TAP

Test of Attentional Performance

Version 2.2

Peter Zimmermann & Bruno Fimm

English Translation: Marcus Cheetham

Part 1

This demo version is identical with the complete version of the TAP with the exception that only the pretest can be started; it is not possible to run a test and to memorize the data. To see examples of results, data of a subject are included. Instead of the external reaction keys, the keyboard is used for the registration of reactions.

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Vera Fimm, Psychologisches Testsysteme
Kaiserstrasse 100, D – 52134 Herzogenrath

The TAP is registered as a Class 1 Medical Product!

Preface to TAP 2.1

The Test of Attentional Performance (TAP) was first published in 1992. It has generated broad interest in both clinical practice and research over the years. This is reflected in the large number of related publications. The TAP has maintained its good standing throughout the more recent years of intense, largely imaging-based research into specific functions of attention. The development of the TAP is based on the strategy of examining specific attentional abilities by means of simple reaction paradigms. It is therefore pleasing to note that this strategy has been a guiding principle in research over the past years and has formed the basic approach toward gathering information about attentional functions. To some extent, the findings from this research have contributed to the validation of the TAP. While the essential features of the TAP have been retained, a number of new features have been introduced. The most significant of these has been the addition of the test of Sustained Attention. This fills an important gap and, in view of the findings to date, promises to become an important diagnostic tool. The other additions are variants of the current tests of Divided Attention and Visual Field / Visual Neglect. A further modification concerns the Eye-Movement test, the examination of which has been optimised by revising the test's stimuli.

Finally, the use of the TAP has been enhanced by reducing or omitting certain features. The tests are generally preset to the number of trials that apply for the normative values. The option of selecting between different intervals and numbers of target stimuli has been removed from the Vigilance test, and the Visual-Auditory subtest has been omitted entirely.

We hope that this new version of the TAP will meet with the same reception as the preceding version and that the improved user-friendliness of this Windows version will assist colleagues in their use of the TAP.

February, 2010

Peter Zimmermann and Bruno Fimm

Contents

Appendix

1 Attention and deficits of attention

Intact functions of attention are an important prerequisite for effective behaviour in everyday life. Whenever we are unable to fall back on overlearnt, automated behaviour patterns, we must concentrate on the task at hand and continually adapt ongoing behaviour to a given situation. This applies not only for practical activities but also for every kind of social interaction and all forms of mental activity. When we are inattentive and lacking in concentration, important information escapes our notice and we find ourselves subsequently unable to recall pertinent details. Practical actions become difficult to perform, and we commit errors. In this respect, deficits of attention have far-reaching consequences for almost every aspect and every activity in daily life, be it at school, at work, in traffic, or in carrying out other, diverse daily tasks.

Seen from a neuropsychological standpoint, these attentional functions are especially important, because almost every kind of brain damage, brain pathology, or brain illness is accompanied by different attentional impairments[1] that can result in a broad range of limitations in daily life. In keeping with this, Lezak[2] makes the point that "when this sort of impairment (impaired attention and concentration) occurs, all the cognitive functions may be intact and the person may even be capable of better than average performance, yet overall cognitive productivity suffers from inattentiveness, faulty concentration and consequent fatigue." (Lezak, 1995, p.40).

Investigations in the past few years, especially those based on brain-imaging techniques and using diverse paradigms, have clearly shown that "attention" should be understood as a specific kind of processing modus and in no case as a singular function. Indeed, "attention" comprises a large number of in part highly specific functions that control our perception, behaviour, and our thought processes. These functions are supported by different, partially overlapping, and broadly distributed neural networks that embrace all brain structures, as demonstrated by experimental animal research and brain imaging-based investigations. The complexity of these networks renders the attentional systems highly vulnerable to damage: It is hard to conceive of any particular brain lesion or cerebral disease that does not impact on structures important for processes of attention. For this reason, deficits of attention are not only the most frequent to occur but also the most persistent deficits, and they can manifest themselves in a diversity of ways. Problems with attention are therefore among the most frequent complaints reported by patients[3].

Many patients with deficits of attention not only encounter a decline in the general everyday level of performance, but, as first suggested by Zomeren, Brouwer and Deelman[4], also develop mental and psychosomatic problems. This holds in particular for patients who show no overt signs of impairment after brain damage, such as a traumatic brain injury, and whose complaints of, for example, reduced concentration or of tiring easily, are therefore not often taken seriously. In contrast, such patients find themselves being unfairly reproached for failing to make sufficient effort or for letting themselves go. The patients try to cope with this external pressure as well as with their own subjective experience of diminished performance by exerting themselves even more in order to compensate for these limitations. But this often

[1]e.g. Oddy, Humphrey & Uttley, 1978; van Zomeren, 1981; McLean, Temkin, Dikmen, & Wyler, 1983; van Zomeren & van den Burg, 1985; van Zomeren & Brouwer, 1994; Bohnen, Jolles, Twijnstra, Mellink & Wijnen, 1995; Levin, 1995; Leclercq, Deloche & Rousseaux, 2002

[2] Lezak, 1995

[3] Oddy, Humphrey & Uttley, 1978; van Zomeren, 1981; McLean, Temkin, Dikmen & Wyler, 1983; van Zomeren & van den Burg, 1985

[4] van Zomeren, Brouwer & Deelman, 1984

obscures the underlying danger of burdening oneself with permanent excessive strain and subsequent psychosomatic complaints.

Not every patient is aware of the cause or the extent of his or her difficulties, as shown by the inconsistency between the deficits experienced subjectively and those measured objectively[1]. Inaccurately judging actual abilities may lead the patient to either experience greater difficulties than would be assumed on the basis of an objective assessment of their performance, or, conversely, to the patient underestimating his or her difficulties. This discrepancy can be caused by many factors in addition to increased compensatory effort: psychodynamic coping processes; insult-induced denial tendencies of an anosognosic nature; or insult-related depression might also play a role[2].

The accurate diagnosis of deficits in attention functions is therefore of particular importance in the context of neuropsychological rehabilitation, and adequately differentiated instruments are necessary for this diagnosis in order to identify a patient's functional limitations and to assess the impact of these on the patient's neuropsychological rehabilitation and reintegration in everyday life and work. Having identified specific deficits, it should be possible to inform the patient about the causes of those difficulties experienced for which they have no explanation. An understanding of the causes of the problems is an important prerequisite for successful self-management by the patient in daily life.

Not only disturbed attentional functions should be taken into consideration but also the intact attentional functions, because these may potentially constitute an important means of compensating for reduced performance in nearly all domains. Thus, a patient or an older person could try to compensate for his or her limited performance by concentrating on his deficits, for example, a motor impairment or a language disorder. Conversely, it is also true that a patient with reduced attentional capacities is not able to constantly control his or her reduced function. For example, patients or older persons with gait disorders, for whom walking or keeping balance demands full concentration, are at risk of falling when someone speaks to them or when they have to respond to another task that demands attention[3].

The nature of attention

In accordance with the actual situation and the behavioural goals of an individual, attention is directed at those aspects of the situation that are relevant for attainment of those goals[4]. This is a process controlled both internally by monitoring the current goals and externally by the given environmental circumstances. This process requires both concentrating on relevant aspects and shifting concentration between those aspects while exploring a situation, or adapting behaviour to the changing conditions of that situation. This is a dynamic process in which the intention of the individual is continually compared with the actual conditions and expectations, the task at hand, previous experiences, and knowledge[5]. By this means, flexible adaption of behaviour to continually changing conditions of a complex environment is ensured. This adaption takes place while incorporating ongoing sensory, motor and cognitive processes to ensure that those aspects important for the individual in the given situation are

[1] Lannoo et al, 1998; Bernstein, 1999; Leclercq, Deloche & Rousseaux, 2002

[2] McGlynn & Schacter, 1989

[3] Wright & Kemp, 1992; Teasdale, Bard, LaRue & Fleury, 1993

[4] Luu & Pederson, 2004; Astor-Jack & Haggard, 2005; Deubel & Schneider, 2005; Hannus, Neggers, Cornelissen & Bekkering, 2005

[5] Giesbrecht & Mangun, 2005

selected from the abundance of available information and processed, while information that is not relevant is suppressed or filtered out[1].

Attentional processes are not only important for the interaction with the surrounding environment, they are of central importance for purely cognitive tasks such as solving mathematical problems, drawing up a plan, composing a text or searching for a solution. Ultimately, all purely cognitive tasks require control by the attentional system.

Attention is therefore a complex system that engages almost all cognitive and emotional processes. The importance of a particular aspect of reality or of a task is determined by the emotional motivational system. In contrast, effective cognitive processing of this aspect of reality or the control of mental processes is achieved by the focusing of attention. Processes of attention form an essential link that subserves the interplay between emotional, motivational processes and selective cognitive encoding of information.

Orientation of attention and motivation

That processes of attention should not be considered from a cognitive perspective alone has been a point long neglected, although James (1890) did suggest the importance of personal interest in controlling attention. It is only relatively recently that the connection between interest and attentional control has received due consideration and is, indeed, taken for granted by many authors[2]. For example, Parasuraman[3] states: “Of course, an organism’s goals are themselves determined not only by the environment but by the organism’s internal dispositions, both temporary and enduring; that is presumably what links attention to motivation and emotion”.

The orienting of attention in its various forms almost always represents a motivated behaviour. On the one hand, attention is captured by emotionally relevant[4] or interesting stimuli[5], while on the other hand, a sustained, that is, a voluntary, maintenance of attention is inconceivable without the corresponding motivation or interest[6]. Furthermore, James[7] underscores the point that “... without selective interest, experience is an utter chaos. Interest alone gives accent and emphasis, light and shade”.

The fact that our attention is driven by relevant emotional stimuli is critical to advertising psychology, whereas this view has evoked little interest in the domain of experimental psychology. That such a link exists has been suggested by a large number of authors[8], although the empirical basis for this is rather scant. The vast majority of pertinent articles make reference to the association between attention and fear-evoking stimuli[9].

This control of attentional focus consists of both concentration on a relevant aspect as well as the shift of attention between relevant aspects while exploring a situation or adapting

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[1] Corbetta, 1998; Milliken & Tipper, 1998; Liu, Slotnick, Serences & Yantis, 2003; Mort & Kennard, 2003; Aave, Neggers, Cornelissen & Bekkering 2005; Deubel & Schneider, 2005; Giesbrecht & Mangun, 2005; Mesulam, Small, Vandenberghe, Gitelman & Nobre, 2005; Serences, Liu & Yantis, 2005; Serences & Yantis, 2007

[2] e.g. Corbetta, 1998; Bichot. & Schall, 2005; Giesbrecht & Mangun, 2005; Mesulam, Small, Vandenberghe, Gitelman & Nobre, 2005; Hannus, Neggers, Cornelissen & Bekkering, 2005

[3] Parasuraman, 1998, p. 6

[4] Lang, 1990; Simons, Detember, Cuthbert, Schwartz & Reiss, 2003; Compton, 2003 for a review

[5] Lang, Bradley & Cuthbert, 1997

[6] James, 1890

[7] James, 1890, p.4020

[8] e.g. Corbetta, 1998; Bichot. & Schall, 2005; Giesbrecht & Mangun, 2005; Hannus, Neggers, Cornelissen & Bekkering, 2005; Mesulam, Small, Vandenberghe et al., 2005

[9] Reviews in: Derryberry & Tucker, 1994; Compton, 2003; Phelbs, 2006

behaviour to the changing conditions of the situation. It is at this point that motivation and the emotional state of the individual are of decisive importance. In the words of Mesulam, Vandenberghe, Gitelman and Nobre[1], “the term spatial attention designates interrelated sensory, motor, and cognitive processes that collectively enable the selective allocation of neural resources to motivationally relevant parts of the environment”. It may be assumed that the orienting of attention is almost always a matter of motivated processing. We orient to an object because it evokes our interest, or we pursue and concentrate on a task because the task is important for us or because we have received a corresponding instruction to do so.

The interplay between motivational factors and orientation of attention is of central importance for test-based diagnostics in general and the rehabilitation of cognitive deficits, because without sufficient motivation a patient is not able to apply the necessary attention to the test-diagnostic examination or to the therapy.

Focused attention

The control of attentional focus is a critical feature of flexible behaviour that is appropriately adaptive to given situations and one’s intentions. This process is subject to both internal and external mechanisms of control. Attention is regulated by internal voluntary processes and external events. An increase in distractibility and perseverative tendencies are manifestations of impoverished control over the direction of attentional focus that are for the most part associated with frontal lesions[2] and resultant distinctive behavioural disorders. In the case of increased distractibility, these results in impaired realisation of behavioural plans, whereas perseverative tendencies impede the adaption of behaviour to given conditions. The ability to control attentional focus is therefore a central aspect of attention diagnostics.

The direction of attentional focus can be determined equally well through external as through internal control. In the case of *external or stimulus-driven control*[3], unexpected or novel external stimuli[4] capture attention by virtue of their motivational or emotional valence, or because they stand out from the background (“pop-out”[5]). One of the most extreme forms of an external capture of attention is certainly the orientation reflex described by Pavlov[6], in which ongoing behaviour is interrupted and all sensory organs are directed to the relevant change in the surrounding environment. Fright may be considered a specific form of this phenomenon.

In everyday life, externally driven orientation of attentional focus occurs at home, in road traffic or at work, largely as the result of warning and cue stimuli. Furthermore, these are stimuli to which we are emotionally responsive. But the external control of attention is not limited to such stimuli, as may be seen when one considers how events and sequences of events are able to captivate the viewer’s attention, for example, while watching television, even though the viewer’s “role” is only passive.

The *internal or intentional control* of attentional focus is, in contrast, necessary when pursuing or realising a behavioural goal. To this end, one has, for example, to explore the actual situation and control the execution of the behavioural plan. It is not only concrete

[1] Mesulam, Vandenberghe, Gitelman & Nobre, 2005, p.29

[2] Distractibility: e.g. Lhermitte, Pillon & Serdaru, 1986; Lhermitte, 1986.
Perseverationen: Luria, 1966; Sandson & Albert, 1984; Goldberg & Bilder, 1987; Vilkki, 1989; Freedman et al., 1998

[3] James, 1890; Jonides, 1981; Kastner & Ungerleider, 2000; Astor-Jack & Haggard, 2005; Craighero & Rizzolatti, 2005; Giesbrecht & Mangun, 2005; Hopfinger, 2005; Serences & Yantis, 2007

[4] Berlyne, 1958; 1961

[5] Nothdurft, 2000, 2005; Zetzsche, 2006; Serences & Yantis, 2007

[6] Pavlov, 1927; „orientation response“ after Sokolow, 1963

behaviour that is controlled internally: the internal control is in itself essential for concentrating on a mental task such as listening, speaking, reading, and searching for solutions to all kinds of problems. This control is the basis for a deep processing of information[1] and therefore crucial for memory ability and successful learning. The internal or intentional control of attentional focus is an active process that is subject to control by the individual. The capacity to internally control the focus of attention therefore represents the basis for performing mentally demanding activities.

There are fundamental differences in the mental demands made by the external and the internal control of the focus of attention. Externally driven control of attentional focus is rapid, reflexive, passive and occurs without effort, whereas the internal orientation of attentional focus is slow, subject to voluntary control and is associated with effort[2].

The fundamental difference between externally and internally controlled attention is highly important in everyday performance and therefore in the diagnosis of attention performance. The instruments that promise high prognostic validity for assessing, for example, the ability to work are those that are able to establish the capacity to control attentional focus during mentally demanding tasks. However, for the assessment of specific performance tasks that demand simple stimulus discrimination may be sufficient.

The internal control of attentional focus is by no means a simple or single function. The control is much more a means of processing specific perceptual information at both earlier and later stages of processing with a higher priority. From a neurobiological perspective, this internal control is subserved by neuronal networks in which frontal and parietal structures play a crucial role. Experimental animal research and human brain imaging-based investigations have demonstrated that for perception a "response enhancement" takes place in the response of specific neurons or brain regions when the focus of attention is on specific stimulus features, while the processing of other sensory information is inhibited. Evidence of this effect was first provided by Hernandez-Peon, Scherrer & Jouvet[3] in cats. They showed how the response to an acoustic stimulus is suppressed in corresponding structures when a mouse is presented in the visual field of the cat: that is, the cat no longer registers the acoustic signal when concentrating entirely on the visual stimulus. This effect has since been confirmed repeatedly for different stimulus dimensions[4]. This effect is fully compatible with everyday experience. We are able to direct our attention to a particular sensory experience, for example, when we look very closely at a picture, concentrate when listening to something, examine the condition of food on the basis of its odour, or when we use our tactile sense to explore the material composition of an object. We are also able to search for specific stimulus features within a sensory modality, such as when listening for a particular sound or when searching for an object[5] of a particular shape or colour[6], or for a movement[7] in space. After detecting the corresponding object we are able to maintain it in view "from the corner of the

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1 Carr, 2004

2 James, 1890, p.416; Hopfinger, 2005

3 Hernandez-Peon, Scherrer & Jouvet, 1955

4 Steinman, Steinman & Lehmkuhle, 1995; Treue & Martinez Trujillo, 1999; Kastner & Ungerleider, 2000; Treue, 2001, 2003, 2004; Carrasco, Ling & Read, 2004; Thiel, Zilles & Fink, 2004; Somers & McMains, 2005; Carrasco, Ling & Read, 2004; Murray & Wojciuli, 2004; Carrasco, 2005 ; DeYoe & Brefczynski, 2005; Kastner, Schneider & O'Connor, 2005; Martínez-Trujillo & Treue, 2005; Navalpakkam, Arbib & Itti, 2005; Orban, Pauwels, van Hulle & Vanduffel, 2005; Rees & Heeger, 2005; Rezec & Dobkins, 2005; Somers & McMains, 2005; Serences & Yantis, 2007

5 Fink, Dolan, Halligan, Marshall & Frith, 1997; Arrington, Carr, Mayer. & Rao, 2000; Yantis & Serences, 2003; Serences, Schwarzbach, Courtney, Golay & Yantis, 2004; O'Craven, 2005

6 Liu Slotnick, Serences & Yantis, 2003; Wolfe, 2005

7 Wolfe, 2005

eye" by covert shifts of attention, or bring it into the focus of our visual field by saccadic eye movement.

Attention focuses not only on perceptual information. It also exercises sensorimotor control during the execution of movements for grasping or pointing and during movement in space[1], and in the implementation of complex sequences of movement and behavioural plans.

The fact that specific attention abilities are supported by only partially overlapping neural networks means that different brain insults result in very specific deficits of focussed attention and, with these, in very different limitations of everyday life. Reduced ability to focus on specific sensory modalities has been observed such that, for example, individual patients are unable to listen or observe closely[2], control the focus of visual attention by covertly shifting attention[3], or to execute saccadic eye movements[4].

Flexibility

Achieving a behavioural goal normally requires that attention is paid to changing situative conditions, that ongoing behaviour is adapted accordingly, or that the behavioural strategy is altered if necessary[5]. The shift of attentional focus is therefore a prerequisite for efficient behaviour; this makes flexibility one of the central factors in the control of the focus of attention. It is an ability that is essential in all situations requiring rapid orientation, integration of different information, or the rapid adjustment of behaviour according to changing circumstances. This ability is highly important in that it plays a role in many everyday situations: It is for example necessary in order to follow the thread of a discussion, to respond to unexpected situations in road traffic, or to find the solution to a problem.

Flexibility is not a singular function. The concept comprises of a broad spectrum of abilities that include specific functions of attention as well as higher cognitive functions. As a component of attention, it is critical because reduced flexibility impairs practical and intellectual performance to a considerable degree. Eslinger and Grattan[6] wrote: "Cognitive flexibility commonly refers to the ability to shift avenues of thought and action in order to perceive, process and respond to situations in different ways. It is an essential feature of adaptive human behaviour that is frequently altered by brain damage". The well-known significance of flexibility for general performance is formulated even more clearly by Lezak[7]: "The capacity for flexibility in behaviour extends through perceptual, cognitive, and response dimensions. Defects in mental flexibility show up perceptually in defective scanning and inability to change perceptual set easily. Conceptual flexibility appears in concrete or rigid approaches to understanding and problem solving, and also as stimulus-bound behaviour in which these patients cannot dissociate their responses or pull their attention away from whatever is in their perceptual field or current thoughts.... Inflexibility of responses results in perseverative, stereotyped, nonadaptive behaviour and difficulties in regulating and modulating motor acts".

Maladjusted behaviour resulting from reduced flexibility has been observed not only in association with brain damage but is also a very characteristic feature of the ageing process.

1 Allport, 1987; Cohen & Magen, 2005; Deubel & Schneider, 2005; Hannus, Neggers, Cornelissen & Bekkering, 2005

2 Wagensonner & Zimmermann, 1992; Woodruff, Benson, Bandettini, Kwong et al. (1996)

3 Posner, 1980; Posner, 1980; Posner, Walker, Friedrich & Rafal, 1984; Posner & Peterson, 1990; Carrasco, Ling & Read, 2004; Klein, 2004; Reynolds, 2005

4 Fischer & Boch, 1991; Braun, Weber, Mergner & Schulte-Mönting, 1992

5 Swick & Turken, 2004

6 Eslinger & Grattan, 1993. p. 17

7 Eslinger & Grattan, 1993. p. 17

Older people often stand out on account of their sluggish comprehension and behaviour resulting from diminished flexibility.

Aspects of flexibility are addressed whenever reference is made, for example, to concepts such as “shift” or “orienting” (“cross-modality shift”[1]; “covert shift of attention”[2]; “temporal orienting”[3]; “set shifting”[4]). Flexibility is not a singular process; it is the result of a hierarchically structured system of specific functions that are active at every level of processing from the control of sensory focus to strategic control behaviour and of behavioural goals. The loss of control in pursuing behavioural goals in particular leads to extensive limitations in everyday life.

Divided attention

One aspect of selective attention that cannot be incorporated easily into the preceding discussion is the ability to attend to two events or sequences of events simultaneously and, in this way, to “divide” attention. This is because very little is understood about the processes that underpin divided attention.

In terms of theoretical considerations, the ability for divided attention is embroiled in much controversy. The Capacity Model of Attention is advocated by some[5] and heavily disputed by others[6]. According to the Capacity Model, the simultaneous processing of two tasks requires sharing of available resources between both tasks. An opposing model assumes that simultaneous processing of several tasks can only be achieved when the available resources are switched between competing tasks (“switching”). In this case, performance is not limited by capacity, but by speed, that is, the refractory period with which resources can be switched between tasks. To date, it has not been possible to provide empirical evidence in favour of either of these models, although Pashler and Johnson[7] contend that the available evidence does not support the capacity model.

A new perspective has been brought into this discussion following investigations by the group around Lavie[8], who demonstrated the particular importance of working memory for the control of focused attention. High loading of working memory results in an increase in distractibility by irrelevant stimuli. This could be an indication that the capacity of short-term memory plays an important role in the control of attentional focus and possibly therefore also in the ability to process two objects of attention simultaneously.

Despite this controversy, the ability to divide attention, that is, to direct attention to two tasks simultaneously, is one of considerable importance, because, as Lane[9] points out, situations in daily life that require division of attention are the rule rather than the exception.

Deficits of divided attention are a frequent finding in neuropsychological practice. The affected patients complain of particular difficulties at work, for example, when a number of demands are placed on them simultaneously. The situation becomes more difficult for many

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[1] Sutton, Hakerem, Zubin & Portnoy, 1961; Benton, Sutton, Kennedy & Brokaw, 1962
[2] Posner, 1980; Posner & Peterson, 1990
[3] Nobre, 2004; Griffin & Nobre, 2005
[4] e.g. Brown & Marsden, 1988; Rogers et. al.; 1998
[5] e.g. Broadbent, 1958; Kahneman, 1973; Posner & Rafal, 1987
[6] Neisser, 1967; Allport, 1993; Sanders, 1997
[7] Pashler & Johnson, 1998
[8] Rees & Frith, 1997; de Fockert, Rees, Frith & Lavie, 2001; Lavie, Hirst & de Fockert, 2004; Lavie & de Fockert, 2005
[9] Lane, 1982, p.121

patients when the activities they were able to execute more or less automatically before incurring brain damage now require conscious control. For example, language-impaired patients require a higher level of concentration to speak, while walking places such a high demand on patients with gait disorder that they are unable to carry out other activities simultaneously.

In summary, attention is a complex system of specific abilities that is highly susceptible to all kinds of brain damage. The loss of control over the focus of attention, general speed attenuation, reduced long lasting concentration, diminished flexibility, and difficulty in dividing attention represent general impairments that effect on practically all situations in life. The significance of specific deficits of attention depends in a given case on the particular living or working circumstances of the individual.

On the whole, deficits in attentional ability result in a serious handicap in everyday and working life. For many patients, the ability to work is limited or lost fully specifically as the result of the patient’s impaired attention performance. Furthermore, attention performance is particularly important in the context of rehabilitation, both as a precondition for successful therapy and as a potential resource for compensation of other impairment-related deficits. A differential diagnosis of attention is therefore of particular importance.

2 Description of test procedures

2.1 Alertness

Alertness refers to the condition of general wakefulness that enables a person to respond quickly and appropriately to any given demand. It is the pre-requisite for effective behaviour, and is in this respect the basis of every attention performance.

A distinction has been made within the concept of alertness between tonic and phasic arousal[1]. Tonic arousal refers to a general state of wakefulness that is characterised by diurnal variation, whereas phasic arousal concerns the ability to increase the general level of attention in anticipation of a known event ("orienting"[2]). Phasic alertness is necessary, for instance, when an athlete is waiting for the starting signal in order to respond at the appropriate moment to the best of his ability. Increased response preparation is also frequently required when participating in road traffic, especially when confusing or critical traffic situations signal possible danger. Phasic alertness is normally measured in reaction time experiments, in which the target stimulus is preceded by a cue stimulus. This is different to the measurement of simple reaction time, for which the target stimulus is not cued.

Sturm and colleagues[3], however, have pointed out that the critical stimulus is not unexpected in a simple reaction time experiment, that it occurs in fact in a relatively dense and expected sequence, and that this leads to a condition that they refer to as "intrinsic alertness". Knowledge about the anticipated occurrence of a critical event enables the preparatory response to be maintained for a prolonged duration. This experimental situation corresponds to heavy "stop and go" traffic in which one anticipates having to stop and is prepared to brake suddenly.

From a functional perspective the concept of alertness subsumes many different processes, including general wakefulness ("tonic arousal"), maintenance of preparatory response over a long duration ("intrinsic alertness"), and a transient focusing of attention on an anticipated event ("phasic alertness"). It is a matter of definition whether tonic arousal is considered a process of attention or a basic process of general wakefulness, a prerequisite for any efficient cognitive performance. The states of fatigue and general exhaustion may be attributed to low tonic arousal.

In contrast, "intrinsic" and "phasic" alertness or arousal concern specific forms of the focusing of attention over a course of time. Phasic alertness has been investigated intensively by the group around Anna Nobre[4], being referred to as "temporal orienting" of attention. Spatially, an orienting of attentional focus was thus described as a "covert shift of attention"[5]. This refers to the ability to focus attention both in space and time. From a functional perspective, there is a basic difference between these two forms of directed attentional focus: temporal focusing of attention results in increased response preparation (output), whereas the spatial direction of attentional focus facilitates the perception (input) of a relevant stimulus. Examinations using reaction time (intrinsic alertness) rely on a very basic measure. However, different aspects of this measure should be kept in mind:

[1] Posner & Boies, 1972; Posner, 1975

[2] Posner & Petersen, 1990

[3] Sturm, de Simone, Krause et al., 1999; Sturm & Willmes, 2001

[4] Coull & Nobre, 1998; Griffin, Miniussi & Nobre, 2001; Nobre, 2001, 2004; Griffin & Nobre, 2005

[5] Posner, 1978; Posner, Walker, Friedrich & Rafal, 1984

- The *mean reaction time* provides information about the general speed of processing and gives an indication of possible processing attenuation, often seen after traumatic head injury, stroke, and other forms of cerebral disease or ageing processes.
- The *variability of reaction time* (standard deviation of reaction time) is a measure of the stability or instability of the level of performance. In general it may be caused by strong variation in reaction times or by isolated "lapses of attention"[1]. In the event of increased variability, close inspection of the distribution of RT is recommended.
- If a trend is apparent in the *course of RT* towards longer reaction times (for a graphic illustration of the trend line, see 5.7 "Presentation and output of results"), this is indicative of fatigue (that is a fall in tonic arousal).

