VIENNA TEST SYSTEM

MANUAL

PERCEPTION AND ATTENTION FUNCTIONS: ALERTNESS

Test Label WAFA

Version 23 - Revision 1

Mödling, July 2011

Author of the test W. Sturm
Author of the manual W. Sturm

SCHUHFRIED GmbH, Hyrtlstraße 45, 2340 Mödling, Austria
Tel. +43/2236/42315-0, Fax: +43/2236/46597
info@schuhfried.at www.schuhfried.at
Sitz: Mödling, FN 104661p
Landesgericht Wr. Neustadt, UID Nr. ATU 19273809

SCHUHFRIED
passion for psychology

CONTENTS

1 SUMMARY

Author

Walter Sturm

Application

Assessment of sub-functions of attention, suitable for respondents from the age of 7.

Main areas of application: Neuropsychology; clinical and health psychology; aviation psychology; sport psychology

Theoretical background

Modern views of the dimensionality of attention can be summarised by the model proposed by van Zomeren and Brouwer (1994). One of the key features of this model is the distinction between the intensity and selectivity aspects of attention; each of these aspects can in turn be broken down into more specific components. The intensity aspect of attention comprises two elements, alertness and vigilance; alertness involves the short- and longer-term arousal of attention, while vigilance relates to the sustaining of this arousal. With regard to the selectivity aspect of attention processes the model distinguishes between focused or selective attention and divided attention.

The spatial orienting of attention is a separate, additional dimension. It does not form part of the model described above (Posner et al. 1978, 1984) but is included in more recent taxonomies (Sturm 2005).

Both Posner and Raichle (1994) and Fernandez-Duque and Posner (2001) distinguish three types of attention networks: a) Orienting (corresponds to the network of spatial direction of attention), b) Vigilance (corresponds to the intensity dimension) and c) Executive Attention (corresponds roughly to the selectivity dimension).

Administration

The WAF test battery consists of 6 tests that can be administered independently of each other or, as a test battery, in any desired combination. In addition, WAFW can be used to make a differential assessment of sensory impairments.

- **WAFW:** Pre-tests for attention functions
- **WAFA:** Alertness
- **WAFV:** Vigilance / sustained attention
- **WAFS:** Selective attention
- **WAFF:** Focused attention
- **WAFG:** Divided attention
- **WAFR:** Spatial attention and visual field / extinction - neglect

For each of the WAF tests different test forms are available, enabling dimensions of attention to be assessed under different presentation modalities. There are thus separate sub-tests for visual, auditory and crossmodal presentation. In some subtests of the WAF test battery automated and controlled aspects of attention are measured separately; the stimuli either become more prominent because the intensity level is increased (“popping out”), or they become less prominent because their intensity is decreased and cognitively controlled “top down” processes are then required. Both attention processes are relevant in everyday life; both can interact and both can be selectively impaired, for example as a result of brain damage, since they are based on different cerebral networks (Corbetta & Schulman 2002).

WAFW

In order to exclude the possibility that perceptual impairments may influence the processing of the stimuli used in WAF, thus impeding reliable diagnosis, WAFW can be used before the start of an assessment to determine whether the respondent has the perceptual ability necessary for completion of the WAF tests.

WAFA

WAFA measures reaction time in response to simple visual or auditory stimulus material. The stimulus is presented either with or without a warning signal in the same stimulus modality or the contrasting one (intrinsic vs. phasic alertness). A special standardisation process enables fatigue or stress parameters to be measured.

WAFV

In WAFV the respondent is presented with visual and auditory stimuli that occasionally diminish somewhat in intensity. The person’s task is to respond to these occasional cases; when sustained attention is being measured they constitute around 25% of the stimuli while in the case of vigilance they make up some 5% of the stimuli.

WAFR

The spatial orienting of attention is measured using either 4 or 8 spatial positions in a task similar to a Posner paradigm. Peripheral (exogenous) and central (endogenous) spatial cues are used. In the neglect test stimuli are presented at various positions in the right or left visual field or simultaneously in equivalent positions in both halves of the field of vision (extinction condition).

WAFF

The respondent is presented - depending on the subtest – with relevant visual or auditory stimuli against a background of distracting stimuli. The person’s task is to respond when two predefined changes in relevant stimuli occur consecutively; all other stimuli are to be ignored.

WAFS

The respondent receives relevant and irrelevant stimuli in one or both presentation modalities; the task is to react to changes in the relevant stimuli while ignoring irrelevant ones.

WAFG

The respondent receives stimuli on two visual channels or on one visual one and one auditory one. The task is to monitor both channels to determine whether one of the stimuli changes twice in succession.

Test forms / subtests

WAFW: 4 test forms

Separate forms for distinguishing brightness, shape, tonepitch and volume

WAFA: 6 subtests

Intrinsic (visual), phasic (unimodal visual), phasic (crossmodal visual/auditory), intrinsic (auditory), phasic (unimodal auditory), phasic (crossmodal auditory/visual)

WAFV: 4 test forms, 2 short forms (sustained attention 15 minutes) for children and young people

Separate forms for vigilance (visual), vigilance (auditory), sustained attention (visual), sustained attention (auditory). Separate short forms for sustained attention (visual) and sustained attention (auditory).

WAFR: 5 subtests

Subtests with either 4 or 8 stimulus positions and peripheral or central cues. In addition a test for visual field / neglect under extinction conditions.

WAFF: 3 subtests

Unimodal (visual), unimodal (auditory), crossmodal

WAFS: 3 subtests

Unimodal (visual), unimodal (auditory), crossmodal

WAFG: 2 subtests

Unimodal (visual), crossmodal

Scoring

In all WAF tests the reaction times and the various error types are scored. For most of the variables a norm comparison is also carried out, yielding percentile ranks and T scores.

Reliability

Especially given the short testing time, the reliabilities (Cronbach's alpha) obtained for the WAF tests are very good.

- **WAFA:**
  depending on subtest between r=0.93 and r=0.98 (children and young people 0.92 - 0.97)
- **WAFV:**
  depending on test form between r=0.96 and r=0.99 (children and young people 0.96 - 0.97)
- **WAFR:**
  depending on test form between r=0.88 and r=0.97 (children and young people 0.92 - 0.94)
- **WAFF:**
  depending on subtest between r=0.93 and r=0.97 (children and young people 0.91 - 0.96)
- **WAFS:**
  depending on subtest between r=0.94 and r=0.97 (children and young people 0.93 - 0.94)
- **WAFG:**
  depending on subtest between r=0.96 and r=0.97 (children and young people 0.96)

Validity

A study of the tests' construct validity involving a sample of N=256 adult respondents and 270 children and young people provided empirical confirmation of the theoretical model on which the WAF test battery is based and was able to distinguish it from other models.

Norms

For all WAF tests norms representative of the general population are available; the norms relate to N=295 individuals in the age range 16 - 77. The norms are available both for the sample as a whole and also separated according to educational level. In addition, all WAF tests provide raw scores adjusted for age effects for the main variables; this is a particularly efficient method of standardisation for age. A norm sample of N=270 children and young people in the age range 7- 17 is also available.

Time required fort he test

The time required to complete the individual WAF tests is relatively short. It is therefore possible to create batteries of tests for complex assessment purposes without requiring too much of the respondent in terms of time or motivational commitment. It is usually not necessary to administer each test in all stimulus modalities. This must be decided by the user, taking into account any information about a patient's difficulties or disabilities that has already been gathered. The test results cannot be interpreted with confidence unless the client/patient meets the sensory and motor requirements for satisfactory completion of the test.

- **WAFW:** approx. 2 mins. for each pre-test
- **WAFA:** approx. 5 mins. for each subtest
- **WAFV:** 15 – 30 mins., depending on test form
- **WAFR:** approx. 5 mins. for each test form
- **WAFF:** approx. 10 mins. for each subtest
- **WAFS:** approx. 8 mins. for each subtest
- **WAFG:** approx. 12 mins. for each subtest

Note

A standard USB headset is required for administration of the auditory and crossmodal subtests of the WAF tests.

2 DESCRIPTION OF THE TEST

2.1 Theoretical basis of the Perception and Attention Functions test battery

Attention functions are important for the successful handling of the tasks that the individual encounters in daily life. In all situations other than those in which we can apply highly overlearned routine behaviours the application of attention and continuous monitoring of our actions is required. Attention functions are not independent of other skills but are a constituent of many processes of perception, memory, planning and acting as well as playing a part in speech production and reception, spatial orientation and problem-solving. Attention functions are thus basic skills that are required in almost every practical or intellectual activity.

According to psychological and neuropsychological theories, attention cannot be regarded as a single, simple function. In 1890 William James (p. 416) gave a definition of attention which describes only one of the aspects of attention that are today regarded as relevant, that of selectivity.

Everyone knows what attention is; it is the taking possession by the mind, in clear and vivid form, of one out of what seems several simultaneously possible objects or trains of thought. Focalization, concentration of consciousness are of its essence. It implies withdrawal from some things in order to deal better with others.

He sees attention as a sort of “spotlight” that focuses on the aspects of a situation that are currently of importance, whether they be external or mental; aspects which are irrelevant are “left in the dark” or in other words ignored. This view was also a component of the attention theories of the twentieth century. Broadbent (1958, 1971), Deutsch and Deutsch (1963) and Treisman (1969) regard attention as a “selection mechanism” that we have to employ because our information processing capacity is limited. In these theories attention-controlled selection causes particular components of the flow of information with which we are continuously bombarded to be toned down on the basis of specific physical properties. At the same time there is on the reaction side a selective modulation of reaction thresholds (e.g. through active inhibition of responses to irrelevant stimuli). More recent theories of attention distinguish between automatic and controlled methods of processing or emphasise the targeted nature and cognitive control of attention-led behaviour. Modern taxonomies take account of the “energetic” as well as the selective aspects of attention. We must be able to call on a particular level of alertness and if necessary sustain it over a lengthy period of time if we are to concentrate on a task, maintain a demanding level of involvement and separate the important from the unimportant. These “intensity aspects” of attention are thus essential to the utilisation of more complex cognitively controlled attention processes.

2.1.1 Dimensions of attention

A newer model that attempts to bring together modern concepts of the dimensionality of attention was put forward by van Zomeren and Brouwer (1994).

One of the key features of this model is that it distinguishes between the intensity and selectivity aspects of attention; each of these aspects can in turn be broken down into more specific components. The intensity aspect of attention comprises two components, alertness and vigilance, which are basal processes of short- and long-term attention activation and the sustaining of this activation.

With regard to the selectivity aspect of attention processes the model of van Zomeren and Brouwer distinguishes between focused or selective attention and divided attention.

The spatial direction of attention is a separate, additional dimension that does not form part of the model described above (Posner et al. 1978, 1984).

Both Posner and Raichle (1994) and Fernandez-Duque and Posner (2001) distinguish three types of attention networks: a) Orienting (corresponds to the network of spatial direction of attention), b) Vigilance (corresponds to the intensity dimension) and c) Executive Attention (corresponds roughly to the selectivity dimension). Table 1 is an attempt to draw up a taxonomy of attention functions that integrates the ideas contained in the different models. Typical tasks and paradigms are assigned to the different areas and dimensions of attention and also form the basis of this attention test battery.

Table 1: Attempt at a taxonomy of attention dimensions and areas and their associated paradigms in accordance with the models of van Zomeren and Brouwer (1994) and Posner and Raichle (1994; dimensions shown in brackets)

Dimension	Area	Paradigms
Intensity (alerting and vigilance)	**Attention activation** (alertness) (intrinsic, tonic and phasic)	Simple visual or auditory reaction tasks without (tonic or intrinsic alertness) or with (phasic alertness) a cue
	Sustained attention	Simple signal detection tasks over a long period, high proportion of relevant stimuli
	Vigilance	Monotonous signal detection tasks over a long period, low proportion of relevant stimuli
Spatial direction of attention (orienting)	**Visual/spatial attention, change of focus of attention**	Tasks requiring a shift of attention from one spatial focus to another
Selectivity (executive attention)	**Selective or focused attention**	Choice reaction tasks (selective attention); tasks with distractor stimuli (focused attention)
	Divided attention	Tasks that require attention to be divided between a number of information channels (e.g. “dual tasks”); tasks for measuring “cognitive flexibility”

2.1.2 Development of attention functions

A number of more recent studies have shown that visual and auditory attention improve with increasing age (Aylward et al. 2002; Lehman et al. 2006; Gomes et al. 2007). However, it remains unclear whether this development is continuous or whether it takes place in discrete stages. Klimkeit et al. (2004) studied the development of attention and executive functions in children aged between 7 and 12. They suggest that development takes place in stages with the most marked improvement occurring between the ages of 8 and 10; between 10 and 12 a plateau is reached. Similar findings were obtained in a study by Korkmann et al. (2001) in which the authors investigated the development of a large sample of 5-to-12-year-olds using a neuropsychological test battery; they found that neuropsychological functions develop particularly quickly between the ages of 5 and 8 and more slowly in the older group of 9-to-12-year-olds. By contrast, Gomez-Perez and Ostrosky-Solis (2006) found no evidence of development stages in their large-scale developmental study (n=521). They investigated the development of attention and memory over a wide age range spanning the ages of 6 to 85. They found that attention functions improve rapidly during childhood and continue to develop into adolescence. Interestingly, this study appeared to show that different cognitive functions develop in different ways: more complex functions seem to take longer to reach their final level. This accords with findings that showed that 13-year-olds have not yet achieved the same level of performance as adults in situations (such as inhibition control) that make complex demands on attention (Davidson et al. 2006). In contrast to earlier findings that postulate a decline in performance with increasing age (De Luca et al. 2003; Plude et al. 1994), they conclude that attention performance remains relatively constant between the ages of 16 and 85.

Development of the auditory system can be divided into several stages (Werner 2007). The last of these stages (“flexibility in the use of acoustic information”) begins at the age of 8 – 9 years. The specific development of the auditory attention system could be a reason why 15-year-olds are less good than adults at identifying speech against a background of noise or echo (Johnson 2000). In addition, between childhood and early adulthood an improvement in auditory focused attention is found (Pearson & Lane 1991); this accords with the findings of Klimkeit et al. (2004, see above) and suggests that attention functions continue to develop into adolescence. Like the elements of visual attention, various components of auditory attention also develop in different ways depending on their complexity (Gomes et al. 2000). More complex aspects of attention (such as selective attention) develop more slowly than, for example, performance on alertness tasks.

In older people there appears to be a differential decline in aspects of attention (McDowd & Shaw 2000). Studies of the intensity of attention reveal a slight age-related decline, for example in sustained attention. With regard to selectivity the findings are considerably less clear: Hasher and Zacks (1988) suggest that with age there is an increase in distractibility and a decrease in inhibition ability. By contrast, Einstein and McDaniel (1997) found no increase in “mind wandering” in older adults. In addition, a relatively recent meta-analysis (Verhaeghen and Cerella, 2002) reported no systematic age effect for Stroop and negative priming tasks. Age does, however, have a significant effect on divided attention and task switching; the effect is closely related to the level of difficulty of the task involved. In the context of an auditory attention-focusing task, Barr and Giambra (1990) showed that older adults are significantly more susceptible to interference than younger people (the “cocktail party phenomenon”).

2.1.3 Attention disorders

Together with memory impairments, attention problems are among the most common consequences of brain injuries of very varied aetiology and location. They also frequently accompany psychiatric illnesses (schizophrenia, depression, ADHS). Patients with severe attention difficulties are often unable to profit from rehabilitation, even if other cognitive functions are relatively unaffected. Robertson et al. (1997) showed that even the recovery of motor functions after they had been damaged can be affected by the patient’s attention problems. The investigation and rehabilitation of attention skills is therefore of central importance.

2.1.3.1 Manifestations

In a clinical setting the aspects of attention outlined in the preceding section are of direct practical relevance. For example, disorders of intrinsic and possibly also of phasic alertness should be assumed if a patient in an acute condition is unusually unresponsive and shows signs of being disoriented with regard to time, place and personal matters. In addition, patients with alertness problems often complain of increased tiredness and diminished ability to cope.

Patients with sustained attention problems also tire quickly and need to take frequent breaks in the course of any intellectual or practical activity. Many such patients are no longer able to engage in any prolonged form of work. Vigilance situations in the narrow sense are by contrast seldom encountered under everyday conditions. Typical activities involving vigilance include, for example, watching a radar screen, undertaking quality control on an assembly line or driving at night on an empty motorway.

Increased distractibility as a symptom of an attention-focusing disorder is frequently observed after frontal lesions.

