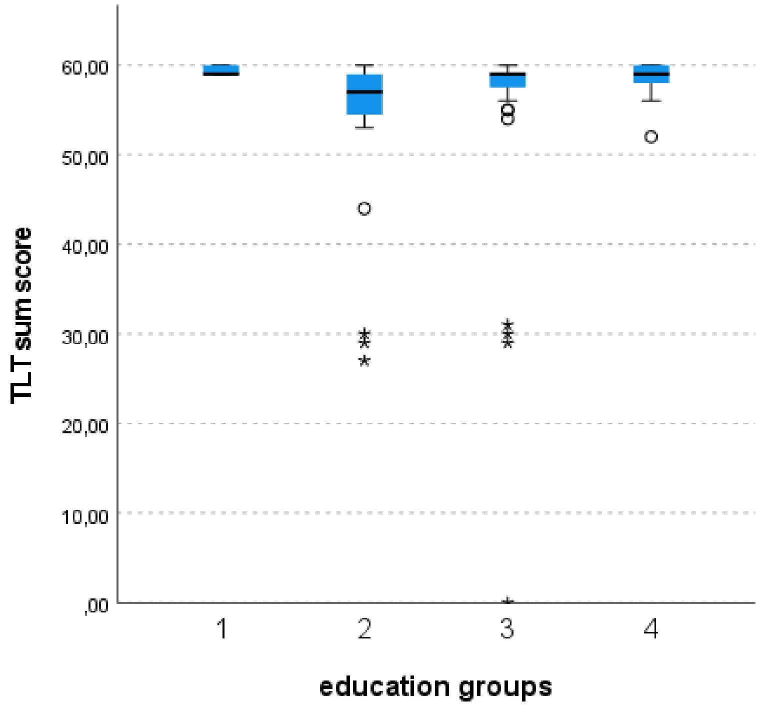
TLT-s Sum Score Distribution



Kruskall-Wallis Test. The Kruskall-Wallis test has shown that there were significant differences in the performance in the Traffic Light Test-short between the education groups, $H(3) = 10.657$, $p = .014$. However, after Bonferroni-correction for multiple comparisons the groups showed no significant differences, $p > .05$. Therefore, the alternative hypothesis number 5 cannot be accepted. Figure 24 illustrates the TLT-s sum score distribution across the four education groups.

Figure 24

Boxplots of TLT Sum Scores across Education Groups



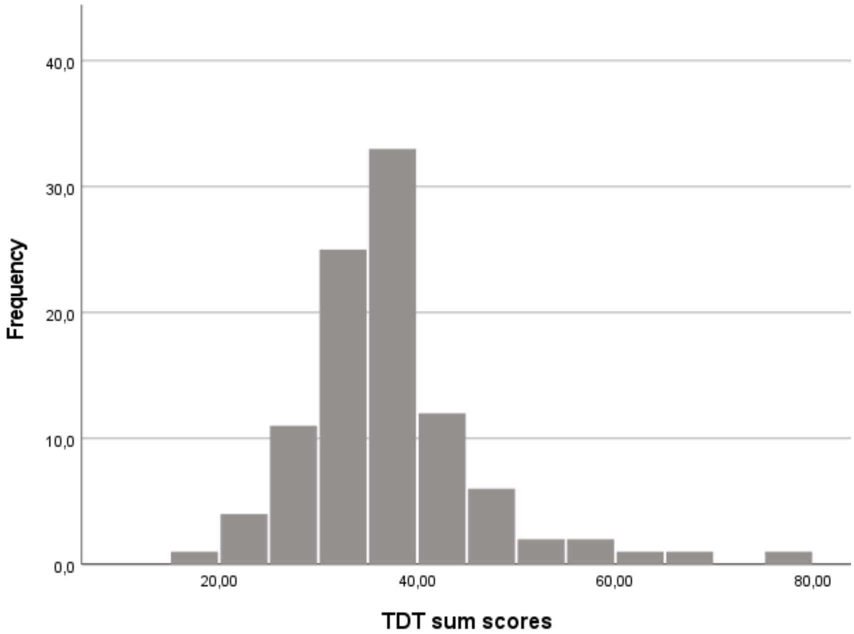
Hypothesis 11: Time Duration Test (TDT)

The final sample for the analysis of the Time Duration Test consisted of *N* = 99 participants. Out of them *n* = 63 were female and *n* = 36 were male. The average age was 38.38 years (*SD* = 17.16) with a range from 18 to 85. The mean years of formal education were 16.31 (*SD* = 3.78) with a range from eight to 27. The mean sum score reached by the present sample was 37.16 (*SD* = 9.13). The actual scores reached from 18.85 to 78.67, representing the sum of absolute differences between the time units presented in seconds (see Fig. 25).

Kruskall-Wallis Test. The Kruskall-Wallis test showed no significant difference in the TDT sum score between the different education groups, *H(3)* = 1.641, *p* = .650. Therefore, the alternative hypothesis 11 could not be confirmed.