Task

In this test, reaction time is examined under two conditions. The first condition concerns simple reaction time measurements, in which a cross appears on the monitor at randomly varying intervals and to which the subject should respond as quickly as possible by pressing a key. Intrinsic alertness is measured in this condition. In a second condition, reaction time is measured in response to a critical stimulus preceded by a cue stimulus presented as warning tone ("phasic arousal", or temporal orientation of attentional focus).

Procedure

To compensate for effects of fatigue the test is constructed according to an ABBA design, that is, the examination comprises four blocks (each with 20 target stimuli) in the sequence:

1. Run: without warning tone
2. Run: with warning tone
3. Run: with warning tone
4. Run: without warning tone

The first two trials of each run are intended for exercise and are not included in the analysis. A run is extended for up to 5 trials for trials without reaction or an anticipation (reaction to warning tones).

Reactions with key "1"

Test duration (without pre-test and instruction): 4.5 minutes.

[1] van Zomeren, 1987

The instructions are presented in two sequential displays on the monitor.

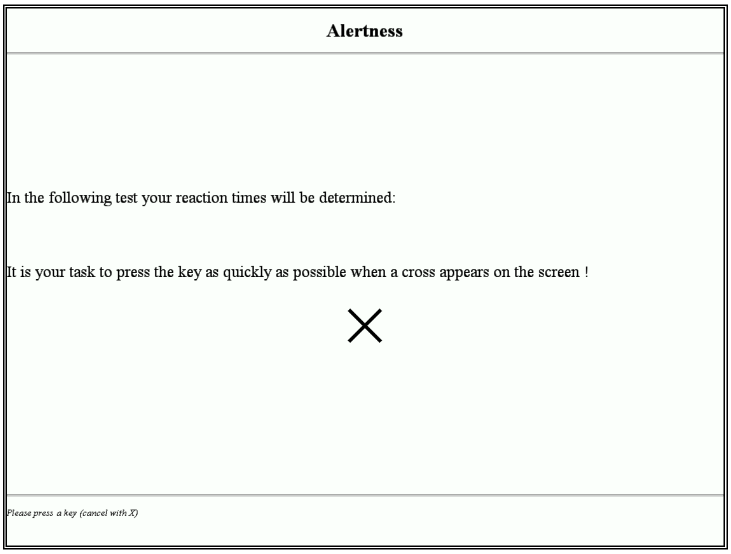


Fig. 2.1: Instruction for Alertness, display 1

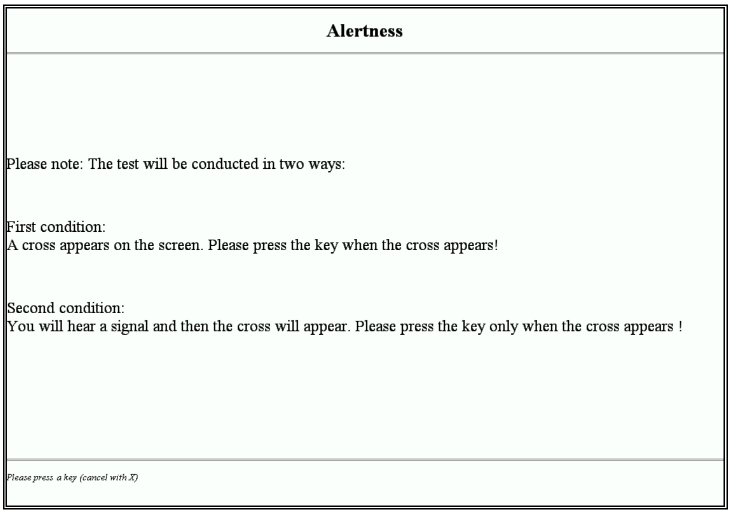


Fig. 2.2: Instruction for Alertness, display 2

The beginning of each run is preceded by a message indicating whether the run is to be presented with or without a warning tone. The test is started by pressing any key.

Results

Mean, median and standard deviation of RT are displayed for each run and for the conditions with and without warning tone, as well as for the entire task, the number of correct responses, of omissions (missing responses), of outliers (= reaction times greater than the average RT plus 2,35 × standard deviation of RT) and of anticipations (reaction to the warning tone).

In addition, an index of phasic alertness is calculated, which is computed in the following way:

$$\textit{Index of phasic alertness} = \frac{\mathrm{MD}_{\mathrm{RT.without}} - \mathrm{MD}_{\mathrm{RT.with}}}{\mathrm{MD}_{\mathrm{total}}}$$

in which: $\mathrm{MD}_{\mathrm{RT.without}}$ = median of RT for Series 1 and 4 (without warning),
$\mathrm{MD}_{\mathrm{RT.with}}$ = median of RT for Series 2 and 3 (with warning) and
$MD_{RT.total}$ = median of RT for Series 1 to 4 (total test).

Normative values will be shown for the median and standard deviation of RT for all runs and conditions with and without the warning tone.

Interpretation

The reaction speed should be considered first, using the median of RT for the runs without warning signal. A slowing of reactions can be a significant handicap in daily life. This reflects a general reaction speed attenuation that manifests itself in all measures of reaction time, and needs to be given due consideration when interpreting the other tests of the test battery. This is however not always the case. It is possible that a subject has specific difficulty in maintaining a high response readiness in this test (intrinsic alertness), whereas for example in the Go/Nogo test their RT is within the range of the normative values.

The standard deviations of RT for the runs without warning tone should be considered next, because the variability of RT provides an indication of the stability of performance, that is, the consistency with which attention is focused.

Following this, the difference in RT for the runs with and without warning signal should be assessed. This difference is the actual measure of phasic alertness. This is shown by the index for phasic alertness, or can be discerned directly on the basis of the difference in the medians of RT for the two test conditions

The standard deviations of RT, the number of outliers (“lapses of attention”) and the anticipatory responses in the runs with warning tone should also be inspected. Increased variability of RT and an increased number of anticipatory responses or outliers, or both, can all occur because the warning signal triggers a response impulse comparable to that in the Go/Nogo-Test. In the absence of any immediate reaction (anticipatory responses), the suppression of the reaction impulse can result in increased reaction latency for the following target stimulus.

The reaction times continue to be seen as a sensitive indicator of signs of fatigue. Rapid fatigue of the subject, should it occur, can be identified over the reaction time course, which will show a distinct increase of the trend line over time.

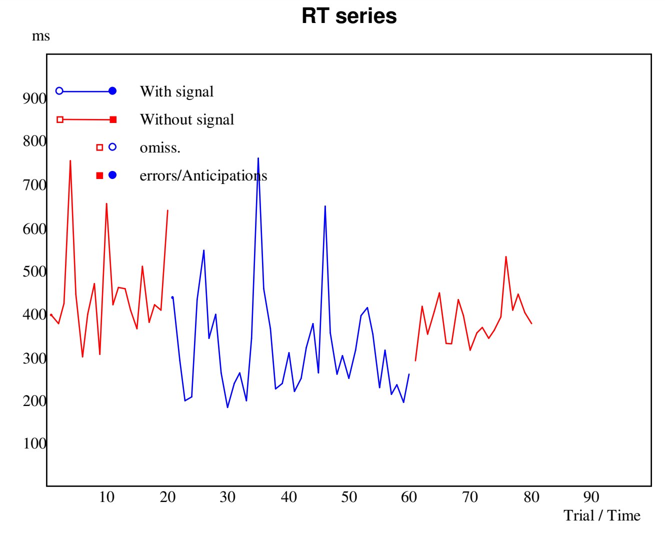
Case example 1: Alertness

Patient:	46 years old, female, O-levels
Aetiology:	Subarachnoidal bleeding following rupture of middle cerebral artery aneurysm with decompression trepanation
Time since damage occurred:	2 years
Impairments:	Aphasia, moderate transcortical sensory aphasia

Results

Condition	Mean	Median	%	Stddev	%	Correct	Omiss.	Outliers	Anticip.
Run 1	436	424	2	91	2	20	0	1	436
Run 2	315	293	12	104	12	20	0	1	315
Run 3	293	265	21	65	21	20	0	1	293
Run 4	380	381	4	44	4	20	0	1	380
Without warning	405	404	**2**	67	**2**	40	0	2	405
With warning	304	280	**14**	86	**14**	40	0	2	304

Index of phasic alertness: 0.341 (% = 99)



Assessment

Overall, the patient shows a clear general attenuation of RT. The decrease in RT due to the warning tone is impressive (percentile range of the index of phasic alertness > 99). Clear instability in performance is evident in the first two runs, which results in an increased standard deviation.

Case example 2: Alertness

Patient: 83 years old, male, A-levels

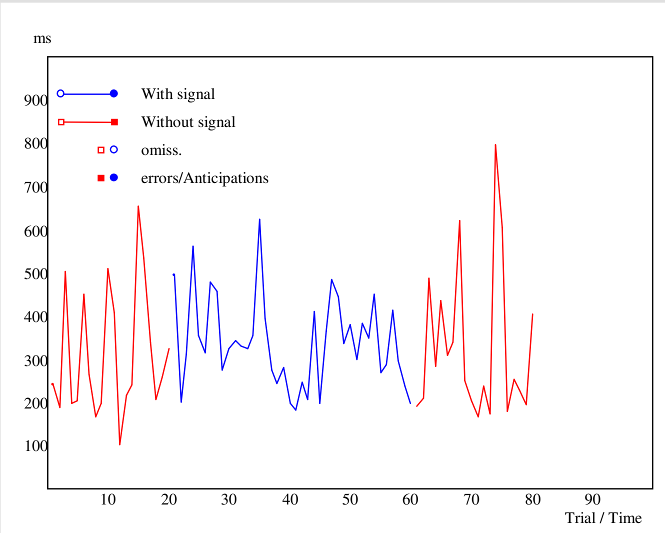
Aetiology: Depression, onset of dementia with cerebral involution and vascular leukoencephalopathy

Results

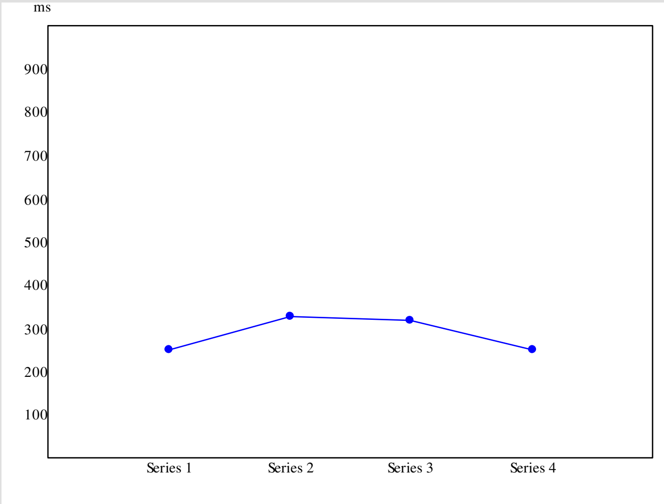
Condition	Mean	Median	%	Stddev	%	Correct	Omiss.	Outliers	Anticip.
Run 1	314	254	58	149	1	20	0	0	0
Run 2	360	332	7	113	2	20	0	0	0
Run 3	325	321	8	93	14	20	0	0	0
Run 4	307	255	58	142	3	20	0	1	0
Without warning	311	255	**73**	144	**2**	40	0	1	0
With warning	335	329	**7**	95	**12**	40	0	1	0

Index of phasic alertness: -0.246 (% = 2)

RT-series



Test-specific graph



Assessment

The patient shows a response readiness that lies above the normative value (PR = 84 in the trials without a warning tone). The patient's performance is however very unstable, as the quick reactions are subject to strong variations, apparent in the high standard deviations. The distinctly slower reactions to the critical stimuli with preceding warning tone are indicative of an inhibition of phasic alertness reaction. The percentile range value of phasic alertness in this patient is 2.

Case example 3: Alertness

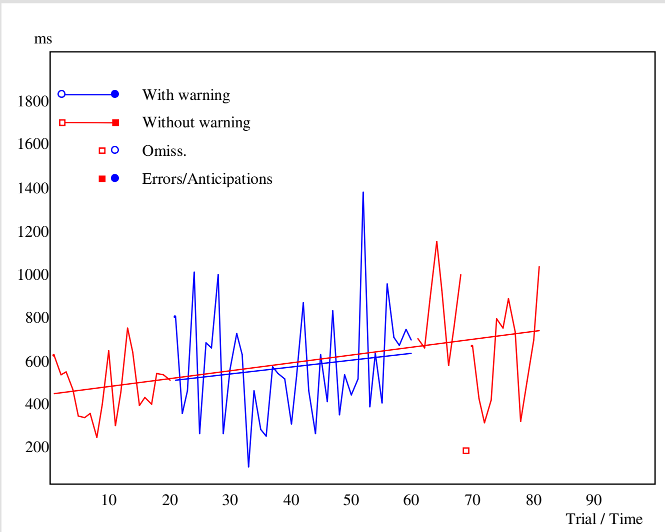
Patient:	47 years old, male, O-levels
Aetiology:	Traumatic brain lesion
Time since damage occurred:	10 month
Impairments:	Left neglect, rapid fatigue

Results

Condition	Mean	Median	%	Stddev	%	Correct	Omiss.	Outliers	Anticipations
Run 1	476	465	1	130	1	20	0	0	0
Run 2	526	534	< 1	247	< 1	20	0	0	0
Run 3	584	539	< 1	190	1	20	0	1	0
Run 4	713	720	< 1	234	1	20	1	0	0
Without warning	580	543	**< 1**	205	**< 1**	40	1	1	0
With warning	554	539	**< 1**	220	**< 1**	40	0	1	0

Index of phasic alertness: 0.007 (% = 34)

RT-series



Assessment

In addition to general slowness (PR = 1 or lower for all runs), there is a marked attentuation of RT over the course of the examination in both runs, ie., with and without warning tone, as shown by the trend lines in the RT-series graph. This negative trend in reaction speed indicates the effect of fatigue in this patient.

2.2 Covert Shift of Attention

Covert shift of attention refers to the ability to focus visual attention to part of the surrounding space without changing the direction of gaze[1].

This shift of attentional focus may be elicited exogenously by stimuli that catch the eye[2], or endogenously by voluntary orientation of attention to an expected or given event at a point in space[3].

An impairment of the endogenous, that is, intentionally controlled direction of attentional focus, can be of particular importance in daily life and for rehabilitation. The control of many situations, such as in traffic, requires a constant shifting of attentional focus. It appears that the importance of such control over visual focus of attention as when reading (especially to the right) has not yet been clarified unequivocally. There is some indication that compensatory training for hemianopsia has only limited success when there is a concomitant impairment of shifting the visual attention to the hemianopic side. Regrettably, it is not possible with the present procedure to assess covert shift of attention in the presence of such a joint impairment.

Initial evidence supporting the importance of parietal cortex structures in underpinning the shift of visual attention focus has been provided in investigations in patients[4] and repeatedly by imaging-based investigations[5]. Deficits in the shift of attentional focus essentially occur in association with neglect, but they are not inextricably linked with neglect symptomatic. Deficits of covert shift of attention to the contralesional side occur with a higher rate of incidence after left than after right-sided parietal damage and correlate mostly - but not always - with corresponding impairments of eye movement[6].

Covert shifting of attention may be ascribed to the system of control processes of attention that facilitate the orientation of attentional focus in time[7], space[8], to objects[9] or to specific stimulus features[10]. According to Nobre, the ability to orient attentional focus to specific channels of information is related to the flexibility of the attentional system[11]. Focusing attention on a specific aspect (time, space, object, feature) increases the selective processing of that aspect in the associated underlying cortical areas[12].

Evidence of this covert shift of attention was obtained with a simple reaction time paradigm[13] in which the target stimulus, which appears at random to the left or right of the fixation point, is preceded by a cue stimulus, which gives either no concrete indication of the expected

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1 Posner, 1980

2 „pop-out“: Nothdurft, 2000, 2005; Zetzsche, 2006; Serences & Yantis, 2007

3 Jonides, 1981; Klein, 2004; Serences & Yantis, 2007

4 Posner, Walker, Friedrich & Rafal, 1984; Posner, Walker, Friedrich & Rafal, 1987; Petersen, Robinson & Currie, 1989; Posner & Petersen, 1990; Zihl & Hebel, 1997

5 Petersen, Corbetta, Miezin & Shulman, 1994; Nobre, Sebestyen, Gitelman, Mesulam, Frackowiak & Frith, 1997; Vandenberghe, Gitelman, Parrish & Mesulam, 2001; Serences, Liu & Yantis, 2006

6 Haufe, 1991

7 Nobre, 2004

8 Posner; 1980; Yantis & Serences, 2003

9 Kanwisher & Driver, 1992; Vecera & Farah, 1994; Arrington, Carr, Mayer & Rao, 2000; Yantis & Serences, 2003; Serences, Schwarzbach, Courtney et al, 2004; O’Craven, 2005

10 Treue, 2001, 2003, 2004; Martínez-Trujillo & Treue, 2006; Murray, 2006

11 Nobre, 2004

12 Steinman, Steinman & Lehmkuhle, 1995; Thiel, Zilles & Fink, 2004; Somers & McMains, 2005; Carrasco, Ling & Read, 2004; Carrasco, 2005; Rezec & Dobkins, 2005

13 Posner, 1980

location of occurrence of the target stimulus, a correct indication of the expected location of the target stimulus (valid cue) or a incorrect indication of the expected location of the target stimulus (invalid cue). Either *peripheral cues*[1], for example, left, central and right frames that briefly light up before the target stimuli appear, or *central cues*[1], for example, arrows that point to the expected side of the target stimulus, have been used as cue stimuli.

The type of cue, whether peripheral or central, has a fundamental relevance for the orientation of attentional focus. The brief illumination of the peripheral cue evokes an external control of attentional focus, whereas a central cue always requires semantic processing and the ensuing intentional orientation (endogenous control) of attentional focus. The essential difference between external and internal control of attentional focus is that the former occurs concurrently with an impulse - that under certain circumstances may be inhibited - for a saccadic eye movement, whereas the internal shift of visual attentional focus happens independently of the saccadic eye movement[2].

It was initially assumed that from a functional perspective the covert shift of attention subserves the determination of the target for a saccadic eye movement. This assumption arose from the fact that a saccade is characterised by a ballistic movement, for which the visual target has to be determined prior to motor execution. An unequivocal answer to this question has yet to be provided. It has been demonstrated that largely overlapping brain areas are involved in the overt and covert shift of attention[3] and that a covert shift of attention to a target normally precedes a saccade[4]. However, as could be shown in the paradigm for covert shifting of attention, this shift is not necessarily followed by a saccadic eye movement[5]. Single cell measurement in animal experiments has also revealed that different neural processes are responsible for visual selection and for executing saccadic eye movement[6].

Task
In the present task, a central cue (an arrow directed to the left or right, see Fig. 2.3) indicates the expected side of the target stimulus. This allows the examination of endogenous control of attention of focus. The cue is correct (valid) in 80 per cent of the trials and incorrect (invalid) in 20 per cent. Following an invalid cue, attentional focus is initially shifted to the cued side (orienting), after which there is a new shift of focus to the actual occurrence of the target stimulus (reorienting).

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[1] Jonides, 1981
[2] Klein, 2004
[3] Corbetta, 1998; Corbetta et al., 1998; Nobre, Gitelman, Dias & Mesulam, 2000 ; Beauchamp, Petit, Ellmore, Ingeholm & Haxby, 2001
[4] Klein, 2004; Murray & Giggery, 2006
[5] Haufe, 1991
[6] Schall, 2002

"Covert shift of attention" paradigm				
Position of the stimulus:		left	central	right
Fixation stimulus:			■	
Condition "valid cue - right target":	cue		→	
	target		■	×
Condition "invalid cue – left target"	cue		→	
	target	×	■	

Fig. 2.3: The covert shift of attention paradigm: the target stimulus, a cross, is preceded by a cue stimulus, an arrow pointing to the left or right, indicating at which side the target stimulus will with higher probability occur. A valid cue stimulus (80% of trials) occurs when the cue stimulus and the position of the target stimulus correspond, an invalid cue stimulus when they do not (20% of trials).

The estimated time for the shift of attentional focus is derived from the difference between the reaction times of trials with valid and those with invalid cue stimulus (reorienting, see Fig.2.4). An asymmetry in the reaction times reflects a problem in the shift of focus to one side, for a shift in general or for reorienting only. The reaction times to the contralesional side of parietal lesions are normally much longer. This is for example the case in a right parietal lesion with neglect but also occurs with a right parietal lesion without neglect[1].

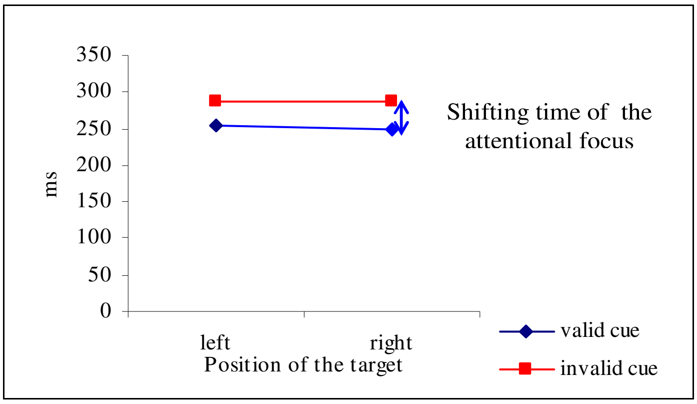


Fig. 2.4: Reaction times (fictitious) for an examination of covert shift of attention with central cue for valid and invalid cue to the right or the left side. The distance between the two lines represents the latency for a reorientation (shifting) of attentional focus when the target does not appear at the expected side.

Procedure

The test comprises 100 trials (80 trials with a valid cue, 20 trials with an invalid cue). It should be verified during testing whether the subject is attending to the fixation point according to the instructions and not performing a saccade to the expected side of the target stimulus on the basis of the cue.

Reactions with key "1"

The test duration (without pretest and instruction): ca. 5 minutes.

[1] Haufe, 1991

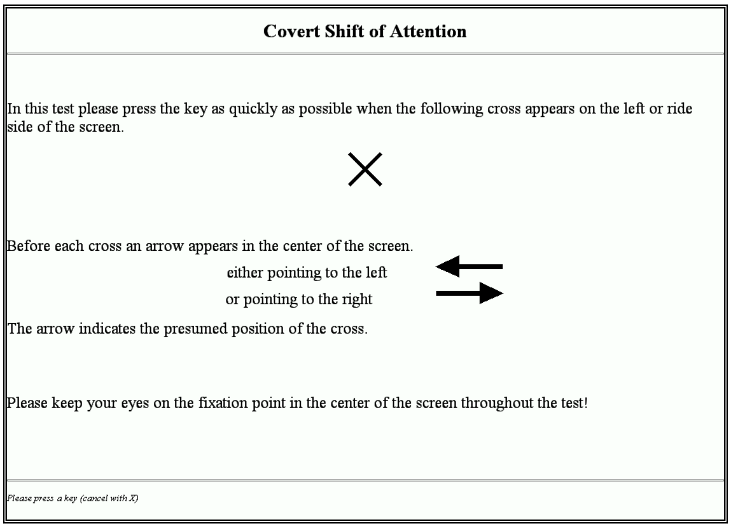


Fig. 2.5: Instruction for Covert Shift of Attention

Results

The mean, the median and standard deviation of reaction time as well as the number of correct reactions, errors, omissions, outliers, and anticipations (reactions to the cue) are provided for the left and right invalid and invalid trials as well as for all valid and invalid trials.

Furthermore, the F-values of the variance analysis for the effects “validity of the cue”, “position of the target”, and “validity x position” are provided in the results output.

Normative values for the median and the standard deviation of reaction times of trials with valid and invalid cues for left or right-sided target stimuli are provided. Normative values are also given for the F-values of the variance analysis.

Interpretation

The primary aim of this test is to expose a slowing in shifting of attentional focus in the left or right visual field. In patients with parietal lesions, for example, a distinct attenuation toward the contralesional side can be expected. To clarify this, the reaction times should be compared for left and right sided target stimuli and for valid and invalid cues. This effect will also be indicated by a significant F-value in “position of target”. The F-value for the effect “validity x side” (direction of cue x side a target stimulus) is also of interest, as this indicates specific problems with reorienting of attentional focus to one side.

F-values

F(Validity of the cue): main effect “validity” of the variance analysis. A high percentile indicates that there is no difference between the valid and invalid stimuli. This is not normally expected. A low percentile points to a very marked validity effect, that is, a general very slow reorienting of attention. An average percentile reflects the expected validity effect in the sense that shorter reaction times occur in the valid conditions compared with the invalid conditions.

F(Position of the target): main effect “side” of the variance analysis. The lower the percentile, the more obvious are the slowed reactions to the stimuli presented on one side, independent of the validity of the cue. Further information may be taken from the test-specific graph.

F(Validity x position): interaction of factors “validity” and “position”. A low percentile means that the reorientation of attention is slower to one side than to the other. This may be indicative of a deficit in the shifting of attention to one side. A value above average percentile means that there is no difference between the reorientation of attention to one side or the other.

Case example: Covert Shift of Attention

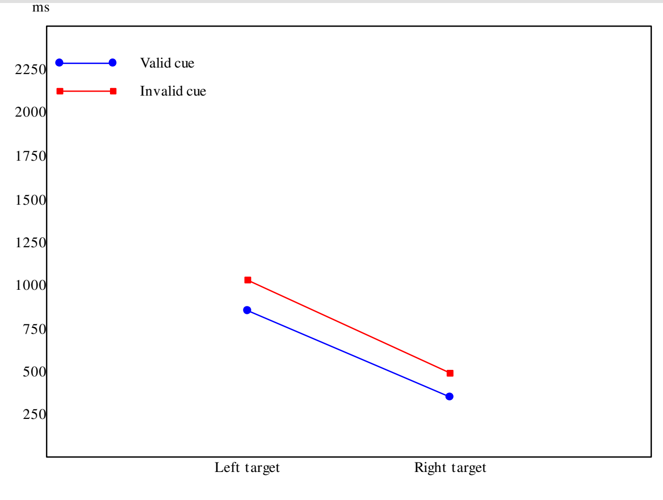
Patient:	47 years old, male, O-Levels
Aetiology:	Traumatic brain lesion
Time since damage occurred:	10 month
Impairments:	Left neglect, rapid fatigue

Results

Condition	Mean	Median	%	Stddev	%	Correct	Omiss.	Outliers
Valid cue - Left target	835	859	< 1	196	< 1	40	0	0
Valid cue - Right target	368	354	10	99	10	40	0	0
Valid cue	617	567		285		80	0	1
Invalid cue - Left target	1013	1038	< 1	187	1	10	0	0
Invalid cue - Right target	503	497	2	104	8	10	0	1
Invalid cue	745	696		299		20	0	1

F(Validity of the cue): 9.683 (% = 1)
F(Position of the target): 108.631 (% < 1)
F(Validity x position): 0.648 (% = 66)

Test-specific graph



Assessment

The patient shows an impairment of attention shifting to the contralesional side (cf. reaction time average target left vs. right for valid and invalid conditions (F-value side: 108.63; PR = <1). There is a marked validity effect (F-value Validity: 9.683; PR = 1) that clearly exceeds the “normal” latency (ca. 20-40 ms. in normal healthy individuals; compare the reaction time averages for the valid with the invalid conditions) and indicates that the controlled shifting of attention is impaired.

2.3 Crossmodal Integration

In everyday life, we recognise a person by their voice or their gait, and an object by its characteristic sounds, smell or tactile features. In short, we have a multimodal impression of persons and objects that enables us to identify them and to localize them rapidly in space. This is also important in, for example, natural situations, or in the media when a verbal statement needs to be ascribed to a certain speaker. Similarly, in road traffic we recognise from which side a car is coming without seeing it. Multimodal perception is therefore of considerable importance in the orientation of our attentional focus. A special form of multimodal control of attentional focus is the phasic alertness reaction[1] when an event is signalled in an other modality.

