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# OPERATIONALIZATION OF THE DIMENSIONS OF A CLASSIFICATION OF MENTAL FUNCTIONS

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**Meiner Familie**

**Stephan und Hannah Sophie**

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## Zur Operationalisierung einer Klassifikation mentaler Funktionen


# ZUSAMMENFASSUNG

**Hintergrund:**

Bislang existierte keine empirisch bestätigte Taxonomie, die die Funktionen des Gehirns aus neuropsychologischer Perspektive zusammenfasst. Besonders in der klinischen Praxis sollte die Weise der Repräsentation von Funktionen im Gehirn berücksichtigt werden, will man sachgerechte Diagnostik und Therapie durchführen. Die Klassifikation mentaler Funktionen von Pöppel (1993, 1997) erklärt aus neuropsychologischer Sicht und auf der Basis der Psychologie der Zeit das Zusammenspiel elementarer psychischer Funktionen und fasst diese in einem theoretischen Modell zusammen. Grundlage ist die Unterscheidung von vier Erlebnisebenen: das Erlebnis von Gleichzeitigkeit, von Folge, von subjektiver Gegenwart und von Dauer. Diese Erlebnisebenen kommen zustande aufgrund von zwei unterschiedlichen Hirnmechanismen zeitlicher Organisation: einem *hochfrequenten Mechanismus*, der diskrete Systemzustände von ca. 30ms bereitstellt, innerhalb derer alle im Gehirn getrennt verarbeiteten Informationen aufeinander bezogen werden und einem *niederfrequenten Mechanismus*, der aufeinanderfolgende Systemzustände von 30 ms bis zu einer Grenze von 3 Sekunden zu Inhaltsgestalten zusammenfasst. Zusammen mit der Funktion, die dafür sorgt, dass ein bestimmtes *Aktivationsniveau* verfügbar ist, bilden diese beiden Funktionen die *logistischen Funktionen*

der Klassifikation. Sie sind aber nicht nur Grundlage des zeitlichen Erlebens, sondern auch des subjektiv Erfahrbaren, d.h. unserer Wahrnehmungen (Reizaufnahme), Erinnerungen (Reizverarbeitung), Emotionen (Reizbewertung) und der Aktion, bzw. Reaktion. Diese vier Bereiche des subjektiv Erfahrbaren bilden die *Inhaltsfunktionen* der Klassifikation mentaler Funktionen.

**Zielsetzung:**

Ziel der vorliegenden Arbeit ist die statistische Analyse der faktoriellen Struktur des theoretischen Modells von Pöppel. Anhand einer theoriegeleiteten Batterie von (neuro-) psychologischen Messinstrumenten wird geprüft, ob die theoretisch postulierten mentalen Funktionen empirisch repliziert werden können. Spezifisches Ziel ist dabei die faktorenanalytische Darstellung der Klassifikation mentaler Funktionen nach Pöppel durch die einzelnen Tests.

**Methoden:**

Die Datenerhebung wurde im Rahmen einer pharmazeutisch unterstützten, monozentrischen, parallel-gruppen, doppelblinden, prospektiven Phase IV Studie mit zwei Messzeitpunkten durchgeführt. Es wurden gesunde Probanden im Alter zwischen 50 und 65 Jahren ohne altersbedingte Beeinträchtigung eingeschlossen. Auf der Basis der Theorie mentaler Funktionen wurden fünfzehn (neuro-)- psychologische Tests ausgewählt, um das Repertoire der inhaltsbezogenen und logistischen Funktionen zu bestimmen; neun Tests zu den Inhaltsfunktionen und sechs Tests zu den logistischen Funktionen des Gehirns. Anhand einer Faktorenanalyse wurde überprüft, inwieweit sich aufgrund der gewonnenen Daten die Zuordnung der Messinstrumente zu der Klassifikation der mentalen Funktionen in der Theorie replizieren lässt.

**Ergebnisse:**

Die inhaltsbezogene Funktion ‚Reizaufnahme' wird durch die korrespondierenden Tests vollständig abgebildet, ebenso die Funktion ‚Reizbewertung'. Die Funktion ‚Aktion/Reaktion' wird durch Variablen zweier von drei Tests repliziert. Zeitliche Reproduktion von <3000ms und ≥3000ms als niederfrequenter Bestandteil der logistischen Funktion ‚Zeitliche Organisation' wird auf zwei Faktoren verteilt. Der hochfrequente Bestandteil der zeitlichen Organisation von 30ms konnte in der vorliegenden Arbeit nicht verifiziert werden, ebenso

die logistische Funktion ‚Aktivation/Aufmerksamkeit’. Ein neuer Faktor verknüpft Variablen zeitlicher Organisation und inhaltlicher Umsetzung. Insgesamt erklären die 6 extrahierten Faktoren 62.1% der gesamten Varianz.

**Schlussfolgerung:**

Großenteils bestätigen die Ergebnisse der faktorenanalytischen Skalenreplikation die vorgegebenen sechs Dimensionen der Klassifikation mentaler Funktionen. Vier der sechs mentalen Funktionen konnten faktorenanalytisch zufriedenstellend dargestellt werden. Des Weiteren werden neue Aspekte der Zuordnung der Instrumente zu der Theorie mentaler Funktionen beleuchtet. Besonders deutlich wird innerhalb der logistischen Funktion ‚zeitliche Organisation’ im niederfrequenten Mechanismus die Differenzierung zwischen reproduzierten Zeitspannen unter und über 3 Sekunden. In der Theorie wird das zeitliche Limit von 3 Sekunden als zeitlicher Übergang von der Wahrnehmung subjektiver Gegenwart zur Wahrnehmung von Dauer verstanden. Zeitliche Organisation um 30-40Hz war faktorenanalytisch nicht replizierbar. Diese Zeiteinheit gilt als Schwelle für die Erfahrung von Gleichzeitigkeit und Folge zweier Stimuli. Außerdem wird in der Analyse ein Faktor sichtbar, der inhaltliche *und* logistische Komponenten des Gehirns verknüpft. Offenbar kann die Testbatterie einige Variablen nicht isoliert voneinander repräsentieren. Dieses Ergebnis liefert Evidenz für die theoretische Annahme der engen Verknüpfung inhaltlicher und logistischer Funktionen. Durch die vorliegende Studie ist ein wichtiger Schritt getan, die Klassifikation mentaler Funktionen für die klinische Praxis zu nutzen. Durch gezielte Diagnose einer fehlerhaften Funktion kann auch gezielt interveniert werden. Besonders die logistischen Funktionen der Klassifikation wurden in der neuropsychologischen Praxis lange vernachlässigt. Für die wissenschaftliche Bearbeitung psychischer Phänomene ist ein sachgerechtes Klassifikationssystem ebenfalls Voraussetzung.

**Schlüsselwörter**:

Klassifikation psychischer Funktionen; Inhaltsbezogene Funktionen: Reizaufnahme, Reizbearbeitung, Reizbewertung, Aktion/Reaktion; Logistische Funktionen: Aktivation/Aufmerksamkeit, Zeitliche Organisation; Zeitverarbeitung, Zeitwahrnehmung, Gleichzeitigkeit, Folge, Dauer, subjektive Gegenwart.

# Operationalization of a classification of mental functions


## ABSTRACT

**Background:**

So far there has been no empirically proven taxonomy of mental functions which summarizes brain functions from a neuropsychological perspective. The classification of mental functions by Pöppel (1993, 1997) explains the correlation of the elementary functions from a neuropsychological point of view, based on a psychology of time. He distinguishes four levels of cognition: the cognition of simultaneity, of succession, of the subjective present, and of duration. These levels of cognition are based on two different brain mechanisms of *temporal organization*: a *high-frequency mechanism* that provides discrete systemic conditions of 30ms, within which all information that is processed separately in the brain is synchronized, and a *low-frequency mechanism* that summarizes subsequent systemic conditions from 30ms up to a limit of 3 seconds. Together with the function that provides a certain level of *activation*, these two functions form the *logistical functions* of the classification of mental functions. They provide not only the basis of temporal cognition, but also of that which can be subjectively experienced, i.e., of our perceptions (representation or perceptual processing of stimuli), memories (stimulus processing or storage of information), emotions (evaluation of stimuli), and action, respectively reaction (response to stimuli). These four domains are the *content-related functions* of the classification of mental functions.

**Objective:**

The objective of this paper is to determine to what extent empirical data collected from a (neuro-) psychological test battery reflect the representation of the mental functions postulated in theory. The specific goal is the factor-analytical representation of the classification of mental functions according to Pöppel (1993, 1997) by means of the individual tests.

**Methods:**

Healthy subjects aged 50 to 65 years without age-associated impairment participated in the pharmacologically-sponsored clinical study. Based on the theory of mental functioning, 15 (neuro-) psychological tests were selected to assess the repertoire of content-related and logistical functions. Nine tests were selected to assess content-related functions and six to assess logistical functions. To further test the dimensionality of Pöppel's classification, a factor analysis was conducted to indicate to what extent the measuring instruments cover the mental functions in Pöppel's classification.

**Results:**

The content-related function *stimulus representation* is covered completely, the function *action/reaction* is covered by variables in two out of three tests. The dimension *emotional evaluation of information* is largely covered. Temporal reproduction units of <3000ms and ≥3000ms as essential components of the low-frequency-mechanism of the logistical function *temporal organization* is distributed in two factors. High-frequency temporal organization of 30ms could not be verified in the present study as well as the function activation/attention. Another factor combines variables of temporal organization and of content implementation. The total variance explained by six factors was 62.1%.

**Conclusions:**

The results of the factor-analytical scale replication generally confirm the six given dimensions of the classification. Four of the six mental functions could be represented satisfactorily through factor analysis. Additionally, new aspects of the attribution of the

instruments to the theory of mental functions can be assessed. The differentiation becomes most evident within time frames of under and over 3 seconds. The temporal limit of 3 seconds is theoretically assumed to be the threshold between subjective present and the perception of duration. Temporal Organization of 30-40Hz could not be reproduced by factor analysis in the given tests. This time unit is thought to be the threshold between the experience of simultaneity and succession of stimuli. In addition, one dimension comes to the fore that combines the content-related and the logistical components of the brain. The test battery obviously cannot represent some functions in isolation from each other. There may be a dimension on a different level of processing that combines content-related and logistical functions. This event provides evidence for the theoretical assumption of a close connection of content-related and logistical functions. With this study, an important move has been made, to use the classification of mental function for clinical practice. Via selective diagnosis of a deficient function, specific intervention can be implemented. In particular, the logistical functions of the classification have been neglected in neuropsychological practice. An appropriate system of classification is a prerequisite for the scientific exploration of psychological phenomena.

**Key index terms**:
The taxonomy of mental functions; content-related functions: stimulus representation, stimulus processing, stimulus evaluation, response to stimuli; logistical functions: activation/attention, temporal organization; temporal neuronal processing, time perception experiences, simultaneity, succession, duration, subjective present.