Figure 25

TDT Sum Score Distribution



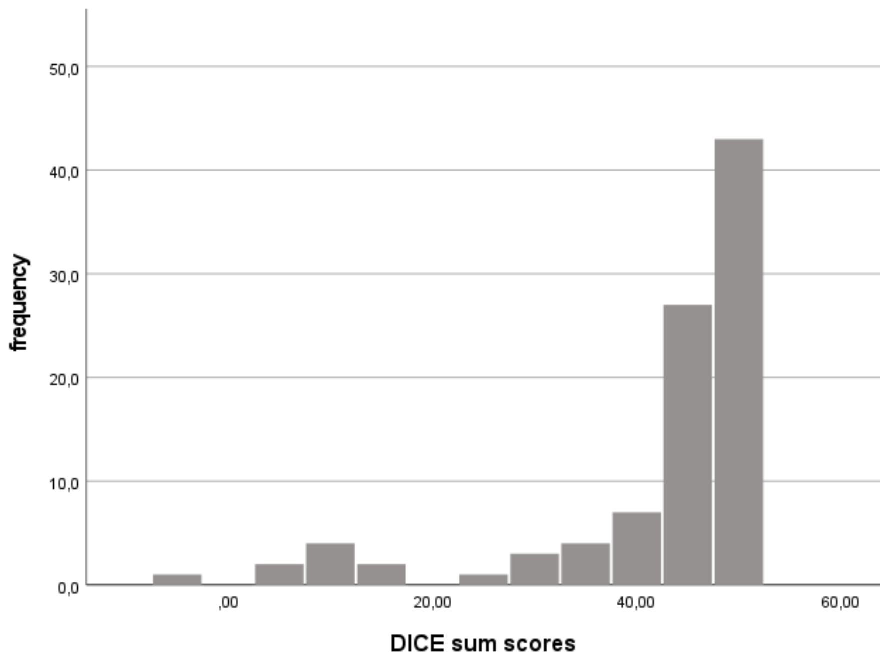
Hypothesis 12: DICE

The final sample for the analysis of the DICE test consisted of *N* = 94 participants. Out of them *n* = 22 were female and *n* = 21 were male. The average age was 37.18 years (*SD* = 15.90) with a range from 18 to 79. The average amount of years of education was 16.55 (*SD* = 3.62) ranging from eight to 27. The mean sum score reached by the present sample was 42.30 (*SD* = 12.29). The actual scores in the present sample reached from -5 to 50 (see Fig. 26).

Kruskall-Wallis Test. The Kruskall-Wallis test showed no significant difference in the DICE sum score between the different education groups, $H(3) = 3.612$, $p = .307$. Thus, the alternative hypothesis 12 could not be confirmed.

Figure 26

DICE Sum Score Distribution

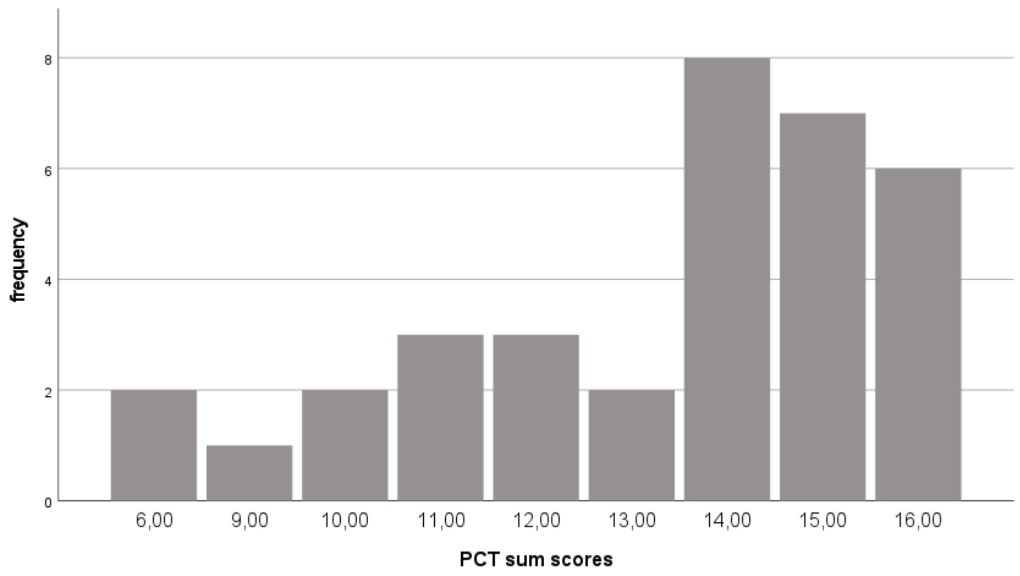


Hypothesis 13: Pattern Cancel Test (PCT)

The final sample for the analysis of the Pattern Cancel Test (PCT) consisted of *N* = 34 participants. Out of them *n* = 22 were female and *n* = 21 were male. The average age was 41.21 years (*SD* = 17.05) with a range from 19 to 76. The mean years of formal education were 17.12 (*SD* = 3.96) with a range from 9 to 27. The mean sum score reached by the present sample was 13.21 (*SD* = 2.67), within a possible range of 0 to 16. The actual scores reached from seven to 16 (see Fig. 27).