But the capacity to integrate multimodal sensory impressions goes well beyond this. For example, the visuo-motor control[2] of any movement requires the integration of visual information with the proprioceptive perception of the course of movement.

The question of the integration of different sensory impressions within the visual modality was first investigated experimentally by Treisman and Gelade. The results delivered the basis for the "Feature Integration Theory"[3]. It was only in subsequent years that an animated interest arose over the issue of integration of multimodal sensory perception and its importance for the identification and localisation of objects[4]. To date studies have proved that multimodal perception triggers selective processing at widely different processing levels[5], and, depending on the interplay of modalities, in different wide spread neural networks[6].

Wagensonner and Zimmermann[7] showed in brain-damaged patients that some patients fail to integrate the information from the auditory and visual modalities. Performance deficits of this kind have a direct impact on rehabilitation. because, as shown in work by Làdavas, Bolognini and Frassinetti[8] and Frassinetti et al.[9], audio-visual integration in patients with neglect or hemianopsia is of central importance for the localisation of objects in space.

Task

In this task, the critical combination of a preceding tone (high or low) and a subsequent visual stimulus (an arrow pointing up or down) should be detected. A target stimulus occurs when the pitch of the tone and the direction of the arrow are in agreement (high pitch and an arrow pointing up or a low tone and an arrow pointing down).

Reactions with key "1"

Test duration (without pre-test and instruction): ca. 2.5 minutes.

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[1] Driver & Spence, 2000; McDonald, Teder-Sälejärvi & Hillyard, 2000

[2] Rushworth & Ellison, 2005

[3] Treisman & Gelade, 1980; Treisman, 1982

[4] Calvert, Brammer & Iversen, 1998; Driver & Spence, 1998; Lalanne & Lorenceau, 2004; Amedi, von Kriegstein, van Atteveldt, Beuchamp & Naumer, 2005

[5] Calvert & Thesen, 2004; Watanabe & Shimojo, 2005

[6] Driver & Spence, 1998; Calvert, 2001; Bushara, Hanakawa, Immisch et al., 2003; Calvert & Thesen, 2004; Lalanne & Lorenceau, 2004

[7] Wagensonner & Zimmermann, 1991

[8] Làdavas, Bolognini & Frassinetti, 2004

[9] Frassinetti et al., 2005

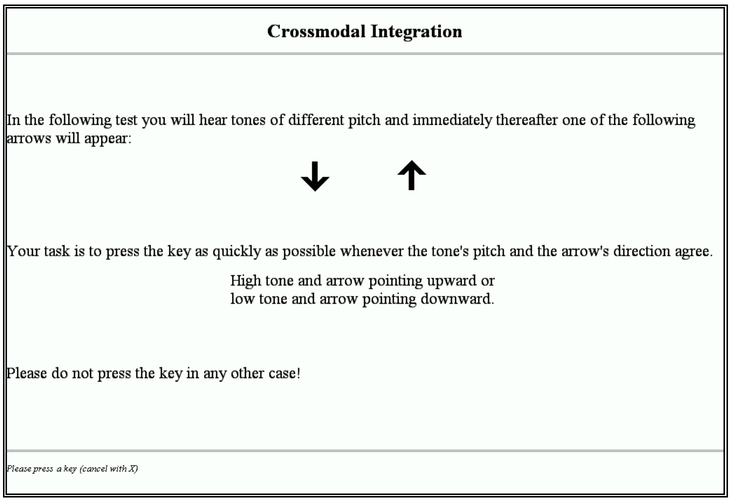


Fig. 2.6: Instruction for Crossmodal Integration

Results

For the whole test, values for mean, median, and standard deviation of RT are given, and for reaction accuracy, the number of correct reactions, errors, omissions, outliers and anticipations. Normative values are shown for the median and the standard deviation of RT as well as for the errors and omissions.

Interpretation

Difficulties can be recognised in the integration of visual and acoustic information modalities on the basis of errors and the omissions of target stimuli. The reaction times are of less importance in this test.

Sometimes difficulties in integrating the input from both sensory modalities may be indicated by the patient's complaint that he is unable to differentiate between pitches although there is no problem in distinguishing pitch in the unimodal presentation of tones (e.g. in the acoustic Vigilance test or in the simple stimulus presentation in the test of Divided Attention). Furthermore, the specificity of this deficit is also demonstrated in certain patients who have no problem in the more difficult test of Divided Attention, in which information from the two sensory modalities has to be processed in parallel, but have a major problem in the present test.

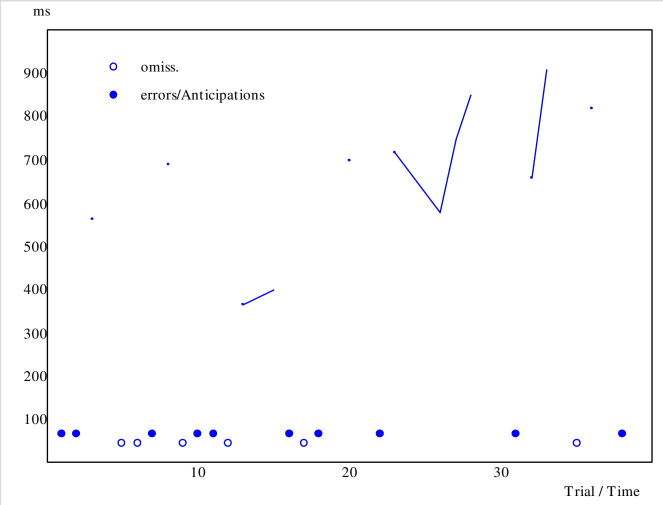
Case example: Crossmodal Integration

Patient:	55 Years-old, male, “A”-Levels
Aetiology:	Probable Chorea Huntington; alcohol abuse; in CT, mild atrophy of the caput nuclei caudati
Time since damage occurred:	Unknown

Results

Condition	Mean	Median	%	Stddev	%	Correct	Errors	%	Omiss.	%
Total	668	697	1	167	8	12	10	**<1**	6	**< 1**

RT-series



Assessment

The large number of errors and the above average number of omissions indicate that the patient has a severe problem in crossmodal processing.

2.4 Divided Attention

In everyday life, the capacity to pay attention to several things at once is of great importance. This requires the ability for divided attention to simultaneously ongoing processes. As Lane[1] once said, this is rather the rule than the exception in daily life.

Deficits of divided attention are frequently diagnosed in neuropsychological practice. The affected patients complain, for example, of difficulties experienced at work when several demands are placed on them simultaneously. The situation is made more difficult for many patients in that activities they previously executed on a largely automatic basis now need to be consciously controlled following the damage. Thus, speech, for example, requires a high degree of concentration for language-impaired patients, while walking for patients with gait difficulties can under circumstances present such high demands on the system of attention that they are unable to perform another activity simultaneously.

Despite its high importance in everyday life, the functional basis of this ability is unclear and the subject of a long drawn-out controversy. On one side are those who postulate the capacity theory [2], while on the other are those who favour the shifting theory[3]. Supporters of the capacity model assume that the simultaneous performance of two tasks requires a division of resources to both tasks such that the capacity, and thus performance, may be increased by exerting a higher level of effort. In contrast to this, the opponents of the capacity model assume that the simultaneous performance of several tasks is only possible by shifting between the competing tasks. In this case, performance is limited by the refractory time, that is, the minimum amount of time that has to be allocated to a task before having to shift to another task. The findings to date do not provide a definitive answer in favour of one or the other point of view, although Pashler and Johnston[4] are of the opinion that the available results tend to speak against the capacity model. The discussion may well be given new impetus by findings regarding the importance of working memory for focussing attention[5].

Task

In this test, a visual and an auditory task must be processed in parallel. Two forms of this test may be administered:

- Test Form I: auditory-visual condition (dual task)

  Visual task: a quadratic field of dots (4 × 4) appears in the central area of the screen, together indicating 16 positions at which between 6 and 8 small crosses may appear during the test in a predetermined rhythm. The subject has to press the reaction key as quickly as possible when 4 crosses appear in neighbouring positions such that they together form the corners of a small square.

  Auditory task: a high and low pitched tone is emitted alternately according to the synchronous rhythm of the changing position of the crosses. From time to time, the high or low tones are emitted twice in succession. The subject must also in this case press the (identical) reaction key as quickly as possible.

[1] Lane, 1982
[2] e.g. Broadbent, 1958; Kahneman, 1972; Posner & Rafal, 1987
[3] e.g. Allport, 1993; Sanders, 1997
[4] Pashler & Johnston, 1998
[5] Rees & Frith, 1997; de Fockert, Rees, Frith & Lavie, 2001; Lavie, Hirst & de Fockert, 2004; Lavie & de Fockert, 2005

In addition to this dual task there is the simple condition in which only the visual or only the auditory task must be processed. These simple conditions serve as a control of whether the patient is able to process the simple tasks, as well as explaining these simple tasks.

- Test Form II: auditory-visual condition

  Visual task: stimuli in the form of a rotated "S" (90°), the mirror image of the rotated "S", a "01" or a "10" appear in the middle of the screen according to a predetermined rhythm[1]. The subject has to press the reaction key as quickly as possible whenever the stimulus "01" or "10" appears.

  Auditory task: a high and low pitched tone is emitted alternately and at varying intervals asynchronous to the appearance of the visual stimuli. From time to time, the high or low tones are emitted twice in succession. The subject must also in this case press the (identical) reaction key as quickly as possible.

  In addition to this dual task there is the simple condition in which only the visual or only the auditory task must be processed. These simple conditions serve as a control for whether the patient is able to process the simple tasks, and for explaining these single tasks.

  In contrast to Test Form I, Test Form II requires no scanning of a spatial pattern of stimuli and is therefore appropriate for application with patients with an impaired visual field or impaired eye movement. For normal healthy subjects, Test Form II is somewhat easier on account of the reduced visual demands. On the other hand, this test form represents more closely the dual task because both tasks place stronger demands on parallel processing due to the asynchronous presentation of visual and auditory stimuli.

Administration

In Test Form I (dual task) 100 visual stimuli are presented, 17 of which are critical stimuli; the number of auditory stimuli amounts to 200, of which 16 are target stimuli. The visual stimuli alternate at the rhythm of two seconds, while the lasting auditory stimuli (duration of 433 ms) alternate at a rhythm of 1 second. The same reaction key should be pressed for the critical stimulus in the visual and the auditory task.

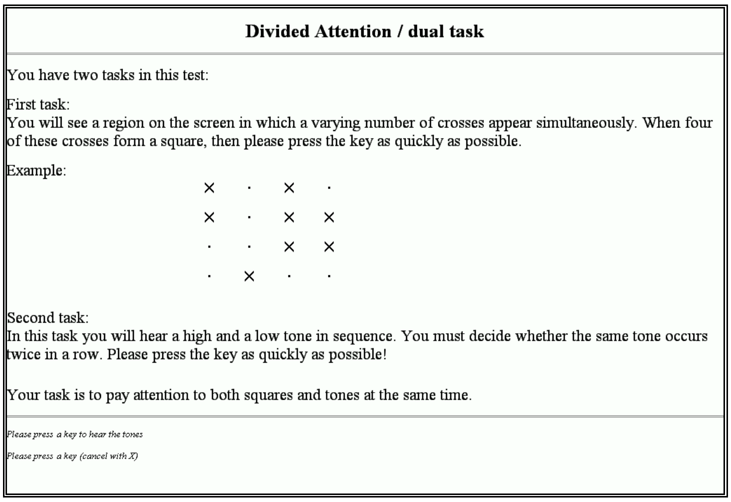
Test duration (without pre-test and instruction): 3 minutes, 25 seconds.

In Test Form II (dual task), the visual stimuli alternate at a predetermined rhythm every 1 second (175 stimuli with 20 critical stimuli), the auditory stimuli with a variable rhythm of between 0.9 and 1.5 seconds. 287 auditory stimuli are presented, 20 of which are target stimuli. The same reaction key should be pressed for the critical stimulus in the visual and the auditory task.

Test duration (without pre-test and instruction): 6 minutes.

Reactions with key "1"

[1] According to Julesz, 1981


Divided Attention / dual task

You have two tasks in this test:

First task:
You will see a region on the screen in which a varying number of crosses appear simultaneously. When four of these crosses form a square, then please press the key as quickly as possible.

Example:

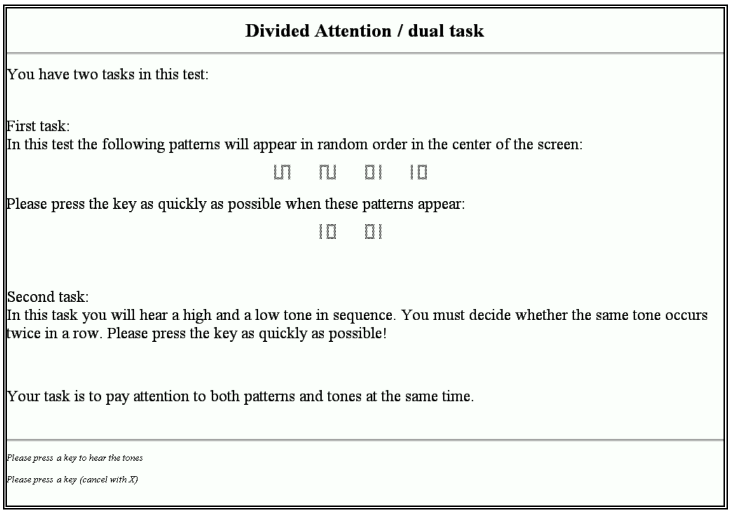
Second task:
In this task you will hear a high and a low tone in sequence. You must decide whether the same tone occurs twice in a row. Please press the key as quickly as possible!

Your task is to pay attention to both squares and tones at the same time.

Please press a key to hear the tones

Please press a key (cancel with X)

Fig. 2.7: Instruction for Divided Attention, Test Form I


Divided Attention / dual task

You have two tasks in this test:

First task:
In this test the following patterns will appear in random order in the center of the screen:

Please press the key as quickly as possible when these patterns appear:

Second task:
In this task you will hear a high and a low tone in sequence. You must decide whether the same tone occurs twice in a row. Please press the key as quickly as possible!

Your task is to pay attention to both patterns and tones at the same time.

Please press a key to hear the tones

Please press a key (cancel with X)

Fig. 2.8: Instruction for Divided Attention, Test Form II

Results

Values for mean, median, and standard deviation of RT time as well the number of correct reactions, omissions and outliers are given for the visual and auditory trials. The number of omissions and errors are displayed for the total test. Errors cannot be attributed to a specific modality, so they are displayed in the table of single trials in italic type.

Normative values are shown for the medians and standard deviations of RT and the number of omissions for the visual and the auditory trials as well as for the total number of omissions and errors.

Interpretation

The decisive criterion for successful division of attention in this procedure is the number of fully missed signals. The reaction times are of secondary importance.

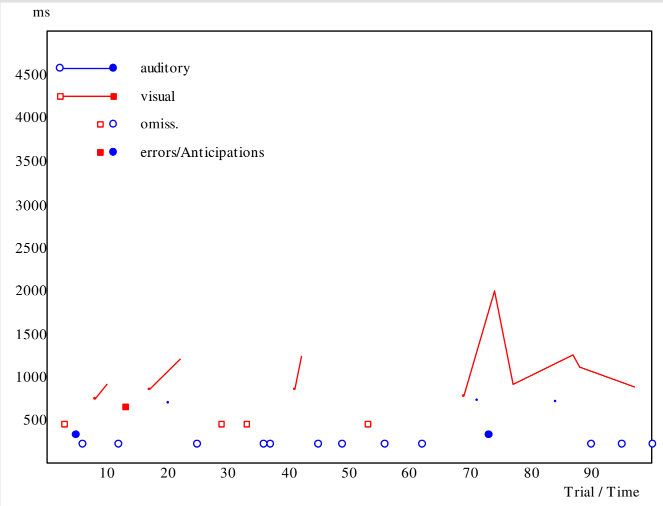
Case example: Divided Attention I

Patient:	42 years-old, female, ”O”-Levels
Aetiology:	Aneurysm of the left middle cerebral artery with subarachnoidal bleeding, and with leftfrontal intracranial bleeding; recurrent bleeding from the treated aneurysm.
Time since damage occurred:	7 months
Impairments:	Global aphasia in remission to Broca’s aphasia

Results

Condition	Mean	Median	%	Stddev	%	Correct	Errors	%	Omiss.	%	Outliers
auditory	730	734	2	15	> 99	3			12	< 1	0
visual	993	926	16	189	46	12			4	5	1
total							2	21	16	**< 1**	

RT-series



Assessment

The high rate of omissions shows a considerable limitation in attention capacity. It is discernible that auditory stimuli are mostly omitted. More precise clarification as to whether the high a rate of tone omissions is entirely attributable to reduced capacity or to an impairment of auditory processing is therefore recommended by means of additional testing in the unimodal condition “tones”

2.5 Eye-Movements

One of the most efficient forms of focusing is to look at something, that is, to change the direction of gaze and fixating on relevant information in the environment. This is a central function, on the basis of which we explore our surroundings and are able to orient ourselves in a given situation. Impaired eye movement can represent a major handicap in road traffic and may result in impaired reading ability, especially when there is a right-sided manifestation. In rehabilitation a deficit in saccadic eye movements can render compensation training of a visual field defect considerably more difficult.

The re-orientation of gaze direction can occur in response to external stimuli or events (externally driven) or in the context of systematic exploration of the surroundings (internally driven). This function is accompanied by a shift in attentional focus that cannot be directly observed, that is, a covert shift of attention[1]. It has been stated a number of times that a covert shift of attention is a preparatory procedure for determining the goal of a saccadic eye movement[2]. This view has not remained unchallenged[3]. A dissociation can be occasionally observed between a clearly attenuated shift of attention to the contralesional side in the Covered Shift of Attention test and a normal latency of the saccadic eye movements in the present test. This could also be seen as an indication that covert shift of attention is not necessarily a preparatory process for saccadic eye movements.

Task

In this task, the latency of saccadic eye movement to the left or to the right is assessed in a reaction task. Either a critical or a neutral stimulus is presented to the left or right of a fixation stimulus (an “S” lying on its side) in pseudorandom sequence. A critical stimulus appears centrally at irregular intervals. The subject should respond as quickly as possible by pressing the key as soon as this critical stimulus appears. The stimuli[4] were selected in such a way that the distinction between the critical and the neutral stimulus is only possible during fixation, that is, the reaction to the target stimulus requires a shift of gaze to the critical stimulus. The difference between the average reaction time to the peripheral stimulus and that to the central stimulus is the basis of the assessed saccadic reaction time. (see Fig.2.9).

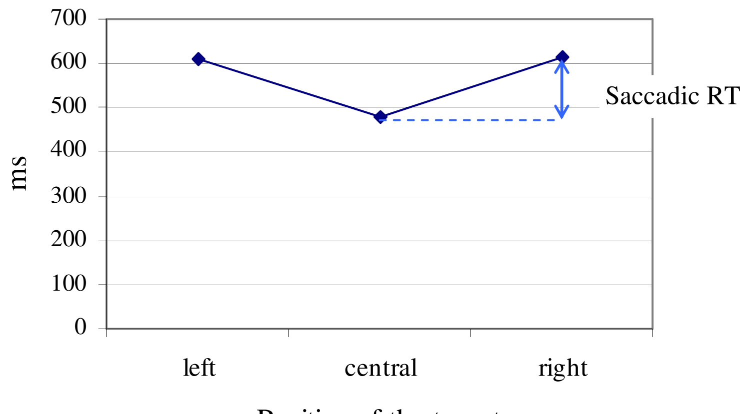


Fig. 2.9: Reaction times to the target stimulus with respect to the position of the target stimulus (left, centre, right). The difference between the reaction time to the left or right position and the central position represents the estimated saccadic reaction time.

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[1] Posner, 1980

[2] Posner, 1980; Fischer, 1987; Hoffman, 1998; Rayner, 1998; Nobre, 2004; Findlay, 2005; Rushworth & Ellison, 2005

[3] Klein & Pontefract, 1994; Stelmach, Campsal & Herdman, 1997; Bichot & Schall, 2005

[4] According to Julesz, 1981

The task is administered under two conditions: a “gap” and an “overlap” condition. In the gap condition, the fixation stimulus disappears shortly before the discriminative stimulus appears, whereas in the overlap condition the discriminative stimulus is shown while the fixation stimulus remains present. For the central presentation of the critical stimulus, the fixation stimulus disappears in the gap condition shortly before the appearance of a discriminative stimulus, while in the overlap condition the fixation stimulus changes suddenly to a critical stimulus (see Fig.2.10).

“Gap / Overlap”- paradigm for eye-movement			
Position of the stimulus:	left	central	right
Central fixation stimulus:			
Condition “Gap” with target left			
Condition “Gap” with non-target right:			
Condition “Overlap” with target right:			
Condition “Gap” / “Overlap” with central target:			

Fig. 2.10: Examples of trials under the gap and overlap conditions with different target stimulus positions (left, centre, right).

The gap and overlap condition address different functions. In the gap condition, the disappearance of the fixation stimulus represents a warning signal that triggers an alertness reaction[1]. In the overlap condition, the presence of the fixation stimulus requires a disengagement[2] of the stabilised gaze direction from this central fixation stimulus before a saccadic movements can be executed.

Procedure

In the gap and overlap condition, 10 critical and 10 neutral stimuli are presented in each of the left, central and right positions (with the exception of “overlap” central where there is no neutral stimulus). The test therefore comprises of 110 trials.

Reactions with key “1”

Test duration (without pre-test and instruction): ca. 8 minutes.

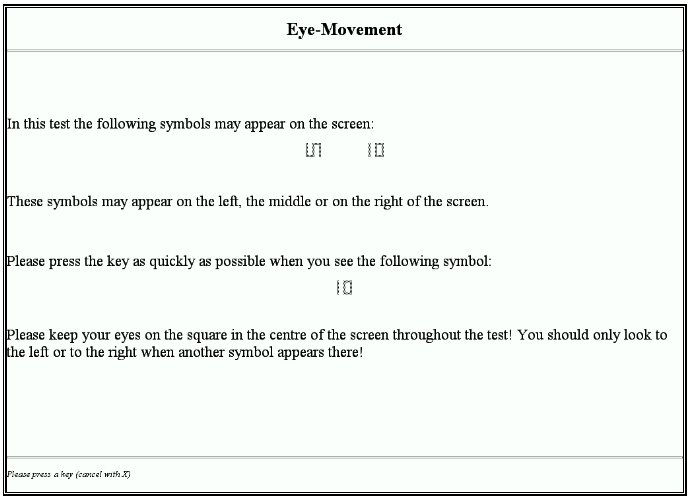


Fig. 2.11: Instruction for Eye-Movement

1 Kingstone & Klein, 1993

2 Posner, Walker, Friedrich & Rafal, 1984

Results
For the gap and the overlap condition, the mean, the median and the standard deviation of RT, the number of correct, errors and omissions as well as outliers and anticipated responses will be shown for the target of stimulus positions left, central and right, respectively.

This procedure has not yet been normed.

Interpretation
For the interpretation, the left-right differences in saccadic latencies should first be inspected. Much longer saccadic latencies to the contralesional side are normally observed for parietal lesions. This is immediately recognisable in the test specific graph.

The reaction time differences for the different positions in the gap and overlap conditions (distance between the curves for the gap and overlap condition in the test-specific graph: see Fig.2.12) provide information about the process of disengagement of attentional focus. In the case of frontal symptoms, extremely short disengagement processes to the left or right are frequently observed, which is an indication of a deficit of focused attention, and frequently associated with increased distractibility.

Much longer reaction times to the central stimulus in the overlap condition compared with the gap condition and even slower reactions in comparison with the peripheral target stimuli are indicative of a frontal symptomatic. This points to a deficit of focused attention, because the change from the neutral to the critical stimulus is registered with some delay in even though the eyes are directed at the fixation stimulus.

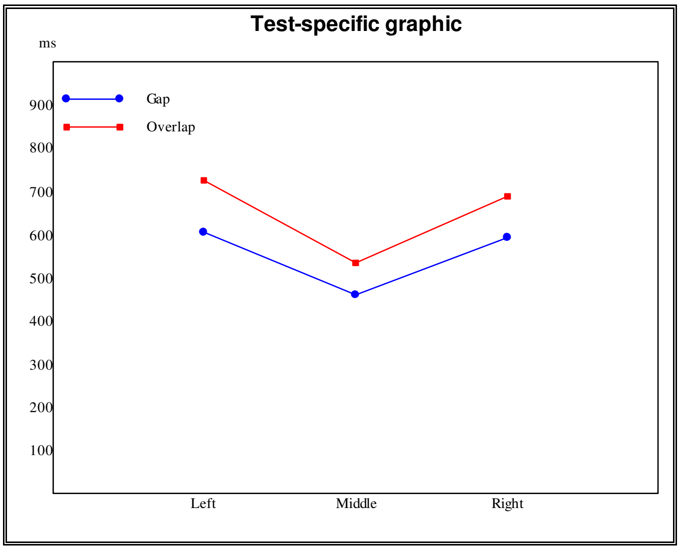


Fig. 2.12: Reaction times of a healthy subject to critical stimuli in the positions left, middle, and right for the gap and overlap condition

Case example: Eye-Movement

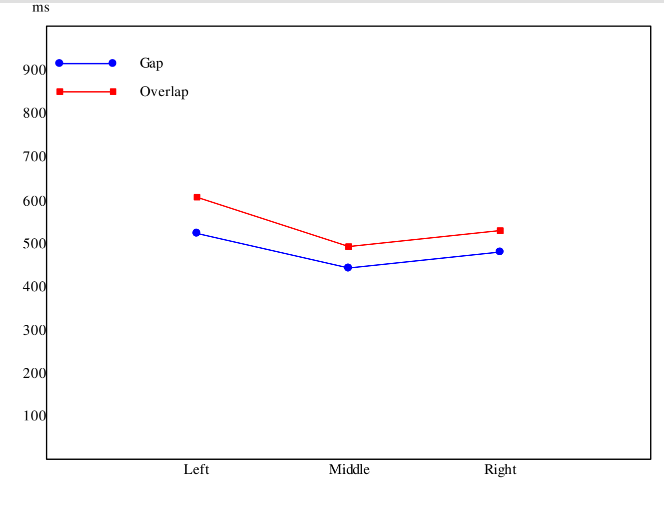
Patient: 51 years-old, female, "O"-Levels
Aetiology: Right basal ganglion infarct with acute haemorrhage
Time since brain damage : 1 months
Impairment: left hemiplegia

Results

Condition	Mean	Median	%	Stddev	%	Correct	Errors	%	Omiss.	%	Outliers	Anticip.
Gap Left	537	524		72		10	0		0		0	
Gap Middle	446	444		27		10	0		0		0	
Gap Right	493	481		55		10	0		0		1	
Overlap Left	606	609		63		10	0		0		1	
Overlap Middle	532	494		89		10	0		0		1	
Overlap Right	521	530		57		10	0		0		0	
Total	522	503		77		60	0		0		3	0

F (condition): 5.75103
F (position): 10.1772
F (condition x position): 1.0276

Test-specific graph



Assessment

Normative values for this test procedure are not yet available for this test procedure. The individual test profile of this patient may nevertheless be interpreted. The patient shows prolonged reaction times to stimuli on the contralateral side of the lesion in both the gap and the overlap condition (F-value Position: 10.1772). This attentional asymmetry thus correlates with the side of the cerebral lesion. It is further evident that the central stimulus is recognised more quickly, whereas the identification of the lateral stimulus requires an additional saccade.

2.6 Flexibility

Paying attention to specific aspects in our surrounding world is not a static process. On the contrary, it is essentially an active process by which, in the words of James[1], we turn our attention away from objects in order to effectively deal with other objects. In daily life and in the execution of work, it is necessary to gear our attention again and again to newly relevant aspects of a situation. Setting up a work schedule requires the permanent reorientation of the attentional focus to the individual steps involved and their adaptation to the given situation and possibilities. A pre-condition of this is an efficient internal control of attentional focus in order to keep in view those aspects that are important for realising behavioural goals. This means that the flexible orientation of attentional focus is an important prerequisite for situationally adaptive behaviour. In the words of Esslinger and Grattan[2]: “Cognitive flexibility commonly refers to the ability to shift avenues of thought and action in order to perceive, process and respond to situations in different ways. It is an essential feature of adaptive human behaviour that is frequently altered by brain damage.”