Central to the discussion of the concept of attention is the aspect of limited capacity. This is clearly relevant to the clinical issue of divided attention. Many patients complain specifically of their difficulties in situations in which a number of different things are required of them simultaneously. A reduced attention capacity acquires additional significance from the fact that a patient may sometimes find that he needs to exercise control – i.e. to apply increased attention – to perform activities such as walking or speaking that he used to do automatically. In such circumstances a reduced attention capacity limits the extent to which the patient can compensate for a deficit.

2.1.3.2 Aetiology of attention disorders

Attention disorders can occur in almost all neurological diseases that affect the central nervous system. The disorder of the attentional functions may be specific or global, depending on whether the neurological disorder leads to localised brain damage (as for example in a stroke) or to more diffuse impairment (as in craniocerebral trauma or degenerative diseases).

Cerebrovascular diseases

After lesions in the brainstem area of the formatio reticularis (Mesulam 1985) and after strokes, particularly those occurring in the area of the middle cerebral artery (A. cerebri media) of the right cerebral hemisphere, disorders both of alertness and of vigilance and the longer-term application of attention can occur (Howes and Boller 1975; Ladavas 1987; Posner et al. 1987).

According to Stuss and Benson (1984), attention processes make use of a network involving the reticular system of the brainstem, the diffuse thalamic projection system and the fronto-thalamic gating system. While the reticular system primes the intrinsic and tonic alertness function (see above), the fronto-thalamic gating system is involved in the selective and directed application of this alertness. Lesions of this system lead to diminished selectivity for external stimuli and to increased distractibility.

Lesions of the frontal areas of the left half of the brain also lead to impairments of the selectivity of attention, especially in situations in which rapid decisions between relevant and irrelevant aspects of a task have to be made (Dee and van Allen 1973; Sturm and Büssing 1986).

The three stages of spatial displacement of the visual focus of attention (see below) can also be selectively impaired by localised brain damage. Injuries to the posterior parietal lobe appear to lead in particular to impairments of the disengaging of attention from a stimulus when attention needs to be transferred to a target in the half of the visual field contralateral to the lesion (Posner et al. 1984). Hemineglect also tends to arise after parietal lesions. Lesions in the colliculus superior in the midbrain or in adjacent areas impair the shifting of attention to the new target, while patients with thalamic lesions (especially in the pulvinar and posterior lateral thalamus) have difficulty engaging their attention focus on the side contralateral to the lesion.

Impairments of the division of attention seem to occur particularly frequently in the wake of frontal vascular injuries (Rousseaux et al. 1996).

Craniocerebral trauma (CCT)

Together with memory problems, attentional impairments are the most common neuropsychological deficit resulting from craniocerebral trauma. A general, non-specific slowing down of information processing functions is consistently found after CCT. However, the cause of these functional impairments after CCT remains to a large extent unclear. “Diffuse axonal injuries” have been proposed as a pathological correlate of injury arising from rotational acceleration of the brain; these show up in CT – or even better in MR – as multiple small lesions or transient oedema.

Fontaine et al. (1999) showed that attention deficits after severe traumatic brain injury are accompanied by hypometabolism in the prefrontal and cingulate areas of the brain.

Neuro-degenerative diseases

Attention disorders are often observable even in the early stages of Alzheimer’s disease. In many cases they appear after memory problems have emerged but before speech and spatial skills are impaired (Perry, Watson & Hodges, 2000). Other findings indicate that cognitive control of alertness and visual-spatial attention is retained for a relatively long time, but that impairments of selective attention appear at an early stage. Impairments of inhibitory control also increase as the disease progresses.

Patients with Parkinson's disease or Huntington's chorea do not normally display any deficits in phasic alertness or in vigilance tasks, in contrast to patients with progressive supranuclear palsy (PSP), whose performance in these fields is often impaired.

Impairments of the division of attention appear to be a general characteristic of dementia disorders in their advanced stages.

Depression and attention disorders

Impairments of memory and attention are among the principal impairments of cognitive functions that accompany depression. It is primarily conscious, cognitively controlled functions that are affected. Impairments of automatic processing occur only in very severe depression (Hartlage, Alloy, Vazques et al. 1993). In contrast to patients with craniocerebral trauma (CCT), depressive patients often gauge their performance to be worse than psychometric investigation actually reveals it to be. Farrin et al. (2003) showed that this negative self-estimate can lead to "catastrophe reactions" when errors are made in sustained attention tasks, causing longer reaction times in the immediate aftermath of the error. CCT patients do not display this reaction.

Schizophrenia

Although attention deficits have long been regarded as a core symptom of schizophrenia, more detailed examination of the different attention skills reveals that the findings are not uniform. Particularly well documented are impairments of sustained attention (usually assessed by means of the Continuous Performance Test – CPT – although this test requires other skills of the patient in addition to attention per se). 75% of all patients tested with the CPT showed some impairment, while on the Trail Marking Test (version B vs. A), which is more a measure of processing speed and the flexibility of attention, 66-68% displayed some impairment. This was shown by a meta-analysis carried out by Heinrichs and Zakzanis (1998). A study by Lussier and Stip (2001) found that untreated patients displayed impairments not only of sustained attention but also of (phasic) alertness, selective attention and working memory. It is rather rarer for patients without negative symptoms to have attention problems (Jones et al. 2001). Attention deficits can also often be explained by other overlying psychiatric symptoms, in particular depression.

ADHD patients

In children with ADHD the intensity rather than the selectivity aspects of attention appear to be impaired. It is usually alertness and the longer-term sustaining of attention that are affected; both of these attention functions are controlled primarily by the right side of the brain. Spatial attention tasks also tend to involve a deficit in the right hemisphere: Nigg et al. (1977) found that when the Posner paradigm was used with non-medicated boys with ADHD, the subjects reacted more slowly to stimuli presented on the left-hand side (without precue) than to corresponding stimuli presented on the right (see also Konrad and Herpertz-Dahlmann 2004).

The influence of drugs on attention skills

Results may be falsified by drugs, most notably by sedatives but also by stimulants or drugs (especially dopaminergic and noradrenergic ones) that affect particular neurotransmitter systems. Attention functions are particularly likely to be affected by drugs taken by the subject (Rockstroh, 1993, 2000). The neuroleptic agents used in the treatment of schizophrenia are dopamine antagonists. Their effectiveness has given rise to the hypothesis that schizophrenia is caused by an excess of dopamine in the limbic system. It is assumed that at the information processing level dopamine plays a role in the filtering of stimuli and the control of the focus of attention. Many of the neuroleptic agents prescribed for psychiatric disorders have an effect on the selectivity of attention. By contrast, Rund and Borg (1999) reported positive effects with atypical neuroleptic agents such as risperidone. Antidepressants are noradrenaline or serotonin uptake inhibitors, or as monoamine oxidase (MAO) inhibitors they block the action of MAO in the nervous system. Depression is thought to involve a lack of noradrenaline or serotonin. At the information processing level noradrenaline appears to play a role in attention processes (orientation reactions, alert wakefulness). Hence antidepressants and MAO inhibitors often have a negative effect on alertness and vigilance and on orientation reactions.

2.1.4 Functional neuroanatomy

Alertness and sustained attention/vigilance

Lesion studies in stroke patients have shown that lesions to the right hemisphere often result in a very significant increase in simple visual and auditory reaction times (Howes & Boller 1975; Posner et al. 1987; Ladavas 1987). Posner and Petersen (1990) view the noradrenergic system, located in the locus coeruleus in the brain stem, as playing a particularly important role in the arousal of attention. Experiments on animals led researchers to hypothesise that this noradrenergic arousal must be regulated by a “top-down” – i.e. cognitively controlled – process taking place in the right frontal cortex. PET studies carried out by Sturm et al. (1999a, 2004b) demonstrated that there is a cortical and subcortical network, located almost exclusively in the right hemisphere, that serves to control and sustain alertness. When compared with a sensomotor control condition with no explicit attentional components, the performance of simple visual or auditory reaction tasks resulted in arousal in the right hemisphere in the anterior gyrus cinguli, the dorsolateral frontal cortex, the inferior parietal cortex, the dorsal fronto-mesencephalic tegmentum (possibly in the area of the locus coeruleus) and the right thalamus. The authors postulate a network in which the anterior cingulum and the dorsolateral frontal cortex, via the nucleus reticularis of the thalamus, “intrinsically” control and channel the arousal of attention that is needed for particular tasks and that is provided by the noradrenergic system in the brain stem. The central role of the anterior cingulum in the cognitive control of intrinsic alertness was demonstrated in a pathway analysis of the data of the PET study mentioned above (Sturm et al. 1999a; Mottaghy et al. 2006).
Paus et al. (1997), in a PET study involving a 60-minute vigilance task, showed that the same network is involved in the sustaining of attention in classic vigilance tasks. The authors found activity that decreased over time in the right ventrolateral and dorsolateral frontal cortex and in areas of the parietal and temporal cortex; arousal in the thalamus correlated significantly with activity in the ponto-mesencephalic tegmentum and in the anterior cingular cortex. At the same time they found that over time there was a significant increase in reaction times and in theta activity in the EEG. The finding that, in addition to the frontal and subcortical arousal, the inferior parietal cortex was also involved, both in the alertness and in the vigilance study, supported the hypothesis of Fernandez-Duque and Posner (1997), which postulates that the elements aroused by the attention arousal network include the posterior attention systems (see below) that are relevant to the orienting of attention. This would explain why damage to the right hemisphere leads not only to general impairment of the intensity of attention but also to persistent neglect symptoms on the left.

Thus Robertson et al. (1995) observed an interesting effect of training designed to improve the sustained attention of patients with right-hemisphere lesions. After therapy, improvement was noticed not only in the patients’ sustained attention but also in their neglect symptoms, even though the neglect symptoms themselves had not been treated specifically, for example by using tasks to improve the spatial directing of attention. The authors interpret the effect as an extension of the activation of attention from frontal to parietal areas of the right hemisphere. This effect of alertness training on neglect symptoms has been subsequently confirmed at both behavioural and functional level in a number of studies (Sturm & Willmes 2001; Thimm et al. 2005). Researchers demonstrated the central role played by the connection between the anterior “vigilance” and the posterior “orienting” system (fasziculus occipitofrontalis) in explaining hemineglect by stimulating the fasziculus occipitofrontalis in two patients during surgery: in a line-halving task there was a clear shift to the right (Thibaut de Schotten et al. 2005).

Spatial attention

According to Posner et al. (1984), three different structures of the brain are involved in the spatial direction of attention and in the spatial shifting of the visual focus of attention. Lesions in the posterior parietal lobe appear to lead in particular to impairments of the ability to disengage attention from a stimulus when attention needs to be shifted to a target stimulus in the half of the field contralateral to the lesion. Lesions in the colliculus superior or adjacent areas impair the shifting of attention to a new target stimulus. By contrast, patients with thalamic lesions, especially lesions in the pulvinar and posterior-lateral thalamus, have difficulty engaging the focus of attention on the side contralateral to the lesion and in ignoring distractions arising from irrelevant events in other surrounding positions. In a PET activation study, Corbetta et al. (1993) required subjects to fixate a central stimulus while allowing their visual attention to travel along a series of predictable stimulus positions in the right or left visual field so that they could react as quickly as possible to the appearance of small visual stimuli. Significant bilateral activation changes were found in the superior parietal cortex and in the frontal cortex; irrespective of the side on which the stimulus was presented, parietal activation on the right was always more marked than the corresponding activation in the left hemisphere. Similar results were obtained by Nobre et al. (1997) and Corbetta et al. (1995) using comparable visuospatial detection tasks. More recent studies have shown that there is considerable overlap between the networks involved in covert shifts of attention and those involved when eye movements occur (Corbetta 1998). These findings indicate that the processes of attention-orienting are closely linked to oculomotor processes. On the other hand there is increasing evidence that attention-directing processes also take place crossmodally in space. This has been studied for visual, auditory and tactile modalities (see Spence & Driver 2004). In an FMRT study, Sturm et al. (2005) found a clear overlap of right-hemisphere networks controlling alertness and visuospatial attention (see section on “Alertness/sustained attention”). These networks involve the posterior parietal cortex around the intraparietal sulcus, the frontal eye fields, the dorsolateral prefrontal cortex and the anterior cingulum.

Selective, focused and divided attention

Both Dee and van Allen (1973) and Sturm and Büssing (1986) found that patients with cortical lesions of the left hemisphere of the brain showed slowed reactions and increased error rates in choice reaction tasks. In addition, Bisiach et al. (1982) and Jansen et al. (1992), in studies involving lateralised stimulus presentation in healthy subjects, found evidence of left-hemisphere dominance for choice reactions. Some studies (Sergent 1982; Robertson & Lamb 1991) have found left-hemisphere dominance for “local” attention and a right-hemisphere preference for “global” attention; this has been confirmed in studies on patients with lateralised brain damage as well as in more recent work using functional imaging (see below).

In a PET activation study, Corbetta et al. (1991) demonstrated the specific role of the left lateral orbito-frontal cortex, the basal ganglia (globus pallidus, nucleus caudatus) and the posterior thalamus in the performance of a selective attention task requiring attention to the shape, colour or speed of stimuli. The orbito-frontal activation in the left hemisphere may represent the inhibition process that is required to suppress reactions to irrelevant stimuli. There was also increased activation in the area of the secondary visual cortex that specialises in the processing of whichever characteristic is being selectively attended to (shape, colour, speed).

In a PET study of local and global processes involved in visual selective attention, Fink et al. (1996) identified left-hemisphere dominance for “local” attention and a right-hemisphere preference for “global” attention. The experimental stimuli were those developed by Navon (1977), which are formed of letters or numbers (global processing) that are themselves made up of a repeated letter or number (local processing). The global letter or number may be identical to the local one or different from it. The subject’s task is to attend to either the global or the local aspect. When attention is directed to the global aspects, the right gyrus lingualis is activated; attention to the local aspects leads to activation of the left inferior occipital cortex. Switching between the two aspects (cognitive shifting of the focus of attention) co-varied with temporo-parietal activation.

The fronto-thalamic system involved in controlling the intensity of attention also appears to be relevant for particular aspects of attention selectivity (thalamic gating). Frontal influences cause the nucleus reticularis thalami to be selective in opening for reticular activation only the thalamic gates that are required for the processing of a particular item of information. Lesions of this system lead to diminished selectivity for external stimuli and to increased distractibility.

Studies of patients who had experienced severe craniocerebral trauma (McDowell et al., 1997; van Zomeren & van den Burg, 1985) or patients with ruptures caused by aneurysms of the anterior A. communicans (Rousseaux et al. 1996) show that divided attention skills are closely linked to frontal brain functions. PET activation studies of healthy subjects have found either bilateral (Madden et al. 1997) or right unilateral (Corbetta et al. 1991) prefrontal activation in divided attention tasks. However, the study by Corbetta et al. was carried out under experimental conditions more closely resembling a sustained attention task paradigm, and these results must therefore be interpreted with reservation. Loose et al. (2003) found left prefrontal activation in the FMRI during the performance of the visual/auditory divided attention task of the TAP (Testbatterie zur Aufmerksamkeitsprüfung - Test Battery for Attentional Performance; Zimmermann & Fimm 2002). While attention was divided, activation in the sensory processing areas decreased; this contrasts with the situation when a single task (only visual or only auditory) is performed. The authors interpret this as indicating that processing capacity is limited under divided attention conditions.

In an fMRT study involving two unimodal divided attention tasks and one crossmodal one, right-hemisphere activation in the inferior frontal cortex, the superior parietal cortex and the claustrum was found in all the experimental conditions. Under the crossmodal (visual/auditory) condition, though, there was additional bilateral activation in the middle and superior frontal cortex, the anterior cingulum and the thalamus (Vohn et al. 2007). The authors interpret this as an indication of an additional (top-down) control function that is required for the rapid switch between different stimulus modalities.

Automated vs. controlled attention processes

Corbetta and Shulman (2002) distinguish between a target-oriented and a stimulus-independent network of attention. In the target-oriented network (“top-down” selection of stimuli and reactions) attention is directed towards aspects of the situation that are relevant to the goal. Attention can, however, also be determined and controlled by characteristics of the stimulus (“bottom-up” control): a stimulus “automatically” attracts our attention. This type of arousal of the stimulus-dependent network is able to modulate our target-oriented attention. This illustrates the close cooperation that exists between the two systems. The “top-down” network involves the posterior dorso-parietal regions and the dorso-lateral frontal cortex. The stimulus-dependent attention network (“bottom-up”) is largely lateralised on the right side; it involves temporo-parietal areas and the ventral frontal cortex.