Figure 27

PCT Sum Score Distribution



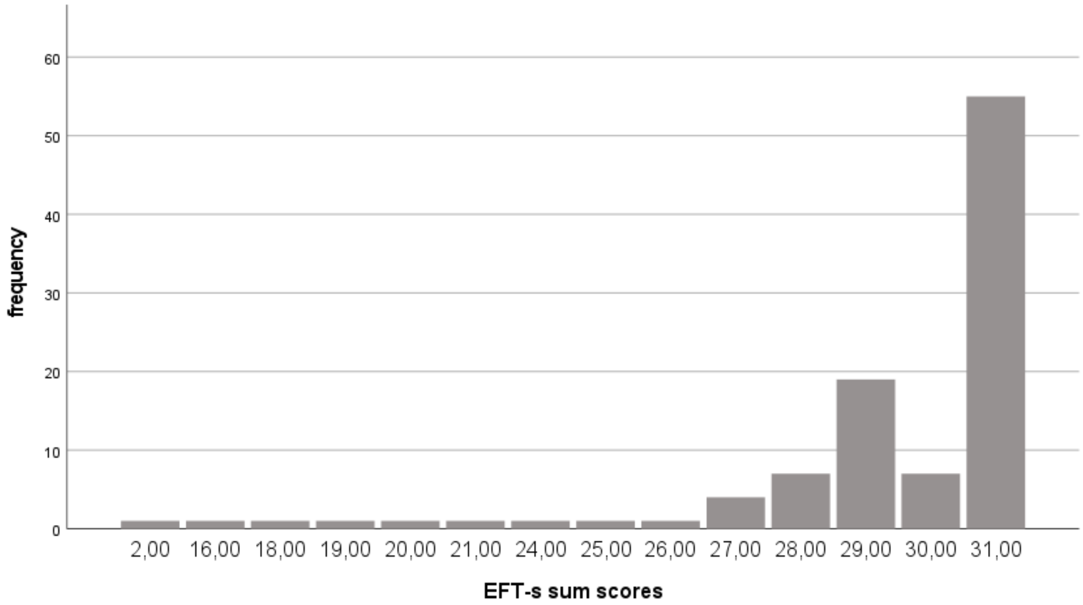
Kruskall-Wallis Test. The Kruskall-Wallis test showed no significant difference in the PCT sum score between the different education groups, $H(3) = 2.818$, $p = .421$. Thus, the alternative hypothesis 13 could not be confirmed.

Hypothesis 14: Emotion Face Test-short (EFT-s)

The final sample for the analysis of the Emotion Face Test-short consisted of $N = 101$ participants. Out of them $n = 59$ were female and $n = 42$ were male. The average age was 38.95 years ($SD = 17.13$) with a range from 18 to 80. The mean years of formal education were 16.43 ($SD = 3.77$) with a range from eight to 26. The present sample showed a mean score of 29.12 ($SD = 3.95$), within a possible range of 0 to 60. The actual scores reached from two to 31 (see Fig. 28).

Figure 28

EFT-s Sum Score Distribution



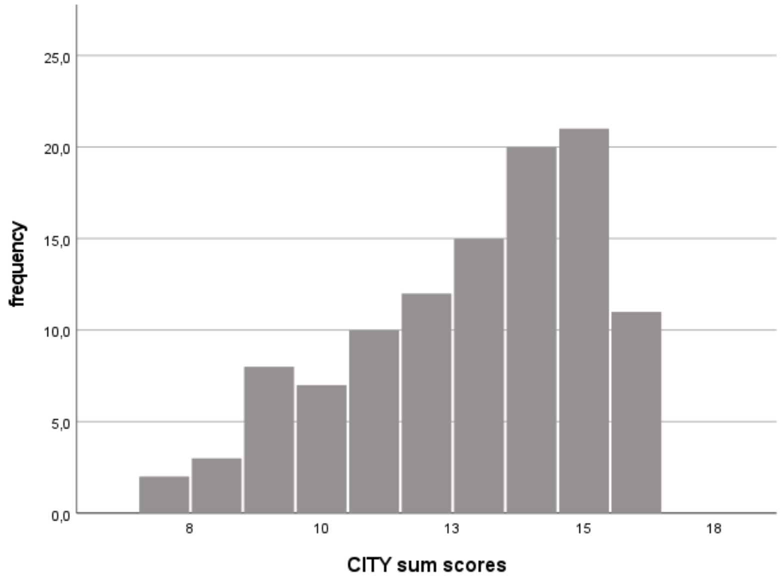
Kruskall-Wallis Test. The Kruskall-Wallis test revealed no significant difference in the EFT-s sum score between the different education groups, $H(3) = 3.651$, $p = .302$. Thus, the alternative hypothesis 14 could not be verified.