In accordance with this, Lezak[3] emphasises the importance of flexibility in clinical settings. “The capacity for flexibility in behaviour extends through perceptual, cognitive, and response dimensions. Defects in mental flexibility show up perceptually in defective scanning and inability to change perceptual set easily. Conceptual flexibility appears in concrete or rigid approaches to understanding and problem solving, and also as stimulus-bound behaviour in which these patients cannot dissociate their responses or pull their attention away from whatever is in their perceptual field or current thoughts.... Inflexibility of responses results in perseverative, stereotyped, nonadaptive behaviour and difficulties in regulating and modulating motor acts.”

Stereotypical, inflexible behaviour is often observed after damage to the prefrontal cortex[4]. Reduced flexibility is a particular problem in everyday life, because the patient as a result has great difficulty in adjusting to new situations and requirements. Patients with limited flexibility frequently complain, for example, of their difficulties in following the course of a conversation involving several people. Many patients therefore feel overtaxed in situations with several other individuals and withdraw from such situations.

On the other hand, a decline in flexibility may really be seen as characteristic of human ageing processes. Older people have increasing difficulty in adjusting to unexpected situations and in responding appropriately. This also applies, for example, in road traffic situations, in which older subjects often stand out because of their slow driving behaviour, by means of which they try to gain some leeway in adapting to possible, unexpected situations.

The flexible control of attentional focus comprises of almost all levels of perception, behaviour, and cognitive processing and therefore does not represent a singular function. Aspects of flexibility are being addressed whenever reference is made to, for example, a “shift” or “orienting” (“covert shift of attention”[5]; “temporal orienting”[6]; “cross-modality shift”[7]; “set shifting”[8]). Flexibility is not a singular process, it is the result of a hierarchically

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[1] James, 1890, p. 404
[2] Esslinger & Grattan, 1993, p. 17
[3] Lezak, 1995, p. 666
[4] Luria, 1966; Sandson & Albert, 1984; Goldberg & Binder, 1987; Freedman et al., 1998
[5] Posner, 1980; Posner & Peterson, 1990
[6] Nobre, 2004; Griffin & Nobre, 2005
[7] Sutton, Hakerem, Zubin & Portnoy, 1961; Benton, Sutton, Kennedy & Brokaw, 1962
[8] e.g. Brown & Marsden, 1988; Rogers et. al.; 1998

structured system of specific functions that are active at every level of processing from the control of sensory focus to the strategic control of behaviour and of behavioural goals.

Although deficits in the flexible control of attentional focus at different levels of processing can result in limitations in specific everyday situations, the most far-reaching consequence of this is loss of control in pursuing behavioural goals.

Task

This procedure is a “set shifting” task. Either a letter and a number (condition “verbal”) or angular and round figures (condition “non-verbal”) are simultaneously presented to the right and left of the centre of the monitor. For both conditions, there is the possibility to choose between a simple test mode with a fixed target stimulus (e.g. requiring a reaction only to letters or only to the angular shapes) or a complex mode, with alternating types of target stimuli (i.e. requiring a reaction to the complementary target stimulus on an alternate basis from trial to trial, for example, the sequence under the condition “verbal”: letter – number – letter – number …). The subject has the possibility to press a left or a right key. The subject’s task is to press the left or right key according to whether the target stimulus (e.g. letter or number) appears to the left or the right of the centre of the monitor.

Procedure

Difficulty is frequently encountered in explaining the concept of alternating target stimuli to patients with a frontal symptomatic or an onset dementia. To ensure that the task is understood, especially in these cases, a simple mode of execution should be chosen, that is, the patient first completes the task with non-alternating target stimuli, for example, always letters (or always angular shapes). The problems in understanding often render it necessary to administer the pre-test repeatedly. How often the pre-test should be performed has yet to be determined. Some colleagues share the view that the number of repetitions necessary to achieve comprehension is in itself an important diagnostic criterion.

The simple condition (without alternation of the target stimulus) comprises 50 trials, the complex condition (with alternating target stimulus) 100 trials.

The respective target stimulus is marked at the beginning of the test as well as for trials following an error by a surrounding square. For this reason, all trials where the target stimulus is highlighted in this way are not included in the assessment.

Attention: Key “1” = left, key “8” = right!

Test duration (variable because the test is reaction-dependant, without pre-test and instruction):

- simple conditions: at least 1.5 minutes
- complex conditions: at least 3.5 minutes

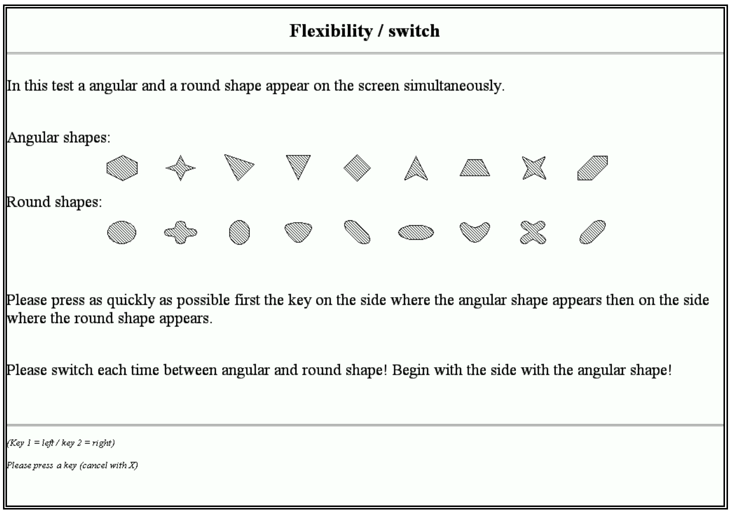


Fig. 2.13: Instruction for Flexibility, Condition “non-verbal”

Results

The mean, median and standard deviation of RT as well as the number of correct reactions, errors, and outliers are given for the test as a whole.

In addition, indices for the total performance and for “speed-accuracy trade-off” are calculated and displayed. T-values for the median of RT and for the number of errors are entered into the calculation (for details of the calculation see Section 6.1 “Test parameters”).

Note: the sum of correct reactions and errors is smaller in this test than the number of trials, because the trials in which the correct target stimulus is highlighted by a frame (the trial at the beginning of the test and the trials after an error) are not included in the assessment.

Normative values are displayed for the median and the standard deviation of RT, for the number of errors, the total performance-, and “speed-accuracy trade-off”-index.

Interpretation

The aim of this procedure is to measure flexibility: for the assessment of the performance, both precision and speed should be taken into account. The most important parameters are therefore the number of errors and the median of RT. There is a complementary relationship between these parameters because of a “speed-accuracy trade-off”. Depending on the subject’s chosen strategy, poor performance is characterised by either an increased number of errors or by much slower RT (see Fig. 2.14). For this reason, the total performance-index, based on both the median of RT and the number of errors, may be seen as the most important parameter of performance.

Indices

Total performance: a highly negative value in the total index represents a below-average total performance (high rate of errors and/or slow reactions), the highly positive value represents an above average total performance (few errors, quick reactions). An index of +/- 0 means an average performance.

Speed-accuracy: a negative value in this index (low%-rank) represents a proportionally high rate of error with short reaction times (speed-up based strategy), a positive value (high %-rang) represents a proportionately low rate of error with long reaction times (precision based strategy).

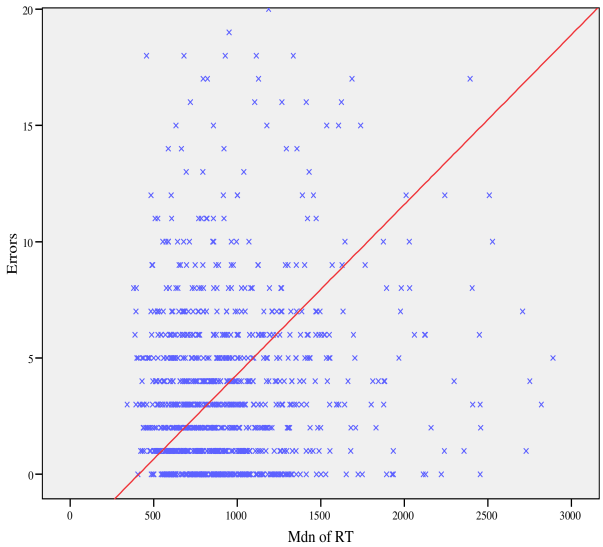


Fig. 2.14: The proportion of reaction time to errors in the reference sample. The subjects below the fitted line pursue an accuracy-based strategy.(few errors and relatively long reaction times); the subjects above this line pursue a speed-based strategy (short reaction times and a relatively large number of errors).

As already mentioned, the number of pre-test repetitions should also be considered in the interpretation of the results for patients with a frontal symptomatic or onset dementia who have difficulty in comprehending the concept of alternating between target stimuli.

Case example: Flexibility

Patient: 68 Years-old, male, High school

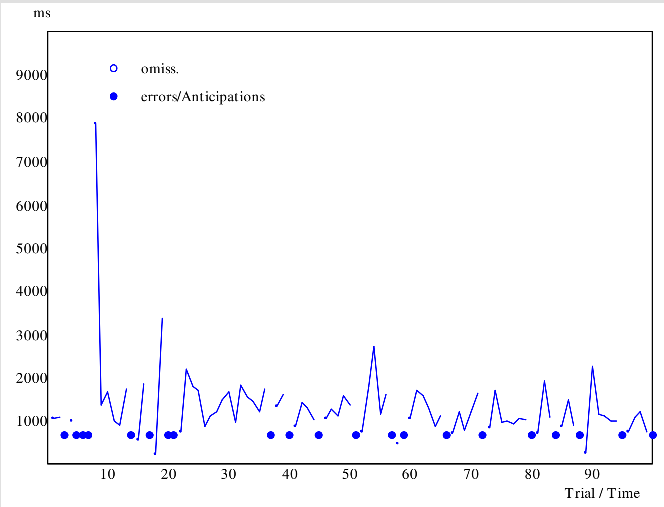
Aetiology: history of years of job-related exposure to perchloroethene

Results

Condition	Mean	Median	%	Stddev	%	Correct	Errors	%	Outliers
With change of hand	1158	1112		249		25	0		1
Without change of hand	1493	1615		381		36	18		1
Letter	1296	1155		357		32	9		1
Number	1412	1413		379		30	9		1
Total	1352	1260	27	369	42	62	18	3	2

Total performance index: -17.675 (% = 4)
"Speed-accuracy"-index: -9.191 (% = 14)

RT-series



Assessment

The high a number of errors shows a distinct deficit of flexibility. This is also apparent in the high negative value of the total performance index. The negative index of the "speed-accuracy trade-off" index indicates that the patient pursued a more speed-based strategy in which an average reaction speed was achieved at the cost of accuracy, as shown by the high number of errors.

2.7 Go/Nogo

An important aspect of behavioural control is the ability to perform an appropriate reaction under time pressure and to simultaneously inhibit an inappropriate behavioural response. The Go/Nogo paradigm[1] was developed to test this form of behavioural control, in which it is important to suppress a reaction triggered by an external stimulus to the benefit of an internally controlled behavioural response. In this paradigm, the focus of attention is directed to predictably occurring stimuli that require a selective reaction, that is, to react or not to react.

A deficit in this form of behavioural control is particularly seen in patients with a frontal symptomatic. These patients frequently show above-average reaction speeds in simple reaction tasks, where as in a Go/Nogo task they show either a much higher number of incorrect reactions, or much higher reactions times compared with the simple reaction task. The latter deficit is indicative of difficulties in decision processing in the control of behaviour. Luria[2] described this as "disturbance of voluntary actions". Investigations with imaging techniques have provided evidence for the role played by frontal structures in executing a Go/Nogo task[3].

Task
Two administrative forms of this test may be administered:

- Test Form "1 of 2" (1 of the 2 stimuli is critical): an up-right ("+") and a diagonal ("×") cross are presented in an alternating sequence on the screen. The subject has to react as quickly as possible with a key press whenever the diagonal cross appears; no reaction is required when the up-right cross appears.
- Test Form "2 of 5" (2 critical stimuli amongst 5 stimuli): A sequence of five squares with different patterns appears on the screen. Two of these squares are defined as target stimuli, upon the appearance of which the subject should react as quickly as possible with a key press; no reaction is required to the other squares.

Different abilities are addressed with the two test forms, for which reason they have different diagnostic relevance:

- In the Test Form "1 of 2" the stimuli are easily distinguishable and trigger an immediate impulsive response. This largely corresponds to the notion of a go/nogo-task, that is, of exercising control over an appropriate behaviour. The findings of Lavie and colleagues may provide a background for this effect[4]. They showed that a distracting stimulus is most effective under a low perceptual load, whereas under a higher perceptual load the distractor is filtered out at an earlier level of processing.
- In the Test Form "2 of 5" the identification of a stimulus requires a higher memory demand through which the reaction latency clearly increases and the immediate impulsive reaction is largely suppressed[5]. This test variant therefore corresponds more closely to a choice reaction task.

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[1] Drewe, 1975a; 1975b
[2] Luria, 1996
[3] Kawashima et al., 1996; Watanabe, Sugiura, Sato, et al., 2002
[4] de Fockert, Rees, Frith & Lavie, 2001; Lavie, Hirst & de Fockert, 2004; Lavie, 2005b; Lavie & de Fockert, 2005
[5] Cohen & Magen, 2005

The Test Form "1 of 2" is therefore recommended for examining behaviour control in the sense of Luria[1].

Administration

- In the Test Form "1 of 2" 40 stimuli are presented in the middle of the screen (20 critical stimuli "×" and 20 noncritical stimuli "+"). The presentation of the stimulus is short (200ms) in order to provoke a rapid reaction.

Reactions with key "1"

The test duration (without pre-test and instruction): 2 minutes.

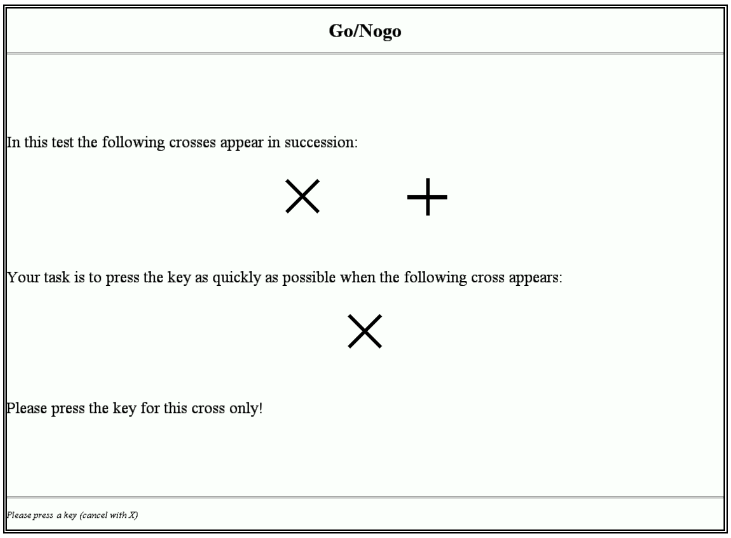

Fig. 2.15: Instruction for Go/Nogo, Test Form "1 of 2"

- In the Test Form "2 of 5" 60 stimuli are presented in the middle of the screen (24 critical stimuli).

Reactions with key "1"

The test duration (without pre-test and instruction): 2'45" minutes.

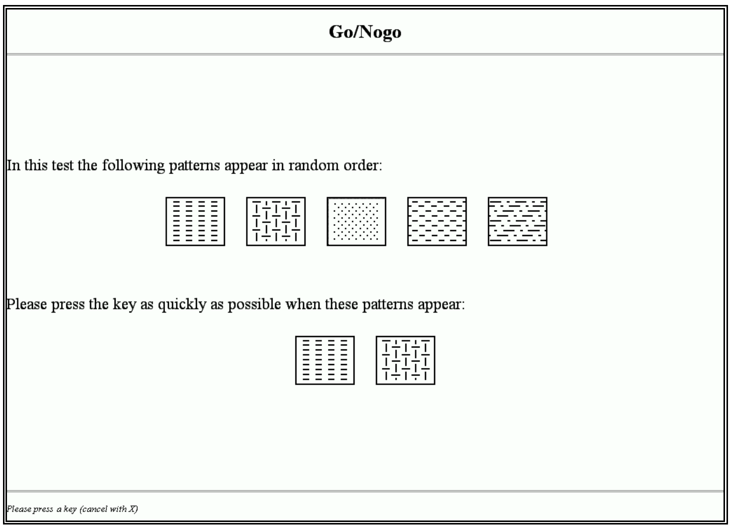

Fig. 2.16: Instruction for Go/Nogo, Test Form "2 of 5"

[1] Luria, 1996

Results
For the whole test, the mean, median and standard deviation are provided as values for RT as well as the number of correct reactions, errors, omissions and outliers.

Normative values are displayed for the median and standard deviation of RT as well as for incorrect reactions and omissions.

Interpretation
The number of incorrect reactions in the test condition “1 of 2” is especially important in the assessment of the subject’s ability to control reactions. An increased number of errors is an indicator of impaired impulse control. A deficit in impulse control can also be seen in the test Alertness in the condition “with warning tone” in which an increased number of anticipatory responses, of outliers (lapses of attention) and / or of an increased variability in RT may be observed. The reason for this is that the warning signal triggers an impulsive reaction. Provided that an anticipatory reaction does not occur, the suppression of the impulsive reaction results in increased reaction latency to the target stimulus.

The median of RT is a further important parameter, giving an indication of the speed of decision processing. For this, the reaction times in the test Alertness (without warning tone) should be drawn upon for comparison. Very short reactions are frequently observed in the test Alertness in patients with a frontal symptomatic, whereas the reaction times in the test Go/Nogo are distinctly slower (for an example, see Fig. 2.17).

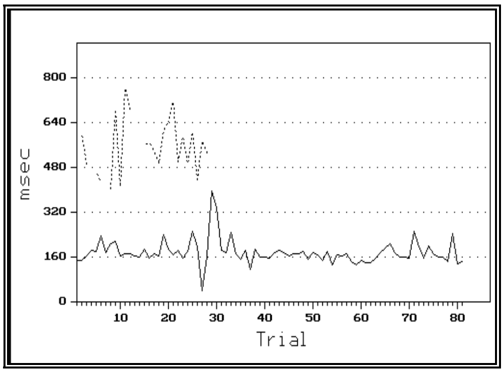

Fig. 2.17: Reaction time course in the test Alertness (lower continuous curve) and Go/Nogo (upper dotted curve) of a patient with frontal lesion.

Case example: Go/Nogo "1 of 2":

Patient: 54 years-old, male, "A"-Levels
Aetiology: Intracerebral left fronto-parietal bleeding with OP
Time since damage occurred: 6 years
Impairments: Nonclassified aphasia with mild apraxia and dysarthria

Results

Condition	Mean	Median	%	Stddev	%	Correct	Errors	%	Omiss.	%	Outliers
Total	492	502	14	81	34	20	5	7	0	> 14	0

Assessment

The standard deviation of RT is within the average range in this patient. However, median of RT and rate of errors are increased. Given that the results contain not a single omission of critical stimuli, this could on the whole be a manifestation of an augmented impulsive tendency. The patient obviously experiences difficulty in suppressing undesired reactions.

Case example: Go/Nogo "2 of 5":

Patient: 82 years-old, male, "A"-Levels
Aetiology: Unexplained intrasellar tumor; ischemic brain insult in the region supplied by the left middle cerebral artery
Time since damage occurred: 18 months

Results

Condition	Mean	Median	%	Stddev	%	Correct	Errors	%	Omiss.	%	Outliers
Total	1063	894	< 1	358	< 1	17	1	38	7	2	0

Assessment

At a percentile of <1, the median and standard deviation of RT are clearly impaired. The patient committed only one error, but his number of omissions is clearly below-average. This can be taken as evidence of a highly impaired response selection performance.

2.8 Incompatibility

Incompatibility occurs in a conflict situation in which divergent stimulus information has to be processed in parallel, thus triggering different reaction tendencies. The Simon[1] and the Stroop[2] effects (in the Colour-Word Interference Test) are classic examples of this effect. The Stroop test, in particularly, is one of the procedures frequently applied in investigating patients with frontal lesions. Although the results in the literature are contradictory[3], a meta-analysis has demonstrated the sensitivity of the Stroop test for frontal lesions[4]. In contrast to the Stroop test, the Simon paradigm has apart from its use in this test battery, rarely been used in the examination of brain-damaged patients.

The less well-known Simon paradigm is based on a cueing procedure in which a cue is provided in the left or right visual field indicating with which hand, a response should be executed. A conflict arises when the left or right spatial position of the cue does not correspond with the left or right cued position of the response. This conflict is however characterised by rapid resolution because the impulsive reaction quickly subsides upon appearance of the cue stimulus in the right or left visual field[5].

Task
The present procedure tests the interference tendency in terms of stimulus-reaction incompatibility (Simon effect)[6]. For this test, arrows that are directed to the left or the right are presented on the left or the right of a fixation point. Depending on the direction of the arrow, the test person should respond with the right or left hand irrespective of the side on which the arrow is presented. The compatible condition is when the side of the stimulus in the visual field and the side of the responding hand (direction of arrow) correspond. The incompatible stimulus condition is when the side of presentation of the arrow and the direction in which it points do not correspond (see Fig. 2.18).

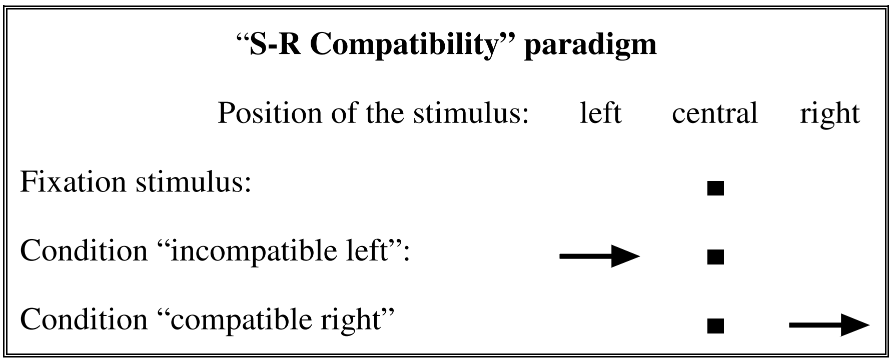

Fig. 2.18: In the S-R paradigm, arrows that are directed to the left or the right are presented to the left or the right of the fixation stimulus. The direction of the arrow indicates, independently of the side on which it appears, the hand with which a response should be made. The compatible condition is when the direction of the arrow and the side of its presentation match. The incompatible condition is when the direction of the arrow and the side of its presentation do not match.

For cueing the hand to respond, preference was given to arrows, which are processed automatically. Each stimulus presentation is announced by a warning tone in order to

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[1] Craft & Simon, 1970; Simon & Berbaum, 1990
[2] Stroop, 1935
[3] e.g. Perret, 1973; McLean, Temkin, Dikman & Wyler, 1983; Stuss et al, 1985
[4] Demakis, 2004; Langenecker, Nielsen & Rao, 2004; Alvarez & Emory, 2006
[5] Cohen & Magen, 2005; Wascher, 2005
[6] Nicoletti & Umiltà, 1991; Drewe, 1975b; Cohen & Magen, 2005

encourage a high reaction preparedness. The presentation of the stimulus is short (100ms) in order to additionally provoke a rapid reaction.

Procedure

The procedure comprises 60 stimulus trials (15 compatible and 15 incompatible Trials in the right and in the left visual field).

Attention: Key "1" = left : the arrow points to the left
Key "8" = right : the arrow points to the right

The test duration (without pre-test and instruction): ca. 3 minutes.

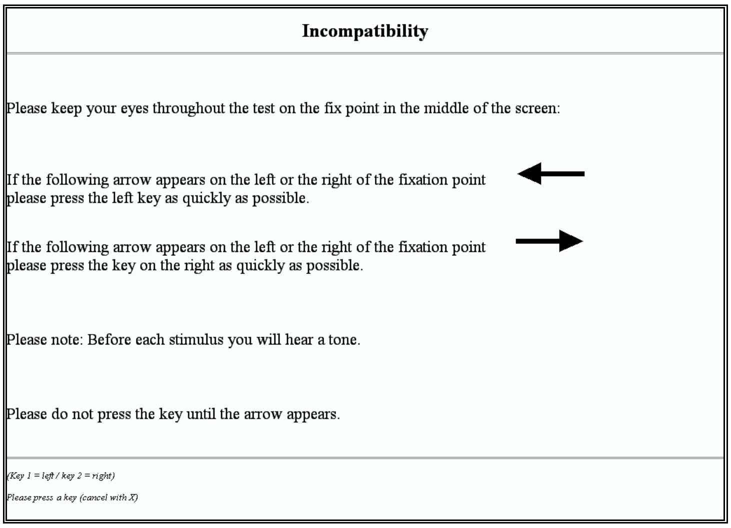


Fig. 2.19: Instruction for Incompatibility

Results

Mean, median and standard deviation of RT, the number of correct reactions, errors, omissions, outliers and anticipations (reactions to the cue stimulus) are provided for the left and right presentation side in the compatible and incompatible trials as well as for all compatible and incompatible trials and for the total test. "Compatible / Incompatible" refers to stimuli for which the direction of the arrow and the side of its presentation correspond or do not correspond, respectively. "Left visual field / Right visual field" refers to the side where the stimulus was presented. For example, "Incompatible - Left visual field" means that the arrow was presented on the left side but was pointing to the right.

Furthermore, the output shows the result of a two-factor variance analysis with the F-values for "visual field" (side of stimulus), "hand" (direction of arrow) and the interaction "visual field x hand".

Normative values for the median and the standard deviation of RT, for the errors and for the F-values of the variance analysis are provided for all conditions.

Interpretation

The incompatibility effect can manifest itself in the incompatibility condition compared with the compatibility condition both in the F-value "validity of the cue" and in an increased number of errors.

Take note however that with slowed reactions the conflict is resolved before the execution of a reaction and in this way the incompatibility effect disappears.

F values

F(Visual field): this value refers to the main effect “visual field” of the variance analysis. Impairment is indicated by a low percentile. The subject reacts more slowly to stimuli in one of the visual hemifields. Accordingly, an average or above-average percentile is normal because there are no obvious differences between the visual hemifields.

F(Hand): The main effect “hand” in the variance analysis. A low percentile indicates a clear difference in reaction time between the right and left hand.

F(Visual field x Hand): variance analysis with the interaction of factors “visual field” and “hand”. A high percentile indicates the absence of an incompatibility effect. This can for example occur when overall there are strongly slowed reaction times and the conflict that would be expected between the stimulus and reaction is resolved before the response. An incompatibility effect can always be expected in healthy subjects, normally resulting from slow reactions when the arrow direction and the side of the response hand do not correspond. A lower percentile indicates a very prominent incompatibility effect. An average percentile reflects the expected incompatibility effect, that is, shorter reaction times in compatible compared with incompatible conditions.