2.1.5 The theory-led assessment of attention

As has been shown, attention skills are an important requirement for coping with the demands of everyday life and attention functions are basic skills that are called on in almost every practical or intellectual task. It follows, therefore, that the differentiated assessment of attention functions is central to the process of psychological assessment both in general assessment situations and in the context of more specific investigations such as the assessment of fitness to drive. The assessment of attention has acquired particular importance in psychiatry and neuropsychology, since attention deficits are among the main symptoms of many psychiatric and neurological disorders.

A reliable assessment of attention impairments is also very important in the context of rehabilitation. Since attention disorders have many facets and attention impairments are often co-morbid with other deficits affecting perception, memory or speech, the accurate diagnosis of attention disorders is no trivial matter.

Since different psychiatric and/or neurological diseases can lead to very specific impairments of attention, any investigations where attention deficits are suspected should include at least one test for intensity of attention (e.g. alertness test, possibly administered both at the beginning and the end of the test session in order to assess fatigue effects and impairments of coping ability) and one for selectivity (e.g. test of divided attention with separate assessment of the individual components of the task). Following damage to the right hemisphere of the brain, particularly in the parietal area, the spatial direction of attention should always be assessed, even if there is no clinically significant neglect.

2.1.6 Assessment of specific functions with the WAF test battery

The WAF test battery contains subtests for assessing all the attention functions listed in Table 1. Testing is normally carried out in both visual and auditory modalities in order to provide separate assessments of modality-specific attention abilities. In a study of longer-term attention (Wagensonner and Zimmermann, 1991) attention was tested using stimuli in different modalities (visual/auditory). Modality-specific deficits were found in the patients. This dissociation of auditory and visual attention deficits indicates that there are probably specific mechanisms for controlling input in the different modalities. Two steps are taken to exclude the possibility that perceptual impairments may be affecting the processing of the stimuli used in the WAF during assessment, thus making a reliable assessment of attention impossible: a) throughout the test battery only very few visual and auditory stimuli are used, and they are very simple ones, and b) before testing starts the ability of the respondent/patient to perceive these stimuli should be checked using WAFW. This ensures that an important requirement of neuropsychological assessment is met – namely the need to take into account the possibility of pre-existing impairment of sensory functions (see Sturm 2000, 2005).
At an early stage in attention research a distinction was made between **controlled vs. automated** attention processes (see Schneider 1985). The direction of selective attention can be controlled either by external factors such as particularly prominent or relevant stimuli, or by internal factors such as the expectation of a particular stimulus, or by the way in which a particular task is formulated. External factors tend to lead to an unconscious, automated ("bottom-up") application of attention, while internal factors result in a cognitively controlled ("top-down") approach to the task.

Triesman and Gelade (1980) also emphasise the need to distinguish between automatic ("pre-attentional") and controlled processes in information processing. At the level of perception they postulate the rapid, automatic parallel processing of visual characteristics such as shape, colour, spatial orientation etc. For example, in searching for an object with a specific property (such as green colour) among other objects, none of which have this property (for example, they are all red), the search time is independent of the number of objects. The sought object appears to jump out at the observer ("popping out" effect).

However, if the sought object is less easy to distinguish from the surrounding stimuli, the information processing function appears to depend on a directed (focused) application of attention; the search processes are carried out serially (one after the other), as though each stimulus in turn must be studied with the aid of a "spotlight" to identify whether it has the required characteristic. In the WAF test battery these automated and controlled aspects of attention are measured separately; the stimuli either become more prominent because the intensity level is increased ("popping out", for example by increasing the volume of a sound), or their intensity is decreased and more controlled "top down" processes are required. Both attention processes are relevant in everyday life; both can interact and both can be selectively impaired, for example as a result of brain damage. In a survey of the functional neuroanatomy of stimulus-dependent and cognitively controlled (goal-directed) attention skills, Corbetta and Shulman (2002) showed that these skills involve different cerebral networks. The method of attention control in the goal-oriented network can be described as the "top-down" selection of stimuli and reactions: attention is directed towards features that are relevant to the goals that have been set. Attention can also be determined and controlled by characteristics of the stimulus ("bottom-up" control). In this situation a stimulus attracts our attention. This type of arousal of the stimulus-dependent network is able to modulate our goal-oriented attention. This illustrates the close cooperation that exists between the two systems. The "top-down" network involves the posterior dorso-parietal regions and the dorso-lateral frontal cortex. The stimulus-dependent ("bottom-up") attention network is primarily lateralised on the right; it involves the temporo-parietal areas and the ventral frontal cortex (Corbetta and Shulman 2002). The ventral and dorso-lateral areas of the frontal cortex also play a central role in executive functions and form part of the functional network of working memory (Fletcher and Henson 2001; Kopelman 2002). However, the fact that parts of the frontal cortex play a specialised "executive" role in attention and memory tells us little about the way in which attention, memory and executive functions interact. It simply highlights for the diagnostician the interactions with other neuropsychologically relevant functions that need to be taken into account in the assessment of attention processes.

2.2 Theoretical basis of the Alertness test

Typical tasks used to test short-term alertness involve reactions to simple visual or auditory stimuli. These can be presented with or without a warning signal before the stimulus requiring a reaction. The reaction time without the cue represents intrinsic alertness – i.e. alertness that is endogenously cognitively controlled – while the reaction time with the cue represents phasic alertness, which receives additional exogenous stimulation from the cue (Posner 1975). This sudden increase in alertness immediately following a cue is reflected electro-physiologically in the EEG expectancy wave (Walter et al. 1964; Brunia and Dahmen 1988) and on the behavioural level in shorter reaction times. In EEG and reaction time studies both Lansing et al. (1959) and Posner and Boies (1971) showed that a cue leads to optimal pre-arousal with the most significant reduction in reaction time if it is presented 0.5 – 1 second before the reaction stimulus. In certain cases, however, the presentation of a cue can lead to a lengthening of reaction times. Patients with lesions of the left brain hemisphere appear to have particular difficulty in dealing with choice reaction tasks (Dee and van Allen 1973) and they tend to react more slowly in tasks of phasic alertness after a cue has been presented (Tartaglione et al. 1986). This can also be interpreted as a general impairment of attention selectivity, since under phasic alertness conditions reactions to the cue have to be actively inhibited.

However, reaction speed without a cue remains the most important measure of the ability to call on the level of arousal most appropriate to the performance of a task, since only under this condition is the level of arousal determined exclusively by the respondent – in other words, it is cognitively controlled. Reaction times without a cue can also be used to measure the level of tonic alertness – the intensity of which is determined by the physiological state of the organism – over the course of the day. As a result of these fluctuations in level, the period between 1 and 3 p.m. is unlikely to produce optimal results for intrinsic alertness.

The patient's resilience and resistance to fatigue can be assessed by repeating the measurement of reaction times. If comparison of performance at the beginning and end of a neuropsychological investigation lasting several hours reveals a significant decline in performance in the second test, this can be interpreted as indicating that the patient's resilience is diminished. The performance of respondents whose resilience is not impaired shows very little change in this situation.
Recent research indicates that goal maintenance may be especially challenged under "simple" conditions with no interference, conflict, or dual-task demands (Dreisbach & Haider 2007; Goschke & Dreisbach 2008; Kane & Engle 2003). The higher level of challenge presented by more complex tasks can stimulate the arousal system, thereby concealing fatigue effects.

Data are available for WAFA for changes in performance after lengthy testing (a period of approx. 2-3 hours with continuous cognitive demands during this time). For administration of the entire WAF in the norm sample see Section 6.

2.3 Subtests

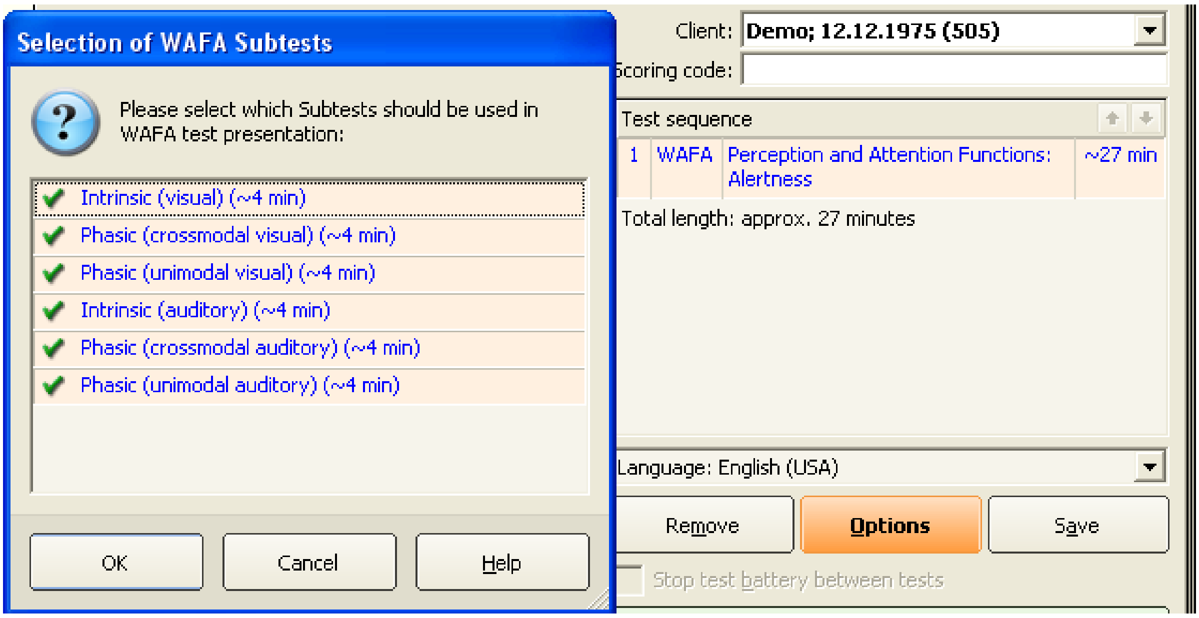
WAFA consists of 6 subtests which measure alertness under various stimulus presentation conditions. They differ in the modality in which the stimuli are presented and in whether and in which modality cues are given.

Table 2**:** Construction and stimulus conditions of the WAFA subtests

Subtest	Cue	Stimulus
Intrinsic (visual)	None	Circle
Phasic (crossmodal visual)	Low tone (200 Hz)	Circle
Phasic (unimodal visual)	Square	Circle
Intrinsic (auditory)	None	High tone (1 kHz)
Phasic (crossmodal auditory)	Square	High tone (1 kHz)
Phasic (unimodal auditory)	Low tone (200 Hz)	High tone (1 kHz)

Each subtest contains 50 relevant stimuli and takes around 3 minutes to complete, excluding the test instructions.

It is not always necessary to administer WAFA in full. If specific hypotheses are to be checked for assessment purposes by means of the tests, it is often appropriate to administer only selected subtests.



Selection of WAFA Subtests

Please select which Subtests should be used in WAFA test presentation:

- ✓ Intrinsic (visual) (~4 min)
- ✓ Phasic (crossmodal visual) (~4 min)
- ✓ Phasic (unimodal visual) (~4 min)
- ✓ Intrinsic (auditory) (~4 min)
- ✓ Phasic (crossmodal auditory) (~4 min)
- ✓ Phasic (unimodal auditory) (~4 min)

Client: Demo; 12.12.1975 (505)

Scoring code:

Test sequence			
1	WAFA	Perception and Attention Functions: Alertness	~27 min

Total length: approx. 27 minutes

Language: English (USA)

☐ Stop test battery between tests

Figure 1: Selecting the WAFA subtests. Subtest selection can be found under the Vienna Test System presentation options. All the subtests that are marked in colour are presented. Clicking on a subtest includes it in the test sequence or excludes it from it.

2.4 Description of variables

Main variables

Mean reaction time

This variable is a logarithmic mean of the individual reaction times. The advantage of using a logarithmic mean is that it takes account of the expected skew of the distribution of the reaction times.

Dispersion of reaction time

This is the logarithmic standard deviation of the reaction times.

Subsidiary variables

Number of missed reactions

This is the number of stimuli to which no response was made within 1500 ms.

Number of false alarms

This is the number of times a response key was pressed when no stimulus had been presented.

Number of premature reactions

In the subtests for phasic alertness, reactions which occur between the cue and the actual stimulus are classed as “premature reactions”.

3 EVALUATION

3.1 Objectivity

Test administrator independence exists when the respondent's test behaviour, and thus his test score, is independent of variations (either accidental or systematic) in the behaviour of the test administrator (see e.g. Kubinger 2003). Since WAFA is a computerised procedure, instruction and test presentation are standardised and the interaction between respondent and administrator is kept to a minimum; administration objectivity can therefore be assumed to exist.

Scoring objectivity exists when the test performance of each respondent leads to the same result, regardless of who scores the text (e.g. Kubinger 2003). The automatic computerised calculation of the test results ensures scoring objectivity for all the test variables of the WAFA.

Interpretation objectivity exists when the same conclusion is drawn from particular test results even when they are interpreted by different people. If the test in question has been normed, it is always unambiguous in its interpretation: the norm value unequivocally determines the respondent's "position" within the reference population with regard to the measured trait (e.g. Kubinger 2003). Because it has been normed, WAFA is therefore unambiguous in its interpretation.

3.2 Reliability

Reliability aims at formal exactness of the trait measurement (measurement precision) - that is, a score obtained in testing should be correct in the sense of being exact (see Kubinger 2003).
For the subtests of WAFA the norm sample yielded the following reliabilities (internal consistency as measured by Cronbach's α)

Table 3: Reliability of the main variables of the WAFA subtests (norm sample of adults).

	Total	**Educational level EU 1 – EU 3**	**Educational level EU 4 – EU 5**
Intrinsic (visual)	0.93	0.95	0.95
Phasic (crossmodal visual)	0.93	0.90	0.88
Phasic (unimodal visual)	0.93	0.91	0.87
Intrinsic (auditory)	0.94	0.97	0.95
Phasic (crossmodal auditory)	0.98	0.93	0.94
Phasic (unimodal auditory)	0.95	0.90	0.92

Table 4: Reliability of the main variables of WAFA (norm sample of children and young people).

	Total
Intrinsic (visual)	0.96
Phasic (crossmodal visual)	0.92
Intrinsic (auditory)	0.97
Phasic (crossmodal auditory)	0.95

3.3 Validity

Construct validity exists when it can be demonstrated that a test not only meets certain pragmatic requirements but also implements a particular theory-led approach (Kubinger 2003).
In a study of the test's construct validity the norm sample of the WAF test battery completed additional tests for determining convergent validity (Cognitrone (Wagner & Karner, 2001), Discrimination Test (Schuhfried 1998) and Reaction Test (Schuhfried & Priele 1997)) and discriminant validity (SPM Plus (J. Raven, J.C. Raven & J.H. Court 1997)).

The structure of the tests' main variables was first explored by means of factor analysis. This yielded three factors, which between them explain 60.9% of the variance.

Table 5: Factor structure of the WAF test battery obtained exploratively by principal component analysis and subsequent varimax rotation. For the sake of clarity loadings of less than 0.4 have been omitted.

	Factor 1	**Factor 2**	**Factor 3**
WAFA – Mean reaction time Subtest 1		**0.703**	
WAFA – Mean reaction time Subtest 2		**0.761**	
WAFA – Mean reaction time Subtest 3		**0.741**	
WAFA – Mean reaction time Subtest 4		**0.757**	0.412
WAFA – Mean reaction time Subtest 5		**0.753**	
WAFA – Mean reaction time Subtest 6		**0.744**	
WAFF – Mean reaction time Subtest 1	**0.653**		
WAFF – Mean reaction time Subtest 2	**0.643**		
WAFF – Mean reaction time Subtest 3	**0.645**		
WAFS – Mean reaction time Subtest 1	**0.727**		
WAFS – Mean reaction time Subtest 2	**0.687**		
WAFS – Mean reaction time Subtest 3	**0.664**		
WAFG – Mean reaction time Subtest 1	**0.724**		
WAFG – Mean reaction time Subtest 2	**0.599**		0.534
WAFV - Missed reactions Test form 2			**0.429**
WAFV – Missed reactions Test form 4			**0.740**
WAFV – Missed reactions Test form 6			**0.679**
WAFV – Missed reactions Test form 8			**0.702**
WAFR – Mean reaction time Test form 1	**0.648**		
WAFR – Mean reaction time Test form 3	**0.631**		
COG – Mean time "correct rejection"	**0.634**		
DT – Correct responses	**0.571**		
RT – Mean reaction time	**0.545**		
RT – Mean motor time	**0.580**		
SPM PLUS – Correct responses			

The content of the three factors can be clearly interpreted. Factor 1 represents the selectivity aspect, while Factor 2 draws together tests that load primarily onto the short-term control of the intensity of attention (intrinsic and phasic alertness). Factor 3 comprises tests which require attention to be sustained over a lengthy period of time (sustained attention, vigilance).