**GLOSSARY OF ABBREVIATIONS**

| | |
|---|---|
| AMG | German Drug Law (Arzneimittelgesetz) |
| AOT | Auditory Order Threshold |
| ART | Auditory Choice Reaction Time |
| CRF | Case Record Form |
| CWT | Colour Word Test |
| DCT-G | Digit Connection Test-General |
| EEG | Electro-Encephalography |
| ERP | Event-Related Potentials |
| GCP | Good Clinical Practice |
| $h^2$ | Communality |
| Hz | Hertz |
| ICH | International Conference Harmonization |
| IL | The Incidental Learning Test |
| ISI | Inter-Stimulus Interval |
| ITT | Intention To Treat |
| ITVS | Increment Threshold for Visual Stimuli |
| KMO | Kaiser-Meyer-Olkin |
| KMS | Cognitive Minimal Screening |
| KTT | Key Touching Time |
| LTM | Long-Term Memory |
| MH | Mental Health |
| MT | Maximal Tempo |
| PCA | Principal Component Analysis |
| PET | Positrone-Emission Tomography |
| PI | Pause Interval |
| POMS | Profile of Mood States |
| PT | Personal Tempo |
| QoL | Quality of Life |
| SAS | Statistical Analyses System |
| SD | Standard Deviation |
| SDS | Self-Rating Depression Scale |
| Sec | Seconds |
| SIS | Subjective Intensity Scale |
| SIS-M | Subjective Intensity Scale Mood |
| SIS-T | Subjective Intensity Scale Tiredness |
| SMS | Sensorimotor Synchronization Test |
| SPSS | Statistical Program for Social Sciences |
| STM | Short-Term Memory |
| TDD | Tasten Druck Dauer |
| TR | Temporal Reproduction |
| WHO | World Health Organization |
| WL | Word List Test |

## BACKGROUND

When studying the representation of psychological issues, like human behavior and experience, these issues are often examined in isolation from each other, resulting in a reduction of complexity. Since Fechner (1889), a more physically oriented way of thinking has influenced psychology. Despite changes in paradigms, such as represented in Gestalt psychology or modern psychological physics, this tradition has been effective until today. One of the consequences of this reductionary view is, that until today no appropriate classification of psychological phenomena exists. The representation of function of the brain should be considered, particularly during the neuro-psychological treatment of patients, if effective diagnosis and therapy is to be achieved. Pöppel (1989, 1993, 1994, 1997 and 1999) provides a suggestion that is empirico-theoretically founded. He assumes that "experience is the representation of a neuronal function" (Pöppel, 1993). His classification of mental functions explains the correlation of the elementary functions from a neuropsychological point of view, based on a psychology of time.

In its centennial history, the psychology of time has been influenced by other disciplines, like psychophysics and biology: Today three different branches of research investigating the perception of time can be distinguished.

The first branch focuses on the perception of time, i.e. the experience of time. Time is not regarded as a one-dimensional entity, but comprises several qualitatively different components which can be called elementary experiences of time (Pöppel, 1978, 1985). In this context, the central questions are: WHAT is the perception of time, and WHICH experiences of time can be distinguished.

The second branch of research is concerned with the neuroanatomic and physiologic bases of the perception of time and the cerebral structures responsible for the perception of time or the processing of time. It addresses the question of WHERE the processing of time takes place.

The third branch of research is concerned with how temporal information is processed in the brain, i.e. HOW the brain is able to perceive or experience time.

This paper presents a classification of mental functions that combines the first and the third branch of research. It not only presents the experience of time, but also postulates the neuronal mechanisms forming the basis of these experiences. These mechanisms are postulated here not only as a basis for the experience and the perception of time, but also as a general basis of mental processes, i.e. those of perception, information processing, emotional evaluation, and action/reaction. In his classification, Pöppel accordingly distinguishes two functional domains (Pöppel, 1993):

A Content-related functions that provide the content of experience or subjective representation (”What”-functions), and

B Logistic or formal functions that provide a necessary basis for the content-related functions (”How”-functions”).

Within the class of content-related functions, four domains of subjective representations can be distinguished:

A1 Stimulus representation or perceptual processing (e.g. seeing, hearing)

A2 Information processing or storing of information as reflected in different memory systems (learning and memory)

A3 Emotional evaluation of information as reflected in feelings and motivations

A4 Response to stimuli as reflected in voluntary control of decisions or movements (action, reaction, volition, and decision).

In everyday language, we refer to these four domains as **perception**, **learning** and **memory**, **emotion,** and **action** or **reaction**. Neurobiologically, these four domains are characterized by a modular representation of function, i.e., functions are locally represented in the brain, as indicated by numerous neuropsychological observations (Kandel et al., 1996). For example, the local diencephalic or limbic representation of different emotions has been proven by neuro-ethological and neurological observations (Pöppel, 1993). For more than 100 years it has been known that particular lesions in the brain result in specific functional losses. For example, a patient who has suffered a local injury in the occipital lobe may exhibit circumscribed blindness in his visual field, like homonymous hemianopsia. Another patient with an injury to a different occipital site may no longer perceive colors (Pöppel et al., 1978). An example for local representation of stimulus processing is the patient who suffered a selective memory loss following bi-lateral surgical ablation of the hippocampus. He lost the capacity to store new information. For the emotional evaluation of information, it also seems true that different evaluative functions are represented in a modular fashion in the amygdala (LaBar, 2003; Dolcos et al., 2004; Phelps, 2002). The local diencephalic or limbic representation of different emotions has been proven by many observations (Ploog, 1980). The basal ganglia and the cerebellum are essential areas for the initiation of motor action belonging to the function 'action and reaction'.

The principle of the localization of functions may only apply to content-related functions, i.e. they are represented modularly. Neuronal programs that are restricted to a small area in the brain accordingly convey the content-related functions. Various functions can take place in a spatially overlapping or parallel manner by using different neuronal programs, like the use of different transmitters. As long as, for example, a chair is the content of our perception, several spatially separate areas of the brain are involved. If one is emotionally moved by the chair that leads to a reaction or response (e.g. taking a seat, Cieza, 2000; Roth, 2000). Several separate areas in the brain are involved in the contemplation of the chair. That leads directly to the question of how the brain integrates these pieces of information and perceives them as related to the stimulus (in this case "chair"). Even if the modules are regarded as mentally independent from one other, the content-related functions cannot be regarded as completely autonomous.

On the basis of modern imaging technology, this modular representation raises the question of how the different brain states are linked if complex functions are implemented by simultaneous neuronal activities in spatially distributed areas, which is apparently the case (Cieza et al., 2003). In the theoretical model presented here, they depend on the "logistical" functions of the brain:

B1 Activation/Attention, and

B2 Temporal organization of the content-related functions.

For the brain to function or for the subjective to be available, **activation** in general is necessary. Reduced activation and attention result in a reduced functional level of mental competence. Alternatively, increased activation leads to a higher performance level of content-related function. The reticular formation is considered to be the source of activation. This means that this function is represented locally, although its consequences are not localized. It extends over all domains of the psyche. The activation is responsible for the fact that content-related functions exceed a certain threshold that turns them into subjective representations and modulates their intensity.
Several dispersed areas in the brain may be implicated in the development of attention, as is indicated by some results of Positron-Emission Tomography (PET) and of measurements of changes in regional cerebral blood flow (rCBF) as commonly measured in functional magnetic resonance imagery (fMRI; Sabel & Steinbüchel, 1994).

In the theoretical model, the **temporal organization** of different brain activities is provided by specific temporal organizational mechanisms. It is not performed with continuity, but in temporal quantums. This assumption is founded on the necessary integration of spatially distributed information in the brain that possibly takes place in temporal asynchrony (e.g. vision). To achieve temporal integration of information of spatially separate origins, the brain may provide systemic states by means of neuronal oscillations that integrate the different pieces of information (**high-frequency mechanism**). The high-frequency mechanism is expressed by neuronal oscillations in the gamma range with a frequency of 30-40 Hz (Pöppel 1970, 1978, 1997). These oscillations can be observed in the mid-latency response of the evoked potential and can be derived from experiments on temporal order threshold, multimodal distributions of reaction time, or other experimental paradigms (Pöppel, 1994).

For example, experimental research on the temporal order threshold shows that no “before-after relationship” can be adduced for intervals shorter than 30ms. If a certain external stimulus causes a periodical neuronal oscillation that pulsates with periodical lengths of about 30 ms and if a second stimulus follows within the subsequent 30 ms, both stimuli are perceived within the same period and registered as co-temporal. Only when the temporal distance between two stimuli exceeds 30ms, are they processed in different periods of the same oscillatory process and perceived in sequence (Pöppel et al., 1990; Wittmann, 1999). Accordingly, this high-frequency mechanism is considered a necessary basis for the maintenance of the functioning of the content-related functions, as well as for the experience of **simultaneity** and **succession**. A further indication of its existence is provided by measurements of latency periods showing intermodal distances of 30ms to 40ms that occur before saccadic eye movements. Pöppel & Logothetis (1986; Ruhnau & Haase, 1993) assume that eye movements are possible only every 30 to 40 ms, which indicates that they are based on the same temporal conditions.

In addition to the high-frequency mechanism, Pöppel describes a low-frequency mechanism. This **low-frequency mechanism** integrates events which follow each other up to a temporal limit of approximately 3 seconds in a perceptual unit. James (1890) already described that time intervals of up to a few seconds are perceived qualitatively different from time intervals of a considerably longer duration. He maintained that intervals with duration of up to a few seconds can be perceived as a unity, whereas intervals of a longer duration are encoded symbolically and can no longer be perceived, but only be estimated. Short intervals of time that are perceived as a unit were already called the psychological respectively subjective present or “Präsenzzeit” in the early years of psychology (Stern, 1897; Wundt, 1911; Quasebarth, 1924). According to Fraisse (1984), one can only speak of temporal perception within the temporal limits of the psychological present. Beyond the psychological present, memory processes and attention play a considerable role, and time intervals can consequently only be estimated.

The phenomenon of the indifference interval described by Vierordt (1968) can be assessed through the method of temporal reproduction. This can be taken as an experimental indication of the fact that the integrational faculty of humans is limited to a few seconds (Pöppel, 1978). In an experiment involving nonverbal reproduction, acoustic or visual durations of stimuli are provided. These are to be reproduced as exactly as possible. Intervals of up to 3 seconds are mostly reproduced with considerable precision. Beyond that, precision decreases and variability increases (Pöppel, 1978, 1985; Fraisse, 1978). Pöppel (1994) calls the point of time at which duration is reflected with the greatest precision and variation is lowest “the interval of indifference”. Time intervals of up to 3 seconds are apparently perceived in total. That may be the result of a low-frequency mechanism that integrates successive systematic conditions of 30ms up to 3 seconds. This mechanism forms the basis of our experience of the **present**. Research with a metronome provides empirical evidence (Szelag et al., 1996; Szelag, 1997). If the intervals between the individual beats of the metronome exceed 3 seconds, no subjective integration can be made, they no longer form a time structure (Pöppel, 1994).

Further evidence of the time limit of 3 seconds is provided by experiments on sensory motor synchronization in which sequences of tones with different inter-stimulus intervals are synchronized by pressing a key. In stimulus intervals of 2-3 seconds, no stimulus anticipation takes place; the subject reacts to the stimulus. In contrast to the shorter intervals, a positive asynchrony takes place (Mates et al., 1994).

Experimental research of short-term memory shows that information can be retained for up to approximately 3 seconds (Lashley, 1951; Schleidt & Kein, 1997; Pöppel, 1985). Spoken language is interrupted by short breaks every 2-3 seconds (Turner & Pöppel, 1988; Kowal et al.; 1975, Vollrath, et al., 1992; Schleid & Kein, 1997).

According to Pöppel (1978), **continuity or duration** is experienced by connecting a succession of closed figures lasting approximately 3 seconds. This process of combination occurs spontaneously through the content of our consciousness; i.e. e. it may be referred to as a semantic connection. Thus it is no longer noticeable that the interval of integration is limited to a few seconds. The temporal structure of consciousness itself is not a content of consciousness (Pöppel, 1993).

In summary, these two mechanisms, the high-frequency mechanism and the low-frequency mechanism, are a necessary but not sufficient condition to trigger mental content-related functions. Additionally, activation is necessary to experience time and to experience in general.