Case example: Incompatibility

Patient: 69 years-old, male, “A”-Levels

Aetiology: Brief periods similar to absence status; probable epilepsy; mild microangiopathy; EEG: strong left temporal dysrhythmia with sharply peaking alpha waves

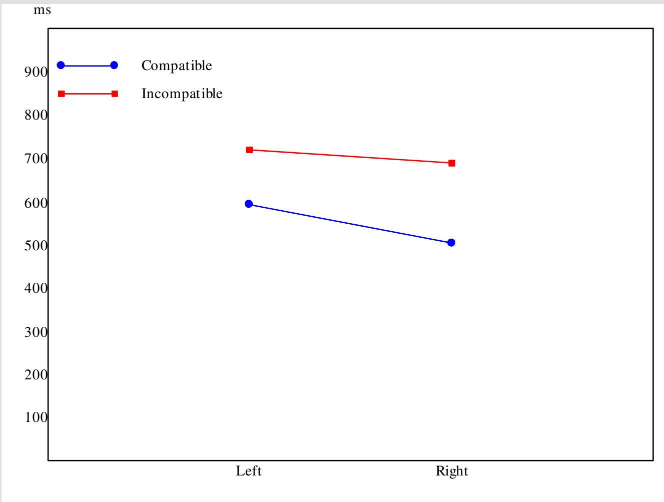
Time since damage occurred: 5 years

Results

Condition	Mean	Median	%	Stddev	%	Correct	Errors	%	Omiss.	Outliers	Anticip.
Compatible - Left visuel field	688	595	12	237	7	13	4	4	0	0	
Compatible - Right visuel field	574	505	27	148	18	12	3	4	0	1	
Compatible	636	583	14	205	8	25	7	4	0	1	
Incompatible - Left visuel field	715	721	12	156	21	13	1	69	0	0	
Incompatible - Right visuel field	734	690	14	152	27	7	4	14	0	0	
Incompatible	722	708	12	151	27	20	5	27	0	0	
Total	675	640	12	186	16	45	12	8	0	1	0

F(Visual field): 0.717 (% = 46)
F(Hand): 1.371 (% = 42)
F(Visual field x Hand): 2.725 (% = 73)

Test-specific graph



Assessment

The patient does not show a clear incompatibility effect (interaction Visual field x Hand in the variance analysis: percentile = 73) and no noteworthy reaction time differences in the comparison between the two visual hemifields (percentile 46) and the hands (percentile 42).

2.9 Sustained Attention

Sustained attention is not an ability that can be captured by a single type of task. On the contrary, continued maintenance of attention is required in tasks with very different cognitive demands, ranging from simple stimulus detection tasks to tasks with a high cognitive load.

Concentrating on a task is a typical requirement in working life. This involves focusing attention on a mentally demanding activity for a sustained period of time. A large number of perceptual, practical and cognitive activities place demands on our concentration. In general, healthy individuals experience no difficulty in maintaining their attention over a long period of time, especially when the tasks are interesting. In contrast, patients, especially after a traumatic brain lesion, frequently report difficulties with tasks that require their attention for a longer period of time. This is often an important handicap to their chances of returning to their job. In the words of Lezak[1]: "Impaired attention and concentration are among the most common mental problems with brain damage. When this sort of impairment occurs, all the cognitive functions may be intact and the person may even be capable of better than average performance, yet overall cognitive productivity suffers from inattentiveness, faulty concentration and consequent fatigue."

In this context, it may be asked to what extent sustained attention in mentally demanding tasks should be differentiated from vigilance. A vigilance experiment is, with its extremely monotone stimulus conditions, clearly distinguishable from an experiment with variable stimulus conditions or a task with higher cognitive requirements. It may be assumed that this distinction is not simply conceptual in nature, but that different processes underlie a vigilance decrement on the one side and fatigue in cognitively demanding tasks on the other. This distinction is of primary clinical relevance, because demands on vigilance performance are rather the exception than the rule in everyday life and at work, in contrast to the sustained attention required by tasks with higher cognitive demands.

Therefore, examination of vigilance performance would seem likely to have poor ecological validity in patients with brain damage. In accordance with this view, Davies and Parasuraman[2] strongly suggested abandoning examinations of vigilance in a narrower sense. They demand "... broadening of the scope of laboratory research, so that tasks with a complex response requirement, in which observation is not necessarily continuous and uninterrupted, and in which different types of multi-dimensional signals are presented which varying probabilities of occurrence during the work period, may be more extensively investigated in situations approximating more closely to the operational environment" (p. 227). In agreement with this, Mathews, Davies and Holley[3] state that only demanding tasks with a higher frequency of stimuli are able to predict performance in attentionally challenging situations. This view was confirmed in a study by Berberich[4] in which the predictive validity of this test for return to work after cerebral damage was investigated. Patients who were able to process the more complex condition of this test resumed their work to a greater extent and reported much fewer attentional problems at work.

Task

In this test, a sequence of stimuli is presented on the monitor. The stimuli vary in a range of feature dimensions: colour, shape, size and filling (see Fig. 2.20). A target stimulus occurs whenever it corresponds in one or the other of two predetermined stimulus dimensions with

[1] Lezak, 1995

[2] Davies & Parasuraman, 1982

[3] Mathews, Davies & Holley, 1993

[4] Berberich, 1996

the preceding stimulus (e.g. the same shape but with different colour, size and filling). In order to adapt the difficulty of the task to the performance level of a subject, different levels of difficulty, that is, reactions to "shape" only or to "colour or shape", may be selected.

According to Parasuraman[1], this kind of examination corresponds to a "successive discrimination task" in contrast to a "simultaneous discrimination task" in which a pre-defined critical stimulus has to be detected. The "successive discrimination task" generally places higher demands on cognitive resources, especially on working memory, because each presented stimulus has to be maintained for a short period and compared with the following stimulus.

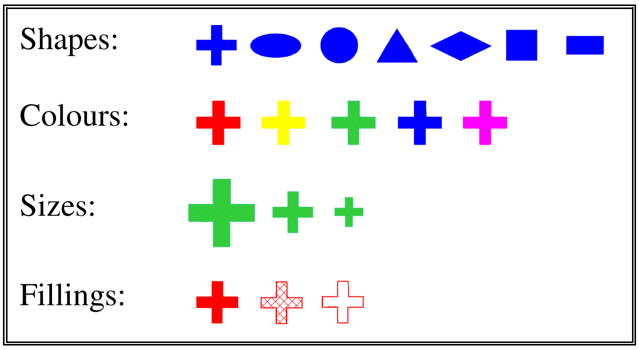


Fig. 2.20: The stimulus dimensions

Besides working memory, other components of attention are involved in this type of task, depending on the chosen level of difficulty. As the stimuli can vary in several stimulus dimensions and given that only one or two dimensions are critically relevant, this task requires not only the identification of identical stimuli but also the discrimination of one or more critical stimulus dimensions of continuously varying stimuli, a demand on selective attention. The essential point of this kind of task is that successful performance requires a purely internal control of attentional focus. It is therefore a pure concentration task.

Procedure

In both conditions of this test ("shape" or "colour or shape") 450 stimuli are presented in regular intervals. The number of critical stimuli is 54 (18 per interval of 5 minutes).

Reactions with key "1"

Test duration (without pre-test and instruction): 15 minutes.

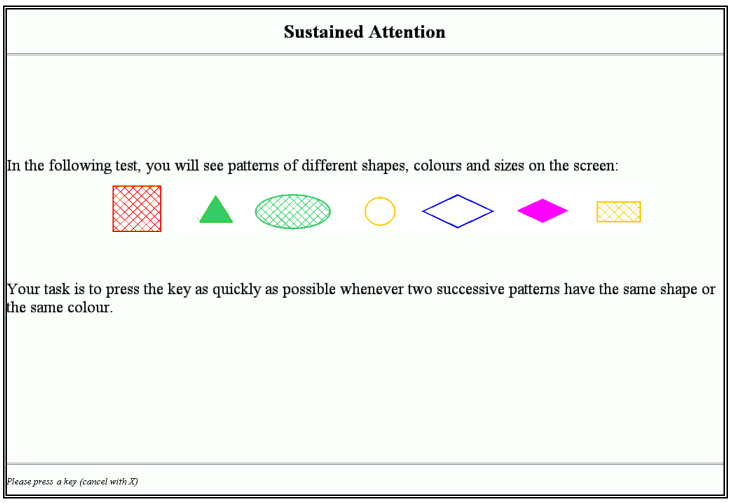


Fig. 2.21: Instruction for Sustained Attention, Condition "Colour or shape"

[1] Parasuraman, 1998

Results

The mean, median and standard deviation of RT and the number of correct reactions, errors, omissions and outliers are given for the total test as well as for each of the five-minute interval.

Normative values for the median and the standard deviation of RT, for the errors and for the omissions are provided for condition 2 (“colour or shape”).

Interpretation

The number of omissions is the most important measure of concentration while performing this task. An attenuation in concentration over the course of a test is reflected in an increase in the number of omissions over time. A look at the graph “RT-series” provides additional information about the precise distribution of omissions. Also, a phasic attenuation in concentration may be observed in some cases. The number of incorrect reactions (errors) during the course of the test can be drawn on as an additional criterion, because this indicates that the subject may have noticed that he or she was not concentrating and is therefore uncertain whether or not a target stimulus happened. The parameters of reaction time are of secondary importance in this test.

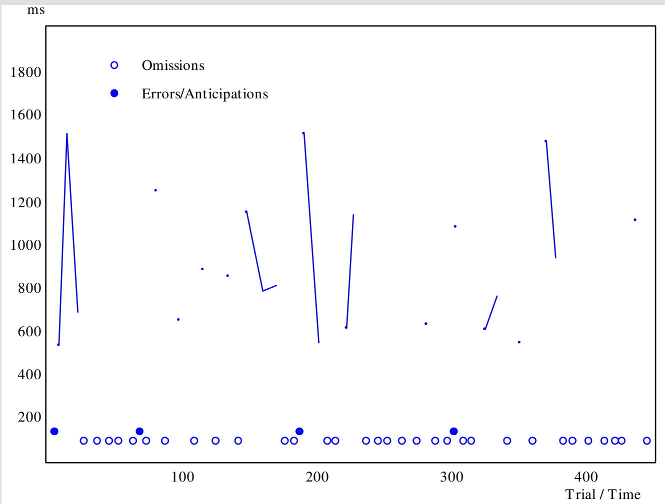
Case example: Sustained Attention condition “Colour and shape”

Patient:	52 years-old, male, secondary
Aetiology:	subarachnoidal bleeding
Time since damage occurred:	4 years
Deficiency:	rapid fatigue

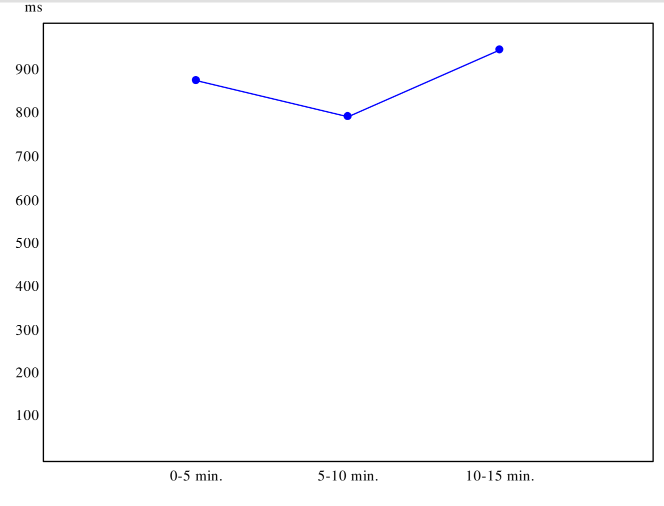
Results

Condition	Mean	Median	%	Stddev	%	Correct	Errors	%	Omissions	%	Outliers
0-5 min.	945	874	2	335	1	8	2	62	10	< 1	0
5-10 min.	868	791	10	347	2	7	1	62	11	< 1	0
10-15 min.	938	947	4	324	2	7	1	58	11	1	0
total	918	837	5	321	< 1	22	4	**54**	32	**< 1**	0

RT-series



Test-specific graph



Assessment

A striking aspect of this patient's performance is the great number of omissions throughout testing; this evidences a lack of concentration but no specific sign of fatigue. The few false reactions may be the consequence of slow reactions that were no longer within the permissible response time.

2.10 Vigilance

The measurement of vigilance is based on a paradigm stemming from Mackworth[1]. This investigative approach concerns the detection of rare critical events that are difficult to discriminate and presented under extremely monotonous stimulus conditions. The starting point for Mackworth was the examination of performance of radar operators over a sustained period of time. He found a characteristic fall in detection performance over the course of the examination, the fall being referred to as "vigilance decrement". Such a decrement in detection performance is already apparent after a few minutes in normal healthy persons[2].

Vigilance is a form of sustained attention in which the attentional focus is maintained by exerting mental effort over a longer period of time. The effect of monotony is however an essential aspect for the level of performance under vigilance conditions. This effect serves to clearly differentiate the vigilance paradigm from other tasks with higher cognitive demands. It would be more appropriate to refer to the latter as sustained attention in a "narrower sense" or as concentration.

The question as to what extent vigilance, sustained attention or concentration performance represent different processes is of high clinical relevance. This is because everyday and workplace demands on vigilance performance in a narrower sense are rather an exception compared with the longer-lasting focusing of attention on tasks with higher demands on processing capacity. The ecological validity of a vigilance test is therefore somewhat limited. In view of this, Davies and Parasuraman recommended limiting examinations of vigilance performance in this narrow sense[3]. They advocate "... broadening of the scope of laboratory research, so that tasks with a complex response requirement, in which observation is not necessarily continuous and uninterrupted, and in which different types of multi-dimensional signals are presented with varying probabilities of occurrence during the work period, may be more extensively investigated in situations approximating more closely to the operational environment." Despite these objections, many authors equate vigilance with sustained attention[4].

Neuropsychological examinations of patients with traumatic brain injury also indicate that vigilance and sustained attention are different forms of focusing of attention. The majority of patient-based investigations of vigilance performance in a narrow sense reveal an apparently unimpaired performance, that is, show no vigilance decrement, even after severe traumatic brain injury[5]. On the other hand, patients with brain damage typically complain of being quickly exhausted in everyday activities and of needing frequent breaks during such activities.

A vigilance test should therefore be administered only for very specific questions. Examples of this would be conditions following chronic insomnia or an obstructive sleep apnoea syndrome[6] that are frequently associated with considerable daytime tiring and severe difficulties in keeping awake in certain situations (e.g. driving a car during light traffic conditions).

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[1] Mackworth, 1948

[2] Parasuraman, Warm & See, 1998

[3] Davies & Parasuraman, 1982, p. 227

[4] e.g. Parasuraman, 1984; Coull et al. 1996; Parasuraman, 1998; Parasuraman, Warm & See, 1998; Milstein, Dalley & Robbins, 2005

[5] Brouwer & van Wolfelaar, 1985; van Zomeren et al., 1988; Stuss & al., 1989; Parasuraman & al., 1991; van Zomeren & Brouwer, 1994; Spikman et al., 1996

[6] Redline, Strauss, Adams et al., 1997; Findley, Suratt & Dinges, 1999; Adams, Strauss, Schluchter. & Redline, 2001; Beebe, Groesz, Wells et al., 2003; Mazza, Pepin, Naegele et al., 2005

As a rule, testing of sustained attention for everyday or work-related demands seems better suited for patients with brain damage in order to provide a better prediction of performance[1]. The ethical aspect needs to be borne in mind when considering whether too much is being expected in a vigilance examination of patients with considerably reduced mental load capacity, especially in view of the limited ecological validity of this form of examination.

Tasks

Three test conditions are available for the vigilance examination:

- an auditory task,
- a visual task “jumping square”, and
- a visual task “moving bar”.

The requirement for a vigilance test is met in all three conditions, that is, low frequency of critical stimuli under monotone task conditions. In addition to vigilance performance, the subject’s exertion of effort is also measured by this sort of task.

- The auditory condition: an irregular sequence of high and low tones is presented through a loudspeaker. When the regular sequence is interrupted by two successive high or low tones, the subject should respond by pressing the reaction key as quickly as possible.
- The visual condition “jumping square”: two squares are presented one above the other in the middle of the screen between which a grate pattern “jumps” up and down. From time to time this sequence of movements is interrupted in that the raster appears twice in succession in the same square, upon which the subject should respond as quickly as possible by pressing the reaction key.
- The visual condition “moving bar”: a light-coloured strip moves up and down in the centre of the screen, the deflection of the vertical movements from the centre varying in extent. On rare occasions, the upward deflection is much larger. In this case, the subject has the task of pressing the reaction key as quickly as possible.

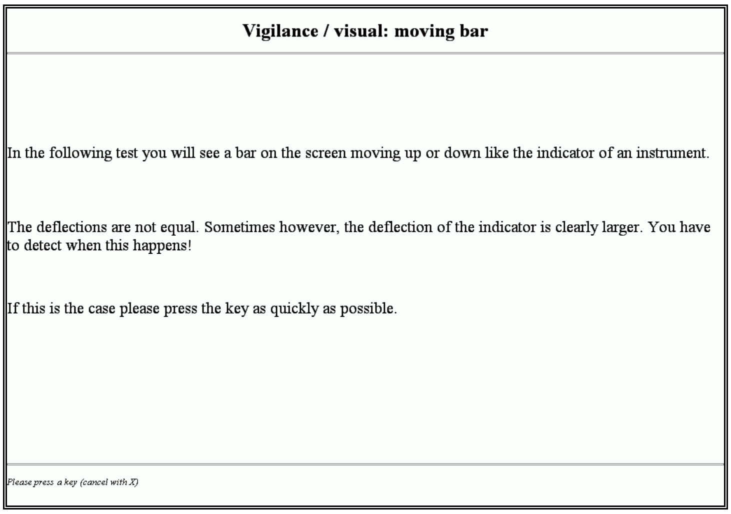
Procedure

There are 36 critical stimuli in all three conditions (in each test, 18 per test half) with a total of 1200 stimuli in the auditory condition and visual condition “jumping square” and 2800 stimuli in the visual condition “moving bar”.

Reactions with key “1”

The test duration time (without instruction and pre-test): 30 minutes.

[1] Berberich, 1996; Robertson, Manly, Andrade, Baddeley & Yiend, 1997


Vigilance / visual: moving bar

In the following test you will see a bar on the screen moving up or down like the indicator of an instrument.

The deflections are not equal. Sometimes however, the deflection of the indicator is clearly larger. You have to detect when this happens!

If this is the case please press the key as quickly as possible.

Please press a key (cancel with X)

Fig. 2.22: Instruction for Vigilance, visual, condition “moving bar”

Results

Results are provided for the first and second test halves as well as for the total test, including average mean, median and standard deviation of RT as well as the number of correct reactions, errors, omissions, outliers, and anticipations.

Normative values for the median and standard deviation of RT, for misses and false alarms are provided for the auditory condition and for the visual condition “moving bar”.

The visual condition “jumping square” has yet to be normed.

Interpretation

The main parameter for vigilance performance is the vigilance decrement, that is, the number of misses over the course of testing. To assess the vigilance decrement, the comparison should be drawn between the number of misses between the first and second halves of the test. Inspection of the graph “RT-series” provides additional information about the exact distribution of misses. The number of false alarms over the course of the test can be used as a secondary criterion. The parameters of the reaction times are of lesser importance in this test.

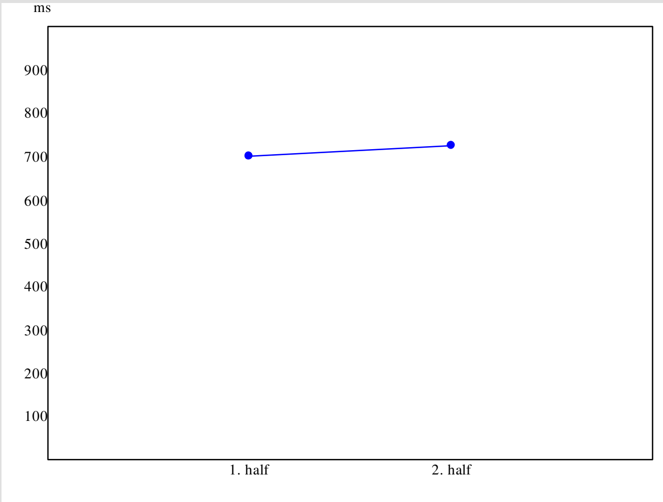
Case example: Vigilance / "moving bar"

Patient: 59 years-old, male, "O"-Levels
Aetiology: Right middle cerebral artery infarct
Time since damage occurred: 18 days

Results

Condition	Mean	Median	%	Stddev	%	Correct	Errors	%	Omiss.	%	Outliers
1. half	691	704	50	68	88	17	12	4	0	> 73	0
2. half	723	729	54	48	99	8	0	> 54	11	1	0
Total	701	704	54	63	97	25	12	12	11	8	0

Test-specific graph



Assessment

This patient shows a clear decrement of vigilance in the second half of the test that is, however, reflected in omissions and not in reaction times. Although there are a large number of false alarms ("errors") in the first half of the test, the numerous misses in the second part are more important.

2.11 Visual Field / Neglect

Visual field defects represent a serious handicap for the affected patients. Pronounced visual field defects render the exploration of the environment difficult[1], with corresponding consequences for daily work procedures. Furthermore, reading ability may be considerably limited by a hemianopsia or a larger defect of the horizontal visual field, especially to the right side[2]. Visual field defects - independently of the question of fitness to drive - frequently constitute an acute risk in road traffic when compensation for the visual field deficit is insufficient.

Information about visual field deficits is also important for the feasibility of administrating different tests of this battery, for the planning of rehabilitative measures, and especially for compensation training of the visual field defect.

Task

To record vision in circumscribed areas of the visual field, a flicker stimulus is presented at different points of the screen and at varying intervals. A simultaneous central task should hereby insure that the subject fixates on the middle of the screen throughout the entire test run. Whenever the peripheral stimulus appears the patient should press the reaction key as quickly as possible.

Two variants of the test, referred to as the Visual Field test and the Neglect test are available. When administering the Visual Field test, a peripheral flicker stimulus appears on an otherwise empty background. In the condition Neglect test, the screen is filled with a mask of numbers in order to provoke extinction[3]. Both variants serve the measurement of visual field deficits. Under precise conditions of administration (darkened room, no other visual distracting stimulus), the comparison of detection performance in both variants also provides an indication of extinction following neglect.

A further variation in the tests arise from the different design of the central task: In the first condition a letter that changes at irregular intervals is presented in a small square in the middle of the screen. The patient has to name the letter every time it changes. In the second condition a “texton”, after Julesz[4] (a lying, mirror-imaged “S”), is presented as a fixation stimulus in the middle of the screen. For the purpose of fixation control, the central stimulus changes for a short duration (a lying “S” or lying “10”). The patient should press the reaction key as quickly as possible whenever the “10” appears (the reaction key is the same for the central and the peripheral task). The shape of the central target stimulus has been selected so that it is recognisable at fixation only.

Work by Hildebrandt has shown that under modification of the standard procedure (darkened room, larger screen of 21“, visual control of fixation by the examiner instead of the patient having to name the central letter), the test variant “Neglect” enables a relatively reliable screening of deficits in the central visual area[5].

An alternative to the set up suggested by Hildebrandt would of course be to use a beamer in order to cover a larger visual area than is possible with the standard set up (17“ monitor and an eye-to-monitor distance of 60 cm or a corresponding ratio according to monitor size).

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[1] Zihl, 1995, 2000; Ziehl & Habel, 1997; Hildebrandt, Gießelmann & Sachsenheimer, 1999; Tant, Cornelissen; Kooijman & Brouwer, 2002; Mort & Kennard, 2003

[2] Zihl, 2000; Leff, Scott, Crewes et al., 2000

[3] Heilman, 1979; Mesulam, 1985; Karnath, 1988; Weintraub & Mesulam, 1989; Rafal, 1998

[4] Julesz, 1981

[5] Hildebrandt, 2006

Procedure

This procedure allows the administration of the following variants:

- The “visual field test”, with the naming of the letter as fixation control in a short form (48 peripheral stimuli, 12 per quadrant; test duration: 5’35“) and a long form (92 peripheral stimuli, 23 per quadrant; test duration: 10’45“). For the instructions, see Fig. 2.23.
- The “visual field test”, with central reaction task (Julesz figures; see Fig. 2.24) for fixation control (48 peripheral stimuli, 21 per quadrant; test duration: 5’35“).
- The “neglect test”, with the naming of the letter as fixation control in a short form (44 peripheral stimuli, 11 per quadrant; test duration: 5’10“).
- The “neglect test”, with central reaction task (Julesz figures; see Fig. 2.24) for fixation control (44 peripheral stimuli, 11 per quadrant; 18 critical central stimuli; test duration: 5’10“).

Reactions with key “1”

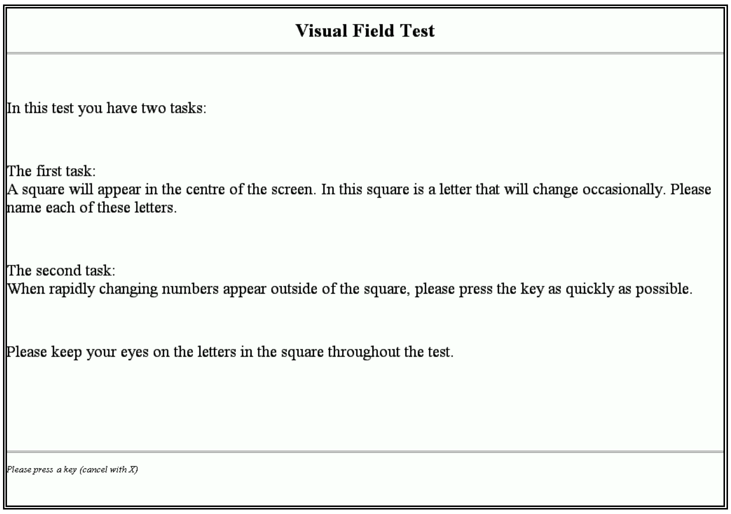


Fig. 2.23: Instruction for Visual Field Test with naming the letter

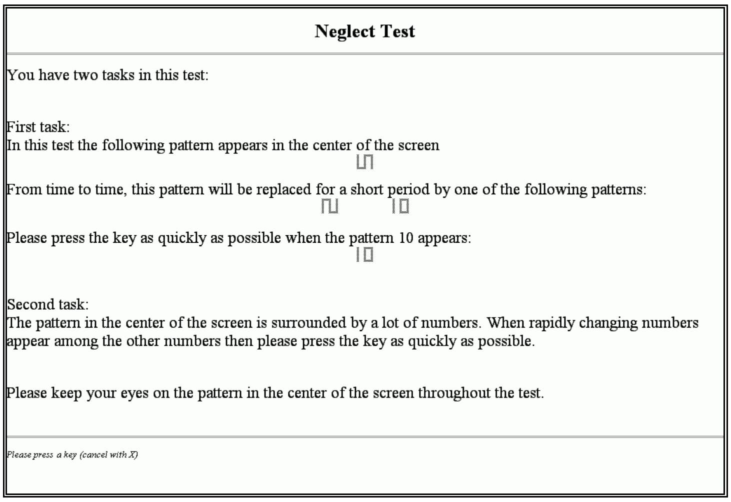


Fig. 2.24: Instruction for Neglect Test with central reaction task

Results

Values for mean, median, and standard deviation of RT as well the number of correct reactions, errors, omissions for the peripheral stimuli are given for all quadrants, the two hemifields, and the total visual field.

For the task with the central reaction task, the mean, median and standard deviation of RT as well the number of correct reactions, errors, omissions are additionally given for the central task.

An additional graph ("single trials") displays the reaction times to the peripheral stimuli for the different screen positions in all the task variants. The missing reactions are shown in this graph as "-1"; missing reactions permit an estimation of the defective visual field or the unattended stimuli in the Neglect Test (see Fig. 2.25).

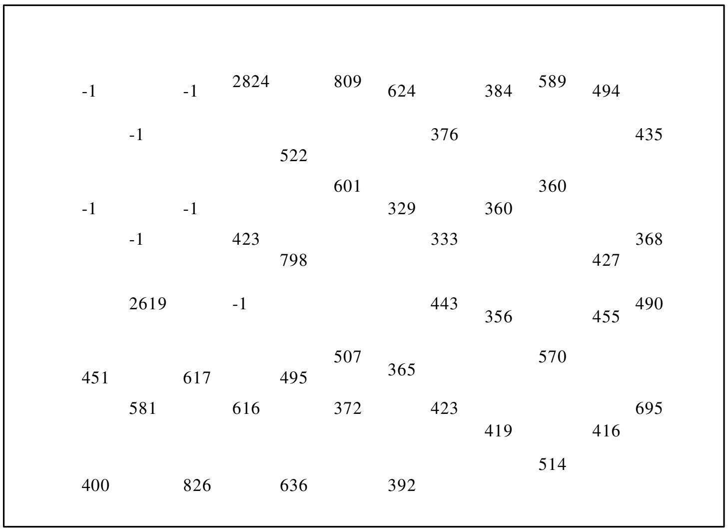


Fig. 2.25: Reaction times in the condition "Visual Field Test - short" for the individual single stimulus positions of a patient (47 years-old; condition after TBI). One can identify a visual field deficit (as indicated by a "-1") in the left upper quadrant reaching to just under the centre line. Altogether, the reactions to the stimuli in the left visual field are much slower than those in the right (mean RT left = 557 ms; mean RT right = 431 ms).