Hypothesis 17: CITY Identification

The final sample for the analysis of the CITY test consisted of $N = 109$ participants. Out of them $n = 68$ were female and $n = 41$ were male. The average age was 39.77 years (SD = 17.28) with a range from 18 to 85. The mean years of formal education were 16.32 (SD = 3.92) with a range from 8 to 26. The present sample showed a mean score of 12.84 (SD = 2.34), within a possible range of 0 to 16. The actual scores reached from seven to 16 (see Fig. 29).

Figure 29

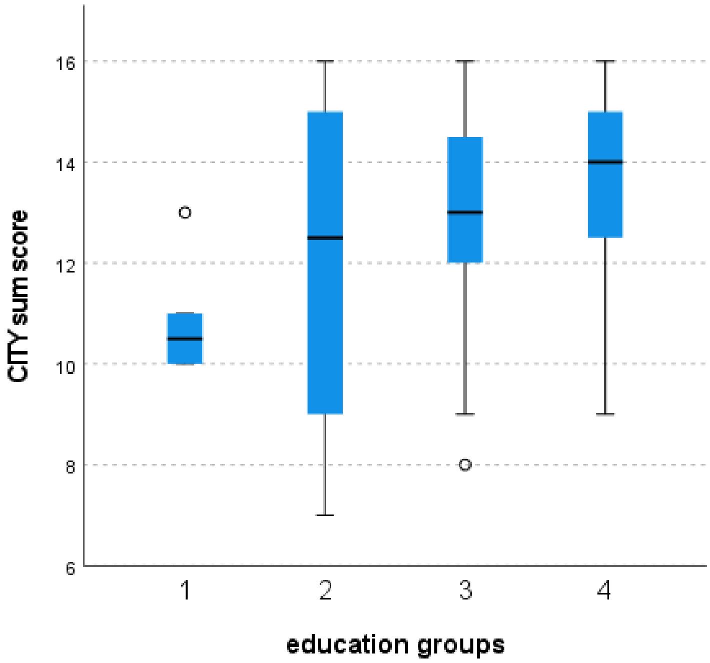
CITY Sum Score Distribution



Kruskal-Wallis Test. The Kruskal-Wallis test showed that there were significant differences in the performance in the CITY test between the education groups, $H(3) = 9.189$, $p = .027$. The Post-hoc analysis has shown significantly different mean scores between education group 1 and group 4 with a medium effect, $p = .027$, $r = .495$. The other groups did not differ significantly regarding their performance in the CITY test, $p > .05$ Therefore, as group 4 showed significantly higher mean results than group 1, the alternative hypothesis number 17 can be partly accepted. Figure 30 illustrates the CITY sum score distribution across the four education groups.

Figure 30

Boxplots of CITY Sum Scores across Education Groups

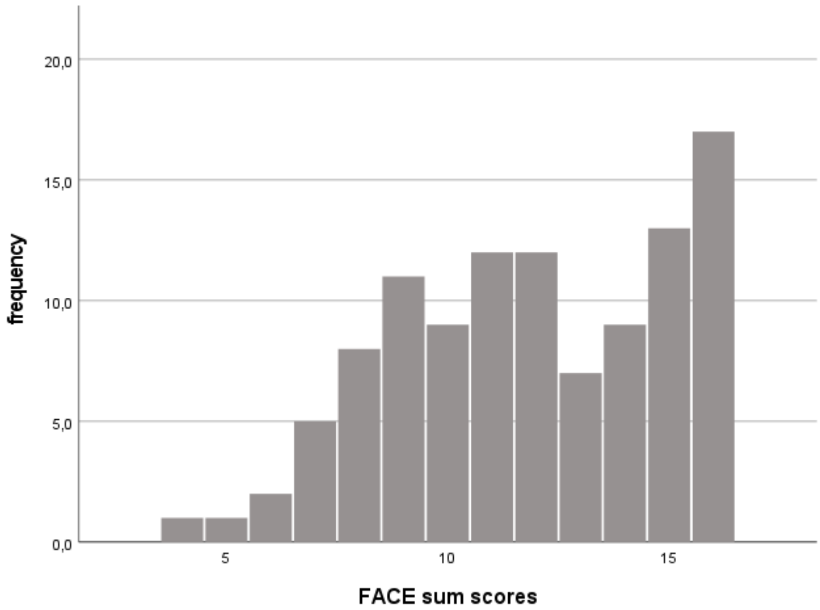


Hypothesis 18: FACE Identification

The final sample for the analysis of the FACE test consisted of *N* = 107 participants. Out of them *n* = 61 were female and *n* = 46 were male. The average age was 40.06 years (*SD* = 17.31) with a range from 18 to 80. The mean years of formal education were 16.45 (*SD* = 4.01) with a range from eight to 27. The mean sum score reached by the present sample was 11.86 (*SD* = 3.09), within a possible range of 0 to 16. The actual scores reached from four to 16 (see Fig. 31).