All the tests that were used to check convergent validity load onto Factor 1. This means that even in single-choice reaction tests such as the RT the selectivity aspect plays a dominant role since the different signal elements (red light, yellow light) by implication induce a choice. This underlines the particular usefulness of a tool such as WAFA which makes it possible to measure the intensity aspect specifically.

For SPM Plus, which measures language-free general intelligence, there are no relevant loadings onto any of the three attention factors. From this it can be concluded that the aspects of attention measured by the WAF test battery can be clearly distinguished from the “G factor” of intelligence.

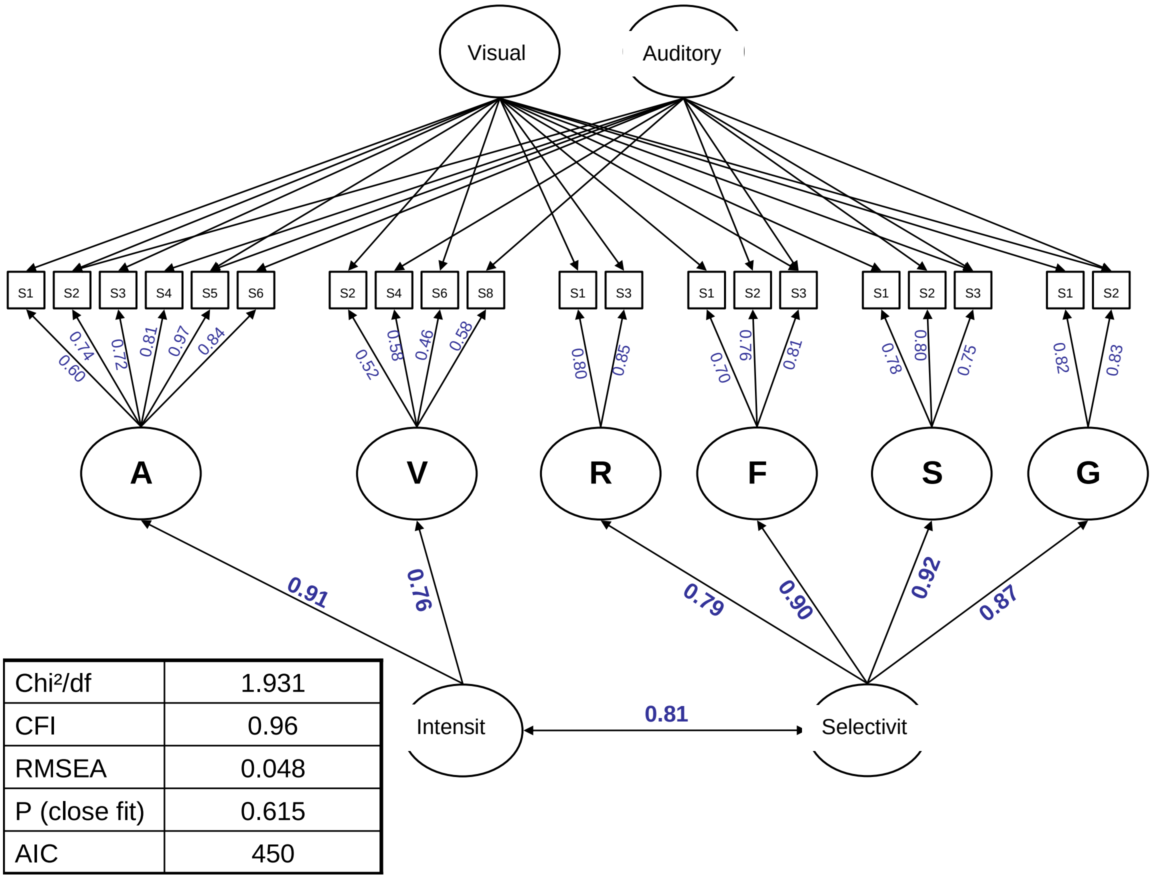
Since a factor-analytical approach is not entirely appropriate for the model of Zomeren and Brouwer (1994) or the expanded attention model of Sturm (2005), the same data was explored using a linear structural equation model which was drawn up on the basis of the theoretical model.

From the results of the LISREL modelling it can be seen that the empirical data fit the theoretically postulated model and therefore provide confirmation of it. This provides evidence for the construct validity of the WAF test battery and the tests contained in it.

LISREL methods can also be used to test whether alternative models fit the data. An initial study investigated the hypothesis that the data could be explained by a general factor of attention that would render the postulated structure of the attention aspects unnecessary.

Table 6: Model fit for a general factor model.

Chi² / df	2.728
CFI	0.921
RMSEA	0.066
P (close fit)	**0.001**
AIC	561



Chi²/df	1.931
CFI	0.96
RMSEA	0.048
P (close fit)	0.615
AIC	450

Figure 2: Linear structural equation model for the WAF tests. The path weightings are given as standardised regression coefficients. On the first level the latent factors of Alertness (A), Vigilance (V), Spatial Attention (R), Focused Attention (F), Selective Attention (S) and Divided Attention (G) are estimated. At the second level the latent factors of the intensity and selectivity aspects are estimated. In addition, factors are obtained which depend on the modality of the test presentation – cross-modal presentation is shown to be a combination of the visual and auditory modalities.

Chi²/df is the ratio of the chi² distributed test statistic to the degrees of freedom of the model. A high value indicates that the model does not fit the data. Values greater than 2 are usually taken to indicate that the model is not valid (Byrne, 1989).

For the comparative fit index **CFI** (Bentler, 1990) values < 0.9 are generally interpreted as indicating that the model does not fit (Backhaus et al. 2004).

RMSEA is a test statistic for the validity of the model that takes account of the model's complexity. The associated significance test is **P(close fit)**; if the test is significant this indicates that it is very unlikely that the data would have been obtained if the postulated model were valid.

The Akaike Information Criterion (**AIC;** Akaike 1973) is an information theory measure of the economy of a model. This takes account of the fact that data can more easily be described by a more complex model. When two models are being directly compared, the one with the lower AIC should be preferred.

The data obtained deviate more than by chance from the underlying model of a general attention factor. It can also be shown that the theoretical model explains the data by more than a chance extent more than the hypothesised modification does ($\text{chi}^2=113$, df=1, $p<0.001$).
The hypothesis was therefore rejected: a differentiated structure of attention is necessary to explain the existing data.

A second study investigated the hypothesis that the structure of the different presentation modalities might be unnecessary – that is, the distinction might not be actually reflected in the data.

Table 7: Model fit for a model that does not take account of test presentation modalities.

chi² / df	3.246
CFI	0.880
RMSEA	0.075
P(close fit)	**< 0.001**
AIC	663

The data obtained deviate more than by chance from the underlying model which does not take presentation modality into account. It can also be shown that the theoretical model explains the data by more than a chance extent better than does the hypothesised modification ($chi^2=263$, df=25, $p<0.001$).
The hypothesis should therefore be rejected: the presentation modalities used in the subtests have a clearly identifiable effect on the results.

Factor structure of WAF in children and young people

The structure of the main variables of the WAF subtests was also explored by means of factor analysis for the sample of children and young people (n=270).

This, too, yielded three factors (see Table 8). Factor 1 represents the selectivity aspect; it is noticeable that, unlike in the adult sample, the WAFV variables also load onto this factor. It is likely that this is because the sample of children and young people worked short versions of the WAFV test with a higher stimulus density (sustained attention). These short versions have a significantly lower intensity aspect and correspond to relatively long-term attention tasks with a low selectivity aspect. By contrast, Factor 2 combines tests that load primarily onto the short-term control of the intensity of attention (intrinsic and phasic alertness). It is interesting to note that aspects of the spatial orienting of attention are also represented here (although with low loadings, since spatial attention loads primarily onto Factor 3). This demonstrates the close connection between intensity and spatial aspects of attention. Factor 3 comprises the main loadings for spatial attention together with subsidiary loadings for various tests of attention selectivity. This – together with the subsidiary loadings on Factor 2 – shows that spatial attention in children, even more than in adults, involves both selectivity and intensity aspects of attention and occupies the ground between the two.

Table 8: Factor structure of the WAF test battery obtained exploratively by principal component analysis and subsequent varimax rotation for the sample of children and young people. For the sake of clarity loadings of less than 0.4 have been omitted.

	Factor 1	**Factor 2**	**Factor 3**
WAFA – Mean reaction time Subtest 1		**0.788**	
WAFA – Mean reaction time Subtest 2		**0.806**	
WAFA – Mean reaction time Subtest 4		**0.729**	
WAFA – Mean reaction time Subtest 5		**0.693**	
WAFF – Mean reaction time Subtest 1	**0.625**	0.424	0.445
WAFF – Mean reaction time Subtest 2	**0.610**		0.554
WAFS – Mean reaction time Subtest 1	**0.551**	0.408	0.501
WAFS – Mean reaction time Subtest 2	**0.665**		0.458
WAFG – Mean reaction time Subtest 1	**0.630**		0.463
WAFV – Missed reactions Test form 5 (15 mins.)	0.732		
WAFV – Missed reactions Test form 7 (15 mins.)	0.730		
WAFR - Mean reaction time unilateral left		0.468	**0.794**
WAFR - Mean reaction time unilateral right		0.479	**0.803**
WAFR - Mean reaction time bilateral			**0.830**

3.4 Scaling

The quality criterion of *scaling* is met when the empirical behavioural relationships under consideration can be represented exactly by the test scores (Kubinger 2003). To confirm the scaling of WAFA it is necessary to show that the reaction time relationships are a sufficient statistic for the latent dimension they are intended to measure. This was done for the validation sample using model tests for the Latency Model of Scheiblechner (1985). This model can be used to investigate the unidimensionality of tests in which the latency time of a behaviour is the variable of particular interest. In order to test the validity of the model empirically, Scheiblechner recommends the use of a Likelihood Quotient Test (LQT) according to Andersen (1973) on the basis of a CML estimation of the item parameter. In this LQT the likelihoods of model estimates of varying restrictiveness are related to each other, and this estimate is transformed into a χ^2 statistic for inferential statistical corroboration. According to Rost (2004) this corresponds to the testing of person homogeneity – that is, the statistical equivalence of item parameter estimates in different subgroups of individuals in relation to the total sample.

Table 9: Results of the LQT for the test variable Mean Reaction Time for different splitting criteria in the WAFA subtests.

Subtest 1 – Intrinsic (visual)

Splitting criterion	Chi²	df	p
Internal splitting criterion	8	49	0.999
Gender	8	49	0.999
Age	54	49	0.289
Education	6	49	0.999

Subtest 2 – Phasic (crossmodal visual)

Splitting criterion	Chi²	df	p
Internal splitting criterion	10	49	0.999
Gender	16	49	0.999
Age	14	49	0.999
Education	10	49	0.999

Subtest 3 – Phasic (unimodal visual)

Splitting criterion	Chi²	df	p
Internal splitting criterion	20	49	0.999
Gender	14	49	0.999
Age	18	49	0.999
Education	14	49	0.999

Subtest 4 – Intrinsic (auditory)

Splitting criterion	Chi²	df	p
Internal splitting criterion	14	49	0.999
Gender	8	49	0.999
Age	8	49	0.999
Education	6	49	0.999

Subtest 5 – Phasic (crossmodal auditory)

Splitting criterion	Chi²	df	p
Internal splitting criterion	18	49	0.999
Gender	14	49	0.999
Age	14	49	0.999
Education	14	49	0.999

Subtest 6 – Phasic (unimodal auditory)

Splitting criterion	Chi²	df	p
Internal splitting criterion	12	49	0.999
Gender	22	49	0.999
Age	18	49	0.999
Education	12	49	0.999

The analysis shows that none of the model tests is statistically significant. Thus no deviations at more than a chance level from the underlying probabilistic test model can be identified.

For WAFA this means that the latency times contain all the relevant information about the latent dimension to be measured and depict this latent dimension fairly. Taking into account the validation at scale level described in Section 3.3, these results can be summarised as indicating that the construct of the WAF test battery can be confirmed at both item and scale level.

3.5 Economy

Since they are computerised, the tests of the Vienna Test System are very economical to administer and score. The administrator's time is saved because the instructions at the beginning of the test are computerised, relieving him of the need to provide time-consuming verbal explanations. Because the test results are calculated automatically, the time needed for manual calculation of raw and norm scores is also saved.

3.6 Usefulness

The quality criterion of *usefulness* is met if, firstly, a test measures a relevant trait and, secondly, this trait cannot be measured by other tests which meet all the other quality criteria to at least the same extent (Kubinger 2003).

A wide range of neuropsychological hypotheses can be investigated with WAFA either on its own or in combination with other tests of the perception and attention functions. This demonstrates the usefulness of the WAF test battery.

3.7 Reasonableness

In order to meet the quality criterion of *reasonableness*, tests must be so constructed that the respondent is not overstretched physically and is not put under psychological stress either emotionally or in terms of energy and motivation. This applies at all times, but needs in particular to be borne in mind in relation to the diagnostic context in which the test is being used (e.g. Kubinger 2003).
With regard to test presentation and length WAFA can be said to be entirely reasonable.

3.8 Resistance to falsification

A test that meets the meets the quality criterion of *resistance to falsification* is one which can prevent a respondent answering questions in a manner deliberately intended to influence or control his test score (e.g. Kubinger 2003). Since WAFA is an ability test, falsification in the sense of “faking good” is not possible. “Faking bad” can be prevented by creating a test setting in which the respondent feels at ease and by remaining observant and carrying out plausibility checks during the testing session.

3.9 Fairness

If tests are to meet the quality criterion of fairness, they must not systematically discriminate against particular groups of respondents on the grounds of their sociocultural background (e.g. Kubinger 2003). WAFA is demonstrably fair because separate norms exist for the subgroups for which relevant mean differences were found.

4 NORMING

The norm scores were obtained by calculating the mean percentile rank *PR(x)* for each raw score *X* according to the formula (from Lienert & Raatz 1998):

$$PR_x = 100 \cdot \frac{cum\ f_x - f_x/2}{N}$$

cum fx corresponds to the number of respondents who have achieved the raw score *X* or a lower score, *fx* is the number of respondents with the raw score *X*, and *N* is the size of the sample.

Norm tables for the normed test variables can be found in the Vienna Test System under the menu option **Extras** => **Norm Table Explorer**. The tables there show the distribution of all the normed test variables in the total sample and in the subsamples.
Descriptive statistics of the test variables will be found in **Appendix A** of the manual.
Contrary to widely held expectations, there is very little difference between reaction times under visual stimulus conditions and those under auditory stimulus conditions (in both cases for intrinsic alertness). As long ago as 1971 Kohfeld demonstrated that, although shorter reaction times have frequently been reported under the auditory condition as opposed to the visual condition, this difference disappears if both tasks are presented with sufficient intensity. This highlights the fact that standardised volume control – such as is ensured by WAF – is essential for the measurement of auditory reaction times.

4.1 Adult norms

A norm sample is available for WAFA consisting of 295 individuals representative of the general population (46.4% men; 53.6% women) aged between 16 and 77 (Md=39; sd=15.1). The distribution of the sample in terms of educational background is as follows:

Table 10: Distribution of educational level in the norm sample. Respondents are assigned to an educational level on the basis of the highest qualification they have obtained.

Educational level	Description	%
EU 1	No school-leaving qualification	0.0 %
EU 2	Compulsory schooling or intermediate secondary school	11.5 %
EU 3	College or vocational training	41.0 %
EU 4	Higher secondary school with university entrance qualification	39.7 %
EU 5	University	7.8 %

Norming was carried out between December 2005 and April 2006 under standardised test conditions in the research laboratory of SCHUHFRIED GmbH.

For the main variables corrections that take account of age effects are also available. The corrections take the form of z-standardised residues of a regression with regard to the age variable.

Table 11: Degree of the polynomial used for the regression and associated explained variance for the subtests of WAFA. While linear functions describe the age effect by means of a straight line, quadratic functions depict a relationship with one bend and cubic functions a relationship with two bends.

	Regression polynomial	Explained variance
Intrinsic (visual)	quadratic	9.6 %
Phasic (cross-modal visual)	quadratic	16.0 %
Phasic (unimodal visual)	quadratic	10.3 %
Intrinsic (auditory)	quadratic	3.1 %
Phasic (cross-modal auditory)	quadratic	5.2 %
Phasic (unimodal auditory)	quadratic	11.7 %

4.2 Norms for children and young people

In addition to the norm sample of adults, a norm sample of children and young people is also available for selected WAFA subtests. These norms were developed in the context of a research project funded by the SCHUHFRIED company at schools in the greater Aachen area.