This taxonomy, as well as supporting investigations, opens up the possibility of classifying pathological phenomena of mental functioning (Pöppel, 1993):

- Local modules can be lost (loss of content related functions).
- Disturbances may be found in the area of activation and its long-term modulations (e.g. may result in a reduced state of vigilance or depression).
- Disturbances may be found in temporal short-term organization and synchronization (could result in defective event identification due to a failure of the integration of different modules, which could endanger personal identity)
- Problems may arise in the area of the temporal integration and semantic connection of integrated intervals" (could lead to a discontinuity of mental processes, as found in some

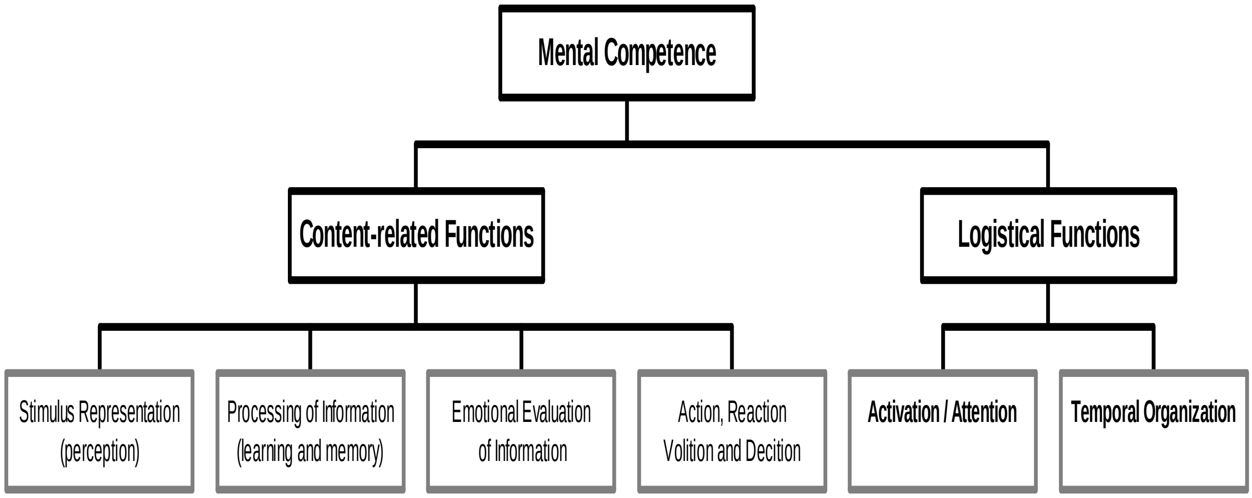
forms of schizophrenia, because the normal process of keeping thoughts together is no longer available).

Only one early study has attempted to verify the taxonomy of mental functioning (Cieza, 2000) based on data collected from healthy young men.

The present study was performed to corroborate the results of this early study, but with healthy elderly subjects of both sexes.

The aim of this investigation was to study the factorial structure of the empirical data collected to assess the functions listed in this classification of mental functioning (Figure 1, Cieza, 2000) and to find out to what extend that structure corresponds to the classification itself.

**Figure 1: Overview of mental functions**



## MATERIALS AND METHODS

### Design

Analyses were performed with data collected in a monocentric, parallel-group, and double-blind prospective, clinical phase-IV study with two time points of assessment. The first time point prior to treatment was used for analysis of the present study. The neuropsychological assessment was performed at 06:30 p.m. in each subject, to assure comparable research conditions and that no circadian variation could influence the test results. Within 1 week prior to randomization of subjects into the treatment groups, the investigator performed an extensive medical evaluation, including electrocardiogram, drug screening, and laboratory tests (blood cell count and routine clinical chemistry) to ascertain subject suitability for entering the trial. The study was performed according to the principles of the current edition of the Declaration of Helsinki, the German drug law (AMG), and Good Clinical Practice (GCP).

### Participants

66 healthy volunteers aged 50 to 65 years without age-associated cognitive impairment (as judged by the "Cognitive Minimal Screening" (Kessler et al. 1991)) completed the study according to the protocol and provided valid data sets. These 66 subjects constituted the ITT population, which was used for the statistical analyses.

### Measures

For this study the selection of tests was based on the theory of mental functioning developed by Pöppel et al. (Pöppel, 1993, 1994, 1999).

On the basis of the classification presented above, fifteen different tests were selected to assess the repertoire of content-related and logistical functions.

Nine tests were selected to assess content-related functions:

1. Increment Threshold for Visual Stimuli (ITVS; Strasburger & Pöppel, 1999; Pöppel & Harvey, 1973);
2. Digit Connection Test G (DCT – G; Oswald & Fleischmann, 1995)
3. Word List (WL; Oswald & Fleischmann, 1995)
4. Profile of Mood States (POMS; McNair et al. 1982; Bullinger et al., 1990),

5. Subjective Intensity Scale - Mood (SIS – M; Limm, 1999)
6. Self-Rating Depression Scale (SDS; Zung, 1965)
7. Finger Tapping (Personal Tempo; Pöppel & Wittmann, 1999; Wittmann, 1999))
8. Finger Tapping (Speed; Steinbüchel et al., 1999)
9. Auditory Choice Reaction Time (ART; Pöppel et al., 1990)

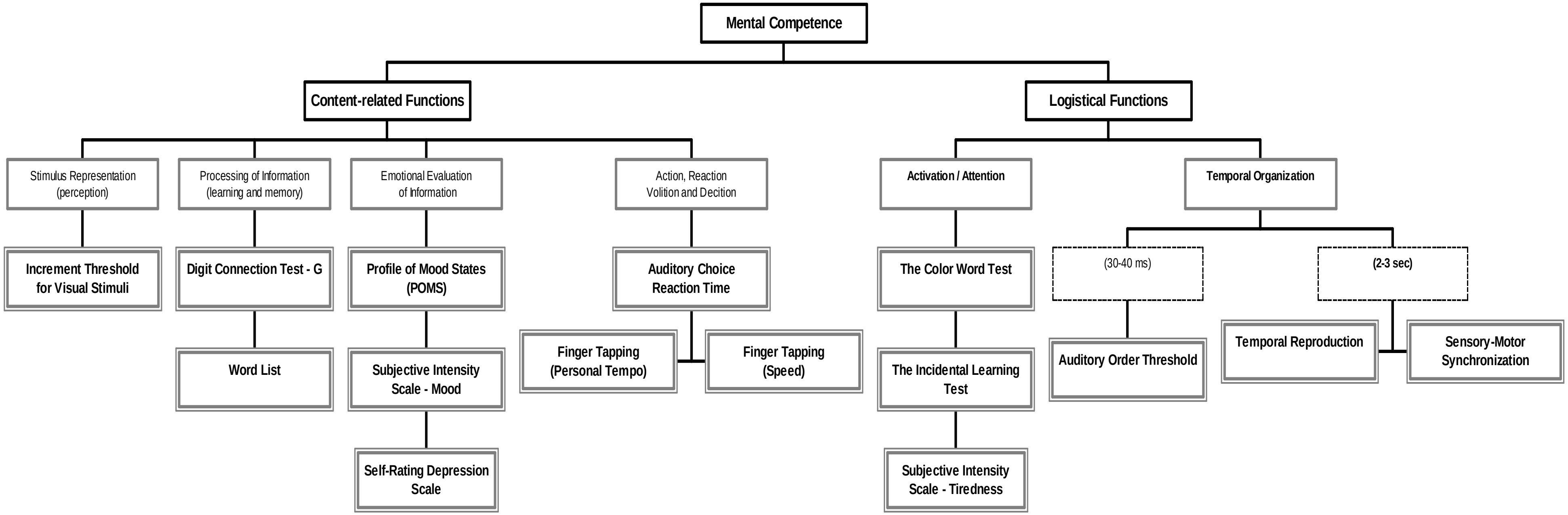
Six tests in order to assess the logistical functions:

1. The Color Word Test (CWT-W; Oswald & Fleischmann, 1995)
2. The Incidental Learning test (IL; Oswald & Fleischmann, 1995)
3. The Subjective Intensity Score - Tiredness (SIS – T; Limm, 1999)
4. Auditory Order Threshold (AOT; Hirsh & Sherrick, 1961; Treutwein, 1995, 1997)
5. Temporal Reproduction (TR; Pöppel, 1973)
6. Sensory-Motor Synchronization (SMS; Mates et al., 1994)

The indicated tests fall primarily, but not exclusively, into the categories outlined above.

An overview of the tests employed and the corresponding functions is given in Figure 1.

**Figure 2: Overview in the selected tests and their corresponding mental functions**



## Neuropsychological Tests Selected to Assess Mental Competence

### Increment Threshold for Visual Stimuli

Stimulus representation (perception) was operationalized with the test ”Increment Threshold for Visual Stimuli” (ITVS) (Strasburger & Pöppel, 1999; Pöppel & Harvey, 1973). This test measures the subjective sensitivity for visual stimuli along the horizontal meridian up to an eccentricity of 20 degrees of visual angle. The threshold is determined in steps of 0.1 log units for visual angles 2°, 4°, 6°, 8°, 10°, 12°, 14°, 16°, 18°, and 20°. The higher the score, the poorer the sensitivity.

### Digit Connection Test-G (DCT - G)

The DCT - G (Oswald & Fleischmann, 1995) is a paper-pencil test, which was developed on the basis of ”The Trail-Making Test” (Reitan, 1956) and assesses speed of cognitive processing (information-processing time) on the basis of five matrices with digits that have to be connected, so that the subjects have to make 29 decisions. Each decision has between one and eight different alternatives. The mean time needed (sec) for each of the two last matrices represents the test result. The higher the score, the poorer the performance.

### Word List (WL)

The Word List Test (Oswald & Fleischmann, 1995) measures short-term memory, verbal processing of information, and long-term memory. The investigator reads aloud eight two-syllable words which have to be immediately repeated by the subject. After 20 minutes, the subject is asked to recognize the eight words within a list of 16 words. The total score is the sum of the free-repetition score (number of words immediately remembered) and the recognition score (number of words recognized after 20 minutes). The higher the score, the better the performance.

### Profile of Mood States (POMS)

The POMS (McNair et al., 1982; Bullinger et al., 1990) assesses the emotional well-being and mood of a subject on the basis of a list of 35 adjectives, which the subjects have to evaluate on a 5-point Likert scale (from "not at all” to "severe”). The adjectives are classified into the following four subscales: Fatigue, Depression, Vigor, and Anger. Scores range from 0 to 4. The higher the score, the better the emotional well-being and mood of a subject.

### Subjective Intensity Scale - Mood (SIS - M)

The SIS-M (Limm, 1999) indicates the actual mood state of the subject in relation to the previously-judged mood state, i.e., the subject judges the change in his/her mood-state in comparison to the last mood-state estimation. The previous mood-state estimation is accorded 100 points. The mood state of the subject has become worse whenever the score of the current mood state is lower than 100 (%). If, however, the mood state of the subject has improved, the score of the current mood state is higher than 100 (%). The point differences reveal the improvement or deterioration in the mood state of the subject. The analysis of the Subjective Intensity Score – Mood was carried out on the basis of the mood state of the subject after one, two, and three weeks and at the final examination in relation to the last-judged mood state. The higher the score, the better the mood state.

**Self-Rating Depression Scale (SDS)**

The SDS (Zung, 1965) is a self-rating scale to detect depression. The analysis of the SDS is carried out on the basis of subjects' answers to the single items. All items on the questionnaire were summarized and finally reduced to a sum score. The sum score of the questionnaire was used as a variable of the investigation. The higher the SDS-score, the more severe the depression.