Normative values are provided for the long version (92 trials) of the "Visual Field Test" with letter naming and for the variant "Neglect" with letter naming. The medians of the RT in all quadrants and in both hemifields in the Visual Field Test had been normalised. The norms for the medians of RT are provided for both hemifields in the Neglect Test.

The tests with the central reaction task are not yet normalised.

Interpretation

The graph presentation Visual field of a potential visual field defect provides key information for interpretation (see Fig. 2.25).

Furthermore, slowed reaction times in one of the hemifields are indicative of attenuated shift of attention or reduced contrast sensitivity in that hemifield. Contralesional slowing is characteristic of parietal lesions independent of the presence or absence of a neglect syndrome.

Attenuated reaction times in a hemifield usually occur in conjunction with correspondingly slowed shifts of attention and increased saccadic latencies toward that hemifield and an impaired scanning[1].

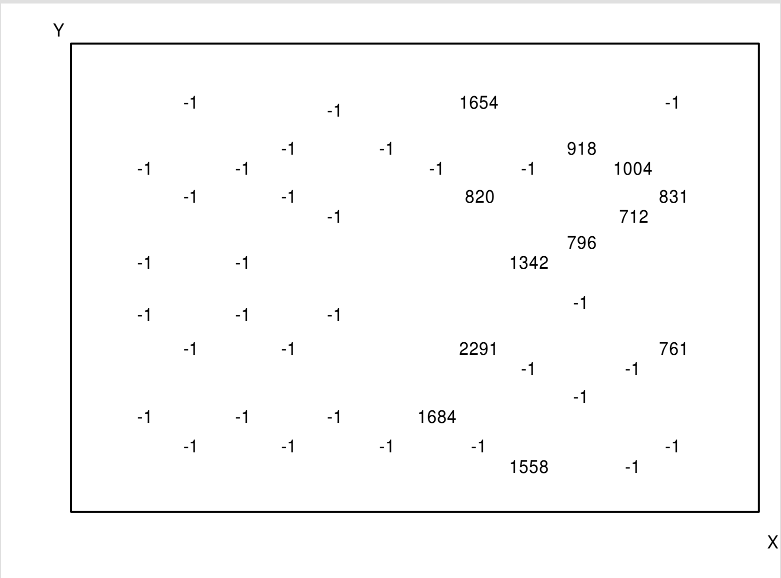
Case example: Neglect

Patient:	63 years-old, male, "A"-Levels
Aetiology:	Extended infarct the right middle cerebral arthery with secondary bleeding
Time since damage occurred:	6 months
Impairments:	left Hemiplegia

Results

Condition	Mean	Median	%	Stddev	%	Correct	Errors	%	Omiss.	%	Outliers
left						0			22		0
upper left						0			11		0
lower left						0			11		0
right	1198	961	< 1	502		12			10		0
upper right	1010	875		324		8			3		0
lower right	1574	1621		629		4			7		0
peripheral	1198	961		502		12			32		0
central						0	0		0		0

Test-specific graph



Assessment

A contralesional neglect is apparent extending as far as the right lower visual field. There are no reactions to stimuli in the left visual hemifield. The reactions on the right side are also clearly slowed (PR<1 for the median of reaction times). To differentiate in this test between the hemianopsia-related and neglect-related deficits the additional administration of the "Visual Field Test" is necessary. If in this test no or only marginal deficits are discernable, this would be indicative of a neglect in accordance with the above finding.

[1] Haufe, 1991

2.12 Visual Scanning

The exploration of the visual environment is one of the most basic abilities subserving the safe movement in space, the search for an object, when regarding an object or picture, or in monitoring and controlling a traffic situation. It is a complex process for which the intention and prior knowledge of the individual, the ability to plan ahead, an unrestricted visual field, the ability to shift visual attentional focus, and unimpaired eye movements are important. Equally diverse are the causes of a deficit in exploring the environment after brain damage, which in many cases presents an obvious handicap in daily life. The most marked impairments in exploration ability occur when there is a non-compensated visual field deficit[1], parietal lesion[2], neglect or residual neglect[3], or a Balint-syndrom[4]. Frontal lesions are also of importance when the resultant inability to proceed systematically renders an efficient exploration impossible[5].

Task
In this task, a matrix-like arrangement of 5 x 5 stimuli is used, the aim being to detect whether this arrangement includes a critical stimulus or not. One reaction key is used for the answer “present” and another for the answer “not present”.

The stimuli are small squares, each of which has a small opening on one of its four sides. The critical stimulus is represented by a square with an opening along its upper horizontal side. The stimuli were selected so that the critical stimulus is not immediately obvious (“pop-out” effect) and so that the stimuli are only partly recognisable parafoveally. The matrix-like arrangement of the stimuli requires a systematic exploration. The requirement to explore the matrix on a row-by-row or column-by-column basis permits testing of the ability to shift the required search strategy, which can be impaired, for example, in the case of frontal brain damage.

Procedure
The test comprises 100 trials (50 critical and 50 non-critical trials, with 10 critical trials per column and row, respectively). The following trial begins immediately after a reaction.

Attention: Key “1” = left, key “8” = right!

Test duration (variable because the test is reaction-dependant, without pre-test and instruction): at least 5 minutes and much longer with impaired exploration performance.

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[1] Zihl, 1995, 2000; Hildebrandt, Gießelmann & Sachsenheimer, 1999; Tant, Cornelissen, Kooijman & Brouwer, 2002; Mort & Kennard, 2003

[2] Haufe, 1991; Zihl, 1995; Zihl & Hebel, 1997; Mort & Kennard, 2003

[3] e.g. Heilman, 1979; Rizzolatti & Gallese, 1988; Weintraub & Mesulam, 1989; Rafal, 1998; Mesulam, Small, Vandenberghe, Gitelman & Nobre, 2005

[4] Newcombe & Ratcliff, 1989; Zihl, 2000; Mort & Kennard, 2003

[5] Luria, Karpov & Yarbus, 1966; Yarbus, 1967; Weintraub & Mesulam, 1989; Zihl & Hebel, 1997; Mort & Kennard, 2003

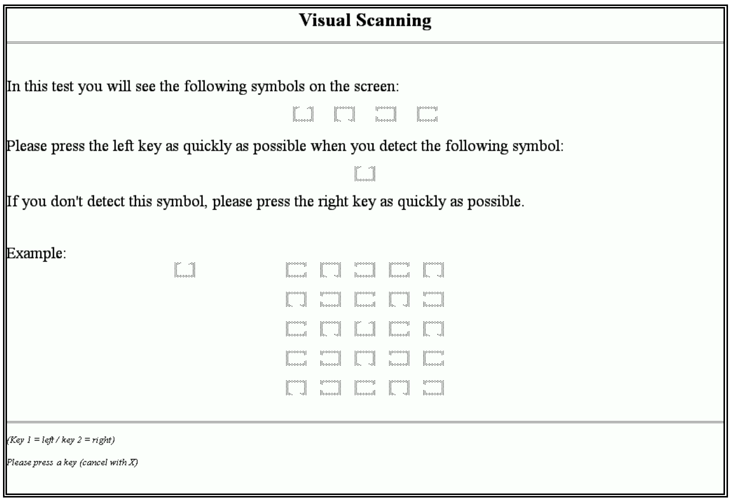


Fig. 2.26: Instruction for Visual Scanning

Important advice for instruction: the subject has to be asked to search the stimulus arrangement row-by-row (as when reading) in order to comply with the intention of the test and to reasonably apply the normative values. To verify whether the subject is able to shift strategy, the instruction may also be given to search the matrix on a column-by-column basis. In this case however, the normative values for the medians and standard deviations of the single rows and columns as well as for the rows and column correlations should not be used for the purpose of interpretation.

The subsequent matrix will be presented immediately after every correct or incorrect reaction of the subject. The subject should not therefore try to correct a false reaction. If this should happen, it is recommended to advise the subject accordingly.

Results

The mean, median and the standard deviation of RT as well as the number of correct reactions, errors ("false positive responses": pressing the left key in a non-critical trial) and misses ("misses": pressing the right key in a critical trial) are displayed for every row and column as well as for all critical and non critical trials. A correlation between the reaction time and the position of the critical stimulus in the row or column is also computed. The correlation between reaction time and row position of a stimulus is for example high when the subject systematically scans the rows from top to bottom. The strength of the correlation diminishes when the subject does not proceed in a systematic row-by-row manner or shows a large variability in scanning times.

A Test-specific graph shows the reaction times in the critical trials for the single rows and columns as well as for all non-critical trials (see Fig. 2.27).

An additional graph (scatterplot) shows the reaction times to the critical stimuli at different positions of the matrix.

Normative values for critical stimuli are displayed for the medians and standard deviations of RT as well as for errors in the single rows and columns and the total matrix and also the medians and standard deviations of RT and of errors for all non-critical trials.

Interpretation

The most important parameter is the number of overlooked critical stimuli (misses), although consideration should be given to the distribution of the misses in the different columns. A large number of misses in the most peripheral columns, mostly in the left column, can be a sign of neglect or a residual neglect. But in such cases, much longer reaction latencies are occasionally found in the affected column without or with only few misses, especially when the symptomatic is only mild or improving. Patients with a frontal symptomatic frequently show a much higher number of unsystematically distributed errors. This may be interpreted as an impairment of focusing.

Next to be considered is the total scanning time, that is, the median of reaction times for all trials without critical stimulus. This provides information about the average speed of scanning for the entire matrix.

The course of reaction times across the rows and columns (see Fig.2.27) as well as the corresponding correlations shows the row-wise or column-wise scanning and provides information about the systematic approach. Patients with a frontal symptomatic, in particular, are discernible on account of their unsystematic approach.

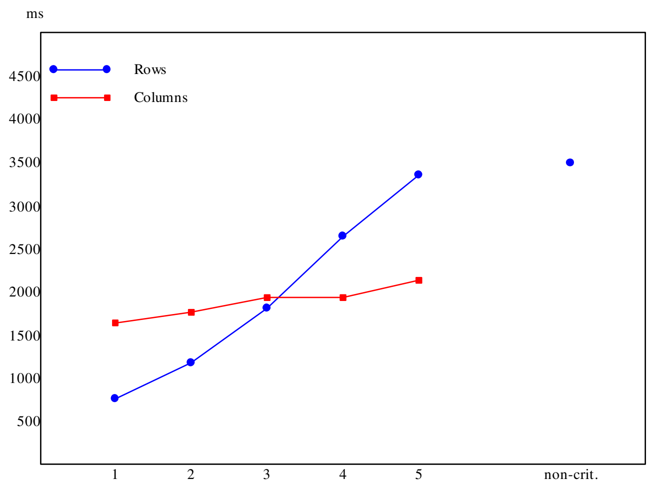


Fig. 2.27: The linear increase in detection times of critical stimuli in the different rows reflects a very systematic scanning of rows in the matrix. The last point in the graph ("non-crit.") represents the median of the response times to trials without a critical stimulus, that is, the time for scanning the entire matrix. The total scanning time, when proceeding systematically, is practically identical with finding a critical stimulus in the 5th row. But a "safety strategy" is mostly indicated when the total scanning time lies above the average scanning time for the 5th row, that is, the subject ensures that nothing has been overlooked by scanning the entire arrangement again.

Case example: Visual Scanning

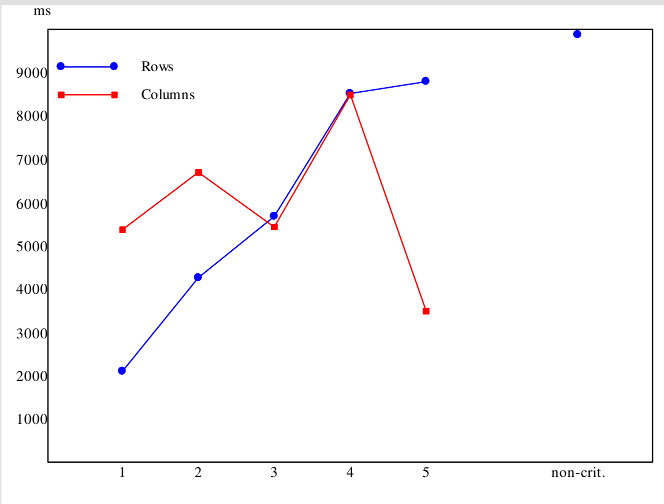
Patient: 52 years-old, female, High School
Aetiology: left middle cerebral artery infarct
Time since damage occurred: 9 months
Deficits: aphasia, speech apraxia

Results

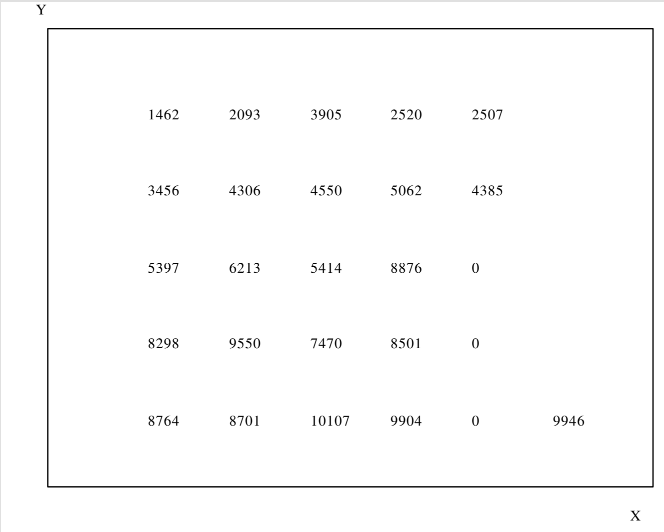
Condition	Mean	Median	%	Stddev	%	Correct	Errors	%	Omiss.	%	Outliers
Row 1	2175	2150	7	613	18	9			1	27	1
Row 2	4272	4295	1	606	31	9			1	62	0
Row 3	6251	5702	1	1396	8	6			4	12	0
Row 4	8611	8525	< 1	850	31	6			4	8	0
Row 5	9369	8805	1	1180	14	8			2	34	0
Column 1	5475	5397	2	2968	3	10			0	99	0
Column 2	6626	6718	< 1	2695	4	9			1	50	0
Column 3	6251	5449	1	2861	1	8			2	18	0
Column 4	6755	8501	< 1	3384	2	7			3	10	0
Column 5	3446	3526	34	1252	69	4			6	5	0
critical	5933	5449	1	2870	2	38			12	18	0
non-crit.	9829	9902	1	1980	4	50	0	> 24			1

Rows r: 0.928 (% = 73)
Columns r: -0.079 (% = 90)

Test-specific graph



Single trials



Assessment

The patient demonstrated a very systematic visual search strategy (from top to bottom, row for row), recognisable on the basis of the row and column correlations with reaction time. The patient however misses many critical stimuli, half of which are in the 5th (i.e. right) column. The depiction of “single trials” shows that the majority of misses are in the bottom three rows of column 5 (no correct reactions). Given the left middle cerebral artery infarction, a hemianopsia to the bottom right, an eye movement deficit, or an attentional asymmetry to the detriment of the right bottom visual field come into question for differential diagnostic purposes.

2.13 Working Memory

Working memory[1] may be understood as a system that maintains the information necessary for solving complex problems and processing multi-level tasks or aspects of a situation in order to generate an overall picture. An essential aspect of this is that, depending on the task and the goals of the individual, the content of working memory must be updated continually. Deficits in working memory can therefore lead to considerable difficulties in solving problems, structuring complex work processes or adapting to a given situation, independent of problems in memory in the form of impaired encoding, consolidation, and retrieval.

The distinction between a memory system and an attentional system is particularly difficult in the case of working memory, as Baddeley[2] himself acknowledged. This becomes apparent, for example, in the updating of information in working memory that is in itself a process controlled by selective attention. A quite different association between working memory and processes of attention has been shown in the investigations of Lavie and colleagues[3]. They were able to show an increase in distractibility by irrelevant information when working memory is highly loaded. This suggests that working memory plays an important role in controlling the focus of attention[4]. Working memory has been previously shown to be a central component of controlled, that is, attention-driven processing[5].

Working memory has thus been demonstrated to be an important component of a broad range of attention-driven processes, with correspondingly important consequences when a deficit arises.

Task
This task examines the control of information flow and the updating of information in working memory.

A sequence of numbers is presented to the subject on the monitor. The subject is required to determine whether each number - depending on the condition - corresponds with the previous number or the one before that. The task requires a high degree of cognitive attentional control, not because the previously determined critical stimulus has been recognised, but because the critical stimulus in the sequence of stimuli is being continually redefined. In this way, this test places much higher demands on cognitive processing and on the internal control of attention than would a test procedure requiring simple detection of a predetermined critical stimuli. Given that numbers are strongly conducive to verbal coding, this test can be used generally as a measure of the control of the articulatory loop of working memory[6].

Procedure
Three conditions with different levels of difficulty can be selected:

- Level of difficulty 1: two digit numbers are presented. The critical stimulus is defined as a number which is identical to the previously presented number.
- Level of difficulty 2: two digit numbers are presented. The critical stimulus is defined as a number which is identical to the number presented one before last.

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[1] Baddeley & Hitch, 1974; Baddeley, 1986, 2003
[2] Baddeley, 1993, 2003
[3] de Fockert, Rees, Frith & Lavie, 2001; Lavie, Hirst & de Fockert, 2004; Lavie & de Fockert, 2005; Lavie, 2005a, 2005b
[4] See also Frith, 2005
[5] Zimmermann & Fimm, 1992
[6] Baddeley, 1986

- Level of difficulty 3: single digit numbers are presented. The critical stimulus is defined as a number which is identical to the number presented one before last.

The test comprises a total of 100 stimuli across all levels of difficulty. The stimuli are presented at 3 second intervals. Each condition contains 15 critical stimuli.

If possible, the test should be administered at the third level of difficulty.

The test is not suitable for patients with language disorders because of its verbal material.

Reactions with key "1"

Test duration (without pre-test and instruction): 5 minutes.

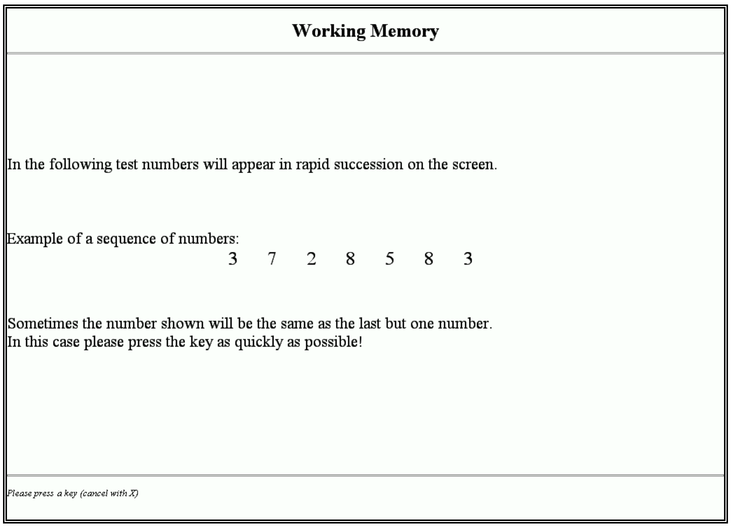


Fig. 2.28: Instruction for Working Memory, Level of difficulty 3

Results

The mean, median, standard deviation of RT, and the number of correct responses, errors, omissions, and outliers will be presented for the entire task.

Normative values are shown for the median and standard deviation of RT and for the number of errors and omissions.

Interpretation

The most important parameter of performance in this test is the number of omissions, because these point to a lack of control in the flow of information. Errors may also indicate lapses of attention because of uncertainty on the part of the subject as to whether a number had already just been shown that was identical with the one before it or the one before that.

The reaction times are of secondary importance in this test.

Case example: Working Memory

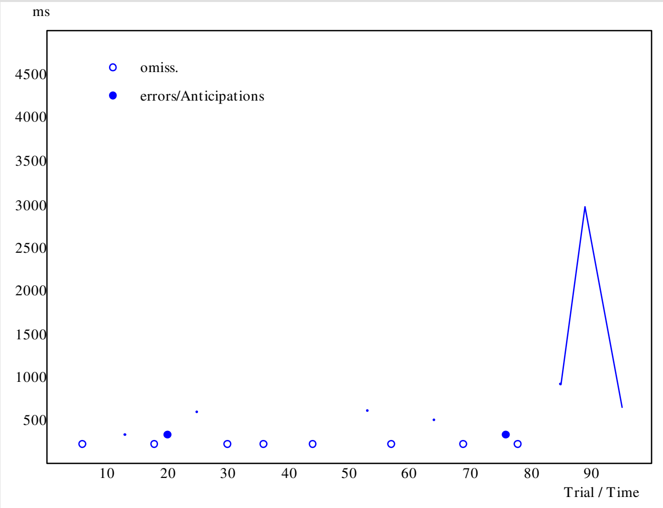
Patient: 39 years-old, male, “O”-levels

Aetiology: Chorea Huntington

Results

Condition	Mean	Median	%	Stddev	%	Correct	Errors	%	Omiss.	%	Outliers
Total	949	627	50	914	< 1	7	2	50	8	1	0

RT-series



Assessment

On the whole, the patient performs poorly in this test. The number of omissions is below average, and there are enormous variations in performance over the course of the test. The median of RT is, on account of the high variability of reactions, of little importance. On the basis of this test profile, one can assume a distinct impairment of working memory performance.

3 Guidelines for administration of tests

3.1 General guidelines

Every effort should be made to perform the specific tests under standardised conditions. This requirement will undoubtedly be subject to some limitations on account of the condition of a given subject and the different test conditions of a given test procedure.

Performance can vary in a relatively important way depending on the size of the screen used. For the development and the normalisation of the tests, a screen of 32 cm (12", measured diagonally) and a width-height proportion of 4 : 3 was used at a distance of 50 to 60 cm between monitor and subject. If a screen has other dimensions, it will be possible to maintain the same proportions by choosing the "native" resolution of the screen (see "Options in section 5.2.). Even when the stimuli seem very small with a large border around (see figure 3.1 at the right), the proportions will correspond to the screen used for the normalisation.

The "native" resolution is the maximal resolution of given screen. Above all, one should pay attention that the screen does not display the stimuli in an distorted way as occurs with widescreens that have a proportion of 16 : 9 (see figure 3.1 at the left).

You will find the information for the "native" resolution on the back of your monitor, in the manual that accompanies the monitor or on the website of the manufacturer of the monitor.

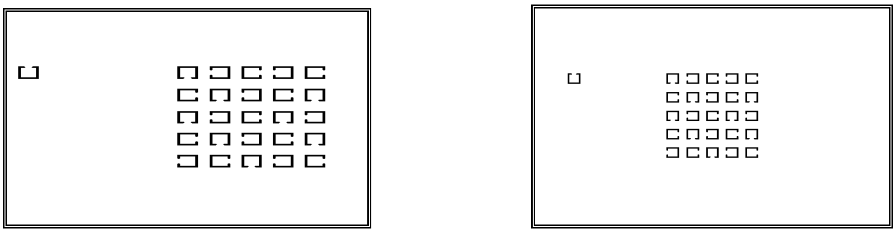


Fig. 3.1 : To judge whether the presentation of the stimuli is distorted, the matrix of test Visual Scanning can be used. On the left the display of the matrix can be seen on a widescreen with the original resolution of the TAP with 1024 × 768 points without any graduation of the graphic driver or the display of the screen. On the right, the same matrix is shown using the "native" resolution of the screen. Even if the matrix is somewhat smaller, it conforms to the dimensions of the stimulus used for the normalisation of the TAP.

Differences in the brightness and contrast of the monitor are difficult to norm, but in general neither daylight nor artificial light from a strong lamp should fall on the monitor, and the light source should not be behind or beside the monitor.

The reaction keys should be placed in such a way relative to the sitting position of the subject that the subject can reach the key or keys with the forearm resting on the working surface as comfortably as possible. Optimally, the subject should be instructed to press the foremost area of the red spot on the reaction key.

In the different subtests, the subject should be advised to hold the finger directly over the response button in order to ensure quicker reactions. Unintentional continued pressing of the key is prevented by the programme displaying in such cases the message "Please keep your finger off the key!" During a test some subjects tend to move the resting position of the finger or hand further away from the reaction key. A short verbal reminder is often sufficient to ensure suitable positioning of the hand or finger.

After installation of the programme (see 4 "Installation instructions"), the test battery is started by clicking on the TAP-icon on the Windows desktop. The individual tests can be activated by selecting the desired test from the menu. Details about operating the menu system are provided in Chapter 5. Once the desired test has been activated, one of the different test versions must be selected. The test can begin once a subject has been selected or the details of the subjects have been specified (for more details, see 5.4 “Enter / selection of subject”).

Each test begins with the display of the instructions on the monitor. At the bottom edge of this instruction window, directions are given to the examiner as to how the programme will proceed and how the instruction window may be cancelled. A precondition of using the TAP for diagnostic purposes is to make absolutely certain that the subject has understood the instruction. As a general rule, it has proved insufficient simply to allow the subject read aloud the instructions displayed on the monitor. It is much better that the examiner also imparts the instructions verbally. Principally, the main test should only start after the pre-test has first been carried out. Should the subject have difficulty understanding the task it is advisable to perform a pre-test more than once, until the examiner is sure that the subject has understood the task. Repeated application of the pre-test should always be documented, because this provides important qualitative information for the findings.

Whenever problems arise with the administration of the test: for example when the subject has questions or is exhausted, the standard course of the test can be aborted both during the pre-test and in the main test. Interrupting the course of a test is only possible by pressing one of the two reaction keys for several seconds, upon which a message is displayed on the monitor to indicate that the test can be aborted by pressing the key “X” or that the test can be resumed by pressing the key “C” on the keyboard.

The subject should be reminded several times during the course of examination that they should respond as quickly as possible while concomitantly maintaining a high degree of accuracy. It is on the whole advisable to begin the first examination session with more simple tests (e.g. Alertness) in order to familiarise the subject with the operation of the test and to reduce any possible anxiety that subjects who have never used a computer may have (e.g., older subjects). It should be emphasised at this point that the experience with the application of the tests with older individuals has been extremely positive.

When testing with slower (e.g. older) subjects is obviously going to take a long time, or when fatigue speaks against continuation of the examination, then a second examination session should be arranged, if necessary, or a break should be taken during testing. This should however be noted in the documentation.

Consideration should be given to the importance of visual field defects or neglect (in neurological patients) for all test procedures using presentation of lateralised stimuli or more complex patterns of stimuli.

It is important to ensure in those tests that measure spatial orientation of attention (Eye-Movement, Visual Field Test / Neglect, Covert Shift of Attention, Visual Scanning) that the central axis of the monitor and subject coincide as closely as possible.

The results may be viewed after a test has been completed by double-clicking the corresponding test from the list of administered tests (for details, see 5.7 “Presentation and output of results”). The results will be displayed directly on the monitor and can be printed or pasted into a Word document. The list contains the reaction times of single trials, data of the individual test parameters with corresponding normative values, and a variety of graphs. Immediate presentation of the results in the graphic form is especially useful in providing the examiner with the opportunity to discuss with the subject any deficits in performance as a whole or during the course of the test.

3.2 Guidelines for the application of specific tests

Alertness

It is sometimes necessary to provide further instruction for certain subjects: "After you have reacted to the cross by pressing the key, the cross will disappear. After this cross has disappeared, please wait until the next cross appears. You should also respond to this next cross as fast as possible. After you have pressed the key in response to a cross, you should always wait for the next cross to appear".

Covert Shift of Visual Attention

The subject should be informed in this test of the importance of eye fixation on the centre of the monitor throughout the test.

It should also be emphasised that the subject should wait for the critical stimulus and not respond to the cue stimulus.

Crossmodal Integration

It should be ensured that the subject is able to differentiate between the acoustic stimuli. To do this, the subject should name the tones while the instructions are displayed on the monitor. It is often apparent at this point whether tone discrimination is being achieved reliably and whether further assessment with this test procedure should continue.