For WAFA the norm sample comprises 270 children and young people (47.0% boys, 53.0% girls) aged between 7 and 17 (Md=11; sd=3.2).
A regression-based age correction is also available for this sample; this meshes smoothly with the age regression of the adult sample but has a noticeably more curved path.

Because – as expected – there are significantly more marked age effects for children and young people than for adults, the age correction should always be applied when interpreting the results obtained by children and young people.

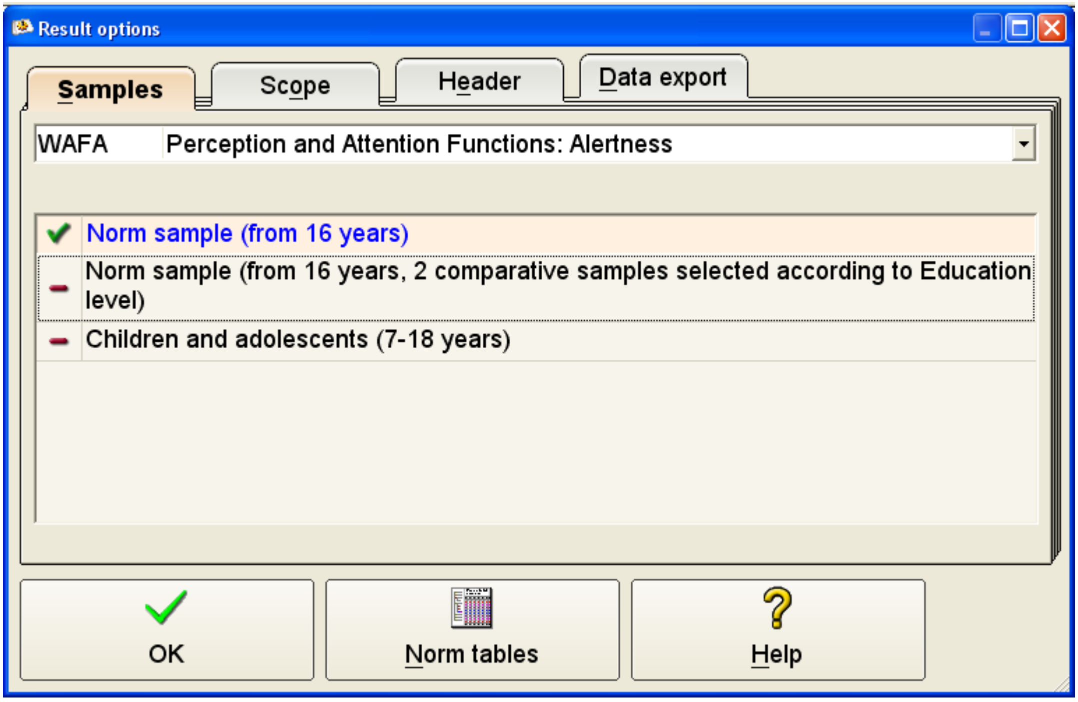
Table 12: Degree of the polynomial used for the regression and associated explained variance for the subtests of WAFA (for the sample of children and young people). While linear functions describe the age effect by means of a straight line, quadratic functions depict a relationship with one bend and cubic functions a relationship with two bends.

	Regression polynomial	Explained variance
Intrinsic (visual)	quadratic	32.8 %
Phasic (crossmodal visual)	quadratic	18.7 %
Intrinsic (auditory)	quadratic	37.2 %
Phasic (crossmodal auditory)	quadratic	24.0 %

4.3 Selecting the norm sample

The norm sample to be used can be selected in the test scoring options: click the **Options** button on the scoring screen.

In the *Options* window the **Samples** tab enables the choice to be made between an overall norm and a norm partitioned according to educational group.

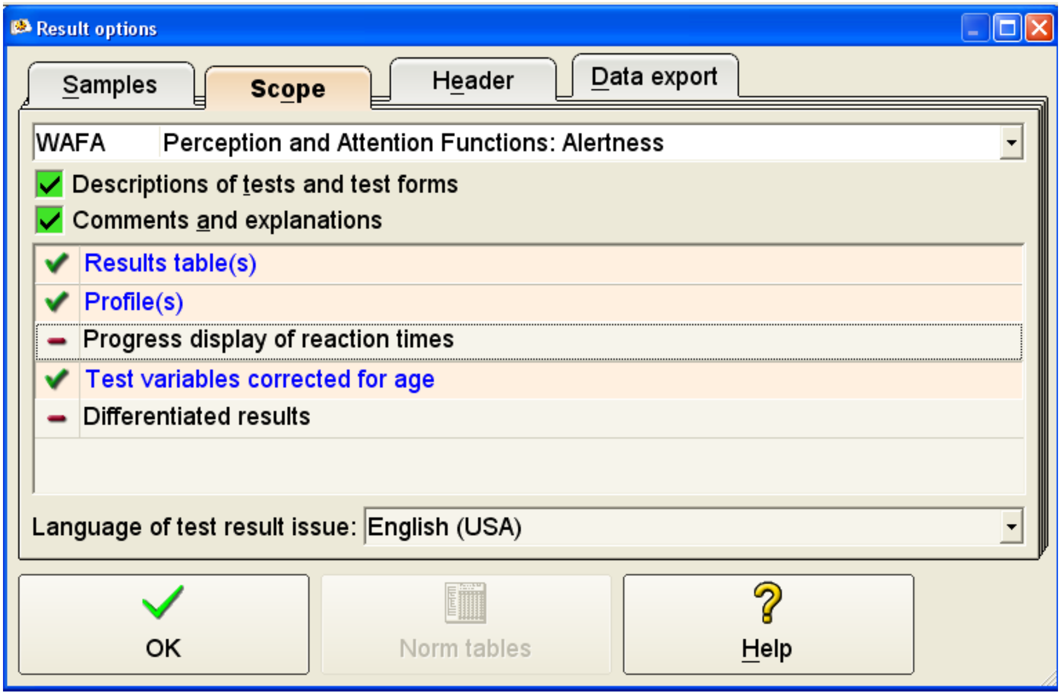


WAFA Perception and Attention Functions: Alertness

✓ Norm sample (from 16 years)
− Norm sample (from 16 years, 2 comparative samples selected according to Education level)
− Children and adolescents (7-18 years)

Figure 3: Options window for selecting the norm sample(s)

It is also possible to select both norms; the two norm comparisons are then carried out separately.
The procedure for obtaining age-corrected results is very similar. The age-corrected test variables can be selected or de-selected on the *Scope* tab.



WAFA Perception and Attention Functions: Alertness

☑ Descriptions of tests and test forms

☑ Comments and explanations

- ✓ Results table(s)
- ✓ Profile(s)
- − Progress display of reaction times
- ✓ Test variables corrected for age
- − Differentiated results

Language of test result issue: English (USA)

Figure 4: Options window for selecting scoring options. Age-corrected test scores will now be displayed.

The norm comparison can thus be carried out in a number of ways.

Table 13: Various norm options for WAFA.

Sample	Age correction	Norming
Total	off	total norm
Total	on	age norm
educational norm	off	educational norm
educational norm	on	age and educational norm

4.4 Critical values for non-normed test variables

The variables *Number of missed reactions, Number of false alarms* and *Number of premature reactions* are not normed in WAFA in its present form. This is because the distributions of these variables in a normal sample are very uninformative on account of their extreme skew.

In relation to the normal population it can, however, be assumed that for each of these variables values > 3 are highly unlikely (<< 5%) and can therefore be classed as abnormal.

5 TEST ADMINISTRATION

Before the start of testing it is recommended that those subtests are selected that on the basis of hypothesis are likely to be relevant to the purpose of the assessment. The relevant subtests can be combined with other tests to form a test battery.

5.1 Pre-testing sensority capability with WAFW

When using the tests of the WAF test battery for the purpose of psychological assessment, it is recommended that steps are first taken to clarify whether a respondent has the necessary sensory capability to be able to complete the tests. If this is not done there can be no certainty that any performance deficits identified are in fact the result of attention problems; the possibility will always remain that poor sensory capability (e.g. lack of sensitivity to contrast, residual symptoms of scotoma, inadequately compensated sharpness of vision, non-compensated hearing impairments etc.) may be the cause of the poor performance.

WAFW uses the same material as the other WAF tests but presents it without time pressure, so that the test result is as far as possible independent of the respondent's attentional performance. The WAFW results will indicate whether the respondent meets the sensory requirements for the use of WAFA.

Table 14: Recommended WAFW pre-tests and minimum scores for the use of the WAFA subtests.

	WAFW test form	**Minimum % correct**
Intrinsic (visual)	---	---
Phasic (cross-modal visual)	---	---
Phasic (unimodal visual)	S3 – Distinguishing shapes	95 %
Intrinsic (auditory)	---	---
Phasic (cross-modal auditory)	---	---
Phasic (unimodal auditory)	S5 – Distinguishing pitch of sounds	90 %

5.2 Technical precision of measurement

Measuring reaction times to the nearest millisecond is not straightforward. Many test programs or neuropsychological experiment generators quote reactions times in milliseconds in the test results but may nevertheless be affected by measurement errors of several times this amount, depending on the hardware and software used (cf. Häusler, Sommer & Chroust 2007; Plant, Hammond & Turner 2004).

Tests for measuring aspects of attention are particularly time-critical. Even measurement errors of only a few milliseconds can cause a significant shift of the normed test score and thus result in incorrect interpretation of the test results.

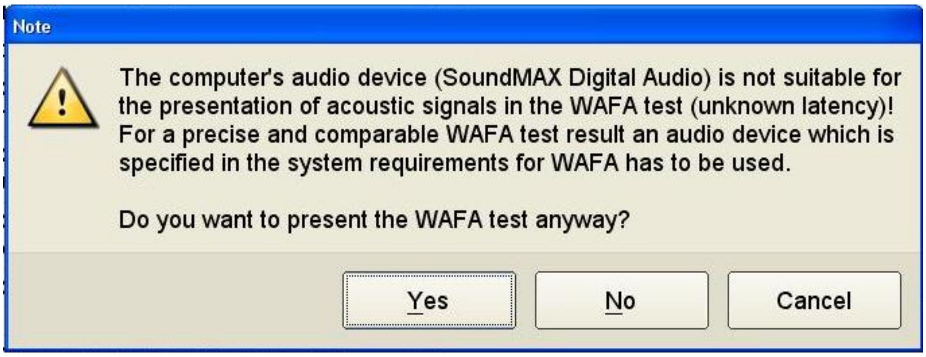
5.2.1 Visual stimulus material

The display of visual stimulus material in the Vienna Test System is extremely precise – on both CRT and LCD monitors. If WAFA is administered on an uncalibrated system, minor technical measurement errors of up to ± 3 PR may occur (depending on the hardware and software used).
To achieve greater precision of measurement, the exact screen delay can be measured using the Hardware Test. This figure is then used as a correction value in all time-critical tests. Calibrated test systems are guaranteed to yield measurements that can be converted accurately into percentile ranks.

Figure 5: Calibrating a monitor with the calibration device. The VTS workstation should be calibrated every six months and whenever changes are made to the hardware (e.g. new monitor).

5.2.2 Auditory stimulus material

In order to ensure the highest level of precision for auditory stimuli, we recommend the use of a standard audio output device. If external loudspeakers or a non-standard headset are used for audio output, there is a risk that the driver software of these devices will produce measurement errors of up to 100 ms. In addition, these devices may have a different sound curve, so that – for example – low sounds may be reproduced more softly in comparison to other tones than was the case in the standardisation of the WAF tests.



The computer's audio device (SoundMAX Digital Audio) is not suitable for the presentation of acoustic signals in the WAFA test (unknown latency)! For a precise and comparable WAFA test result an audio device which is specified in the system requirements for WAFA has to be used.

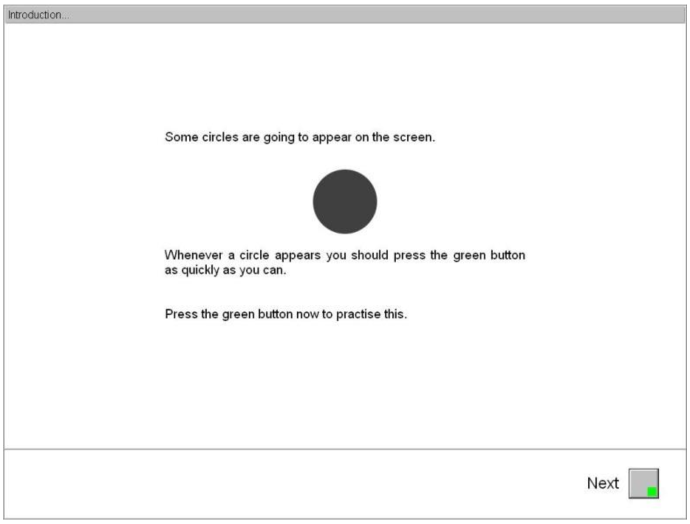
Do you want to present the WAFA test anyway?

Figure 6: Warning issued when a non-standard audio output device is used.

If the audio output device used does not conform to the standard, you will be informed of this before the test session starts. A comment will also be included in the test results to the effect that the results were obtained under non-standard conditions.

5.3 Instruction phase

The instructions at the start of the test can be followed independently by the respondent on his screen; the test administrator is not required to provide any further explanation. Each subtest is preceded by standardised instructions with practise examples. With patients it is recommended nevertheless that the test administrator supervises the patient during the instruction phase and also checks from time to time during testing that the instructions are being adhered to. The administrator is informed if the respondent does not comply with the instructions or if his behaviour indicates that the instructions have not been understood. In this case the instruction and practise phase must be repeated. Before the test phase begins the respondent is informed of the time that will be needed for the task.



Some circles are going to appear on the screen.

Whenever a circle appears you should press the green button as quickly as you can.

Press the green button now to practise this.

Figure 7: Instruction screen from Subtest 1 of the WAFA test**.**

5.4 Test phase

WAFA uses black circles (subtests 1 to 3) or a 1 kHz tone (subtests 4 to 6) as a signal to which the respondent must react as quickly as possible. The signal is presented for 1500 ms and then disappears. Between the signals there is an inter-stimulus interval of 3-5 seconds.
In the subtests for measuring intrinsic alertness (subtests 1 and 4) the reaction signal only is presented. In the subtests for assessing phasic alertness the respondent receives a warning signal or cue which is presented 400 – 1000 ms before the signal and lasts for 200 ms.
In subtests 3 and 5 the cue is a black square. In subtests 2 and 6 the cue is a 400 Hz tone.

6 WAFA FOR CHILDREN AND YOUNG PEOPLE

The WAF test battery can be used with children from the age of 7, provided that the norms for children and young people are used. However, in order to make administration of the test as stress-free and reasonable as possible, some of the WAFA test forms are not used and should not be presented.

Table 15: Recommended WAFA subtests for children and young people.

Subtest	Form
1	Intrinsic (visual)
2	Phasic (crossmodal visual)
4	Intrinsic (auditory)
5	Phasic (crossmodal auditory)

The transition from the norms for children and young people to those for adults is fluid. The switch from one set of norms to the other can be made at any point in the age range 16 - 18 years without risk of error effects, provided that the age-corrected test variables are used.

7 INTERPRETATION OF TEST RESULTS

When interpreting the main variables the percentile rank should normally be used. A percentile rank can be understood here as the proportion of the comparison sample who obtained an equal or a lower (worse) result (Kubinger, 1995). A high percentile rank can therefore be viewed as indicating that the trait being measured is present in strongly marked form.

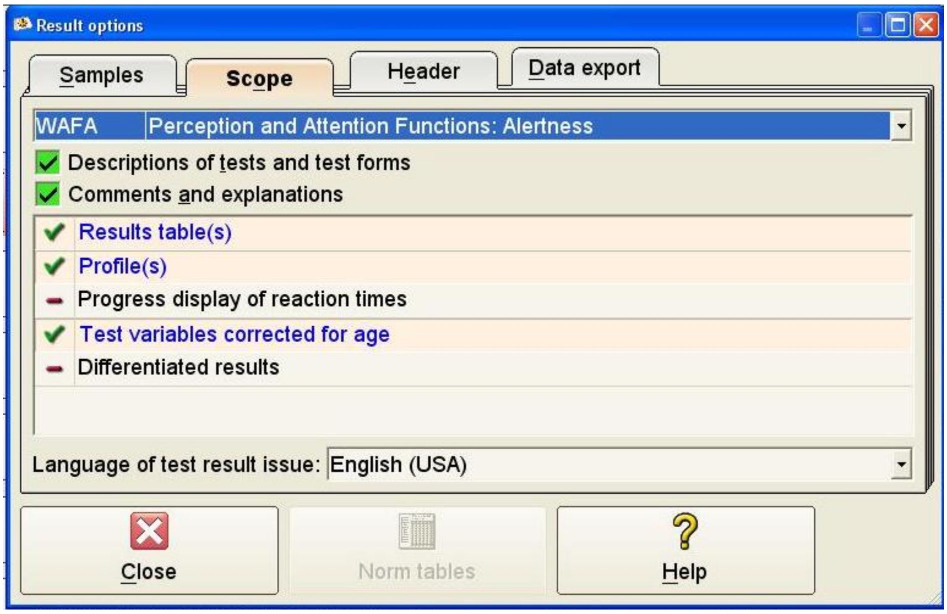
Table 16: Interpretation of percentile rank scores.