**Finger Tapping (Personal Tempo & Speed)**

In the Finger-tapping Test – personal tempo (Pöppel & Wittmann, 1999; Wittmann, 1999), the subject is asked to tap the button on a keyboard at a pace that feels "comfortable" to her/him for 30 taps with the right and left index fingers. In the Finger-tapping Test – speed (Steinbüchel et al., 1999), the subject is asked to tap 50 times - twice with the left index finger and twice with the right index finger - as fast as possible. Both tests are evaluated for key-touching time and pause-interval time and provide information about the velocity and motor cerebral programs of the subject. The experimental differentiation between key-touching and pause-interval time allows a separation of different aspects of the movement. Key-touching time is the interval between the end of an agonistic and the beginning of an antagonistic movement or contact time of the index finger on the button. The pause interval is the interval between two finger taps and reflects the central component of the motor execution. The analysis of Finger Tapping - personal tempo was carried out on the basis of the 30 taps performed with the right hand and 30 taps performed with the left hand. The analysis of Finger Tapping – speed was carried out on the basis of 100 taps performed with the right hand and 100 taps performed with the left hand. The computer automatically separated and recorded the two different motor components of each single tap: Key-Touching and Pause-Interval Time. The means of the 30 or the 100 key-touching times from each subject and the 30 or 100 pause intervals from each subject were used as variables of the investigation. The higher the score, the poorer the performance.

**Auditory Choice Reaction Time**

The Auditory Choice-Reaction Time Test (Pöppel et al., 1990) measures the time necessary for decision making and stimulus discrimination. The subject is asked to discriminate between two different stimuli which are presented either to the right or to the left ear. These two auditory stimuli are randomized for each condition. In addition to the randomization of stimulus presentation (right/left), the inter-stimulus interval is randomized within an interval of 2 - 5 seconds. The subject keeps his/her index finger of the dominant hand on a ”go” button. The subject moves the finger to one of two different target buttons (right and left) according to the presentation side of the stimulus. The experimental differentiation between release time and movement time allows a separation of primarily central from primarily peripheral (motor) aspects of the reaction. The release time is the time needed to release the key before the movement begins. This provides information about decision-making processes. Movement time is the time needed for the subject to move the index finger from the ”go” button to the right or left target button. Movement time reflects the motor components involved in choice reaction-time tasks.

The experimental session contains 40 acoustic stimuli. The analysis of choice reaction time was carried out on the basis of 20 reactions performed when the stimulus was presented to the right ear and the subjects had to react to a right target button and on the basis of 20 reactions performed when the stimulus was presented on the left ear and the subjects had to react to a left target button. The computer automatically recorded and saved the release time and the movement time. The means of the 40 release times and the 40 movement times from each subject were saved as variables of the investigation. The higher the score, the poorer the performance.

**The Color Word Test (CWT-W)**

The CWT (Oswald & Fleischmann, 1995) assesses selective attention, the distractibility of subjects, and the information-processing time. In this task, the investigator presents three different panels to the subject. The first panel has 36 black-printed color words. The second panel has 36 color-printed figures. The third panel has 36 color-printed color words, but the colors and the color words are non-congruent. The task consists of reading aloud the black-printed color words on the first panel, naming the colors of the figures on the second panel, and naming the colors of the non-congruent color-printed color words on the third panel. The analysis of the Color Word Test was carried out on the basis of the time (sec) needed to name the 36 colors on a panel (color panel) and on the time (sec) needed to name the colors of 36 color-printed color words (color-word panel). The time needed for the color-word panel minus the time needed for the color panel is the test value and was used as a variable in the investigation. The higher the score, the poorer the performance.

**The Incidental Learning Test (IL)**

The Incidental Learning Test (Oswald & Fleischmann, 1995) is performed after the completion of all other tests, and the subjects are asked to name all the tests they have performed. This test is performed without prior knowledge at the end of the test session. This procedure permits the assessment of latent or incidental learning, information processing, attention, and retrieval processes. The test score is the number of named tests and tasks performed by the subject. The higher the score, the better the performance.

**The Subjective Intensity Score - Tiredness (SIS - T)**

The Subjective Intensity Scale – Tiredness (Limm, 1999) provides information about the actual state of tiredness of the subject in relation to the last-judged state of tiredness, i.e., the subject judges the change in his/her state of tiredness in comparison with the last estimation. Like the SIS-M, the analysis of the SIS – T was carried out on the basis of the judged tiredness after assessments one, two, three, and at the final examination in relation to the last-judged state of fatigue. The higher the score, the greater the fatigue.

**Auditory Order Threshold**

The auditory order threshold (Hirsh & Sherrick, 1961) is measured with a computer-assisted program (Treutwein, 1995, 1997). Two short acoustic stimuli (clicks) are presented in a temporal order. The subject is asked to discriminate the order of two clicks presented to both ears (binaural stimulation) with a defined interstimulus interval. The order threshold is measured by an adaptive psychophysical procedure that maximizes the likelihood of obtaining a good estimation of the threshold and provides information about the information-processing time of the subjects. The program automatically finishes the measurement when it can be assumed that the order threshold lies with a probability of 75% within $\pm 10$ ms of the estimated threshold. The higher the score, the poorer the performance.

**Temporal Reproduction**

In this test (Pöppel, 1973), stimuli with durations ranging between 1-5 seconds (in steps of 0.5 seconds) are presented, and the subject is asked to reproduce each duration accurately. Each stimulus duration is presented five times in random order. The analysis of temporal reproduction was carried out on the basis of the means of the 5 reproductions for the 9 different stimulus durations. The computer automatically recorded and saved the 45 reproductions of each subject. The absolute values of the stimulus reproductions per duration minus the real duration of the stimuli are variables of the investigation. The higher the score, the poorer the performance.

**Sensorimotor Synchronization**

The Sensorimotor Synchronization Test (Mates et al., 1994) is performed to assess integration mechanisms of the brain, which are close to 3 sec. Acoustic stimuli of 50ms duration are presented at a constant rate with constant inter-stimulus intervals (ISI) for a given trial. The subject's task is to tap with the index finger at a rate synchronized with the stimulus sequence. The quality of sensorimotor synchronization can be estimated by varying the length of the ISIs. Two ISIs were selected, i.e. 1000 and 4000 ms. The analysis of sensorimotor synchronization was carried out on the basis of the inter-response intervals of 29 taps for sensorimotor synchronization with 1000 ms and on the basis of 22 taps for sensorimotor synchronization with 4000 ms. The computer program automatically recorded and saved the asynchrony of the subjects` taps with respect to the presented inter-stimulus interval. The means of the absolute values of the asynchrony for each tap were used as variables of the investigation. The higher the score, the poorer the performance.

**Data collection**

Data were collected within the trial of a clinical study. Subjects were neuropsychologically tested at the same time of day in sound-proof labs at the Institute of Medical Psychology in Munich.

All Case Record Forms (CRFs) were checked for completeness, plausibility, and correctness by investigators and monitors. Data-source verification was performed by the monitor in all CRFs; i.e. e. 100% data-source verification was performed. Confidentiality of patient data was maintained.

Data of computer-aided tests, as well as paper-pencil tests, were analyzed with SPSS® format (Version 8.0). All assessed data were entered continuously and were rechecked for completeness, plausibility, and correctness in compliance with Good Clinical Practice (GCP).

## Statistical methods

For statistical methods, analysis of the data was conducted with the software system SPSS® for Windows, release 8.0. According to confidentiality guidelines, no data which can directly be assigned to participants were recorded.

For ordinally- or nominally-scaled anamnestic data, absolute and relative frequencies were determined. The variables of neuropsychological measurements were interval scaled and described by the following statistics: mean, standard deviation, minimum, median, and maximum; skewedness and kurtosis were calculated. Descriptive statistics were also performed to account for missing data in the database.

Prior to further analysis, the normal distribution of all the investigation variables was verified by a Kolmogorov-Smirnov Test. Although the normally distribution of variables is not a restrictive condition to successfully perform factor analysis (Backhaus et al., 1994), it is desirable to have a homogeneous sample, and, associated with this, to have normally distributed variables within the analysed sample. The extend of correlations between the variables may be influenced by the level of the sample's homogeneity. As a criterion for the decision whether the analyzed variables were normally distributed or not, a significance level of 0.2 was chosen.

To assess the suitability of the data for factor analysis, first Kaiser-Mayer-Olkin's Measure (KMO) of Sampling Adequacy Test and Bartlett's Test of Sphericity were conducted. The Kaiser-Mayer-Olkin Measure of Sampling Adequacy is a statistic that indicates the proportion of variance in the variables which is common variance, i.e., which might be caused by underlying factors. This index ranges from 0 to 1, reaching 1 when each variable is perfectly predicted without error by the other variables. The measure can be interpreted with the following guidelines: 0.9 or above is marvellous, 0.8 is meritorious, 0.7 is middling, 0.6 is mediocre, 0.5 is miserable and below 0.5 is unacceptable. Values below .5 should not be interpreted (Kaiser, 1974; Hutcheson & Sofroniou, 1999).

The Bartlett Test of Sphericity is a statistical test for the presence of correlations among the variables (items). It shows whether the correlation matrix is an identity matrix, which indicates that the variables (items per specific construct) are unrelated. The significance level gives the result of the test. Small values indicate that the data do not produce an identity matrix and, hence, are suitable for factor analysis.

**Factor Analysis**

Factor analysis was used to study the factorial structure of the empirical data collected to assess the functions distinguished in the classification of mental functions.

In general, factor analysis is a statistical procedure used to identify the interrelationships that exist among a large number of variables. When variables are related to each other, there are said to be a set of underlying dimensions called factors which can explain the variance of each variable. Factor analysis can be used to either summarize or reduce data. In data summary, factor analysis derives the underlying dimensions, or factors, which describe the data in a smaller number of concepts than the original variables. In data reduction, scores are calculated for each factor, and these scores are then substituted for the original variables.

Factor analysis can also be used for either exploratory or confirmatory purposes. As an exploratory procedure, factor analysis is used to search for a possible underlying structure in the variables.

**Confirmatory Factor Analysis** (CFA) seeks to determine if the number of factors and the loads of measured (indicator) variables in them conform to what is expected on the basis of pre-established theory. Indicator variables are selected on the basis of prior theory, and factor analysis is used to see if they load as predicted on the expected number of factors. The researcher's *a priori* assumption is that each factor (the number and labels of which may be specified *a priori*) is associated with a specified subset of indicator variables. A minimum requirement of confirmatory factor analysis is that the number of factors in the model is hypothesized beforehand. Furthermore, expectations about which variables will load on which factors are made (Kim and Mueller, 1978). The researcher seeks to determine whether measures created to represent a latent variable really belong together or load on the same factor with comparable weights.

In general, in confirmatory research, the researcher evaluates how similar the actual structure of the data revealed by factor analysis is to the expected structure. The major difference between exploratory and confirmatory factor analysis is that the researcher has formulated hypotheses about the underlying structure of the variables when using factor analysis for confirmatory purposes. This was done in the present study trying to verify Pöppel`s theory of mental functioning.

A Principal Component Analysis (PCA) with Varimax Rotation with Kaiser Normalization and theory-based extraction of 6 factors was performed to show a replication of the dimensionality of Pöppels classification of mental functions.

Component analysis is a factor model in which the factors are based on the total variance. With component analysis, units (1s) are used in the diagonal of the correlation matrix; this procedure computationally implies that all the variance is common or shared. Factors represent the linear combination of the original variables. Factors also represent the underlying dimensions (constructs) that summarize or account for the original set of observed variables. Component analysis was done with Varimax Rotation which is the most common process of manipulation or adjusting the factor axes to achieve a simpler and pragmatically more meaningful factor solution. Varimax Rotation is an orthogonal rotation of the factor axes to maximize the variance of the squared loadings of a factor (column) on all the variables (rows) in a factor matrix, which has the effect of differentiating the original variables by an extracted factor. This means it minimizes the number of variables which have high loadings on any one given factor. Each factor will tend to have either large or small loadings of particular variables on it. A varimax solution yields results which make it as easy as possible to identify each variable with a single factor. This is the most common rotation option.