Figure 31

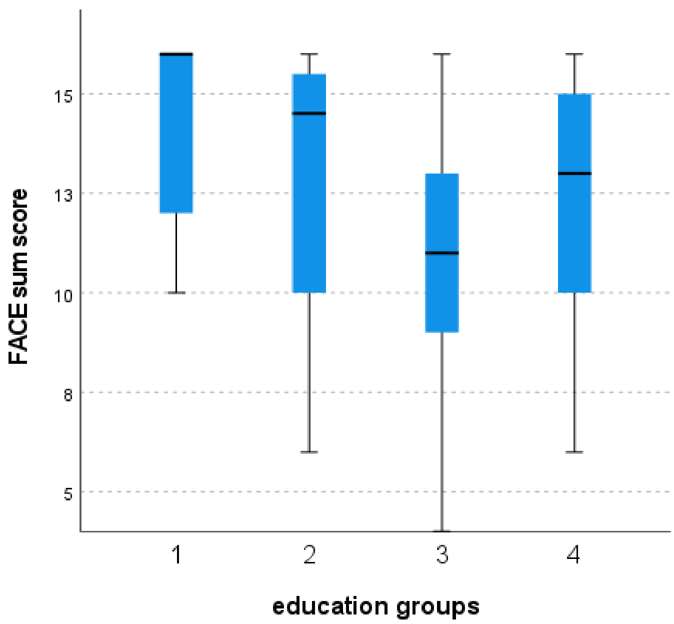
FACE Sum Score Distribution



Kruskal-Wallis Test. The Kruskall-Wallis test has shown that there were significant differences in the performance in the FACE test between the education groups, $H(3) = 13.460$, $p = .004$. Group 1 and group 3 showed significantly different mean results with a medium effect, $p = .013$, $r = .404$. The other groups (group 1 and 2, group 1 and 4, group 2 and 4, group 1 and 4, group 3 and 2, group 3 and 4) showed no significant differences, $p > .05$. Therefore, group 3 showed significantly lower results than group 1 and the alternative hypothesis number 18 can be partly accepted. Figure 32 illustrates the FACE sum score distribution across the four education groups.

Figure 32

Boxplots of FACE Sum Scores across Education Groups



Additional Exploratory Analysis

In order to investigate the general association between the years of formal education and performance in the subtests, an exploratory correlation analysis was conducted. Spearman's correlation coefficient (*rS)* was used due to violation of normal distribution in various variables and higher robustness regarding outliers. Furthermore, bootstrapping with 1000 bootstrap samples was carried out to gain robust confidence intervals. The resulting correlation coefficients are presented in Table 6. A significant positive correlation between years of education and the CITY sum score with a small effect size was found. Additionally, there were highly significant positive correlations between years of education and the Digital Symbol Test score and the Figure Fluency Test with a medium effect size. Years of education and the Traffic Light Test-short showed a significant positive correlation with a small effect. Neither of the confidence intervals included the value 0, leading to the conclusion that the assumption of significant associations can be retained (Field, 2018). The scores of the other subtests (FACE, TDT, DICE and EFT-s), however, did not show a statistically significant association with the duration of formal education ($p > .05$).

Table 6

Bivariate Correlations between Years of formal Education and the relevant INCP Subtests

Variable	*N*	*rS*	Sig.	95% CI
CITY	109	.209*	.029	[.009; .394]
FACE	107	-.124	.203	[.004; .109]
DST	75	.375**	.001	[.140; 1.00]
TDT	99	-.032	.753	[-.227; .177]
DICE	96	.163	.112	[-.052; -368]
PCT	34	.165	.352	[-.217; -476]
EFT-s	101	.164	.101	[-.048; .363]
FFT	85	.348**	.001	[.144; .544]
TLT-s	104	.229*	.020	[.013; .406]

Note. *N* = sample size with relevant data, *rS* = Spearman correlation coefficient with years of formal education, 95% CI = confidence interval resulting of bootstrapping with 1000 samples, *p < .05, **p < .001 (two-tailed)

Discussion

Summary of Findings

The objective of the present study was to investigate whether years of formal education show an effect on the performance in each subtest of the INCP. For this first explorative analysis of the newly developed tablet-tests no specific a priori assumptions regarding potential education effects have been made. Potential education as well as age and gender effects have to be investigated in the development of psychological assessment tools in order to ensure valid testing. In the case of the International Neurocognitive Test Profile this means the actual assessment of cognitive performance with as low as possible confounding influences.

The results of this study suggest significant differences between the education groups regarding their performance in the CITY identification, FACE identification, Figure Fluency

Test, and Digital Symbol Test sum scores with a medium effect. In the CITY test, group 4 showed significantly higher rates than group 1. DST sum scores differed significantly between group 1 and 3, and group 2 and 3. In contrast, group 1 showed significantly higher scores in the FACE test than group 3. In the FFT, group 3 and group 4 performed significantly better than group 2. Contrary to the primary hypotheses of the study there were no significant education effects in the TDT, DICE, EFT-s, TLT-s and PCT.