Percentile rank	Proportion of reference group	Description
< 16	15 %	Below average
16 to 24	10 %	Low average to slightly below average
25 to 75	50 %	Average
76 to 84	10 %	High average to slightly above average
> 84	15 %	Above average

Additional notes on interpretation and on the planning of an assessment session can be found in Section 2.2. In particular, the possibility of repeating a task in order to assess a tendency to fatigue or diminished resilience should be borne in mind (see below).

Additional test variables:

There are a number of subsidiary variables that may be of relevance for more precise interpretation of the test results. These variables can be selected or de-selected via the options **Test variables corrected for age** and **Differentiated results** in the **Result options** window.



WAFA Perception and Attention Functions: Alertness

☑ Descriptions of tests and test forms
☑ Comments and explanations

✓ Results table(s)
✓ Profile(s)
— Progress display of reaction times
✓ Test variables corrected for age
— Differentiated results

Language of test result issue: English (USA)

Figure 8: Selecting the display options for the WAFA test.

The age-corrected test variables relate the respondent’s test score to his age. The **Parameter** column gives the standardised residual of the test score with regard to the age regression. This indicates the extent to which the test score lies above or below the score to be expected of a person of this age on the basis of the norm sample.

This residual is quoted as a z-transformed variable; scores < -1 therefore reflect poor performance, while scores > +1 indicate good performance. Scores between -1 and +1 are in the normal range.

In addition, the **Raw Score** column gives the score of a 20-year-old person that would correspond to this particular test score. Percentile ranks are of course also given for the age-corrected test scores.

Investigation of fatigue effects

Because of the simple structure of its tasks (and hence the minimal influence of task difficulty as an external factor influencing the level of arousal), WAFA is particularly suitable for investigating fatigue effects (see Dreisbach & Haider, 2008):

Finally, recent research indicates that goal maintenance may be especially challenged under "simple" conditions with no interference, conflict, or dual-task demands (Dreisbach & Haider, 2007; Goschke & Dreisbach, 2008; Kane & Engle, 2003). Hence, for goal maintenance in SRT tasks, individuals are assumed to need more effortful control to "stay on the job," which, in turn, may lead to even stronger fatigue over time.

Fatigue can be tested by administering one or more WAFA subtests both at the beginning and again at the end of a test battery (i.e. repeating the subtest after around two hours of effort).

In healthy respondents there should be no non-random change in test scores between the first and second testings (see Table 17). If the score obtained on the second testing lies below **the** lower limit of the confidence interval of the first testing, it can be assumed that fatigue over the course of the test battery has led to a decline in performance.

Table 17: Results of first testing and re-resting at the beginning and end of a 2-hour attention test battery. The sample comprises N=224 healthy normal individuals. No fatigue-induced deterioration in performance is observable for these respondents in any of the WAFA subtests.

	T	**P**	**Effect strength d**	**Retest reliability**
Intrinsic (visual)	-1.822	0.070	0.23	0.72
Phasic (crossmodal visual)	0.532	0.595	0.06	0.74
Phasic (unimodal visual)	1.176	0.241	0.16	0.72
Intrinsic (auditory)	-0.894	0.372	0.12	0.74
Phasic (crossmodal auditory)	0.346	0.730	0.04	0.76
Phasic (unimodal auditory)	-0.099	0.921	0.02	0.76

Investigation of modality-specific differences in performance

When a number of WAFA subtests are administered with differing presentation modalities (e.g. intrinsic visual and intrinsic auditory), it is possible to check whether the respondent's alertness varies in the different modalities.

This involves comparing the main variables of the two subtests. If **at least one of the two test scores lies within the confidence interval of the other score** it can be assumed that the same capability is present in both modalities. If this is not the case, there are modality-specific differences in performance.

Main variables

Mean reaction time

This variable is a logarithmic mean of the individual reaction times. A high test score leads to a low percentile rank and indicates a low level of alertness.

Dispersion of reaction time

This is the logarithmic standard deviation of the reaction times. A high standard deviation leads to a low percentile rank and indicates a marked intra-individual variability in alertness.

Subsidiary variables

Number of missed reactions

This is the number of stimuli to which no response was made within 1500 ms.

Number of false alarms

This is the number of times a response key was pressed when no stimulus had been presented. A high number of false alarms indicates that the test has not been worked in accordance with the instructions. A note in the printout of results indicates the test variables on which only a limited interpretation can be placed as a result of this.

Number of premature reactions

In the subtests for phasic alertness, reactions which occur between the cue and the actual stimulus are classed as “premature reactions”. A high number of premature reactions indicates that the test has not been worked in accordance with the instructions. A note in the printout of results indicates the test variables on which only a limited interpretation can be placed as a result of this. **Behaviour of this type may reveal problems in the inhibition of non-required reactions – that is, the very early stage of an impairment of selectivity.**

In general, reaction tasks with a cue (phasic alertness) lead to shorter reaction times than tasks without a cue (intrinsic alertness). Patients with lesions of the right brain hemisphere are often unable to control their alertness in a cognitive (“top-down”) manner. This may be manifested in a particularly noticeable discrepancy between intrinsic and phasic alertness performance, since the external stimulation provided by the cue leads to temporary normalisation of the reaction ability. The most important measure of the ability to call on the level of alertness most appropriate for a task must therefore be the measurement of reaction speed without a cue, since only under this condition is the level of arousal determined exclusively by the respondent and thus cognitively controlled.

In certain cases the presentation of a cue can lead to a lengthening of reaction times. Patients with lesions of the left brain hemisphere appear to have particular difficulty in dealing with choice reaction tasks (Dee and van Allen 1973) and they tend to react more slowly in tasks of phasic alertness after a cue has been presented (Tartaglione et al. 1986). This can also be interpreted as a general impairment of attention selectivity, since under the phasic alertness condition reactions to the cue have to be actively inhibited.

8 MEASUREMENT OF CHANGE

The tests of the WAF test battery can also be used to investigate change that may have occurred. This is useful if it is necessary to measure the effect of an intervention or a spontaneous change in a respondent over a particular period. Table 18 gives critical T-score differences (d_{crit}), for the reaction time parameters of each of the WAFA subtests. If these are exceeded, a statistically provable change has occurred. A detailed introduction to the measurement of change can be found in Kubinger, Rasch & Häusler (2006).

Table 18: Critical T-score differences (d_{crit}) for the reaction time parameters of the WAFA subtests at a statistical certainty of 90% and 95%. If the critical T-score difference is exceeded, a significant change (at the given level of statistical certainty) has occurred.

	Critical T-score change (d_{crit})	
	Statistical certainty 90%	**Statistical certainty 95%**
Intrinsic (visual)	6	7
Phasic (cross-modal visual)	6	7
Phasic (unimodal visual)	6	7
Intrinsic (auditory)	6	7
Phasic (cross-modal auditory)	3	4
Phasic (unimodal auditory)	5	6

9 COGNITIVE TRAINING WITH COGNIPLUS

9.1 Training specific attention functions

A meta-analysis by Robert (1990) came to the conclusion that computerised training of attention functions is on the whole effective, although some studies have yielded negative results.

Cicerone et al. (2000, 2005) published meta-analyses of evidence-based cognitive rehabilitation in the field of attention therapy. They found that the studies demonstrate the effectiveness of specific attention training in ways that go beyond the effects of non-specific cognitive stimulation, both for patients who have suffered craniocerebral trauma and for stroke patients. Therapy should involve training in different sensory modalities and at a range of complexity levels.

There is, however, inadequate evidence of the effectiveness of attention therapy in the early phase of rehabilitation, since the effects of attention therapy cannot be distinguished from those of spontaneous remission.

9.2 Development and evaluation of the Aixtent attention training program

Sturm et al. (1993) have developed computerised training programs **(AIXTENT)** in the style of games for treating impairments of alertness, vigilance, selective attention and divided attention:

Alertness training: A racing car or motorcycle that is travelling at speed must be brought to a halt promptly in front of an obstacle.

Vigilance training: Radar observation (detection of flying objects that appear only infrequently); conveyor belt task (detection of faulty articles).

Selective attention training: While clay pigeon shooting or on a photo safari only specified objects or combinations of objects are to be attended to.

Divided attention training: In the cockpit of an airplane the client must simultaneously observe the horizon, the flight speed and untoward engine noises.

Patients with vascular, unilateral brain lesions and attention deficits in at least two areas of attention underwent 14 training sessions in one of the impaired function areas. The results showed that only the relevant specific training was effective, particularly in the attention areas of alertness and vigilance (Sturm et al. 1994, 1997). The authors were also able to show that, where elementary attention functions are impaired, the “wrong” training – which makes over-complex demands on attention – can lead to further worsening of attentional performance.

Almost identical results were obtained in a multi-centric study of the effectiveness of the same programmes for TBI patients (Sturm et al. 2003) and in use of the AIXTENT programs with patients with multiple sclerosis (Plohmann et al. 1998) or epilepsy (Engelberts et al. 2002). It seems that an improvement in elementary attention functions, in particular – in contrast to, for example, memory functions – can be brought about through stimulation therapy, without the need for the patient to acquire special strategies.

The conclusion to be drawn from these research results is that any attention therapy must be preceded by careful diagnosis of attention problems, in order to identify specific attention deficits in individual patients or clients. The Test Battery for Perception and Attention Functions (WAF) is particularly well suited to this purpose, as it enables a complete assessment of relevant attention functions to be made.

Taking advantage of the most up-to-date computer tools used in professional game development, the MS-DOS program AIXTENT has been used as the basis for a number of

training programs of the cognitive training software CogniPlus. All the modules have been created from scratch, but they follow the same paradigms that were successfully used in AIXTENT. Particular importance was attached to embedding the typical attentional tasks in realistic everyday situations. Here, too, the motor demands made on the patient are extremely small, being limited to the pressing of a reaction button. Care was taken to ensure that patients with visual field restriction or hemineglect could use the training system. In accordance with the latest taxonomies of attention, two additional modules were added to the training programs:
spatial orienting of attention (in particular for treatment of hemineglect)
focused attention (for treatment of increased susceptibility to distraction and disruption)

Table 19: WAF tests and the corresponding CogniPlus attention training programs.

Test program of the Vienna Test System	Training program in CogniPlus
WAFA - Alertness	ALERT
WAFV - Vigilance / sustained attention	VIG
WAFF - Focused attention	FOCUS
WAFS - Selective attention	SELECT
WAFG - Divided attention	DIVID
WAFR - Spatial attention	SPACE

CogniPlus is adaptive; by analysing reaction times and errors it automatically adapts the difficulty level of the program to the patient’s performance.
The progress of therapy should not be evaluated through changes in performance during the training itself; instead, external tests (such as the WAF subtests, see above) should be used. This is the only way to distinguish generalised therapy effects from trivial practice effects.

9.3 ALERT - The CogniPlus training program for alertness

Task

A motorcycle is driven along a winding road. The client's task is to carefully observe the stretch of road in front of him and to press the reaction key as quickly as possible when obstacles appear. If he reacts in time the motorcycle slows down and the obstacle disappears so that the rider can continue on his way. If he reacts too late there is a collision, represented by the sounds of a crash and a cloud of dust which have a negative reinforcement function.

Figure 9: The ALERT training program.

Difficulty structure

Each of the two training forms is made up of 18 difficulty levels. The degree of challenge is increased by shortening the maximum permitted reaction time. At the first level the client has 1.8 seconds in which to react to an obstacle, but at the highest level only 0.3 seconds elapse between the sudden appearance of an obstacle and the collision.
At the first session the speed of the client's initial reactions is assessed and he is assigned to a difficulty level appropriate to his ability. This ensures that from the outset the training program is optimally adapted to the client's skill and is never either too easy or too difficult for him.

10 REFERENCES

Akaike, H. (1973). Information theory and an extension of the maximum likelihood principle. In B.N. Petrov & F.Csaki (Eds.), *Proceedings of the 2nd International Symposium on Information Theory*. Budapest: Akademiai Kiado.

Andersen, E.B. (1973). A goodness of fit test for the Rasch model. *Psychometrika*, *38*, 123-140.

Aylward, G. P., Brager, P., & Harper, D. C. (2002). Relations between visual and auditory continuous performance tests in a clinical population: a descriptive study. *Developmental Neuropsychology*, *21*(3), 285-303.

Backhaus, K., Erichson, B., Plinke, W. & Weiber, R. (2004). *Multivariate Analysemethoden: Eine anwendungsorientierte Einführung*. Berlin: Springer.

Baker, D. B., Taylor, C. J., & Leyva, C. (1995). Continuous performance tests: a comparison of modalities. *Journal of Clinical Psychology*, *51*(4), 548-551.

Barr, R.A., & Giambra, L.M. (1990). Age-related decrement in auditory selective attention, *Psychology and Aging, 5 (4)*, 597–599.

Bentler, P.M. (1990). Comparative fit indices in structural models. *Psychological Bulletin*, *107*, 238-246.

Bisiach, E., Mini, M., Sterzi, R., & Vallar, G. (1982). Hemispheric lateralization of the decisional stage in choice reaction times to visual unstructured stimuli. *Cortex, 18,* 191-198.

Broadbent, D. E. (1958). *Perception and communication*. London: Pergamon Press.

Broadbent, D. E. (1971). *Decision and stress*. London: Academic Press.

Brunia, C. H. . & Damen, E. J. (1988). Distribution of slow brain potentials related to motor preparation and stimulus anticipation in a time estimation task. *Electroencephalography and Clinical Neurophysiology*, *69*, 234-43.

Byrne, B.M. (1989). *A primer of LISREL: Basic applications and programming for confirmatory factor analytic models.* New York: Springer.

Cicerone, K., Dahlberg, C., Kalmar, K., Langenbahn, D. M., Malec, J. F., Bergquist, T. F., Felicetti, T., Giacino, J. T., Harley, J. P., Harrington, D. E., Herzog, J., Kneipp, S., Laatsch, L. & Morse, P. A. (2000). Evidence-based cognitive rehabilitation: recommendations for clinical practice. *Archives of Physical and Medical Rehabilitation*, *81*, 1596-1615.

Cicerone, K., Dahlberg, C., Malec, J. F., Langenbahn, D. M., Felicetti, T., Kneipp, S., Ellmo, W., Kalmar, K., Giacino, J. T., Harley, J. P., Laatsch, L., Morse, P. A. & Catanese, J. (2005). Evidence-based cognitive rehabilitation: updated review of the literature from 1998 through 2002. *Archives of Physical and Medical Rehabilitation*, *86*, 1681-1692.

Corbetta, M. (1998). Frontoparietal cortical networks for directing attention and the eye to visual locations: identical, independent, or overlapping neural systems? *Proc. Natl. Acad. Sci. U.S.A.*, *95*, 831-838.

Corbetta, M., Miezin, F. M., Dobmeyer, S., Shulman, & G. L., Petersen, S. E. (1991). Selective and divided attention during visual discriminations of shape, color, and speed: functional anatomy by positron emission tomography. *Journal of Neuroscience*, *11*, 2383-2402.

Corbetta, M., Miezin, F. M., Shulman, G. L. & Petersen, S. E. (1993). A PET study of visuospatial attention. *Journal of Neuroscience*, *13*: 1202-1206.

Corbetta, M., Shulman, G. L., Miezin, F. M. & Petersen, S. E. (1995). Superior parietal cortex activation during attention shifts and visual feature conjunction. *Science*, *270*, 802-805.

Corbetta, M., Shulman, G.L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Review Neuroscience*, *3*, 201-215.

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia*, *44*(11), 2037-2078.

Dee, H. L., & Van Allen, M. W. 1973. Speed of decision-making processes in patients with unilateral cerebral disease. *Archives of Neurology*, *28*, 163-166.

De Luca, C. R., Wood, S. J., Anderson, V., Buchanan, J. A., Proffitt, T. M., Mahony, K. et al. (2003). Normative data from the CANTAB. I: development of executive function over the lifespan. *Journal of Clinical and Experimental Neuropsychology*, *25*(2), 242-254.