For the description of factor analysis within this paper three terms are essential:

**Common variance:** Variance shared with other variables in the factor analysis.

**Communality:** Total amount of variance an original variable shares with all other variables included in the analysis ($h^2$). The communalities measure the percent of variance in a given variable explained by all the factors. That is, the communality is the squared multiple correlation for the variable using the factors as predictors. Communality for a variable is the sum of squared factor loadings for that variable (row). Thus, the percent of variance in a given variable is explained by all the factors. For full orthogonal PCA, the communality will be 1.0, and all of the variance in the variables will be explained by all of the factors, which will be as many as there are variables.

**Factor loadings:** This is the correlation between the original variables and the factors and the key to understanding the nature of a particular factor. Squared factor loadings indicate what percentage of the variance in an original variable is explained by a factor.

# RESULTS

## Subjects

All participants were Caucasian (100.0%). With 37 females (56.1%) and 29 males (43.9%), the gender ratio was shifted towards the women (Table 1).

**Table 1: Gender**

| | Total | |
|---|---|---|
| | N | % |
| Male | 29 | 43.9 |
| Female | 37 | 56.1 |
| Sum | 66 | 100.0 |

The mean age of the patients was 56.3 years (SD 3.6 years). The evaluation of demographic data stratified by gender revealed slight differences in the variables *weight*, *height* and *body-mass index (BMI;* Table 2). Males were on average heavier (15.9kg) and also taller (12.5cm) than females. Mean body-mass index was 24.7kg/m² for males and 23.4kg/m² for females.

**Table 2: Age, weight and height (quantitative statistics) by gender**

| | N | Min | Max | Mean | SD |
|---|---|---|---|---|---|
| | Total | | | | |
| Age | 66 | 50.0 | 64.0 | 56.3 | 3.6 |
| Weight | 66 | 49.0 | 95.0 | 70.1 | 11.5 |
| Height | 66 | 153.0 | 190.0 | 170.6 | 8.5 |
| | Male | | | | |
| Age | 29 | 51.0 | 64.0 | 56.2 | 3.5 |
| Weight | 29 | 66.0 | 95.0 | 79.0 | 6.8 |
| Height | 29 | 164.0 | 190.0 | 177.6 | 5.6 |
| | Female | | | | |
| Age | 37 | 50.0 | 63.0 | 56.4 | 3.8 |
| Weight | 37 | 49.0 | 89.0 | 63.1 | 9.5 |
| Height | 37 | 153.0 | 175.0 | 165.1 | 5.9 |

The following table shows descriptive statistics for each variable. Skewedness and kurtosis >¦1¦ point to a distribution declining from normal distribution (Table 3).

**Table 3: Descriptive statistics**

| | N | Min | Max | Mean | SD | Skewedness | Kurtosis |
|---|---|---|---|---|---|---|---|
| ITVS 2 | 66 | .40 | 1.70 | .7603 | .2510 | **1.249** | **3.226** |
| ITVS 4 | 66 | .30 | 1.50 | .6894 | .2419 | .639 | .535 |
| ITVS 6 | 66 | .30 | 1.50 | .7164 | .2323 | .584 | .772 |
| ITVS 8 | 66 | .40 | 1.50 | .6970 | .2205 | **1.141** | **1.878** |
| ITVS 10 | 66 | .40 | 1.50 | .8333 | .2144 | .198 | .234 |
| ITVS 12 | 66 | .20 | 1.40 | .6818 | .2493 | .515 | -.056 |
| ITVS 14 | 66 | .30 | 1.70 | .6924 | .2470 | **1.144** | **2.873** |
| ITVS 16 | 66 | .30 | 1.60 | .8091 | .2410 | .693 | .828 |
| ITVS 18 | 66 | .30 | 1.70 | .7621 | .2479 | .969 | **2.086** |
| ITVS 20 | 66 | .40 | 1.50 | .8152 | .2129 | .556 | .775 |
| DCT-G (SEC.) | 66 | 11.50 | 33.00 | 18.8636 | 4.1506 | **1.004** | **1.198** |
| WL-STM | 66 | 3.00 | 8.00 | 6.2576 | 1.2808 | -.729 | .241 |
| WL-LTM | 66 | 2.00 | 10.00 | 6.1667 | 1.5047 | -.656 | .932 |
| POMS-VIGOR | 66 | .00 | 3.57 | 2.3680 | .6677 | -.625 | **1.226** |
| POMS-FATIGUE | 66 | 1.14 | 4.00 | 2.9935 | .6745 | -.845 | .401 |
| POMS-DEPRESSION | 66 | 2.00 | 4.00 | 3.6459 | .3742 | **-2.076** | **5.599** |
| POMS-ANGER | 66 | 1.43 | 4.00 | 3.1807 | .5710 | **-1.007** | **1.298** |
| SIS-MOOD | 66 | 10.00 | 100.00 | 76.7121 | 20.4117 | **-1.520** | **2.343** |
| SDS | 66 | 22.00 | 45.00 | 32.3030 | 4.9239 | .356 | -.060 |
| PT RIGHT - KTT (MS) | 66 | 75.79 | 648.34 | 209.9603 | 99.6891 | **2.297** | **7.303** |
| PT LEFT - KTT (MS) | 66 | 80.31 | 640.79 | 205.5596 | 96.1425 | **2.302** | **7.357** |
| PT RIGHT - PI (MS) | 66 | 90.45 | 1104.90 | 341.7712 | 211.2662 | **1.681** | **2.822** |
| PT LEFT - PI (MS) | 66 | 74.21 | 1078.28 | 325.0737 | 198.3928 | **1.697** | **3.571** |
| MX RIGHT - KTT (MS) | 66 | 46.88 | 198.30 | 93.7868 | 26.7313 | **1.750** | **5.057** |
| MX LEFT - KTT (MS) | 66 | 59.71 | 181.86 | 100.0348 | 24.3234 | .993 | **1.552** |
| MX RIGHT - PI (MS) | 66 | 56.55 | 318.03 | 103.5280 | 39.2783 | **3.020** | **13.679** |
| MX LEFT - PI (MS) | 66 | 61.97 | 316.92 | 109.8324 | 36.3217 | **3.064** | **15.561** |
| ART-RELEASE TIME (MS) | 66 | 187.89 | 548.26 | 333.7390 | 73.4815 | .876 | .931 |
| ART-MOVEMENT TIME (MS) | 66 | 53.58 | 257.97 | 158.0131 | 45.6987 | .094 | -.167 |
| CWT | 66 | 8.00 | 41.00 | 18.9545 | 7.7468 | .894 | .337 |
| IL | 65 | 4.00 | 16.00 | 9.2308 | 2.2345 | .238 | .470 |
| SIS-TIREDNESS | 66 | 1.00 | 95.00 | 31.1515 | 23.3681 | .791 | -.286 |
| AOT | 66 | 16.00 | 140.00 | 75.8030 | 24.9030 | .127 | .243 |
| TR 1000 | 66 | 19.17 | 767.80 | 175.6939 | 140.1308 | **1.649** | **3.793** |
| TR 1500 | 66 | 12.40 | 1301.83 | 234.1558 | 202.6051 | **2.632** | **11.132** |
| TR 2000 | 66 | 1.40 | 905.00 | 268.6437 | 196.1816 | .794 | .694 |
| TR 2500 | 66 | 8.14 | 1270.60 | 329.1559 | 251.1549 | **1.351** | **2.408** |
| TR 3000 | 66 | 3.88 | 1216.80 | 440.3360 | 253.0768 | .644 | .373 |
| TR 3500 | 66 | 45.20 | 1084.80 | 572.8556 | 259.1044 | -.042 | -.697 |
| TR 4000 | 66 | 47.20 | 1762.57 | 702.6389 | 338.8009 | .415 | .623 |
| TR 4500 | 66 | 54.80 | 1781.00 | 765.8120 | 343.0785 | .285 | .078 |
| TR 5000 | 66 | 13.60 | 2062.00 | 824.7225 | 450.8345 | .389 | .173 |
| SMS 1000 MS | 66 | .18 | 775.14 | 96.0750 | 137.4851 | **3.343** | **12.242** |
| SMS 4000 MS | 66 | .76 | 573.59 | 150.5154 | 88.8241 | **1.638** | **7.367** |

## Missing data

Missing data were only present in the Latent Learning (n=1) Test, which means 1.5% within this test. Related to 44 test values in each of 66 patients, this adds up to less than 0.1%.

## Kolmogorov-Smirnov Test

The prerequisite of a normal distribution was not given in the variables presented in Table 4. A significance level of 0.2 was chosen as a criterion for the decision whether the analyzed variables were normally distributed or not.

**Table 4: Abnormally-distributed variables**

| Variable | p-value |
|---|---|
| DCT-G (SEC.) | .145 |
| ITVS 18 | .128 |
| ITVS 16 | .128 |
| ITVS 8 | .085 |
| ITVS 10 | .124 |
| ITVS 12 | .065 |
| ITVS 20 | .124 |
| ITVS 2 | .165 |
| SIS-Mood | .010 |
| SIS-Tiredness | .080 |
| WL-STM | .008 |
| WL-LTM | .024 |
| PT Left – KTT (MS) | .027 |
| PT Left – PI (MS) | .089 |
| PT Right – KTT (MS) | .038 |
| PT Right – PI (MS) | .007 |
| SMS 1000 MS | .000 |
| SMS 4000 MS | .108 |
| MX Left – PI (MS) | .168 |
| MX Right – PI (MS) | .030 |
| POMS-Depression | .012 |
| POMS-Anger | .145 |
| IL | .157 |
| TR 1000 | .027 |
| TR 1500 | .048 |
| TR 2500 | .171 |

## Factor analysis

Measured by the Kaiser-Meyer-Olkin statistics, sampling adequacy predicts if data are likely to factor well based on correlation and partial correlation. Because the Kaiser-Mayer-Olkin's Measure of Sampling Adequacy Test the criterion of .60 was not reached, the indicator variables with the lowest individual KMO statistic values were dropped until overall KMO rose above 60. Based on the KMO criterion, the variables *Latent Learning*, *Sensorimotor Synchronization (1000ms)*, and *Color Word Test* did not meet the requirements for factor analysis. After dropping these variables, the Kaiser-Mayer-Olkin measure reached 0.613, which is satisfactory for factor analysis. Bartlett's Test was highly significant (Table 5). That means the sample intercorrelation matrix did not come from a population in which the intercorrelation matrix is an identity matrix. It indicates that the variables (items per specific construct) are unrelated. Therefore, factor analysis could be appropriate. In summary, the results of Kaiser-Mayer Olkin Measure of Sampling Adequacy and Bartlett Tests show that the data fulfil the fundamental requirements for factor analysis.

**Table 5: KMO- and Bartlett-Test**

| | | |
|---|---|---|
| **Kaiser-Meyer-Olkin Criterion** | | .613 |
| **Bartlett Test of Sphericity** | approximate Chi-Square | 2259.874 |
| | df | 820 |
| | Significance | .000 |

## Replication of Scales

Table 6 shows the results of the Principal Component Analysis with Varimax Rotation with Kaiser Normalization and extraction of 6 factors.

The communalities ($h^2$) of the variables and their loadings on the factors are displayed. For reasons of clarity, all loadings less than .1 are suppressed in the output. Loadings higher than |.4| or the highest loading of a variable if |.4| was not reached (Auditory Order Threshold, Auditory Reaction Time - movement time, and Profile of Mood States – Anger) are marked in the output.