The generalizability and interpretability of the results are limited due to the general small sample size and even smaller sample sizes within the education groups. Because there were only few participants with less than nine and between nine and 13 years of formal education, the results of the Kruskal-Wallis test show limited power. An additional exploratory correlation analysis indicated significant positive associations between years of formal education and the CITY, DST. FFT and TLT-s subtest results. Thus, the more years of education the better participants performed in these subtests on average. As the study was planned with an exploratory approach, several subtests could not have been analysed according to the initial hypotheses due to random item presentation and consequent small sample sizes per item.

Interpretation & Integration in the State of Research

Main Question of Research

Hypotheses on the effects of education on the INCP subtest were not specifically based on former findings and carried out exploratory for the INCP prototype, assuming education effects on all neurocognitive domains. The general effect of education on overall neurocognitive function found in previous studies could not be supported. The significant differences between education groups in the CITY, FACE, FFT (medium effects) and DST (large effect) indicate potential significant education effects. Effects could thus be found in the domains of memory skills (CITY, FACE), complex attention (DST), and executive function (FFT, TLT-s). No effects were found in social cognition (EFT-s), and other measures of complex attention (PCT) and executive function (TDT, DICE). Measures of language (INT, AVT, VVT, WS-s) could not be further analysed in the present study. Former findings on the effect of the duration of education on the semantic memory measure, the World Capital Knowledge (WCK; Heidinger & Lehrner, 2020), could not be analysed in the present study.

Nevertheless, in further studies the sample should be more equally distributed regarding age across the education groups in order to minimise confounding age effects. Therefore, the present results can neither be interpreted as education effects nor be generalized.

In general, the sample shows a high average duration education with a mean of 16.14 years of education, which represents an academic level of formal education. Additionally, the age distribution across education groups is unequal with means ranging from 31.98 in group 3 to 59.22 in group 1 in the final sample after exclusion. In addition to the overall unequally distributed recruitment of participants, cognitive exclusion criteria also lead to the decrease of older, less educated individuals. Since the sample sizes in each subtest was different, sample compositions regarding age and education also differ per subtest. Furthermore, several variables were not normally distributed. Thus, potential biases have to be assumed and taken into account when interpreting the results of the present study. Statistically significant results are therefore interpreted only carefully in the following, emphasising the need for future research on the subtests.

CITY. In the CITY identification test, group 1 showed significant lower scores than group 4, suggesting possible differences in semantic memory test performance between the lowest and highest educated groups.

FACE. In contrast to the other findings in this study, group 1 has shown significantly higher scores in the FACE subtest than group 3. The boxplot graphic illustrates the highest mean in this group compared to all other groups. As in the FACE test photos of celebrities of the former century are shown and participants in the lowest education group show the highest average age, this result might be caused by a generation effect. Older participants might thus be better at recognising the faces. This raises the questions whether memory functions are tested validly in this test.

Figure Fluency Test. In the Figure Fluency Test group 2 and 3, and group 2 and 4 showed significantly differing mean scores. Group 2 performed worse than group 3 and 4 on average, while group 1 showed a higher mean score than group 2 as well. The descriptive analysis of the Figure Fluency Test measures has shown several outliers with low sum scores, indicating possible difficulties understanding the instructions.

Digital Symbol Test. In the Digital Symbol Test group 1 and 2, and group 2 and 3 showed significantly different results. Group 2 showed lower results than group 1, while group 3 showed the highest scores on average. As group 2 performed lower results than group 1 and the difference between group 1 and 4 was not statistically significant, there is no clear effect of the duration of education observable. The Digital Symbol test depends on the speed of the participant and measures attention skills which might be biased by age distributions across the groups, with group 4 showing a lower mean age than group 3.

Additional Exploratory Analysis

An additional exploratory analysis was carried out to further investigate the relationship between education and performance in the relevant INCP subtests. The results have shown a significant positive association with small effects between years of formal education and the CITY test, and TLT-s test performance. Furthermore, a positive association between the DST test and FFT test and years of formal education with medium effects were found. This emphasizes the results of the group comparison on these tests, indicating possible education effects. Furthermore, the finding of the positive correlation between years of education and the CITY test and not in the FACE test support former findings by Lehrner et al. (2017). However, just as for the main question of research, generalizability and interpretability are limited due to small sample sizes per test: The final sample size was 109 for the CITY test, 75 for the DST, 85 for the FFT, and 104 for the TLT-s. Nevertheless, continuing research on the INCP should further investigate the possible education effect in these tests within a larger sample.

Limitations & Challenges

Study Design

Even though a pilot study design enables flexibility within the process of an interim evaluation, it also involves general limitations and challenges. In the present study different sample sizes per subtest result from adding further tests in the newer versions of the INCP. The current study involves data of the first three versions of the INCP, which included different amounts of subtests. Throughout the assessment period an error in the Faces Couples Test (FCT) has occurred which led to an exclusion of the subtest for the rest of the study. The ongoing development and adaption due to errors result in different amounts of data for the subtests with different sample sizes and compositions. Therefore, methodological analysis had to be conducted carefully regarding the different sample distributions per sum score and demographic variable. Small sample sizes in group comparisons lead to smaller effect sizes, as the power is based on the size of the smallest group (Field, 2018).