Deutsch, J. A., & Deutsch, D. (1963). Attention: Some theoretical considerations. *Psychological Review*, *70*, 80-90.

Dreisbach G.; & Haider H. (2008). That's what task sets are for: shielding against irrelevant information. *Psychological Research, 72,* 355-361.

Einstein, G.O., & McDaniel M. (2007). Aging and mind wandering. Reduced inhibition in older adults? Experimental Aging Research, 23(4), 343-354.

Engelberts N., Klein, M., Adèr, H. J., Heimans, J. J., Kasteleijn-Nolst Trenité, D. G. A. & van der Ploeg, H. M. (2002). The effectiveness of cognitive rehabilitation for attention deficits in focal seizures: a randomized controlled study. *Epilepsia*, *43*, 587-95

Farrin, L., Hull, L., Unwin, C., Wykes, T., & David, A. (2003). Effects of depressed mood on objective and subjective measures of attention. *Journal of Neuropsychiatry and Clinical Neuroscience*, *15*, 98-104.

Fernandez-Duque, D., Posner, M. I. (1997) Relating the mechanisms of orienting and alerting. *Neuropsychologia, 35,* 477-486

Fernandez-Duque, D., & Posner, M. (2001). Brain imaging of attentional networks in normal and pathological states. *Journal of Clinical and Experimental Neuropsychology*, *23*, 74-93.

Fink, G. R., Halligan, P. W., Marshall, J. C., Frith, C. D., Frackowiak, R. S. J., & Dolan, R. J. (1996). Where in the brain does visual attention select the forest and the trees? *Nature*, *382*, 626-628.

Fletcher, P.C., & Henson, R.N.A. (2001). Frontal lobes and human memory. Insights from functional neuroimaging. *Brain*, *124*, 849-881.

Fontaine, A., Azouvi, P., Remy, P., Bussel, B., & Samson, Y. (1999). Functional anatomy of neuropsychological deficits after severe traumatic brain injury. *Neurology*, *53*, 1963-1968.

Gomes, H., Duff, M., Barnhardt, J., Barrett, S., & Ritter, W. (2007). Development of auditory selective attention: event-related potential measures of channel selection and target detection. *Psychophysiology*, *44*(5), 711-727.

Gomes, H., Molholm, S., Christodoulou, C., Ritter, W., & Cowan, N. (2000). The development of auditory attention in children. *Frontiers in Bioscience*, *5*, D108-120.

Gomez-Perez, E., & Ostrosky-Solis, F. (2006). Attention and memory evaluation across the life span: heterogeneous effects of age and education. *Journal of Clinical and Experimental Neuropsychology*, *28*(4), 477-494.

Goschke, T., & Dreisbach, G. (2008). Conflict-triggered goal shielding: response conflicts attenuate background monitoring for prospective memory cues. *Psychological Science*, *19*, 25-32.

Hartlage, S., Alloy, L,B., Vasquez, C., et al. (1993). Automatic and effortful processing in depression. *Psychological Bulletin*, *113*, 247-278.

Häusler, J.; Sommer, M.; Chroust, S. (2007). Optimizing technical precision of measurement in computerized psychological assessment on Windows platforms. *Psychology Science*, *49*, 116-131.

Heinrichs, R.W., Zakzanis, K.K. (1998). Neurocognitive deficit in schizophrenia: a quantitative review of the evidence. *Neuropsychology*, *12*, 426-445.

Howes, D., & Boller, F. (1975). Simple reaction time: Evidence for focal impairments from lesions of the right hemisphere. *Brain*, *98*, 317-332.

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

Jansen, Ch., Sturm, W., & Willmes, K. (1992). Sex specific "activation"-dominance of the left hemisphere for choice reactions: An experimental study regarding lateralization of attention functions. *Zeitschrift für Neuropsychologie, 3,* 44-51.

Johnson, C. E. (2000). Children's phoneme identification in reverberation and noise. *Journal of Speech, Language, and Hearing Research*, *43*(1), 144-157.

Jones, L.A., Cardno, A.G., Sanders, R.D., Owen, M.J., Williams, J. (2001). Sustained and selective attention as measures of genetic liability to schizophrenia. *Schizophrenia Research*, *48*, 263-272.

Kane, M. J., & Engle, R. W. (2003). Working-memory capacity and the control of attention: the contributions of goal neglect, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General, 132,* 47-70.

Klimkeit, E. I., Mattingley, J. B., Sheppard, D. M., Farrow, M., & Bradshaw, J. L. (2004). Examining the development of attention and executive functions in children with a novel paradigm. *Child Neuropsychology*, *10*(3), 201-211.

Kohfeld, D.L. (1971). Simple reaction time as a function of stimulus intensity in decibels of light and sound. *Journal of Experimental Psychology*, *88*, 251-257.

Konrad, K., Herpertz-Dahlmann, B. (2004). Neuropsychologie der Aufmerksamkeitsdefizit-Hyperaktivitäts-Störung. In S. Lautenbacher, & S. Gauggel (Eds.), *Neuropsychologie psychischer Störungen*. Berlin: Springer.

Kopelman, M.D. (2002). Disorders of memory. *Brain*, *125*, 2152-2190.

Korkman, M., Kemp, S. L., & Kirk, U. (2001). Effects of age on neurocognitive measures of children ages 5 to 12: a cross-sectional study on 800 children from the United States. *Developmental Neuropsychology*, *20*(1), 331-354.

Kubinger, K.D. (1995). *Einführung in die Psychologische Diagnostik.* Weinheim: Beltz

Kubinger, K.D. (2003). Gütekriterien. In K.D. Kubinger & R.S. Jäger (Eds.), *Schlüsselbegriffe der Psychologischen Diagnostik* (pp. 195-204). Weinheim: Beltz.

Kubinger, K.D.; Rasch, D.; Häusler, J. (2006). Moderne statistische Ansätze in Forschung und Anwendung der klinischen Neuropsychologie. In J. Lehrner, G. Pusswald, E. Fertl, W. Strubreither & I. Krispin-Exner (Eds.), *Klinische Neuropsychologie* (pp. 195-204). Vienna: Springer.

Ladavas, E. (1987). Is hemispatial deficit produced by right parietal lobe damage associated with retinal or gravitational coordinates? *Brain*, *110*, 167-180.

Lansing, R. W., Schwartz, E., & Lindsley, D. B. (1959). Reaction time and EEG under alerted and nonalerted conditions. *Journal of Experimental Psychology*, *58*, 1-7.

Lehman, E. B., Olson, V. A., Aquilino, S. A., & Hall, C. A. (2006). Auditory and Visual Continuous Performance Tests: Relationships with Age, Gender, Cognitive Functioning, and Classroom Behaviour. *Journal of Psychoeducational Assessment*, *24*, 36-51.

Lienert, G.A. & Raatz, U. (1998). *Testaufbau und Testanalyse*. Weinheim: PVU.

Loose, R., Kaufmann, C., Auer, D .P., & Lange, K.W. (2003). Human prefrontal and sensory cortical activity during divided attention tasks. *Human Brain Mapping, 18,* 249-259.

Lussier, I., Stip, E. (2001). Memory and attention deficits in drug naive patients with schizophrenia. *Schizophrenia Research*, *48*, 45-55.

Madden, D. J., Turkington, T. G., Provenzale, J. M., Hawk, T. C., Hoffman, J. M., & Coleman, R. E. (1997). Selective and divided visual attention: age related changes in regional cerebral blood flow measured by $H_2{}^{15}O$ PET. *Human Brain Mapping, 5,* 389-409.

McDoud, J.M., Shaw, R.J. (2000). Attention and aging: A functional perspective. In F.I.M. Craik T.A. Salthouse (Eds.), The Handebook of Aging and Cognition (2nd ed.). Hillsdale: Earlbaum.

McDowell, S., Whyte, J., & D'Esposito, M. (1997). Working memory impairments in traumatic brain injury: Evidence from a dual-task paradigm. *Neuropsychologia, 35,* 1341-1353.

Mesulam, M.-M. (1985). Attention, confusional states, and neglect. In M.-M. Mesulam (Ed.), *Principals of behavioral neurology* (pp. 125-168). Philadelphia: Davis.

Mottaghy, F.M., Willmes, K., Horwitz, B., Müller, H.-W., Krause, B.J., Sturm, W. (2006). Systems level modelling of a neuronal network subserving intrinsic alertness. *NeuroImage, 29,* 225-233.

Navon, D. (1977). Forest before the trees: The precedence of global features in visual processing. *Cognitive Psychology, 9,* 353-383.

Nigg, J.T., Swanson, J., Hinshaw, S.P. (1997). Covert visual attention in boys with attention deficit hyperactivity disorder: Lateral effects, methylphenidate response, and results for parents. *Neuropsychologia*, *35*, 165-176.

Nobre, A. C., Sebestyen, G. N., Gitelman, D. R., Mesulam, M. M., Frackowiak, R. S. & Frith, C. D. (1997). Functional localization of the system for visuospatial attention using positron emission tomography. *Brain*, *120*: 515-533.

Paus, T., Zatorre, R. J., Hofle, N., Caramanos, Z., Gotman, J., Petrides, M., & Evans, A. C. (1997). Time-changes in neural systems underlying attention and arousal during the performance of an auditory vigilance task. *Journal of Cognitive Neuroscience*, *9*, 392-408.

Pearson, D. A., & Lane, D. M. (1991). Auditory attention switching: a developmental study. *Journal of Experimental Child Psychology*, *51*(2), 320-334.

Perry, R. J., Watson, P., & Hodges, R. (2000). The nature and staging of attentional dysfunction in early (minimal and mild) Alzheimer's disease: Relationships to episodic and semantic memory impairments. *Neuropsychologia*, *38*, 252-271.

Plant R. R.; Hammond, N.; Turner, G. (2004). Self-validating presentation and response timing in cognitive paradigms: How and why? *Behavior research Methods*, *36*, 291-303.

Plohmann, A. M., Kappos, L., Ammann, W., Thordai, A., Wittwer, A., Huber, S., Bellaiche, Y., & Lechner-Scott, J. (1998). Computer assisted retraining of attentional impairments in patients with multiple sclerosis. *Journal of Neurology, Neurosurgery and Psychiatry*, *64*, 455-462.

Plude, D. J., Enns, J. T., & Brodeur, D. (1994). The development of selective attention: a life-span overview. *Acta Psychologica*, *86*(2-3), 227-272.

Posner, M. I. (1975). The Psychology of attention. In M.S. Gazzaniga & C. Blakemore (Eds.), *Handbook of Psychology*. New York: Academic Press.

Posner, M. I., & Boies, S. W. (1971). Components of attention. *Psychological Review*, *78*, 391-408.

Posner, M. I., Inhoff, A. W., & Friedrich, F. J. (1987). Isolating attentional systems: A cognitive-anatomical analysis. *Psychobiology*, *15*, 107-121.

Posner, M. I., Nissen, M. J. & Ogden, W. C. (1978). Attended and unattended processing modes: The role of set for spatial location. In H. L. Pick, & E. Saltzman (Eds.), *Modes of perceiving and processing of information* (pp. 137-157). Hillsdale, NJ: Lawrence Earlbaum.

Posner, M. I. & Petersen S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, *13*, 182-196.

Posner, M. I., & Raichle, M.E. (1994). *Bilder des Geistes*. Heidelberg: Spektrum.

Posner, M. I., Walther, J. A., Friedrich, F. J. & Rafal, R. D. (1984). Effects of parietal lobe injury on covert orienting. *Journal of Neuroscience*, *4*, 1863-1874.

Raven, J.; Raven, J.C.; Court, J.H. (1997). *Handanweisung Standard Progressive Matrices Plus (SPM Plus)*. Mödling: Schuhfried.

Robertson, I. (1990). Does computerized cognitive rehabilitation work? A review. *Aphasiology*, *4*, 381-405.

Robertson, I. H., Ridgeway, V., Greenfield, E., & Parr, A. (1997). Motor recovery after stroke depends on intact sustained attention: A 2-year follow-up study. *Neuropsychology*, *11*, 290-295.

Robertson, I. H., Tegnér, R., Tham, K., & Nimmo-Smith I. (1995). Sustained attention training for unilateral neglect: theoretical and rehabilitation implications. *Journal of Clinical and Experimental Neuropsychology, 17,* 416-430.

Robertson, L. C., & Lamb, M. R. (1991). Neuropsychological contributions to part/whole organisation. *Cognitive Psychology, 23,* 299-330.

Rockstroh, S. (1993). Neurochemische Grundlagen der Aufmerksamkeit. *Z. Neuropsych*., *4*, 44-53.

Rockstroh, S. (2000). Neuropharmakologie, Psychopharmakologie. In W. Sturm, M. Herrmann, & C.-W. Wallesch (Eds.), *Lehrbuch der Klinischen Neuropsychologie* (pp. 265-276). Lisse: Swets & Zeitlinger.

Rost, J. (2004). *Lehrbuch Testtheorie, Testkonstruktion*. Bern: Huber.

Rousseaux, M., Godefroy, O., Cabaret, M., Benaim, C., & Pruvo, J. P. (1996). Analyse et évolution des déficits cognitifs après rupture des anéurysmes de l'artère communicante antérieure. *Revue Neurologique*, *152*, 517-527.

Rund, B.R., Borg, N.E. (1999). Cognitive deficits and cognitive training in schizophrenic patients: a review. *Acta Psychiatrica Scandinavica*, *100*, 85-95.

Schneider, W. (1985). Toward a model of attention and the development of automatic processing. In M. I. Posner & O. Marin (Eds.), *Attention and Performance XI*. Hillsdale: Erlbaum.

Schuhfried, G. (1998). *Handanweisung Determinationstest (DT)*. Mödling: Schuhfried.

Schuhfried, G. & Prieler, J. (1997). *Handanweisung Reaktionstest (RT)*. Mödling: Schuhfried.

Sergent, J. (1982). The cerebral balance of power: Confrontation or cooperation? *Journal of Experimental Psychology: Human Perception and Performance, 8,* 253-272.

Spence, C., & Driver, J. (2004). *Crossmodal Space and Crossmodal Attention*. New York, Oxford University Press.

Sturm, W. (2000). Aufgaben und Strategien neuropsychologischer Diagnostik. In W. Sturm, M. Herrmann, & C.-W. Wallesch (Eds.), *Lehrbuch der Klinischen Neuropsychologie* (pp. 265-276). Lisse: Swets & Zeitlinger.

Sturm, W. (2005). *Aufmerksamkeitsstörungen*. Göttingen: Hogrefe.

Sturm, W., & Büssing, A. (1986): Einfluß der Aufgabenkomplexität auf hirnorganische Reaktionsbeeinträchtigungen - Hirnschädigungs- oder Patienteneffekt? *European Archives of Psychiatry and Neurological Sciences*, *235*, 214-220.

Sturm, W., De Simone, A., Krause, B., Specht, K., Hesselmann, V., Radermacher, I., Herzog, H., Tellmann, L., Müller-Gärtner, H.-W. & Willmes, K. (1999a). Functional Anatomy of Intrinsic Alertness: Evidence for a fronto-parietal-thalamic-brainstem network in the right hemisphere. Neuropsychologia (in press).

Sturm, W., Fimm, B., Zimmermann, P., Deloche, G., & Leclercq, M. (1999b). Computerized training of specific attention deficits in stroke and TBI patients. In M. Leclercq & P. Zimmermann (Eds.), *Applied Neuropsychology of Attention*. Hove: Psychology Press.

Sturm, W., Fimm, B., Cantagallo, A., Cremel, N., North, P., Passadori, A., Pizzamiglio, L., Rousseaux, M., Zimmermann, P., Deloche, G., Leclercq, M (2003). Specific computerised attention training in stroke and traumatic brain-injured patients. A European multicenter efficacy study. *Zeitschrift für Neuropsychologie*, *14*, 283-292.

Sturm, W. Hartje, W., Orgass, B., & Willmes, K. (1993). Computer-Assisted Rehabilitation of Attention Impairments. In F.J. Stachowiak (Ed.), *Developments in the Assessment and Rehabilitation of Brain-Damaged Patients* (pp. 17-20). Tübingen: G. Narr.

Sturm, W., Hartje, W., Orgaß, B., & Willmes, K. (1994). Effektivität eines computergestützten Trainings von vier Aufmerksamkeitsfunktionen. *Zeitschrift für Neuropsychologie*, *5*, 15-28.

Sturm, W., Longoni, F., Fimm, B., Dietrich, T., Weis, S., Kemeny, S., Herzog, H., Willmes, K. (2004b). Network of auditory intrinsic alertness: a PET study. *Neuropsychologia*, *42*, 563-568.