Divided Attention

It is recommended that the instructions are given in the following way:

At the beginning, explain to the subject that they must attend to the two tasks simultaneously. Then, explain the task *squares* using the point matrix of the instruction. The auditory task should then be explained, and it should be made clear that an example of a tone will follow, to which the subject should react *only* by giving a verbal indication (e.g. by saying "Now!") of whether the same two tones are heard one after another. The example of a tone can be obtained by pressing any key of the mouse or the key-board. Once again, it should be explained to the subject what they have to do (react when the square is seen or when the same tone is heard twice in sequence). It should also be made clear that the critical tone and the critical visual stimulus do not appear simultaneously.

Should deficits be apparent in the dual task condition (dual task: auditory and visual task), the unimodal test condition or conditions that correspond to the impaired modality should also be administered. A deficit in attention performance is considered to exist when, and only when, the deficit is entirely or predominantly evident in the dual task test condition.

Eye-movements

In this test, the subjects should be informed of the importance of fixating on the centre of the monitor during the test and of only moving the eyes when a stimulus appears.

Flexibility

In the shift conditions, the subject should *not* name aloud the decision criterion of the following trial.

It should always be noted when a subject only uses one hand, because of, for example, hemiparesis, as this is highly likely to influence the results.

It is recommended that one of the more simple test conditions (letter or number; round or angular) are used first only then followed by the shift condition. The available normative data is largely based on this procedure.

Go/Nogo

When errors occur in the condition “2 of 5” of the pre-test, the instructions and the pre-test should be repeated. The subject then has another opportunity to make a mental note of the stimuli. Even if errors are still being made in the second pre-test, the main test should be administered (unless of course the subject, e.g. an aphasic, has obviously failed to understand the instructions).

Incompatibility

The patient should perform this test with both hands. In the case of hemiparesis, a note should be made of which hand was used to press the key.

It should be made clear to the subject that it is the corresponding direction of the arrow and not the side on which the arrow appears that is important.

Sustained Attention

The subject should first be allowed to read the instructions, after which the instructions should be explained more precisely by using the stimuli of the instruction as an example to explain which stimuli the subject should respond by pressing the key. Again, it should then be pointed out that it is not the size but the colour and/or the overall shape of the stimulus that is important. It should also be mentioned that the choice of stimulus examples in the instructions represent only a small selection of the stimuli that actually occur *one after another* in the test .

Vigilance

Performance in the visual and acoustic test of vigilance can be impaired in different ways.

Visual Field / Visual Neglect

The subject should be instructed not to blink when a “flicker” appears on the monitor, but that this flicker should be perceived. The purpose is not to recognise what appears during the flicker, but to react to it as quickly as possible. Maintaining central fixation is therefore absolutely necessary.

Patients with hemianopsia and/or neglect frequently begin the test procedure by turning or tilting the head or upper body toward the functionally impaired side. These patients should be made aware of this and requested to sit up straight in front of the monitor, and, if necessary, the patients should be provided with appropriate support.

Visual Scanning

The test should be explained using the example of the stimulus matrix in the instruction. It is important to make the following points clear:

The matrix should be scanned systematically, row by row (“as when reading”) in order to detect the target stimulus. If necessary, this instruction should be given several times in order to prepare the subject for the main test.

It should also be made clear that the stimulus matrix will disappear immediately after the key is pressed and that a new matrix will subsequently appear. The subject should be instructed not to correct his reaction after the disappearance of the matrix (e.g., because he may recognize a target at the last moment!).

Working Memory

Level of Difficulty 3 should ideally be selected, as only this condition has been normed (at least for adults). Should the subject be unable to cope with this level of difficulty, the next lower level should be selected.

4 Installation instructions

Installation of the program

To install the application, insert the program CD into the CD drive.

The set-up program begins automatically.

Follow the instructions of the set-up assistant. The language in which TAP should operate can be selected during the installation. You can also change the language settings later (see Appendix A9).

The computer must be restarted after completion of the installation!

Installation of the drivers

When installing the program on the computer, the hardlock driver and the parallel port driver must be installed. During installation, a message box will appear with the commands:

"Install the hardlock driver"
"Install the parallel port driver"

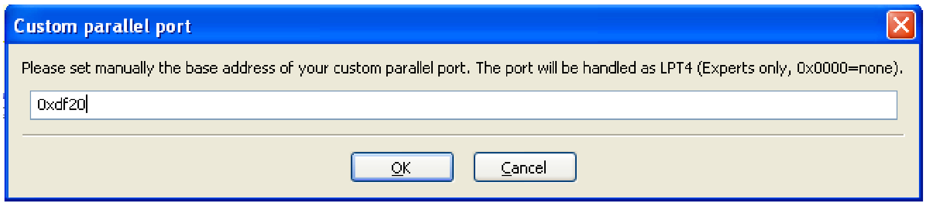
The installation of the driver is pre-selected by default.

Installation of an additional or new parallel port

If a parallel port to which there is no access with a standard address is subsequently installed (e.g. a PCMCIA- or ExpressCard with a parallel port on a notebook) and to which the response buttons should be attached, mark the command:

"Install an additional parallel port"

To enter the address of the parallel port (see Appendix A4 "Installation of the TAP on a notebook without parallel port"), the following box will appear at the end of the installation with the request to enter the address.



Warning: The address must be entered correctly. In the event of an error, a severe system failure may result!

Further important information: we assume no responsibility for additional hardware produced by third parties.

Creating a TAP-Group

During installation the set-up assistant will prompt you to

"Create a TAP group (real-time priority privilege)"

The TAP-group should normally be installed when TAP is used by examiners who can access the computer by registering themselves with their own user code but do not have administrative privileges. A TAP user who does not have administrative privileges should be registered in the TAP-group list. This authorises the user to start TAP with real-time priority, thus ensuring the precision of reaction time measurements. Once the group is set up, the list of users registered in the system will be displayed after completion of the installation. Those individuals who should be members of the TAP-group should be marked by the administrator.

Special case: Creating a TAP-Group when the user profile is saved in network

On a number of systems the profile of the individual users is not saved locally on a computer but centrally on a server. If the TAP is installed locally, it will not be possible after installation to select users registered on the system because the user names will not be displayed. Should this apply, click “ok” to the command “create a TAP-group” anyway and enter the user name manually after the installation is complete. This is done as follows:

- Right-click on the icon “My Computer”
- Select menu option “Control Panel”
- Open “Local users and groups”
- Select “Groups” in the right window
- Select “TAP” from the list
- A window will open displaying the properties of TAP and showing that a TAP-group was established but that no user has yet been set up in the TAP-group.
- Go to “Add”
- You can now enter the user name directly in the dialogue window or click on “Advanced”
- Then select “Search now” and you will receive a list of users. This will normally contain a large number of user names of which however only a few are relevant
- Mark to select the computer user who wishes to use TAP and click “ok” in order to add the user to the TAP-group. All the users will now be shown in the field for the TAP-group. The users who are added in this way are now permitted to use the TAP tests with real-time priority.

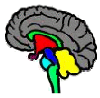
Reinstallation:

It is urgently recommended that you deinstall an earlier version of TAP before reinstalling a new version of TAP on the computer. *The data of previously passed examinations as well as the membership of the TAP-group will be preserved!*

5 User manual

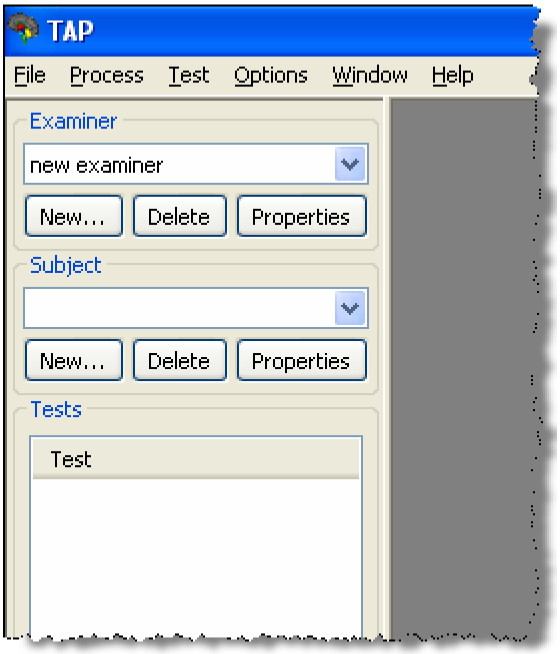
5.1 Starting TAP

To start TAP, click on the icon on the screen.



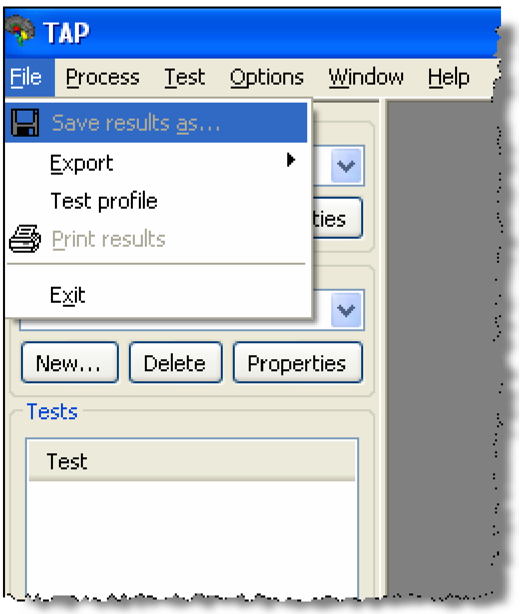
5.2 Main menu

After starting TAP, the main menu will appear as follows:



Navigating through the menu is achieved by a mouse click or by pressing the “Alt” key plus the underlined letter of the relevant menu option (e.g. “Alt”+”F” for “File” menu).

The “File” menu:



The File menu includes the following commands:

"Save results as…": Allows saving an open list of results in Rich Text Format (*.rtf), e.g., to be transformed into a Word document. This command can be performed only when a result is displayed in a window (see 5.7 "Presentation and output of results").

"Export": Enables test results of one or more tests for all or a selection of subjects to be saved as an ASCII- or SPSS-file (see 5.9 "Exporting data").

"Test profile": Allows the test profile of the entered subject to be given as output. For a more detailed description of this function see 5.10 "Creating a test profile".

"Print": Allows an opened list of results to be printed. This command can be performed only when a result is displayed in the right window (see 5.7 "Presentation and output of results").

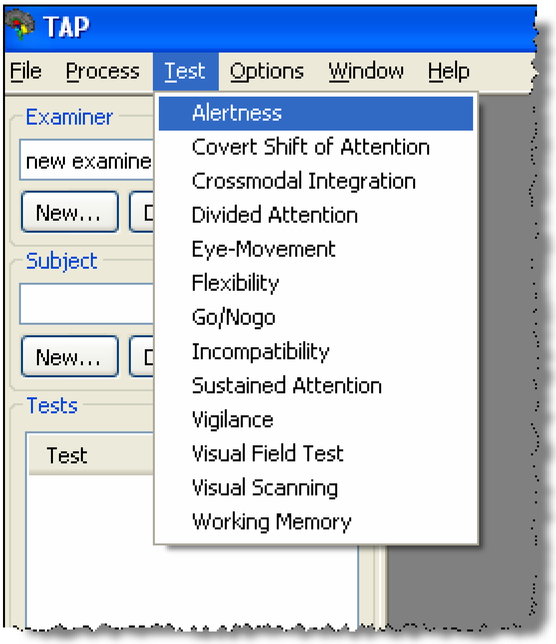
"Exit": Closes TAP

The "Edit" menu:

This menu contains only the command "Copy". This command allows an opened results file to be copied to the clipboard.

The "Test" menu:

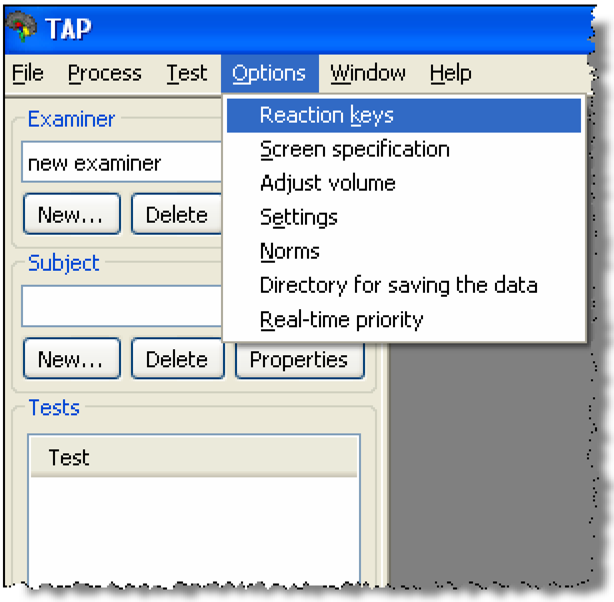
A test can be selected from the pull-down menu by double clicking on it. The pull-down menu appears as follows:



If a subject was not defined before selecting a test you will now be prompted to select a person (see 5.4 "Enter / select subject").

The "Options" menu:

The "Options" menu includes the following commands:



"Reaction key":

This opens a window with a list of possible parallel ports and allows specification of the one to which the reaction keys should be connected.

- If a parallel port has been installed that does not respond to the standard address (see 4 "Installation instructions" and Appendix A4 "Installation of the TAP on a notebook without parallel port"), then select LPT4.
- The correct settings of a parallel port can be verified by pressing any reaction key: a message will be shown in the displayed window indicating which reaction key was pressed

"Monitor settings" :

The colour temperature of the screen display and the resolution of the screen can be adjusted. This may be necessary, depending on which graphics card is installed .These settings have an impact only on the presentation of the subtests.

- ***To prevent a distorted presentation of the stimuli of the different subtests, the native resolution of the monitor should be selected (see section 3.1 "General guidelines").***

"Set volume":

This allows the volume to be set separately for each test procedure with acoustic stimuli.

"User settings":

- This displays the settings of the examiner currently using TAP every time the programme is started (this is recommended when several examiners are using the same computer).
- The menu allows the user to switch off the acoustic animation at the start of the program.

- There is the option of selecting between colour or black and white illustrations for the graphs in the results output. For printing, it is recommended that the black-and-white option is selected.
- For computers without Microsoft Office Word (using instead, e.g. Open Office or Word Pad) improved presentation of the tables can be achieved by deselecting the presentation option “Enhanced Metafile” when exporting the lists of results.

“Normative values”:

The available samples will be automatically selected by TAP during the first installation. For this reason, only the menu command “All” is available. Upon receiving an update, please confirm just once the menu command “All”.

“Directory of saved data”:

The program is preset to save data to the directory “TAP” under “My Documents” in the name of the actual user (see also 4.3 “Enter / selection of examiner”).

If you do not wish to save the data under My Documents, you can for example create a directory with the name “TAP-Data” on the hard disk to save the data. Using this option, you can select the previously created register “C:\TAP-Data” to install the directory “TAP” for saving the data.

Important: The user is advised not to save data over a network because activity on a network can slow down test execution in real-time.

“Real-time priority”:

The option for real-time priority between the options “Always” or “For all test without acoustic stimuli” can be selected here.

Irregularities in the sound output can occur on some systems when using tests with sound output (Alertness, Flexibility Divided Attention, Incompatibility, Crossmodal Integration, Vigilance / acoustic). Should this occur, select the option “test procedures without sound output” for real-time priority. In this case it is important to ensure the precision of reaction time measurement by verifying that no other programme is running in the background during the execution of a test.

The selected options will be saved automatically.

The “Window” menu:

The “Window” menu contains only the sub-menu “Cascade” with which several opened lists of results are rearranged to partially overlap on display (see 5.7 “Presentation and output of results”).

The “Help” menu:

The “Help” menu contains the instructions for installation and the user manual within which particular themes may be searched for.

5.3 Enter / selection of examiner

The test data of each examiner's subjects are saved to their directory. The examiner's directory is defined as the subdirectory "NAME.VL" in the directory "TAP".

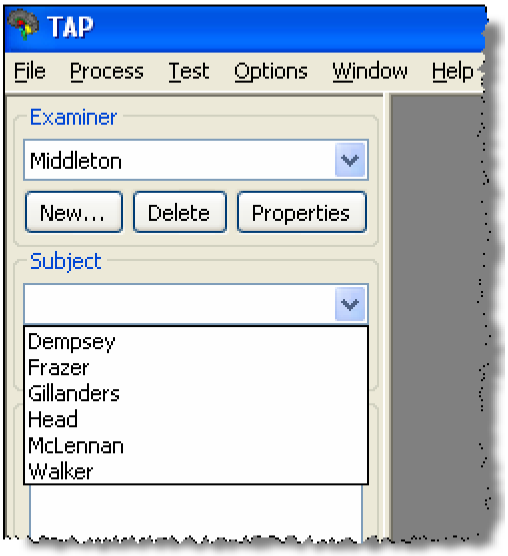
The directory "TAP" is created by default under "My Documents" in the name of the actual user ("My documents\TAP\NAME.VL"). Alternatively, it is possible to create the directory "TAP" within another directory of your choice (see the "Options" menu).

It should be noted that a particular examiner has to be selected or, if necessary, entered for the first time before each investigation. If the examiner's identification code has already been saved, they can be selected by using the roll-down menu. Otherwise, click on the command "New…" to open a window in which the identification code of the new examiner can be entered.

The new examiner should be registered in the TAP-group (see 4 "Installation instructions").

5.4 Enter / selection of subject

The subject must be entered before each test. If a subject has been examined by the same examiner previously, the person can be selected from a list (see window):



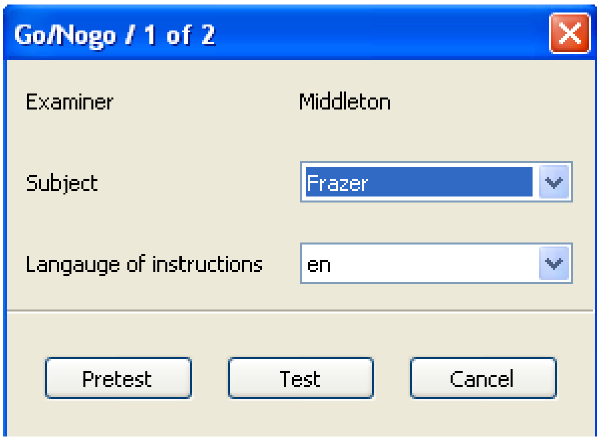
If a subject is being examined for the first time, select the command "New…". A window will appear in which the details (Name (ID), Gender, Educational level, and Date of birth) must be entered.

Take Note: The ID of the subject should not end with a dot because this may cause difficulties in reading subject data.

5.5 Test administration

Use the "Test" menu to select a test procedure. The test can be selected either by using the arrow keys and pressing Enter to start or by clicking on the left mouse key.

A dialog box will appear:



If a subject was not entered beforehand, the field in the drop-down combo box next to the caption "Subject" will be empty. First select the person from a list of existing subjects or enter the new subject in the corresponding field (see 5.4 "Enter / selection of subject").

This window offers also the possibility to present the instruction in a language other than English, if the subject speaks an other language than the examiner. The selected language is only valid for the actually selected test

A pre-test or the main test may now be started.

The test procedure's introductory window will appear for the pre-test and for the main test. Press any key on the keyboard or mouse to start the pre- or main test.

The number of correct reactions, missed critical stimuli, and errors will be displayed after the pre-test. Press the Okay command button to confirm having viewed the results. The Test menu will re-appear with the selection window for pre- and main tests.

On completion of (or exiting an ongoing) main test, the data will be saved automatically in the subject's directory and the name of the test will be displayed under the person's identification code.

Warning: Normative values will not be displayed if a test has been aborted! (see also 5.7 "Presentation and output of results")

5.6 Exit ongoing test

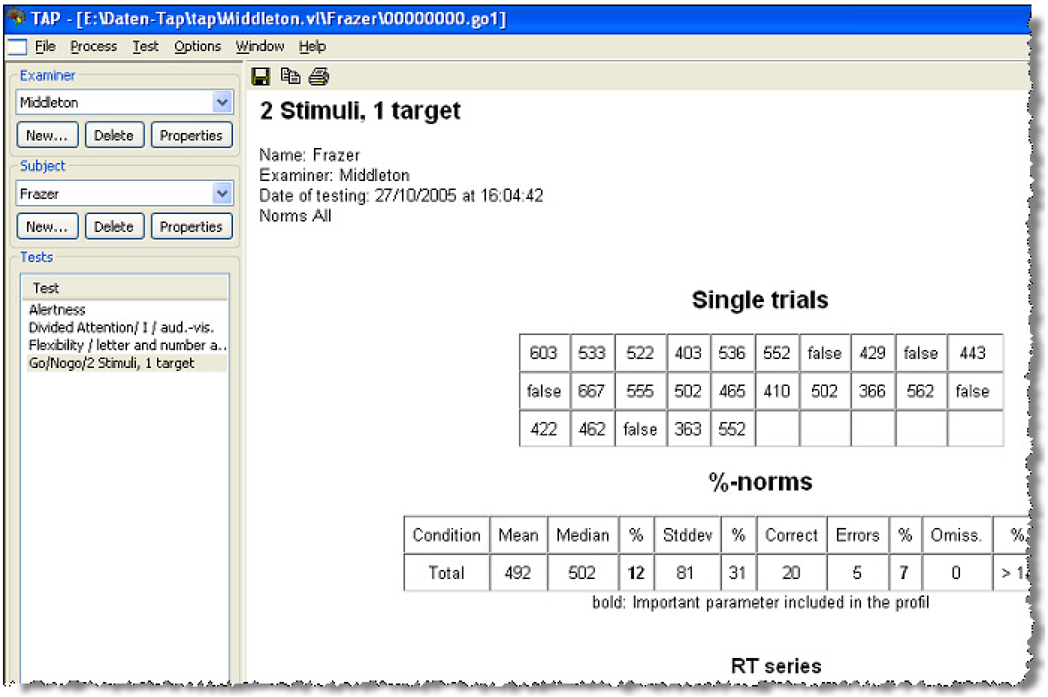
The instruction presentation can be exited by pressing the key "X". An ongoing pre- or main test can be exited by pressing a reaction key for several seconds. If the reaction key is pressed for at least 1 second a message directed to the subject will appear on the monitor, with the request "Keep your finger off the key, please!"; after a further two seconds, the following message appears: "C: Continue – X: Exit". One can exit the test by pressing the key "X" on the keyboard. Hitherto registered data will be saved. The test can be resumed at the point at which it was exited by pressing the key "C".

Warning: trials exited by the examiner will not be available for assessment. In this case, a dialogue box appears at the end of the test with the message that the trial was eliminated.

Once a test has been retrieved it may be exited by pressing the key “X”, provided that the introductory window is still visible.

5.7 Presentation and output of results

The selection of the test for which results should be displayed can be made by means of the list of tests performed by the subject (see Figure below). The desired test can be selected using the arrow keys ↓ or ↑, and the table of results can be retrieved by pressing “show”, or the table of results can be displayed by double-clicking on the test with the left mouse key. The following example shows the results of the test Go/Nogo.



The window displays information about the subject, the examiner, the time at which the test was performed, as well as the table of results with the reactions in the individual trials, and a list of results including details of the individual test parameters. The standard test parameters are mean, median and standard deviation of reaction times, the number of correct responses and errors, and the number of misses of critical stimuli (“omissions”). The norms of all standardised parameters will be shown for the corresponding age, gender and educational level of the subject, respectively (as long as effects were detected in the norm reference population). The norms can be presented as percentile ranks or as T values, as desired. The selection of percentile ranks or T values can be made by ticking the corresponding check box in the bar at the bottom of the results window.

Norms will be displayed only if a test has been completed and the age of the subject lies within the percentile age band of the norms. Table 6.1 (see section 6.2.1. “Description of the normative sample”) indicates for which tests and test conditions and which age band normative values are available.

The options in the bar at the bottom of the results window allow individual results to be included in or excluded from the list (subject, single trials, results, percentile ranks or T value, RT series, test-specific graphs {if available} and RT distribution {if available}). These settings will then be saved but can be changed at any subsequent time.

The results window can be minimised, maximised or closed by clicking on the appropriate box in the top right corner of the window.

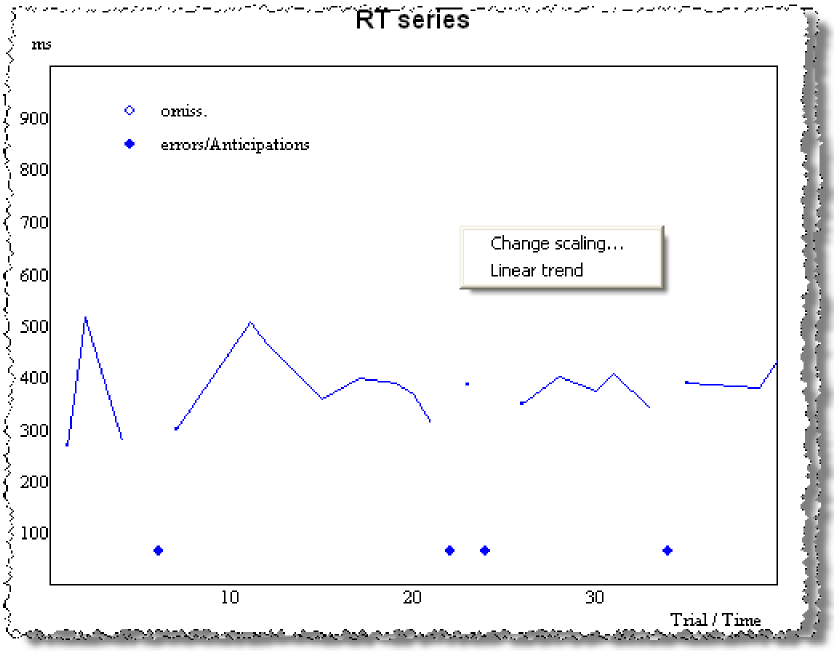
The list of results can be saved, copied to the clipboard or printed (as an alternative to the commands in the "File"- or "Edit" menu) by clicking on the boxes in the top left corner.

Several lists of results can be displayed simultaneously.

Adjusting the graphs

Changing the scaling

The graphical presentation of results is set up in such a way that the program automatically uses the maximum value on the ordinate (y) axis. The scale on the ordinate axis may be altered if required (for instance, when outliers would result in an unsatisfactory presentation). This is achieved by placing the cursor on the graph and pressing the right mouse key. The command button "change scaling…" will appear.



By placing the cursor on command button "change scaling…" and pressing the left mouse key a dialog box allowing selection of the desired minimum and maximum values on the ordinate axis will be displayed.

Trend line

If desired, a further linear trend line can be added to the graph "RT series". Do this by right clicking on the graph and then left clicking on the option "Linear trend". The trend line can be removed by repeating the operation described.

Percent / cumulative

The graph "RT-distribution" is normally shown as a cumulative distribution. By right clicking on the graph and selecting the menu option "percent" a percentual distribution will be shown.

Printing the list of results

The results displayed on the screen can be exported to the respective printer by clicking either on the corresponding symbol in the top left corner of the results list or on the "File" menu and then the command "Print results". The presentation of currently displayed results (recognisable by the blue bar at the top of the window) will be printed. The entire list containing all selected tables and graphs will be printed. If this is not desired, individual tables and graphs can be deselected by removing the ticks from the check boxes at the bottom of the result output.

These options will be saved for all further result displays, and deselected tables and graphs can be reselected by re-entering the ticks.

Saving the list of results

The list of results can be saved on the hard disk in rtf-format or html-format and opened with Word or other text processing software at a later point in time.

To save the list of results, click on the corresponding symbol in the top left corner of the displayed list or select the command “Save result as…” in the “File” menu.

5.8 Deleting directories and files

An examiner’s entire directory can be deleted. This can only be done by first deleting the directories of all of the subjects they have investigated. To delete, press the corresponding button under the examiner’s dialogue box. Confirmation is required before pressing the “Delete” command as to whether the particular examiner XY should really be deleted. This request can be answered with “yes” or “no”.

A subject and all of their data can be deleted. This is done by selecting the command “Delete” under the subject’s dialogue box. This will delete the subject’s entire directory with all of its test data. Confirmation is required before executing the “Delete” command.