According to Guadagnoli & Velicer (1988), interpretation of factors is possible if at least 4 variables load higher than .60 on this factor. Variables with highest loadings are “assigning” variables. In the following, loadings less than .4 will be considered as "weak", of more than .6 as "strong", and otherwise as "moderate" loadings. Table 6 shows the rotated component matrix with communalities and factor loadings according to size. The total variance explained by six factors was 62.1% (Table 7).

**Table 6: Rotated Component Matrix**

| | Component | | | | | | |
|---|---|---|---|---|---|---|---|
| | **$h^2$** | **1** | **2** | **3** | **4** | **5** | **6** |
| ITVS 18 | .895 | **.938** | | | | | |
| ITVS 14 | .849 | **.916** | | | | | |
| ITVS 6 | .848 | **.904** | -.137 | | | | |
| ITVS 8 | .849 | **.896** | | | | | -.136 |
| ITVS 12 | .807 | **.886** | | | | | |
| ITVS 4 | .823 | **.876** | -.138 | -.181 | | | |
| ITVS 16 | .799 | **.862** | | -.129 | | | .163 |
| ITVS 20 | .774 | **.858** | .110 | -.106 | | | .114 |
| ITVS 2 | .706 | **.831** | | | | | |
| ITVS 10 | .712 | **.826** | | | | -.147 | |
| PT LEFT – KTT (MS) | .789 | .101 | **.879** | | | | |
| PT LEFT – PI (MS) | .791 | | **.873** | | | | -.138 |
| PT RIGHT – KTT (MS) | .793 | .148 | **.860** | .124 | | | |
| PT RIGHT – PI (MS) | .755 | | **.817** | | | | -.270 |
| MX RIGHT – PI (MS) | .598 | | **.603** | .141 | **.438** | .105 | |
| MX RIGHT – KTT (MS) | .638 | | **.563** | | **.545** | | .108 |
| MX LEFT – PI (MS) | .577 | -.126 | **.559** | | **.475** | .114 | |
| TR 4500 | .800 | -.166 | .152 | **.846** | | -.165 | |
| TR 4000 | .710 | | | **.834** | | | |
| TR 5000 | .767 | -.180 | .113 | **.815** | | -.155 | .167 |
| TR 3500 | .645 | | | **.706** | .141 | .296 | .189 |
| TR 3000 | .767 | -.223 | .188 | **.685** | | **.459** | |
| WL LTM | .502 | | | | **-.690** | -.133 | |
| WL STM | .449 | | | | **-.651** | -.123 | |
| MX LEFT – KTT (MS) | .728 | | **.504** | -.175 | **.633** | | .195 |
| DCT-G (SEC) | .406 | | .131 | | **.534** | -.234 | .202 |
| ART-RELEASE TIME (MS) | .506 | | -.258 | -.284 | **.491** | -.173 | -.284 |
| SMS 4000 MS | .245 | | -.114 | .105 | **.467** | | |
| AOT | .171 | | | .174 | **.342** | | |
| ART-MOVEM. TIME (MS) | .249 | | .179 | .251 | **.331** | -.192 | |
| POMS-DEPRESSION | .631 | .301 | -.230 | | | **.644** | .265 |
| TR 1500 | .440 | | .155 | | -.132 | **.622** | |
| TR 2000 | .605 | | .294 | .321 | .143 | **.613** | -.104 |
| TR 2500 | .630 | -.203 | .156 | **.401** | | **.613** | -.148 |
| TR 1000 | .446 | -.103 | .105 | -.146 | .282 | **.507** | .259 |
| POMS-ANGER | .276 | -.120 | | -.102 | | **.460** | .201 |
| SIS-MOOD | .593 | | | | | | **.765** |
| SIS-TIREDNESS | .554 | | | -.184 | | .216 | **-.682** |
| POMS-VIGOR | .474 | .143 | | | | .208 | **.636** |
| POMS-FATIGUE | .483 | | -.128 | .183 | | .255 | **.606** |
| SDS | .362 | -.223 | .167 | | .191 | -.164 | **-.464** |

Table 7: **Total variance**

| | Initial eigenvalue | | | Sum of squared factor loading for extraction | | | Rotated sum of squared loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| **Compon.** | **Total** | **% of Variance** | **Cum. %** | **Total** | **% of Variance** | **Cum. %** | **Total** | **% of Variance** | **Cum. %** |
| 1 | 8.646 | 21.087 | 21.087 | 8.646 | 21.087 | 21.087 | 8.208 | 20.019 | 20.019 |
| 2 | 5.541 | 13.514 | 34.601 | 5.541 | 13.514 | 34.601 | 4.740 | 11.561 | 31.580 |
| 3 | 3.815 | 9.304 | 43.904 | 3.815 | 9.304 | 43.904 | 3.778 | 9.216 | 40.795 |
| 4 | 2.779 | 6.779 | 50.683 | 2.779 | 6.779 | 50.683 | 3.206 | 7.821 | 48.616 |
| 5 | 2.564 | 6.253 | 56.936 | 2.564 | 6.253 | 56.936 | 2.810 | 6.853 | 55.469 |
| 6 | 2.098 | 5.116 | 62.053 | 2.098 | 5.116 | 62.053 | 2.699 | 6.584 | 62.053 |
| 7 | 1.835 | 4.477 | 66.529 | | | | | | |
| 8 | 1.510 | 3.682 | 70.211 | | | | | | |
| 9 | 1.369 | 3.338 | 73.549 | | | | | | |
| 10 | 1.088 | 2.654 | 76.203 | | | | | | |
| 11 | 1.045 | 2.549 | 78.752 | | | | | | |
| 12 | .913 | 2.228 | 80.979 | | | | | | |
| 13 | .826 | 2.014 | 82.994 | | | | | | |
| 14 | .753 | 1.836 | 84.830 | | | | | | |
| 15 | .707 | 1.725 | 86.555 | | | | | | |
| 16 | .607 | 1.480 | 88.036 | | | | | | |
| 17 | .553 | 1.348 | 89.384 | | | | | | |
| 18 | .527 | 1.285 | 90.668 | | | | | | |
| 19 | .465 | 1.135 | 91.803 | | | | | | |
| 20 | .423 | 1.032 | 92.835 | | | | | | |
| 21 | .388 | .946 | 93.782 | | | | | | |
| 22 | .309 | .754 | 94.536 | | | | | | |
| 23 | .302 | .738 | 95.273 | | | | | | |
| 24 | .253 | .618 | 95.891 | | | | | | |
| 25 | .252 | .614 | 96.506 | | | | | | |
| 26 | .221 | .540 | 97.045 | | | | | | |
| 27 | .201 | .491 | 97.536 | | | | | | |
| 28 | .161 | .393 | 97.930 | | | | | | |
| 29 | .136 | .331 | 98.260 | | | | | | |
| 30 | .121 | .295 | 98.556 | | | | | | |
| 31 | .113 | .276 | 98.831 | | | | | | |
| 32 | 9.578E-02 | .234 | 99.065 | | | | | | |
| 33 | 8.900E-02 | .217 | 99.282 | | | | | | |
| 34 | 6.577E-02 | .160 | 99.442 | | | | | | |
| 35 | 6.227E-02 | .152 | 99.594 | | | | | | |
| 36 | 4.433E-02 | .108 | 99.702 | | | | | | |
| 37 | 4.233E-02 | .103 | 99.805 | | | | | | |
| 38 | 3.299E-02 | 8.046E-02 | 99.886 | | | | | | |
| 39 | 2.006E-02 | 4.893E-02 | 99.935 | | | | | | |
| 40 | 1.670E-02 | 4.072E-02 | 99.976 | | | | | | |
| 41 | 1.001E-02 | 2.441E-02 | 100.000 | | | | | | |

The variables of the *Increment Threshold of Visual Stimuli Test* were complete and exclusively represented through the **1st factor**, i.e., all variables load high on this factor (.826-.938).

The variables of the tests *Personal Tapping* - personal tempo and speed also load high on one factor (.504-.879, **Factor 2**). The test *Auditory Choice Reaction Time* is represented with weak loadings of .179 (Movement time) and -.258 (Release time).

The variables of the tests *Temporal Reproduction* are distributed on two factors. Five variables of the tests with time intervals of 3000-5000ms load strongly on the **3rd factor** (.685-.846). Further positive but scarcely relevant loadings indicate the variables *temporal reproduction of 2000 ms* (.321) and *temporal reproduction of 2500ms* (.401), as do the central component (*release time*) and motor component (*movement time*) of the *Auditory Reaction Time* (-.284 and .251, respectively). The *Auditory Order Threshold* yields a low loading of .174.

**Factor 4** is formed by the correlations with the variable KTT (central component of the reaction) of the *Personal Tapping - speed* of the left (.633) and of the right (.545) hand and of the variables *PI* (peripheral component of the reaction) of the right (.438) and of the left (.475) hand. The test results of the *Digit Connection Test* (.534), *Sensorimotor Synchronization* 4000ms (.467), both results of the *ART* (.491 and .331, respectively) and the *Auditory Order Threshold* (.342) also load on this factor. The variables short-term memory and long-term memory of the *Word List* load strongly negatively (-.651 and -.690, respectively).

The **5th factor** is formed by the remaining variables of the test *Temporal Reproduction* (1000-2500ms, .507-.622) and by the variables *POMS Depression* and *POMS Anger* with loadings of .460 and .644.

The variables of the tests *SIS-Mood* and *POMS Vigour and Fatigue* load strongly on the **6th factor** (.606-.765). The variables *POMS Depression and Anger* load weakly (.265 and .201, respectively). Additionally, this factor is described by negative loadings of the tests *SIS-Tiredness* (-.682) and *Self-rating Depression Scale* (-.464).

## DISCUSSION

In this study it could be shown that the data collected to assess the mental functions distinguished in Pöppels classification reflect a factorial structure similar to the structure determined in the classification itself. However, some issues require further discussion.

The distribution of some variables was not normal. The descriptive representation of variables shows - in particular after the analysis of the results of the performance test - that these correspond to a sampling of older subjects. It is normal that older subjects score lower in behavioural tests and that their reaction times are longer than those of younger subjects, as can be clearly inferred from standard values. Both components of the Auditory Reaction Time were slower than those of younger subjects, as were both components of the Personal Tapping - Speed. Especially in the interpretation of the results of the Auditory Order Threshold Test, which represents the logistical function 'Temporal organization' of 30ms, the influence of age has to be taken into account. It is common knowledge that the auditory order threshold is higher in elderly subjects. The theoretical ideal of 30ms, which represents the low-frequency domain of neuronal information processing, is exceeded significantly (Wittmann, 1999). In the present study, the average auditory order threshold was about 75ms.
In addition, studies have shown that there is a sex-specific difference in the level of the order threshold; female subjects have higher thresholds than male subjects (Wittmann, 1999, 2003). In the present study, no statistically significant gender differences were found ($p=.76$). The reproduction of the tone duration given in the Temporal Reproduction Test was less precise than that of younger subjects. Accordingly, similar experiments with a possibly larger sample size of particularly younger subjects and with separate gender groups might be interesting. The results of the tests reflecting the emotions were within the normal range (Bullinger, et al., 1990).

Some variables were obviously not at all suitable for a factor analysis, since they did not meet the requirements for factor analysis postulated by the KMO criterion (Latent Learning, Sensory-Motor Synchronization 1000ms, and Colour-Word Test). Cieza (2000) has also shown that the Latent Learning Test is scarcely convincing. 62.1% of variance could be explained might increase if tests which proved weak in this study were dropped from the analysis or substituted by other tests. Therefore, it seems important to further replicate this study with a newly-defined battery of tests, including well-selected, as well as newly-defined tests.

Nevertheless, replication of scales revealed highly satisfying results, which are described below.