Furthermore, due to random presentation of items in the INT, AVT, VVT, WCK, WFK, EST, SCT, SCT, WS-s and FCT the tests could have only be described descriptively. This leads to suboptimal conditions for the analysis of the performance throughout the sample, as the sum score per se cannot be compared throughout the sample. This would require a large overall sample size, leading to proper sample sizes per item and higher power in test results. On the other side, random item presentation in test batteries which are repeated over time could avoid training effects leading to a higher validity in testing.

A further possible limitation of the current study is the assessment of years of education in formal institutions only. This conception merely includes official years at school and university. Apprenticeships which involve further education and private institutions which offer advanced training besides university are therefore not included, leading to the need for caution when interpreting the results. Furthermore, more years of education could also indicate difficulties at school and having had to repeat a class at school. Carrying out the analysis with years of education as a metric variable would attenuate the challenge of unequally distributed education groups. The arrangement of education in clean groups, however, is supposed to be more comparable (Clouston et al., 2020) and was chosen in the present study to reveal more specific effects between each group/level of education.

Sample & Recruitment

The recruitment process in this study was accompanied by several challenges, especially due to Covid-19 measures (such as strict lockdowns) during the assessment period. As a result, it was harder to ensure a balanced sample distribution regarding age, gender, and education groups. Especially lower education groups were harder to reach since participants mainly within the private surroundings of the study conductors were tested in addition to companions of patients of the neurological outpatient clinic of the General Hospital Vienna (AKH). In addition to that, during strict lockdowns fewer patients were allowed and appeared for their appointments. Patients, companions as well as participants of the study have had to stick to certain measures to enter the hospital: a negative Covid-test certificate (max. 48h old), access authorization by the hospital, and wearing an FFP-2 mask. These procedures, frequent changes and insecurity concerning current measures, and possible worry about entering a hospital during the pandemic aggravated the recruitment process.

Furthermore, some participants at the outpatient clinic had to quit the assessment prematurely due to shortage in time. Further earlier terminations have occurred due to technical errors (e.g. due to the FCT). Only a few participants quitted early due to difficulties with concentration or lack of motivation. Additionally, 24 out of 141 persons of the total sample who have performed the Beck Depression Scale II had to be excluded due to scores indicating clinically relevant symptoms of depression. A potential contributory factor for high depression rates could be the overall higher levels of depressive symptoms and anxiety Covid-19 lockdowns in Austria (Pieh et al., 2021). Secondly, companions at the outpatient clinic might experience higher levels of stress, or even anxiety and depression, due to the cognitive symptoms of the person they are accompanying.

Assessment Method

The tablet-based testing design might pose challenges for older or physically impaired individuals: sensory or motor problems (e.g. arthritis, long fingernails) or poor eyesight could impact the testing experience and cause variability in scores. Especially the performance in reaction time tasks could be impacted (Rentz et al., 2016). These conditions could lead to overall age effects, which have to be taken account also in the aspect of education effects. In order to guarantee valid testing and avoid other confounding factors, clear instructions and a common training session are required prior to autonomous testing at-home (Rentz et al., 2016). Overall, learning effects concerning the performance in cognitive tests should be avoided. However, training effects regarding the handling of the tablet-tool are beneficial for successful test completion. In the further course of the study the participant's tablet handling ability should be examined prior to the assessment.

Outliers with very low sum scores were observable in the performance distribution of the FFT, TLT-s and DICE, indicating possible difficulties with understanding the instruction or handling the tablet. The DICE test involves negative sum scores, resulting of more incorrect than correct answers. These results emphasize the need for further investigation of the operability and comprehensibility of these subtests.

The overall assessment procedure in the study with the third version of the INCP lasted between 1.5 and 2 hours on average. Thus, the procedure requires a high level of concentration and attention which can lead to challenges regarding motivation and self-discipline in practise. This is why the idea is to implement shorter test versions for the at-home setting in order to increase compliance and motivation. Immediate feedback should also lead to a higher chance of regular autonomous conduct of the cognitive assessment. However, the longer test battery for the baseline and follow-up assessment enables more thorough investigation of the cognitive status and is important to sensitively detect early cognitive variations. Furthermore, in future practise, individuals are required to have high self-discipline and possess an iPad for regular at-home testing.

Conclusion and Future Research

To sum up, the present study offers first insights in the feasibility of the subtests and suggests possible education effects in the CITY identification, FACE identification, Figure Fluency Test, Traffic Light Test-short and Digital Symbol Test. However, due to suboptimal sampling the explanatory power of this study is limited. Further findings are important in order to adjust the subtests and control for certain adverse education effects prior to implementation in practise.