Sturm, W., Schmenk, B., Fimm, B., Specht, K., Weis, S., Thron, A., Willmes, K. (2006). Spatial Attention: more than intrinsic alerting? *Experimental Brain Research*, *171*, 16-25.

Sturm, W., Willmes, K., Orgass, B., Hartje W. (1997). Do specific attention deficits need specific training? *Neuropsychological Rehabilitation, 7,* 81-103.

Sturm, W., Willmes, K. (2001). On the functional neuroanatomy of intrinsic and phasic alertness. *Neuroimage*, *14*, 76-84.

Stuss, D. T., & Benson, D. F. (1984). Neuropsychological studies of the frontal lobes. *Psychological Bulletin*, *95*, 3-28.

Tartaglione, A., Bino, G., Manzino, M., Spadavecchia, L. & Favale, E. (1986). Simple reaction time changes in patients with unilateral brain damage. *Neuropsychologia*, *24*, 649-658.

Thiebaut de Schotten, M., Urbanski, M., Duffau, H., Volle, E., Lévy, R., Dubois, B., Bartolomeo, P. (2005). Direct evidence for a parietal-frontal pathway subserving spatial awareness in humans. *Science*, *309*, 2226-2228.

Thimm, M., Fink, G.R., Küst, J., Karbe, H., & Sturm, W. (2005). Impact of Alertness-Training on Spatial Neglect: A Behavioural and fMRI Study. *Neuropsychologia, 44,* 1230-1246.

Treisman, A. M. (1969). Strategies and models of selective attention. *Psychological Review*, *76*, 282-299.

Treisman, A. M. , & Gelade, G. (1980). A feature integration theory of attention. *Cognitive Psychology*, *12*, 97-136.

van Zomeren, A. H., & Brouwer, W. H. (1994). *Clinical neuropsychology of attention*. New York: Oxford Univ. Press

van Zomeren, A.H. & van den Burg, W. (1985). Residual complaints of patients two years after severe head injury. *Journal of Neurology, Neurosurgery and Psychiatry*, *48*, 21-28.

Verhaeghen, P. & Cerella, J. (2002). Aging, executive control, and attention: a review of meta-analyses. *Neuroscience and Biobehavioral Reviews, 26*, 849-857.

Vohn, R., Fimm, B., Weber, J., Schnitker, R., Thron, A., Spijkers, W., Willmes, K., Sturm, W. (2007). Management of attentional resources in within-modal and cross-modal divided attention tasks; an fMRI study. *Human Brain Mapping, 28,* 1267-1275.

Wagensonner, M. & Zimmermann, P. (1991). Die Fähigkeit zur länger anhaltenden Aufmerksamkeitszuwendung nach cerebraler Schädigung. *Zeitschrift für Neuropsychologie*, *2*, 41-50.

Wagner, M. & Karner, T. (2001). *Handanweisung Cognitrone (COG)*. Mödling: Schuhfried.

Walter, W.G., R. Cooper, V.J. Aldridge, W.C. McCallum, & A.L. Winter (1964). Contingent negative variation: An electric sign of sensorimotor association and expectancy in the human brain. *Nature*, *203*, 380-384.

Werner, L. A. (2007). Issues in human auditory development. *Journal of Communication Disorders*, *40*(4), 275-283.

Zimmermann, P., & Fimm, B. (2002). *Testbatterie zur Aufmerksamkeitsprüfung (TAP).* Würselen: Psytest

APPENDIX A: DESCRIPTIVE STATISTICS

The Appendix contains descriptive statistics for all the normed test variables.

m	mean
md	median
s	standard deviation

Subtest 1 Intrinsic (visual) – total norm:

Variable	**range**	m	**md**	**s**	**skew**	**kurtosis**
Mean reaction time	[173; 555]	239	230	44	1.97	7.70
Dispersion of reaction time	[16; 211]	53	48	26	2.00	7.09
Mean reaction time (corrected for age)	[-3.38; 1.60]	0.02	0.23	0.96	-2.00	8.41
Number of missed reactions	[0; 2]	0.06	0	0.26	5.02	27.11
Number of false alarms	[0; 2]	0.43	0	0.66	1.23	0.30

Subtest 1 Intrinsic (visual) - EU education level 1-3:

Variable	**range**	**m**	**md**	**s**	**skew**	**kurtosis**
Mean reaction time	[176; 555]	246	234	49	2.08	7.91
Dispersion of reaction time	[18; 211]	55	50	29	2.31	8.25
Mean reaction time (corrected for age)	[-4.91; 1.60]	-0.11	0.13	1.07	-2.14	8.68
Number of missed reactions	[0; 2]	0.04	0	0.22	6.01	39.61
Number of false alarms	[0; 2]	0.42	0	0.66	1.32	0.47

Subtest 1 Intrinsic (visual) - EU education level 4-5:

Variable	**range**	**m**	**md**	**s**	**skew**	**kurtosis**
Mean reaction time	[172; 363]	232	225	36	1.17	1.50
Dispersion of reaction time	[14; 136]	50	46	23	1.11	1.37
Mean reaction time (corrected for age)	[-2.65; 1.51]	0.16	0.32	0.78	-1.16	1.58
Number of missed reactions	[0; 2]	0.08	0	0.30	4.32	19.76
Number of false alarms	[0; 2]	0.45	0	0.65	1.14	0.15

Subtest 2 Phasic (cross-modal visual) – total norm:

Variable	range	m	md	s	skew	kurtosis
Mean reaction time	[149; 513]	227	217	48	1.82	5.42
Dispersion of reaction time	[14; 222]	65	55	39	1.24	1.43
Mean reaction time (corrected for age)	[-4.45; 1.80]	0.02	0.21	0.97	-1.81	5.51
Number of missed reactions	[0; 4]	0.22	0	0.57	3.18	12.47
Number of false alarms	[0; 0]	0	0	0	0	0
Number of premature reactions	[0; 5]	0.84	1	1.07	1.44	1.86

Subtest 2 Phasic (cross-modal visual) – EU education level 1-3:

Variable	Range	m	md	s	skew	kurtosis
Mean reaction time	[149; 513]	235	224	54	1.68	4.41
Dispersion of reaction time	[149; 222]	69	60	40	1.07	0.98
Mean reaction time (corrected for age)	[-4.45; 1.60]	-0.11	0.12	1.07	-1.67	4.34
Number of missed reactions	[0; 4]	0.28	0	0.65	2.98	10.72
Number of false alarms	[0; 0]	0	0	0	0	0
Number of premature reactions	[0; 5]	0.84	1	1.08	1.47	2.00

Subtest 2 Phasic (cross-modal visual) - EU education level 4-5:

Variable	range	m	md	s	skew	kurtosis
Mean reaction time	[158; 446]	218	209	40	1.76	5.92
Dispersion of reaction time	[14; 197]	60	51	37	1.50	2.36
Mean reaction time (corrected for age)	[-3.25; 1.80]	0.17	0.29	0.80	-1.80	6.72
Number of missed reactions	[0; 2]	0.15	0	0.44	2.95	8.23
Number of false alarms	[0; 0]	0	0	0	0	0
Number of premature reactions	[0; 5]	0.83	1	1.05	1.41	1.74

Subtest 3 Phasic (unimodal visual) – total norm:

Variable	range	m	md	s	skew	kurtosis
Mean reaction time	[153; 528]	233	222	52	1.98	6.11
Dispersion of reaction time	[15; 283]	72	60	45	1.66	3.28
Mean reaction time (corrected for age)	[-4.99; 1.63]	0.00	0.19	1.03	-2.00	6.12
Number of missed reactions	[0; 4]	0.24	0	0.64	3.26	12.00
Number of false alarms	[0; 0]	0	0	0	0	0
Number of premature reactions	[0; 5]	0.99	1	1.22	1.45	1.87

Subtest 3 Phasic (unimodal visual) – EU education level 1-3:

Variable	range	m	md	s	skew	kurtosis
Mean reaction time	[156; 528]	242	227	60	1.85	4.76
Dispersion of reaction time	[18; 261]	75	64	46	1.58	2.94
Mean reaction time (corrected for age)	[-5.12; 1.55]	-0.16	0.12	1.18	-1.85	4.60
Number of missed reactions	[0; 4]	0.29	0	0.69	2.89	9.40
Number of false alarms	[0; 0]	0	0	0	0	0
Number of premature reactions	[0; 5]	1.00	1	1.16	1.42	2.13

Subtest 3 Phasic (unimodal visual) - EU education level 4-5:

Variable	range	m	md	s	skew	kurtosis
Mean reaction time	[153; 392]	222	216	39	1.43	3.64
Dispersion of reaction time	[15; 283]	68	55	44	1.79	3.93
Mean reaction time (corrected for age)	[-3.12; 1.63]	0.19	0.26	0.78	-1.61	4.96
Number of missed reactions	[0; 4]	0.19	0	0.58	3.87	17.13
Number of false alarms	[0; 0]	0	0	0	0	0
Number of premature reactions	[0; 5]	0.98	1	1.28	1.48	1.67

Subtest 4 Intrinsic (auditory) – total norm:

Variable	range	m	md	s	skew	kurtosis
Mean reaction time	[167; 546]	244	229	59	1.89	4.84
Dispersion of reaction time	[22; 323]	64	55	38	2.71	10.12
Mean reaction time (corrected for age)	[-4.91; 1.58]	-0.03	0.24	1.04	-1.90	4.91
Number of missed reactions	[0; 5]	0.11	0	0.46	6.03	46.65
Number of false alarms	[0; 15]	0.75	0	1.34	4.49	34.49

Subtest 4 Intrinsic (auditory) – EU education level 1-3:

Variable	range	m	md	s	skew	kurtosis
Mean reaction time	[171; 546]	251	238	63	1.65	4.47
Dispersion of reaction time	[23; 323]	87	59	55	2.27	7.81
Mean reaction time (corrected for age)	[-4.92; 1.58]	-0.13	0.09	1.03	-1.72	4.84
Number of missed reactions	[0; 5]	0.13	0	0.55	5.86	40.70
Number of false alarms	[0; 9]	0.79	0	1.36	2.96	11.54

Subtest 4 Intrinsic (auditory) - EU education level 4-5:

Variable	range	m	md	s	skew	kurtosis
Mean reaction time	[167; 518]	232	218	52	2.27	6.84
Dispersion of reaction time	[22; 210]	57	49	33	2.54	7.53
Mean reaction time (corrected for age)	[-3.51; 1.47]	0.19	0.44	0.92	-2.28	6.88
Number of missed reactions	[0; 2]	0.09	0	0.33	4.09	17.41
Number of false alarms	[0; 19]	0.70	0	1.33	6.44	65.42

Subtest 5 Phasic (cross-modal auditory) – total norm:

Variable	range	m	md	s	skew	kurtosis
Mean reaction time	[147; 620]	243	229	64	1.94	6.15
Dispersion of reaction time	[19; 407]	82	71	51	2.28	8.52
Mean reaction time (corrected for age)	[-4.72; 1.62]	-0.01	0.21	1.04	-2.02	6.61
Number of missed reactions	[0; 4]	0.15	0	0.48	3.90	18.34
Number of false alarms	[0; 0]	0	0	0	0	0
Number of premature reactions	[0; 5]	1.24	1	1.25	0.99	0.50

Subtest 5 Phasic (cross-modal auditory) – EU education level 1-3:

Variable	range	m	md	s	skew	kurtosis
Mean reaction time	[154; 571]	251	238	63	1.65	4.47
Dispersion of reaction time	[17; 407]	87	74	55	2.27	7.81
Mean reaction time (corrected for age)	[-4.72; 1.61]	-0.13	0.09	1.03	-1.72	4.84
Number of missed reactions	[0; 2]	0.17	0	0.47	2.77	6.95
Number of false alarms	[0; 0]	0	0	0	0	0
Number of premature reactions	[0; 5]	1.18	1	1.22	1.04	0.56

Subtest 5 Phasic (cross-modal auditory) - EU education level 4-5:

Variable	range	m	md	s	skew	kurtosis
Mean reaction time	[143; 620]	233	221	64	2.43	9.31
Dispersion of reaction time	[20; 378]	77	66	46	2.20	9.22
Mean reaction time (corrected for age)	[-4.28; 1.62]	0.14	0.38	1.03	-2.49	9.78
Number of missed reactions	[0; 4]	0.13	0	0.49	5.12	30.61
Number of false alarms	[0; 0]	0	0	0	0	0
Number of premature reactions	[0; 5]	1.30	1	1.28	0.95	0.46

Subtest 6 Phasic (unimodal auditory) – total norm:

Variable	range	m	md	s	skew	kurtosis
Mean reaction time	[145; 652]	229	214	58	1.90	7.49
Dispersion of reaction time	[18; 348]	81	69	50	1.68	4.28
Mean reaction time (corrected for age)	[-3.59; 1.85]	0.03	0.24	1.00	-2.01	8.70
Number of missed reactions	[0; 5]	0.20	0	0.64	4.13	19.75
Number of false alarms	[0; 0]	0	0	0	0	0
Number of premature reactions	[0; 5]	1.45	1	1.38	0.92	0.12

Subtest 6 Phasic (unimodal auditory) – EU education level 1-3:

Variable	range	m	md	s	skew	kurtosis
Mean reaction time	[147; 442]	236	224	55	2.27	7.81
Dispersion of reaction time	[18; 348]	86	75	52	1.60	3.96
Mean reaction time (corrected for age)	[-3.47; 1.35]	-0.08	0.11	0.94	-1.08	1.37
Number of missed reactions	[0; 5]	0.22	0	0.69	3.92	17.57
Number of false alarms	[0; 0]	0	0	0	0	0
Number of premature reactions	[0; 5]	1.44	1	1.38	0.88	0.032

Subtest 6 Phasic (unimodal auditory) - EU education level 4-5:

Variable	range	m	md	s	skew	kurtosis
Mean reaction time	[143; 652]	220	207	59	2.86	14.87
Dispersion of reaction time	[18; 332]	75	66	48	1.80	4.95
Mean reaction time (corrected for age)	[-4.31; 1.85]	0.15	0.36	1.04	-2.93	15.69
Number of missed reactions	[0; 4]	0.18	0	0.57	4.39	22.82
Number of false alarms	[0; 0]	0	0	0	0	0
Number of premature reactions	[0; 5]	1.46	1	1.38	0.97	0.24

Subtest 1 Intrinsic (visual) – children and young people:

Variable	**Range**	**m**	**md**	**s**	**skew**	**kurtosis**
Mean reaction time	[191; 700]	327	300	88	1.37	1.87
Dispersion of reaction time	[19; 462]	104	82	72	1.85	4.50
Mean reaction time (corrected for age)	[-4.01; 2.21]	0.00	0.16	0.96	-1.17	2.16
Number of missed reactions	[0; 11]	0.43	0	1.09	4.02	23.59
Number of false alarms	[0; 16]	1.90	1	2.44	2.71	10.05

Subtest 2 Phasic (crossmodal visual) – children and young people:

Variable	**Range**	**m**	**md**	**s**	**skew**	**kurtosis**
Mean reaction time	[151; 707]	284	264	78	1.91	6.00
Dispersion of reaction time	[23; 738]	142	117	101	1.96	5.59
Mean reaction time (corrected for age)	[-5.77; 1.94]	-0.02	0.13	1.01	-1.71	6.07
Number of missed reactions	[0; 18]	0.68	0	1.62	5.90	52.19
Number of false alarms	[0; 9]	0.42	0	0.98	4.23	26.42
Number of premature reactions	[0; 25]	3.05	2	3.07	2.58	11.64

Subtest 4 Intrinsic (auditory) – children and young people:

Variable	**Range**	**m**	**md**	**s**	**skew**	**kurtosis**
Mean reaction time	[182; 679]	309	281	97	1.53	2.64
Dispersion of reaction time	[20; 458]	102	83	66	2.06	5.76
Mean reaction time (corrected for age)	[-4.56; 2.09]	-0.01	0.18	1.01	-1.39	3.16
Number of missed reactions	[0; 4]	0.20	0	0.63	3.95	17.47
Number of false alarms	[0;11]	1.85	1	2.03	1.75	3.95

Subtest 5 Phasic (crossmodal auditory) – children and young people:

Variable	**Range**	**m**	**md**	**s**	**skew**	**kurtosis**
Mean reaction time	[157; 776]	314	289	104	1.50	2.93
Dispersion of reaction time	[24; 490]	153	123	89	1.24	1.35
Mean reaction time (corrected for age)	[-5.71; 1.96]	0.00	0.18	1.00	-1.79	5.72
Number of missed reactions	[0; 6]	0.39	0	0.96	3.48	14.60
Number of false alarms	[0; 10]	0.48	0	1.06	4.40	28.73
Number of premature reactions	[0; 18]	4.90	4	3.57	1.40	1.96