Primary factor analysis investigates the reproduction of the structure of the classification of six mental functions (stimulus representation, stimulus processing, stimulus evaluation, action/reaction, activation/attention, and temporal organization) by demonstrating that the tests selected to measure them load on the same factor. Omitting items which cross-load on more than one or no factor is proposed. Furthermore, it should be established that multiple tests measure the same mental function, thereby justifying the use of fewer tests. High loadings on the predicted factors indicated convergent validity of the test battery selected according to the theory.

A rule of thumb in factor analysis is that factors should have at least four high, interpretable loadings -- fewer may suggest that the researcher has chosen too many factors (Guadagnoli & Velicer, 1988). This criterion was fulfilled in the present study postulating six factors. At least five variables showed high loadings on (exclusively) one factor.

As in the earlier study (Cieza, 2000), the ten variables of the Increment Threshold of Visual Stimuli load strongly on **factor 1,** which could be interpreted as the theoretical function of **'Stimulus representation' or 'perception'**. The attribution of the tests to the content-related function 'Stimulus representation' can be upheld accordingly. This test provided information on the elementary function of stimulus representation or the perceptual processing of stimuli.

The function **'response to stimuli' or 'Activation/Reaction'** is represented in **factor 2** through the variables of the tests Personal Tapping – personal tempo and speed (.504-.879). The individual components of these two tests (KTT and PI) loaded in Cieza's study (2000) on different factors, a fact that can possibly be attributed to the explorative character of her factor analysis, which revealed 9 factors. The variables of the Auditory Choice Reaction Time Test, which was also selected to measure this function, were not clearly correlated with this factor, but with factor 5.

**Factor 3** reflects the low-frequency logistical function **'Temporal Organization' ≥3 sec** (Temporal Reproduction Test, 3000-5000ms); **factor 5**, the corresponding function **<3 sec** (1000-2500ms). In Cieza (2000) the variables of the Temporal Reproduction Test correspondingly were distributed onto two different factors. This result points to the distinction between perception of subjective present and duration made in theory. It can be regarded as one more indication of the fact that the perception of the subjective present and the perception of duration are two qualitatively different kinds of processes. The temporal limit of approximately 3 seconds that was described as a temporal transition from the perception of the subjective present to the perception of duration (Pöppel, 1978; Ilmberger 1986) is confirmed by the present factor-analytic result. The positive loading of the motor component of the Auditory Choice Reaction Time Test on this factor shows that the motor realization of the Temporal Reproduction Test is obviously linked with the motor content-related function as a “tool”.

**The 4th factor** primarily appears to be the most equivocal. It apparently comprises random variables which were originally attributed theoretically to 3 functional domains: the Digit Connection Test and the Word List (Processing of Information), all variables of the tests Finger Tapping Speed and Auditory Choice Reaction Time (Response to stimuli), Auditory Order Threshold (high-frequency range of Temporal Organisation), and Sensory-Motor Synchronization of the 4-sec rhythm (low-frequency range of Temporal Organization). This result can be compared to Cieza’s (2000) factors 5 and 8. The given package of variables is an implementation of mainly high-frequency temporal processing. Finger Tapping Speed aims at the speedy motor realization of an action. For the DIGIT Connection Test, not only quickness in making decisions, but also speedy motor coordination is necessary to obtain a good test result. In the Auditory Choice Reaction Test fast decision making and speedy motor realization are both necessary to achieve better test results. Based on this factor, the close correlation between Temporal Organization as a logistical process and content-related realization comes to the fore.

For the Word List, memory function is tested after a short and after a longer period of time. The subject had to repeat eight words immediately and to recognize them after 20 minutes. The two variables of this test revealed negative loadings on this factor.

Cieza (2000) showed that the Latent Learning Test was positively correlated with the low-frequency mechanism tested with the Temporal Reproduction Test. In the present study, a negative correlation of the Word List being a memory test with performance tests with speed as a determining component was obtained. Obviously the Incidental Learning Test, as well as the Word List Test, can be considered to be both a memory test and a test for measuring activation/attention. Activation and attention play a role in the processing of experienced duration. This result corresponds with Fraisse’s assumption (1984) that within the temporal limits of the psychological present one can speak of the perception/cognition of time. However, when this time limit is exceeded, memory and attention play an important role. The present result could indicate that memory is in practice not even necessary for high-frequency processing of information and action.

The content-related function **‘Emotional Evaluation of Information’** could be totally represented by **factor 6**. The test SIS – Tiredness reflecting the logistical function that was originally used to assess Activation/Attention loads negatively on this factor. Subjectively experienced tiredness obviously comes close to being an emotional state and corresponds less with the objective neurological activation level. In contrast to Cieza (2000), the function ‘Emotional Evaluation of Information’ was included in the present study for the first time.

The factors 1,2,3,5, and 6 presented above represent individual content-related domains of the classification of mental functions (perception; activation, reaction, volition and decision, and emotional evaluation of information) and record the temporal organization of time periods longer or shorter than three seconds. The fourth factor provides insight into the complexity of and the connection between temporal processing and cognitive-motor performance. Accordingly, there is a combination of peripheral and central components which were separated by two factors by Cieza (2000) in her explorative analysis. By the determination of 6 factors in the present study, these two factors coincided.

The function ‘**Activation/Attention’** could not be reproduced by factor analysis in the given tests. That result might be due to the tests selected. The Colour Word Test was not appropriate for factor analysis, as well as the Incidental Learning test. The Subjective Intensity Scale – Tiredness corresponded to the factor *Emotional Evaluation of Information*. Therefore, the function Activation/Attention is probably better assessed by a more objective measurement, like Electro-Encephalography and Event-Related Potentials (EEG/ERPs; Takahashi, et al., 2005). This domain may be more appropriate the SECOND branch of research in the psychology of time, i.e., the objective neuroanatomic and physiologic basis of time processing, and is, therefore, more closely related to the question of WHERE and with what intensity temporal processing takes place.

The tests measuring the function ‘**Processing of Information’ or ‘learning and memory’** were tied to other tests in keeping with factor 5, which indicates a connection between logistic and content-related functions. This event provides evidence for the theoretical assumption of a close connection of content-related and logistical functions. The domain ‘**30-40ms of Temporal Organization’** can also be seen in this context.

Data quality is an indispensable requirement for meaningful data interpretation. The quality of the data set can be evaluated by the rate of missing values. Thorough data validation, which is required in a clinical study, ensured a high level of completeness of data (missing values: n=1; overall rate: <.1%).

A limiting factor in the present study was the relatively small sample size of 66 subjects. Although there are no clear rules for determination of sample size in factor analysis, a higher number would have been appropriate. Hair et al. (1998) at least postulates a minimum number of subjects higher or equal to the number of variables. As a stronger criterion he assumes that the number of subjects should be 3x the number of variables.
In the present study, elderly subjects had to be included because of the limitations imposed in the clinical study. For generalization of the results, comparing studies with different subjects groups may be necessary.
To check the dependency of the content-related functions on the logistical functions, it might be of scientific interest to apply regressional analyses of tests of logistical functions on tests of content-related functions with a revised and newly-defined test battery. It might also be interesting to repeat the measurements of the present study with separate gender groups and with a larger sample of particularly younger subjects.

Nevertheless, the statistical analysis of the present study confirms Pöppel's taxonomy of subjective phenomena. This explains the correlation of elementary mental functions from a neuropsychological point of view based on a psychology of time. A theoretical classification of mental functions was presented that combined the branches of research on time perception or elementary experiences of time and how the brain functions to perceive, and experience time. It not only presented the experience of time, but also postulated the neuronal mechanisms forming the basis of these experiences of time. These mechanisms were postulated not only as a basis for the experience and perception of time, but also as a general basis of mental processes, i.e. those of perception, learning and memory, emotional evaluation, and action/reaction.

In summary, the content-related functions *Stimulus Perception*, *Stimulus Evaluation*, *Activation/Reaction* and the logistical function *Temporal Organization* (=3000ms, < 3000ms) were represented satisfactorily from a factor-analytic point of view. The tests selected to measure this functions proved to be 'valid' instruments and reproduced the proposed functions adequately. The content-related function *Processing of Information,* the logistical functions *Activation/Attention,* and the high-frequency mechanism of the logistical function *Temporal Organization* could not be revealed with the selected test battery.

With respect to the assignment of test instruments to the classification of mental function according to Pöppel, a new selection has to be made in certain cases. The results lead to considerations to interpret some instruments with a new perspective. The present document shows empirical evidence of the theroretical construct and new aspects of classification of the corresponding instruments. With this study, an important move has been made, to use the classification of mental function for clinical practice. Via selective diagnosis of a deficient function, specific intervention can be implemented. In particular, the logistical functions of the classification have been neglected in neuropsychological practice. An appropriate system of classification is a prerequisite for the scientific exploration of psychological phenomena.

## REFERENCES

Backhaus, K., Erichson, B., Plinke, W. & Weiber, R. (1994): Multivariate Analysemethoden. Eine anwendungsorientierte Einführung. Berlin, Heidelberg, New York, Tokyo: Springer-Verlag.

Bullinger, M., Heinisch, M., Ludwig, M., Geier, S. (1990). Skalen zur Erfassung des Wohlbefindens: psychometrische Analysen zum ‘Profile of Mood States’ (POMS) und zum ‘Psychological General Well-Being Index’ (PGWB). Zeitschrift für Differentielle und Diagnostische Psychologie 11: 53-61.

Cieza, A. (2000). Zur Operationalisierung einer Klassifikation psychischer Funktionen: Darstellung einer experimentalpsychologischen Studie. Verlag Dr. Kovač, Hamburg.

Cieza, A., Maier, P. & Pöppel, E. (2003). Effects of Ginkgo biloba on Mental Functioning in Healthy Volunteers. Archives of Medical Research 34 (2003): 373-381.

Dolcos, F., LaBar, K. S., & Cabeza, R. (2004). Interaction between the amygdala and the medial temporal lobe memory system predicts better memory for emotional events. Neuron, 42: 855-863.

Fechner, G. Th. (1889). Elemente der Psychophysik. Leipzig: Breitkopf & Härtel.

Fraisse, P. (1978). Time and rhythm perception. In: E.C. Carterette & M.P. Friedmann (Eds.), Handbook of Perception 8. New York: Academic: 203-247.

Fraisse, P. (1984). Perception and estimation of time. Annual Review of Psychology 35: 1-36.

Guadagnoli, E. & Velicer, W.F. (1988). Relation of sample size to the stability of component patterns. Psychological Bulletin 103, 265-275.

Hair, J.F., Anderson, R.E., Tatham, R.L. & Black, W.C. (1998). Multivariate Data Analysis. Upper Saddle River, NJ: Prentice Hall.

Hirsh, I.J., Sherrick, C.E. (1961). Perceived order in different sense modalities. Journal of Experimental Psychology 62: 423-432.

Hutcheson G, Sofroniou N (1999). The Multivariate Social Scientist. Sage: London: 224-225.

Ilmberger, J. (1986). Auditory Excitability Cycles in Choice Reaction Time and Order Threshold. Naturwissenschaften 73: 743-744.

James, W. (1890). The principles of psychology. New York: Henry Holt, Vol 1.

Kaiser HF (1974). An Index of factorial simplicity. Psychometrika 39: 31-36.

Kandel, E.R., Schwartz, J.H., Jessell, T.M. (Eds.), (1996). Neurowissenschaften. Eine Einführung. Heidelberg, Berlin, Oxford: Spektrum, Akademischer Verlag.

Kessler, J., Grond, M., Schaaf, A. (1991). Kognitives Minimal Screening (KMS). Beltz Test GmbH. Weinheim.

Kim, Jae-On and Charles W. Mueller (1978). Factor Analysis: Statistical methods and practical issues. Thousand Oaks, CA: Sage Publications, Quantitative Applications in the Social Sciences Series, No. 14.