To ensure interpretable and generalizable results the study must be repeated with a bigger and more equally distributed sample collecting more data on the newer INCP subtests. Thus, in a next step, in future well-powered studies the refined neurocognitive test battery should be carried out with a more equally distributed sample regarding levels of formal education to gain further understanding of the effect of education in the INCP subtests. In specific, to ensure results with a strong power the sample should include more participants with lower levels of education. Additionally, future studies should analyse tendencies of the sum scores as well as single items in the subtests more thoroughly regarding effects of age, gender, and education groups. As later birth cohorts have found to perform better in episodic memory tasks even after taking differences in duration of education into account (Berggren et al., 2018), a common assessment and analysis of age and education effects and interactions is necessary.

In conclusion, even though the study could not investigate all the initial stated hypotheses and the sample was too small to draw any strong conclusions on potential education effects, it opens potential for further insights in the feasibility and validity of the International Neurocognitive Test Profile. By identifying difficulties in the analysis of the subtests as part of the pilot study approach it has established a basis for future evaluations. To address the challenges of the pilot study design, changes and adaptions should be well documented and reported throughout the further conduct.

All in all, the development of the tablet-based neurocognitive test battery offers potential for an efficient, easy-to-use, sensitive testing tool which can be applied for prevention of cognitive decline within a large part of the population. Each healthy individual who possesses an iPad and is motivated to monitor her/his own cognitive functions should be able to use the International Neurocognitive Test Profile in the future. Additional findings on age, gender and education effects are needed in order to be able to take them into account for further development of the test battery. Subsequently, norms for specific samples based on age, gender and formal education are required in order to set criteria for standardized comparison of cognitive functions.

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Appendix

Abstract English

With 50 million people living with the diagnosis worldwide, increasing life expectancy, and no effective treatment in sight, dementia is one of the major causes of disability and dependency among older people, posing a big burden for those affected, their carers, families, health and welfare systems. Sensitive, efficient, easy-to-use early detection methods are crucial in order to detect already the stages of Subjective Cognitive Decline (SCD) and Mild Cognitive Impairment (MCI), thus decelerate the progression of the disease. In response to these issues, the International Neurocognitive Test Profile (INCP) is being developed at the Medical University of Vienna, offering a tool for frequent at-home cognitive monitoring. The aim of the present study was to contribute to its first evaluation by assessing potential education effects on the performance in the 18 subtests of the INCP. 279 participants between the age of 18 and 88 participated in the study by complecting the INCP assessment. Due to screening criteria the final sample consisted of 117 individuals. The results suggested significant differences between certain education groups in the CITY identification, FACE identification, Figure Fluency and Digital Symbol Test and a positive association between years of education and the CITY, Figure Fluency Test, Traffic Light Test-short, and Digital Symbol Test. However, due to suboptimal sampling generalizability and interpretability of these results is limited. Further findings on the effect of education in the INCP with bigger, more equally distributed samples are crucial to ensure valid testing and to make the early detection tool accessible for the general population.

Keywords: dementia, preventative cognitive screening, early detection, tablet-based testing, International Neurocognitive Test Profile (INCP)

Zusammenfassung

Aufgrund von 50 Millionen Fällen weltweit, der steigenden Lebenserwartung, und keiner wirksamen Behandlung in Sicht, stellt die Demenzerkrankung eine der Hauptgründe für Beeinträchtigung und Abhängigkeit bei alten Menschen dar. Diese führen zu einer großen Belastung für Betroffene, Pflegende, Familien und Gesundheits- und Sozialsysteme. Sensitive, effiziente, einfach-handhabbare Früherkennungsinstrumente sind notwendig, um die Krankheit bereits in den frühen Stadien von subjektivem kognitivem Abbau (SCD) und leichter kognitiver Beeinträchtigung (MCI) zu erkennen und den Fortschritt zu verlangsamen. Deshalb wird das Internationale Neurokognitive Testprofil (INCP) an der Medizinischen Universität entwickelt, welches eine Methode zur regelmäßigen kognitiven Selbstbeobachtung darstellt. Das Ziel der vorliegenden Studie war es, durch die Erhebung von potenziellen Bildungseffekten auf die Leistung in den 18 INCP Subtests, zu einer ersten Zwischenevaluierung beizutragen. 279 Personen zwischen 18 und 88 Jahren haben an der Studie teilgenommen. Aufgrund von Screening-Kriterien bestand die endgültige Stichprobe aus 117 Teilnehmenden. Die Ergebnisse zeigten signifikante Unterschiede zwischen Bildungsgruppen im CITY Identification, FACE Identification, Figure Fluency und Digital Symbol Test und eine positive Beziehung zwischen den Bildungsjahren und dem CITY, Figure Fluency Test, Traffic Light Test-short und Digital Symbol Test. Die Generalisierbarkeit und Interpretierbarkeit der Ergebnisse sind jedoch durch eine suboptimale Stichprobenzusammensetzung begrenzt. Weitere Ergebnisse zu dem Effekt von Bildung in dem INCP mit größeren, gleichmäßig verteilten Stichproben sind notwendig, um valides Testen zu garantieren und das Früherkennungsinstrument folglich für die Bevölkerung zugänglich zu machen.

Schlagwörter: Demenz, präventives kognitives Screening, Früherkennung, Tablet-basiertes Testen, International Neurocognitive Test Profile (INCP)