Kowal, S., O`Connell, D., Sabin, E.J. (1975). Development of temporal patterning and vocal hesitations in spontaneous narratives. Journal of Psycholinguistic Research 4: 195-207.

LaBar, K. S. (2003). Emotional memory functions of the human amygdala. Current Neurology and Neuroscience Reports, 3: 363-364.

Lashley, K.S. (1951). The problem of serial order in behavior. In: L.A. Jeffress (Ed.), Cerebral mechanisms in behavior. New York: Wiley: 112-136.

Limm H. (1999). Der “Subjektive Instensitäts-Score” (SIS): ein neues Schmerzmeßinstrument. Hamburg, Germany: Verlag Dr. Kovac.

Mates, J., Müller, U., Tadil, T., Pöppel, E. (1994). Temporal integration in sensorimotor synchronization. Journal of Cognitive Neuroscience 6: 332-340.

McNair, D., Lorr, N., Dropelman, L. (1982). Manual for the Profile of Mood States. San Diego, CA: Education and Industrial Testing Service.

Oswald, W.D. & Fleischmann, U.M. (1995). Nürnberger-Alters-Inventar. Göttingen, Bern, Toronto, Seattle: Hogrefe, Verlag für Psychologie.

Phelps, E.A. (2002). The cognitive neuroscience of emotion. In M.S. Gazzaniga, R.B. Ivry & G.R. Mangun (Eds), Cognitive Neuroscience: The Biology of Mind 2nd ed. NY: Norton.

Ploog, D. (1980). Emotionen als Produkte des limbischen Systems. Med. Psychol 6: 7-19.

Pöppel, E. (1970). Excitability cycles in central intermittency. Psychologische Forschung 34: 1-9.

Pöppel, E. (1973). Influence of pause duration on the reproduction of a 2-second interval. Bulletin Psychonomic Society 2: 291-292.

Pöppel, E. & Harvey, Jr. (1973). Light-difference threshold and subjective brightness in the periphery of the visual field. Psychologische Forschung 36: 145-161.

Pöppel, E. (1978). Time perception. In: R. Held, H.W. Leibowitz, H.L. Teuber (Eds.), Handbook of Sensory Physiology, Vol. 8, Perception. Berlin: Springer: 713-729.

Pöppel, E. (1985). Grenzen des Bewußtseins. Über Wirklichkeit und Welterfahrung. Stuttgart: Deutsche Verlags-Anstalt.

Pöppel, E. & Logothetis, N. (1986). Neuronal oscillations in the human brain. Discontinuous initiations of pursuit eye movements indicate a 30 Hz temporal framework for visual information processing. Naturwissenschaften 73: 267-268.

Pöppel, E. (1989). Taxonomy of the subjective: An evolutionary perspective. In: J.W. Brown (Ed.), Neuropsychology of visual Perception. Hillsdale, New Jersey: Lawrence Erlbaum Associates, 219-232.

Pöppel, E., Schill, K. & v. Steinbüchel, N. (1990). Sensory Integration within temporally neutral system states: a hypothesis. Naturwissenschaften 77: 89-91.

Pöppel, E. (1993). Taxonomy of subjective phenomena: a neuropsychological basis of functional assessment of ischemic or traumatic brain lesions. Acta Neurochir 57: 123-129.

Pöppel, E. (1994). Temporal mechanisms in perception. Int Rev Neurobiol 37: 185-202.

Pöppel, E. (1997). A hierarchical model of temporal perception. Trends Cogn Sci 1 (2): 56-61.

Pöppel E, Wittmann M. (1999). Time in the mind. In: R. Wilson, F. Keil (Eds.). The MIT Encyclopedia of the Cognitive Sciences. Cambridge, MA: MIT Press: 836-837.

Quasebarth, K. (1924). Zeitschätzung und Zeitauffassung optisch und akustisch ausgefüllter Intervalle. Arch. Ges. Psychol. 49: 379-432.

Reitan, R.M. (1956). Trial Making Test. Manual for administration, scoring and interpretation. Indianapolis: Indiana University Press.

Ruhnau, E. & Haase, V.G. (1993). Parallel distributed processing and integration by oscillations. Behav Brain Sci 16: 587-588.

Roth, G. & M.F. Wullimann (2000). Brain Evolution and Cognition. Wiley-Spektrum, New York, Heidelberg, 2000.

Sabel, B.A. & Steinbüchel, N.v. (1994): Die Repräsentation psychischer Funktionen im Gehirn. In: Gerber, W.-D., Basler, H.-D. & Tewes, U.: Medizinische Psychologie. München: Urban und Schwarzenberg.

Schleid, M. & Kein, J. (1997). Segmentation in behavior and what it can tell us about brain function. Human Nature 8 (1): 77-111.

Steinbüchel, N.v., Wittmann, M. & Szelag, E. (1999). Temporal constraints of perceiving, generating, and intergrating information: Clinical indications. Restorative Neurology and Neuroscience 14: 167-182.

Stern, L.W. (1897). Psychische Präsenzzeit. Zeitschrift für Psychologie und Physiologie der Sinnesorgane, 13: 325-349.

Strasburger, H., Pöppel, E. (1999). "Visual Field". In: Adelman, G., Smith, B.H. (Eds.), Encyclopedia of Neurosciencia. Amsterdam: Elsevier Science.

Szelag, E., v. Steinbüchel, N., Reiser, M., de Langen, E.G., Pöppel, E. (1996). Temporal constraints in processing nonverbal rhythmic patterns. Acta Neurobiologiae Experimentalis 56: 215-225.

Szelag, E. (1997). Temporal integration of the brain as studied with the metronome paradigm. In: H. Atmanspacher, E. Ruhnau (Eds.), Time, Temporality, Now. Berlin: Springer: 107-120.

Takahashi T, Murata T, Hamada T, Omori M, Kosaka H, Kikuchi M, Yoshida H & Wada Y. (2995). Changes in EEG and autonomic nervous activity during meditation and their association with personality traits. International Journal of Psychophysiology. 55 (2): 199-207.

Treutwein, B. (1995). Adaptative Psychophysical Procedures. Minireview. Vision Research 35 (17): 2503-2522.

Treutwein B. (1997). YAAP: Yet another adaptive procedure. Spatial Vision 7 (11): 129-134.

Turner F., Pöppel, E. (1988). Metered poetry, the brain, and time. In: I. Rentschler, B. Herzberger, D. Epstein (Eds.), Beauty and the Brain. Biological Aspects of Aesthetics. Basel: Birkhäuser: 71-90.

Vierordt, K. (1868). Der Zeitsinn nach Versuchen. Tübingen: Laupp.

Vollrath, M., Kazenwadel, J., Krüger, H.P. (1992). A universal constant in temporal segmentation of human speech. Naturwissenschaften 79 (10): 479-480.

Wittmann M. (1999). Time perception and temporal processing levels of the brain. Chronobiology International 16 (1): 17-32.

Wittmann, M., Szelag, E. (2003). Sex differences in perception of temporal order. Perceptual and Motor Skills, 96, 105-112.

Wundt, W. (1911). Einführung in die Psychologie. Leipzig: Voigtländer.

Zung, W.K. (1965). A self-rating depression scale. Archives of General Psychiatry 12: 63-70.

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| 1999-2000 | Diplomarbeit: Untersuchung des Zusammenhangs zwischen Persönlichkeit, emotionaler Betroffenheit und umweltbewußtem Handeln auf der Basis tiefenpsychologischer Theorie.<br>Entwicklung eines Fragebogens zur emotionalen Betroffenheit im Hinblick auf umweltrelevante Inhalte. |

**Berufliche Positionen/Praktika**

| | |
|---|---|
| 1996 | Praktikum Verhaltenstherapeutische Praxis<br>I. Bögner und H. Grothe IN Köln |
| 1996-1997 | Praktikum Psychosomatische Poliklinik der Rheinischen Friedrich-Wilhelms-Universität zu Bonn |
| 1997 | Praktikum am Humanwissenschaftlichen Institut der LMU München |
| 1998-1999 | Studentische Hilfskraft am Institut für Medizinische Psychologie der Ludwig-Maximilians-Universität München |
| 1999-2000 | Studentische Hilfskraft am Humanwissenschaftlichen Zentrum der Ludwig-Maximilians-Universität München |
| 1999-2000 | Studentische Mitarbeiterin der<br>Sciencia GmbH, Gesellschaft im Gesundheitswesen, München |
| 1999-2001 | Wissenschaftliche Mitarbeiterin am Institut für Medizinische Psychologie der Ludwig Maximilians-Universität München |
| Juli 2000-Dezember 2001 | Wissenschaftliche Projektleiterin der<br>Sciencia GmbH, Gesellschaft im Gesundheitswesen, München |

| | |
|---|---|
| Januar 2002-Februar 2004 | Leitung Projektkoordination für das Institut Dr. Schauerte – Studien und Marketing in der Medizin, München Grünwald |

**Aktivitäten**

| | |
|---|---|
| 1996/ 1997 | Fortbildung in Psychoanalytischer Gruppentherapie Psychosomatische Poliklinik der Rheinischen Friedrich-Wilhelms-Universität zu Bonn. |
| 9. - 10. Juni 1999 | „Der Mensch im Mittelpunkt der Umweltforschung“ - „Mensch und globale Umweltveränderungen - sozial und verhaltenswissenschaftliche Dimensionen“<br>Eine Transferveranstaltung im Rahmen des 4. Kolloquiums des Schwerpunktprogramms der Deutschen Forschungsgemeinschaft (DFG) in Bonn. |
| 25. 9. 1999 | Tagung: „Selbstbewußt vorangehen“ - Ökologische Erkundungen in der Evangelischen Akademie Tutzing. |
| 5. – 8. 11 1999 | Interational Symposium on „Time and Timing in Biological Systems“ dedicated to the commemoration of Iwan P. Pawlow (1849-1936), Kloster Seeon<br>Symposium der SmithKline Beecham Stiftung |
| 26. - 28. 9. 1999 | Tagung der Fachgruppe „Umweltpsychologie“ in der Deutschen Gesellschaft für Psychologie (DGPs) in Magdeburg |
| 22.1. 2000 | Symposium „Palliative Care in Germany and in the United States: Cross-National Perspectives“<br>Bayerische Landesärztekammer und Humanwissenschaftliches Zentrum der LMU |
| März 2000 | Symosium „Envisioning Knowledge“, Messe Riem<br>Humanwissenschaftliches Zentrum der LMU und der Burda Akademie zum Dritten Jahrtausend |
| 27./ 28. 10. 2000 | Einführungsveranstaltungen Evidence Based Health Care, Ludwig Maximilians-Universität München |
| 29.05.2001 | Seminar Projektmanagement Klinischer Prüfungen<br>Kendle College München |

**Lehrtätigkeit**

2000-2001 Kursleiterin für das Seminar "Medizinische Psychologie" am Institut für Medizinische Psychologie der Medizinischen Fakultät der Ludwig-Maximilians-Universität München

**Publikationen**

Flammersfeld, L., Steffen, A. & Ilg, R. (2000): Ethik und Heuchelei. In: Ruhnau, E., Kridlo, S. Busch, B. & Roessler, K: Ethik und Heuchelei. Köln: DuMont.

Flammersfeld, L., Cieza, A. & Ruhnau, E. (2001): Umweltbewußtes Handeln im Zusammenhang mit Persönlichkeit, Selbstsystem und Emotionaler Betroffenheit. Poster bei der Jahrestagung der Deutschen Gesellschaft für Medizinische Psychologie (DGMP) in Greifswald.

Kloker, B. & Flammersfeld, L. (2003): Rheumatherapie mit Teufelskrallenwurzel-Trockenextrakt-Eine multizentrische Praxisstudie. Ärztezeitschrift für Naturheilverfahren 44, 2.