A single test record of a subject or a selection of their test results can be selected from the list of test data by pressing the “Ctrl” key on the keyboard and marking the test with the left mouse key. A whole block can be selected by pressing the shift-key on the keyboard and marking the beginning and the ending of the block with the left mouse key. The marked files or the marked block of files can be deleted by pressing the “delete” command at the end of the list. Confirmation is required before executing the delete command as to whether the corresponding file or files should really be deleted.

5.9 Exporting data

The test results of a group of subjects can be saved as an ASCII-, CVS- (Comma Separated Value, readable with Excel) or SPSS-file, for example, for subsequent statistical data analysis.

In the menu „File” select the function “Export” to save the results. Two options are available for the selection of tests and subjects:

“One test, all subjects...”
“Several tests, several subjects ...”

“One test, all subjects...”: Selects the desired test from a list of test procedures.

- The test results of all subjects for which data is available from the corresponding test will be given from the register of the current examiner.
- If a test is administered to a subject repeatedly, each test result will be presented as a single row of data.
- Missing values (e.g. T-norms) are displayed as “-1”.
- If a subject has a T value of “>XY” or “<XY”, only the value “XY” is exported to the result file.

Example of ASCII-results data for the test “Alertness” (Examiner “Middelton”: 6 subjects; see Appendix A7 for the key to the variables; the table has been shortened by a number of columns).

SUBJECT	EXAMIN	NUMBER	al_COR0	al_LAP0	al_MEA0	al_MDN0	al_MDT0	al_STD0	al_STT0
Dempsey	Middelton	1	20	0	342	331	47	61	48
Frazer	Middelton	2	20	1	438	419	39	89	46
Gillanders	Middelton	3	20	1	400	390	40	84	44
Head	Middelton	4	20	1	314	305	53	56	51
McLennan	Middelton	5	20	1	363	361	40	43	55
Walker	Middelton	6	20	0	538	560	34	127	38

“Several tests, several subjects ...”: Selects the desired tests for analysis from a list of test procedures.

- Select the desired tests by holding down the “Ctrl” key and marking the corresponding tests with the left mouse button.
- After pressing “ok”, a further window with the list of subjects will open. Proceed as above to select the subjects.
- The data of all selected subject will be presented. Missing values are displayed as “-1”.
- In the case of repeated testing of a subject, *only the results of the last administered test will be shown.*

5.10 Creating a test profile

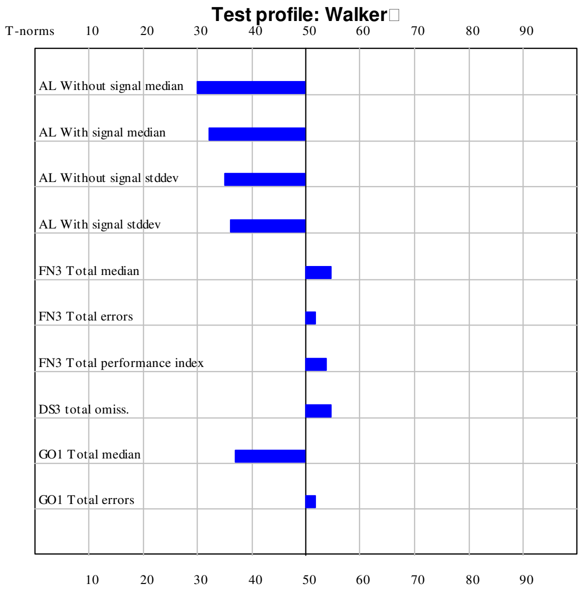
The test profile for any selection of tests and test repetitions performed by a subject can be generated using the option “Profile” at the bottom of the list of a subject or by selecting the menu option “Test profile” in the „File” menu. After activating the option “Profile”, a window opens in which the important parameters of all performed tests and test repetitions are displayed. The desired tests or test parameters can be selected using either the direction keys or the mouse:

- A whole block of tests can be selected by pressing the “Shift” key on the keyboard and marking the beginning and the ending of the block with the left mouse key.
- A selection of single tests can be made from the displayed list by pressing the “Ctrl” key on the keyboard and marking the test with the left mouse key.

The desired test parameters can be selected in the same way in the window that opens after the selection of tests.

The T-norms of the most important parameters of the single tests will be displayed in the profile (see illustration).

The following graph shows the profile of a subject, as displayed by the programme.



AL: Alertness; FN3: Flexibility / Shapes alternating; DS3: Divided Attention/ I / aud.-vis.; GO1: Go/Nogo/2 Stimuli, 1 target

5.11 Exit TAP

Exit TAP by:

- by clicking on the button in the top right corner, or
- by pressing the shortcut keys Alt + F4 on the keyboard, or
- by clicking on the “Exit” command in the “File” menu.

6 Test parameters and standardisation

6.1 Test parameters

The parameters “performance speed” and “performance accuracy” are used as criteria of test performance in the Test for Attentional Performance (TAP). These refer to the parameters “reaction time”, “correct responses”, and “false responses” as principal criteria. The measurement of time of correct responses is considered to be the valid reaction time. *Correct responses* are all responses that are not *erroneous responses* (false alarms), *omissions*, or responses outside the permitted time window (*anticipations*: responses in less than 100 ms; *outliers*: in excess of the normal area as defined by the individual mean average + 2,35 × standard deviations of the subject’s RT). The parameters of “reaction time” (median, mean and standard deviation of RT) are calculated only for correct responses without outliers.

These criteria can be used to ascertain various parameters assessing different aspects of performance ability.

The parameters of performance speed are of somewhat less importance in some of the test procedures. There are however test procedures in which the parameters response speed and response precision can be understood in terms of a mutually opposing “speed-accuracy trade-off”, thus providing information about the different approach or strategy taken in completing the task, either by placing emphasis on precision or on speed.

Parameters of performance accuracy

- The most important parameter here is the *number of correct responses*. The accuracy of the responses is determined after exclusion of responses that are incorrect or occur outside the permissible time window.

The following constraints have been applied to specific test procedures:

For Flexibility in the condition “alternating”: correct responses following an erroneous response are not considered (because the subsequent target stimulus is highlighted by a frame).

In the test Visual Scanning, there are two types of correct responses: The correct acceptance of a target stimulus and the correct rejection of a non-critical stimulus.

- The *number of errors* includes all responses in which there was a response to a non-critical stimulus (false alarm). This serves as a criterion for *impaired selectivity of attention or reduced control of response* (see Go/Nogo).
- The *number of omissions* reports the frequency with which no key response is made following a target stimulus. This is an important *indicator for inattention*.

There is a converse relationship between the number of misses and the number of correct responses, because their sum total normally amounts to the number of critical stimuli (exception: Flexibility, see 2.6 “Flexibility”).

Parameters of performance speed

- The *median of reaction times* is the most appropriate parameter for the average reaction time, because reaction times frequently do not show a normal distribution. A higher median is either a *measure of general slowing,* when this increase is consistent across all procedures, or an *indicator of the specific problems* that the patient has in processing this test when the average reaction time deviates from the average performance speed on the rest of the procedures.

- The *arithmetic mean of the reaction times* is the most frequently used measure for reporting the distribution of reaction times. However, this measure is rather unreliable because of the skewed distribution.
- The *standard deviation of the reaction times* is a sound measure of variability and thus an indicator for the *fluctuations in attention*. If variability of reaction times is a clearly increased, close inspection of the graph output of the distribution of reaction times is recommended, in order to establish whether there is a generally increased variability (instability), whether attenuated responses occur in phases, or whether there are single very slow reactions, interpreted as “lapses of attention”.
- With regard to the distribution of the individual reaction times, *outliers* represent delayed reactions. These are a measure of *lapses of attention*. Responses are judged to be outliers if the reaction time exceeds the threshold of the individual mean value plus 2.35 × the standard deviation. Related to the individual variability of reaction times, such values should only occur with a probability of less than 1%. If outliers are identified, the distribution of reaction time variables (median, mean, and standard deviation) will be re-determined after exclusion of the outlier value or values. This identification of and correction for outliers is performed only once, that is, not iteratively.
- *Anticipations* are responses with reaction times of less than 100 ms. These cannot be responses to the current stimulus because it is impossible to react so quickly. They are an *indicator of an inability to inhibit impulsive reactions*.

Test-specific parameters

- *Alertness*

An *index of phasic alertness* can be computed specifically for the test Alertness by comparing reaction times “with warning” with reaction times “without warning”. This parameter reports the *increase in the level of attention* when it assumes a value of greater than null.

This score is computed in the following way:

$$\textit{Index of phasic alertness} = \frac{\mathrm{MD}_{\mathrm{RT.without}} - \mathrm{MD}_{\mathrm{RT.with}}}{\mathrm{MD}_{\mathrm{RT.total}}}$$

in which: $\mathrm{MD}_{\mathrm{RT.without}}$ = median reaction time for Series 1 and 4 (without warning),
$\mathrm{MD}_{\mathrm{RT.with}}$ = median reaction time for Series 2 and 3 (with warning) and
$\mathrm{MD}_{\mathrm{RT.total}}$ = median reaction time for Series 1 to 4 (total test).

- *Flexibility*

Given that performance assessment in this test is based on both the number of errors as a measure of accuracy as well as on reaction time as a measure of speed, it is necessary to establish a performance measure that accounts for both of these aspects. The following procedure yields such a measure (see also Figure 2.14 in 2.6 “Flexibility”):

1. To begin with, a value of 50 is deducted from the T-values of the median of the RT (speed) and of the numbers of errors (accuracy), respectively. (Thus, average performance in both parameters is positioned at the origin of the coordinate system)
2. Transformation of the axes is then performed by anticlockwise rotation of 45°.
3. The coordinates of the new abscissa represent the total performance index, and the coordinates of the ordinate form an index for the “speed-accuracy trade-off”. The index

for the “speed-accuracy trade-off” is positive when the test person’s strategy is based on accuracy and negative when it is based on speed.

4. Finally, a T-norm or percentiles are calculated for both indices.

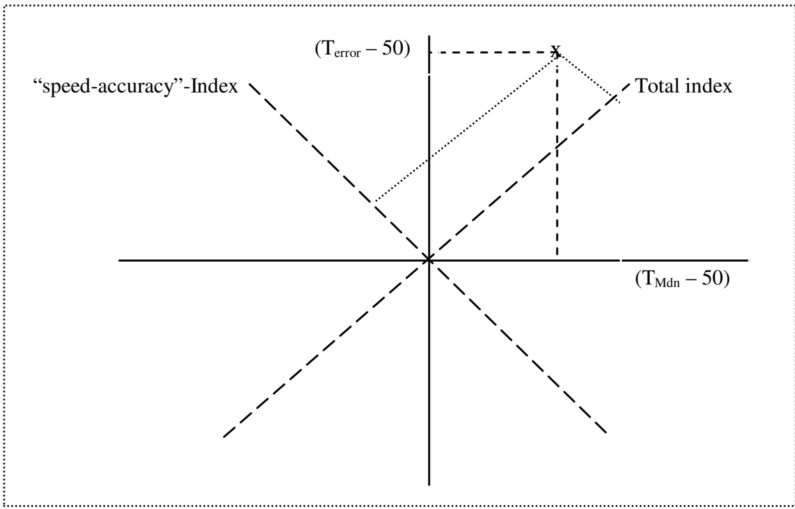


Fig. 6.1: The anticlockwise rotation of the coordinates to find the new indices for the “total performance” and for the “speed-accuracy trade-off”

The indices are calculated as follows:

Total performance index = $0{,}707 * (T_{Mdn} + T_{error} – 100)$
“Speed-accuracy”-index = $0{,}707 * (T_{error} - T_{Mdn})$

The meaning of the indices:

- Both indices have a range from negative to positive values.
- A negative value in the *total performance index* represents a below average performance (higher rate of errors with relatively slow reactions) and a positive value represents an above average performance (low rates of error with relatively short reaction times).
- For the *speed-accuracy index*, a negative value represents a proportionally high a rate of error with short reaction times (speed-based strategy) and a positive value a proportionately low rate of error with long reaction times (accuracy-based strategy).

- *Visual Scanning*

For the procedure Visual Scanning, *correlations* are computed between the reaction time and the position of the critical stimulus in the rows or columns. In order to compute this for the row correlations, the position of the critical stimulus is determined by its occurrence in each row. These are in turn numbered from top to bottom. Correspondingly, for the column correlations, its occurrence is determined in the columns numbered from left to right. These parameters are labelled as *row-* or *column-correlation* in the statistical output of the results. The size of this parameter provides information about the *strategy of the subject*, that is, whether they have scanned the matrix in columns or rows depending on which of the two parameters is significant. The absolute size of this correlation indicates how *consistently this strategy* has been applied.

6.2 Standardisation

The most important parameters of the different tests which had a sufficient reliability were standardized. Dependent on the available data, the standardisation was realised for two age groups, the first for children and young persons (6 - 19 years) and the second for adults (20 years or older).

To control for the influence of age, gender and educational level, multiple regression was calculated to eliminate these effects and provide a table of norms for each age group (for details see below and 6.2.2 “Performing the trend correction”).

6.2.1 Description of the normative sample

The data for the present standardisation were acquired in our own investigations or provided by the following persons and institutions:

Normative data of adult subjects

- Dr. I. Amado, INSERM E 0117, Hôpital Sainte-Anne, Paris
- Guido Baten and M. Strypstein, Institut Belge de la Sécurité Routière, Bruxelles
- Dr. S. Bodenburg, Neuropsychologische Praxis, Hamburg
- Prof. Dr. G. Deloche, Université de Reims Champagne Ardenne, UFR des Lettres et Sciences Humaines
- Dr. Ch. Klein, Psychologisches Institut Freiburg
- Dr. H.-J. Kunert, Psychiatrische Universitätsklinik Aachen
- Dr. B. Romero, Alzheimer-Therapiezentrum der Neurologischen Klinik Bad Aibling
- Dipl.-Psych. A. Scheurich, Psychiatrische Universitätsklinik Mainz
- Prof. Dr. Sturm, Prof. Dr. Willmes, Neurologische Universitätsklinik, Aachen
- Dr. Ann Truche, Centre de retirées, Lyon
- Prof. Dr. P. Zoccolotti, Università “La Sapienza”, Roma
- Various studies within the EU-Project “The evaluation of the efficacy of technology in the assessment and rehabilitation of brain-damaged patients” (Stachowiak et al., 1991), in cooperation with clinics in Belgium, France, Germany and Italy.

Normative data of children and adolescents

- Dr. M. Földényi, Kinder- und Jugendpsychiatrie Zürich
- Dr. H.-J. Kunert, Psychiatrische Universitätsklinik Aachen
- Dr. Ch. Klein, Psychologisches Institut Freiburg
- Dipl.-Psych. K. Titze, Klinik für Psychiatrie, Psychosomatik und Psychotherapie des Kindes- und Jugendalters, Sozialpädiatrisches Zentrum, Berlin
- Dr. Ch. Schmidt-Schönbein, Rudolf-Virchow-Klinikum, Kinderklinik, Berlin
- M. Renom und Dr. Vendrell, Ospital de la Santa Creu i San Pau, Barcelona
- Dr. Galmiche, Besançon

At this point we would like to express our sincere thanks to these individuals for their very helpful co-operation.

The normative samples were constructed according to the variables gender, age and education (the latter however not for children). For education, the number of years of school attendance was dichotomised according to “less than” or “equal to or more than” 12 years. (The limit of 12 years was selected in order to ensure consistency with the conditions between the different European countries). For normative standardisation, the different projects in which TAP normative data were acquired for children and adults comprised different subsets of the TAP subtests, so that the normalised subtests vary with regard to the size of the normative samples. This is presented in greater detail in the description of test norms in Part 2 of the Manual.

The diagnostically relevant parameters were normed for the majority of the tests. But the tests for adults and adolescents are not normed to the same extent.

A revised test (Eye-Movement), two newly-developed subtests (Visual Field Test and Neglect with central task) and a subtest of Sustained Attention (condition “Form”) have still to be normed. Those tests and subtests that have been normed are presented in the following table, Tab. 6.1. The normative values were calculated with the whole sample of each age group, correcting for age, gender and education (see 6.2.2 “Performing the trend correction”).

Tab. 6.1: The normalisation of tests and subtests

Test	Subtest	Children/ adolescents		Adults	
		Age	N	Age	N
Alertness		6 – 18	527	19 – 89	604
Covert Shift of Attention		–		20 – 90	135
Crossmodal Integration		11 – 12	94	19 – 59	237
Eye-Movement		–			–
Flexibility	*Angular shape*	–		20 – 90	158
	Round shape	–		20 – 90	158
	Alternating shapes	–		20 – 90	158
	Numbers	9 – 12	186	20 – 90	172
	Letters	9 – 12	187	20 – 90	159
	Letters and numbers alternating	–		19 – 90	811
Divided Attention 1 (synchronous)	*visual*	9 – 12	187	20 – 90	161
	Auditory	9 – 12	186	20 – 90	161
	Dual task	6 – 18	470	19 – 90	808
Divided Attention 1I (asynchronous)	*Visual*	–		20 – 90	157
	Auditory	–		20 – 90	157
	Dual task	–		20 – 90	157
Go/Nogo	*1 of 2*	6 – 18	529	19 – 90	439
	2 of 5	9 – 18	320	19 – 90	417
Incompatibility		6 – 18	502	19 – 90	459
Sustained Attention	*Shape*	–			–
	Colour or shape	–		19 – 72	188
Vigilance	*Auditory*	–		20 – 69	200
	Visual: alternating square	–			–
	Visual:moving bar	–		20 – 69	200
Visual Field Test Neglect	*Visual field: short (48 Items)*	–			–
	Visual field: long (92 Items)	–		20 – 69	200
	Visual field: with central task	–			–
	Neglect	–		20 – 69	200
	Neglect: with central task	–			–
Visual Scanning		10 – 18	130	19 – 90	397
Working Memory	*Level 1*	–			–
	Level 2	10 – 12	108		–
	Level 3	11 – 18	159	19 – 89	322

A precise breakdown of the samples for each subtest, according to age, gender and education is available in the Handbook Part 2.

6.2.2 Performing the trend correction

When determining age trends it is important to exclude the influence of outliers. This was achieved in an iterative procedure by calculating the corrected values after exclusion of extreme values. First, the influence of gender and age (see next section) were eliminated from the raw data of each of the parameters by a stepwise multiple regression, and the standardised residuals were calculated. Every case with a residual larger than 2.5 or smaller than -2.5 was excluded from the remaining trend analysis of the corresponding parameter. This procedure was repeated until all data with extreme deviations were excluded. The remaining cases were then drawn into the analysis of the influence of gender and age. The calculation of the trend corrected values and the subsequent determination of the normative values was performed with *all data* (that is, including outliers).

Procedure: first, the trend of gender and age effects (including the quadratic and cubic age effect) are eliminated from the raw data (step 1). Bearing in mind that the variability also changes with age, that is, there is a partial change in the homogeneity of the distribution for the age groups, the effects of gender, age, and the quadratic and cubic effects of age are partialled out of the trend-corrected residues. This correction is also performed by multiple regression with the absolute values of the trend-corrected residues (step 2).

The adjusted initial values are subsequently "reconstructed" with regard to the reduced variation of the explained variance. Next, the absolute residues are reconstructed (step 3) and, then, the initial values are reconstructed on the basis of the average value of the trend values plus the residues with correct sign (step 4).

Pas n° 1: *Correction for trends in the raw data*

$$Score_{reg\ i} = c_0 + c_1 \times sex_i + c_2 \times age_i + c_3 \times age_i^{\ 2} + c_4 \times age_i^{\ 3} + c_5 \times edu_i$$

Explication of the variables : c_0 *= Constant*
$c_1 - c_5$ *= Coefficients of regression*
sex_i *= Sex („0" = male, „1" =female)*
age_i *= Age in years*
edu_i *=Number of school years („0"= < 12years; „1" = ≥ 12 years)*

$$Score_{res\ i} = Score_i - Score_{reg\ i}$$

Pas n° 2: *Correction for trends in the residues*

$$Div_{absolut\ i} = |\ Score_{res\ i}\ |$$

$$Div_{absolut\ reg\ i} = d_0 + d_1 \times sex_i + d_2 \times age_i + d_3 \times age_i^{\ 2} + d_4 \times age_i^{\ 3} + d_5 \times edu_i$$

Explication of the variables : d_0 *= Constant*
$d_1 - d_5$ *= Coefficients of regression*

$$Div_{absolut\ res\ i} = Div_{absolut\ i} - Div_{absolut\ reg\ i}$$

Pas n° 3: *"Reconstruction" of the corrected residues (with equal dispersion)*

$$Div_{absolut\ corrected\ i} = (Div_{absolut\ i} / Div_{absolut\ reg\ i}) \times \overline{Div}_{absolut}$$

Explication of the variables: $\overline{Div}_{absolut}$ *= Mean of the residues*

Pas n° 4: *"Reconstruction" of the initial values (with equal mean and equal dispersion)*

$$\text{Si } (Score_{res\ i} < 0)\ Score_{corrected\ i} = \overline{Score} - Div_{absolut\ corrected\ i}$$

$$\text{Si } (Score_{res\ i} \geq 0)\ Score_{corrected\ i} = \overline{Score} + Div_{absolut\ corrected\ i}$$

Explication of the variables: $\overline{Score}$ *= Mean of the initial values*

6.2.3 Calculation of normative values

The normative values were calculated with the trend corrected values on the basis of the whole sample. First, the percentile values were established in the sense of low performance upwards, and then the corresponding T-values is allocated. T is a standardised value with a mean of 50 and a standard deviation of 10.

For reaction time in general a continuous distribution is seen, while for parameters of accuracy with low frequency in the normal population the distribution of normative values is often discontinuous. For example, if 25 % of the normal population commit no errors, there is no discrimination of the performance above a percentile of 75 % (T-value of 57). In such a case, an above-average performance is displayed with a percentile > 75 % (or T-value > 57).

6.2.4 Interpretation of normative values

Percentiles below 25 (T-values below 43) correspond to below-average performance. Average performance (the middle 50 % of the distribution of the normative sample) corresponds to a percentile of between 25 and 75 (T-value between 43 and 57). Percentiles above 75 (T-value over 57) can be seen as above-average performance.

7 Test characteristics

7.1 Objectivity

7.1.1 Administrative objectivity

All tests are administered with standardised monitor instructions. In addition, comprehension of instructions is verified with a pre-test and by observing the guidelines in 3 “Guidelines for Test Administration. Normally, the pre-test should be performed only once, but can be repeated several times on a case-by-case basis when this appears imperative for understanding of the test procedure. The main test should be administered as soon as the pre-test shows that the subject has understood the task.

7.1.1 Assessment objectivity

The results are analysed automatically and therefore objectively.

7.2 Reliability

7.2.1 Odd-even-reliability

The split-half or odd-even reliability is regarded as a suitable measure of reliability/consistency for reaction time tests. In both cases, the test is divided into two equivalent halves in which however the halving procedure is performed according to test time (split half) or to the odd and even numbering of the items (odd-even). While the split-half measure is relatively sensitive to differences in interindividual trends over the course of test application, the odd-even measure is influenced by reaction outliers. These are however excluded on an individual basis by the control for outliers (see 6.1 “Test parameters”) so that the odd-even approach has been selected here as the more appropriate measure.

The Tables A5 and A6 in the appendix provide odd-even reliabilities for the TAP subtests as well as standard errors, critical raw values and T-value differences for p=5 % probabilities of error (in each case on the basis of the odd-even reliability).

The reliabilities of the reaction time medians lie mostly above .90 and are therefore deemed satisfactory to very good and as sufficient for the psychometric case diagnostic. In contrast, the reliabilities of the measures of error are frequently inadequate (cf. the omissions in the Conditions 1 and 2 of the test Divided Attention) and these correlate with the frequency and the distribution of the incorrect responses or omissions in the normative sample. Because of the low frequency of errors or omissions and because of the skewed distribution, no corresponding reliabilities are calculated or indicated for several of the test parameters (e.g. Eye-Movement, different conditions of Flexibility).

From a test-theoretical perspective, the diagnostic utility of incorrect responses and omissions is greatest when they are considered in relation with the test as a whole, or when based on test conditions comprising relatively many trials with a high probability of incorrect responses and omissions i.e. they occur in the normative sample very frequently and with a regular distribution.

It is nevertheless possible to calculate the intra-interindividual differences in the reported parameters on the basis of the critical differences presented in the tables, as calculated according to the formula from Lienert[1] and based on the odd-even reliability coefficient. The greater the reliability, the smaller the corresponding critical T-value difference. For example,

[1] Lienert, 1969, p. 455

in the test of Alertness with warning tone a T-value difference of 2 in the median of RT is already significant at the 5%-level.

The *standard error* given in Table A12 and A17 is calculated thus:

$$s_e = s_x \times \sqrt{1 - r_{tt}}$$

with: s_e = standard error
s_x = standard deviation of the test
r_{tt} = reliability of the test (odd/even)

7.2.2 Critical differences for each test parameter

For assessing *interindividual differences* between two test values of a test, the critical raw values and T-value differences are given in the Tables A5 and A6 at a 5% probability of error. These are calculated according to Lienert[1] as follows:

[1] $$Diff_{crit\ 5\%} = 1.96 \times s_x \times \sqrt{2 \times (1 - r_{tt})}$$ (5% probability of error)

or

[2] $$Diff_{crit\ 1\%} = 2.58 \times s_x \times \sqrt{2 \times (1 - r_{tt})}$$ (1% probability of error)

Two subjects whose raw values or T-value differences exceed this critical difference will be significantly different at a 5% or 1% probability of error.

In analogy to [1] and [2], *intraindividual differences* may be examined. It may be of interest to inquire whether the performance of a subject changes significantly between the first and second run of a test. Bear in mind, however, that a significant difference between two consecutive measurements may be attributable to learning effects, especially in the more complex tests of this test battery (see also 7.2.4.1 “Test repetition and training effects”) or to a change in the latent dimension that the test in question is measuring.

Alternatively, intraindividual differences may be assessed by applying methods used in the psychometric case diagnostic according to Huber[2].

[1] Lienert, 1969, p. 454ff
[2] Huber, 1973

7.2.3 Critical profile differences at the 5% level

Critical differences in profile may still be given on an intraindividual subject basis (according to Lienert, 1969) for test conditions that are relevant for a given case

Tab. 7.1: Critical T-value profile differences at the 5% level of selected TAP variables (acc. to Lienert, 1969, S. 460, formula 162) for the normative sample of adults (20-90 Years)

Variable	Critical difference of T-values
Divided Attention / 20-90 years: Difference between the medians of RT for visual stimuli in condition 3 (dual task) AND in condition 1 (single task)	3.72
Divided Attention / 20-90 years: Difference between the omissions for visual stimuli in condition 3 (dual task) AND in condition 1 (single task)	17.75
Divided Attention / 20-90 years: Difference between the medians of RT for sound-stimuli in condition 3 (dual task) AND in condition 2 (single task)	2.70
Divided Attention / 20-90 years: Difference between the omissions for sound-stimuli in condition 3 (dual task) AND in condition 2 (single task)	19.22
Flexibility verbal/ 20-90 years: Difference between the medians of RT of the total test – condition letters AND alternating, verbal	0.88
Flexibility verbal/ 20-90 years: Difference between the medians of RT of the total test – condition numbers AND alternating ,verbal	0.88
Flexibility nonverbal/ 20-90 years: Difference between the medians of RT of the total test – conditions round AND alternating, nonverbal	0.88
Flexibility nonverbal/ 20-90 years: Difference between the medians of RT of the total test – condition angular AND alternating, nonverbal	0.88
Flexibility alternating, verbal and nonverbal/ 20-90 years: Difference between the medians of RT of the total test of the verbal AND the non-verbal condition.	0.88
Flexibility alternating verbal and nonverbal/ 20-90 years: Difference between the errors of the total test of the verbal AND the non-verbal condition.	14.13
Sustained Attention / 19-72 years: Differences between the medians of RT in the first third AND the last third.	10.32
Sustained Attention / 19-72 years: Differences between the omissions in the first third AND the last third.	15.7
Sustained Attention / 19-72 years: Differences between the false reactions in the first third AND the last third.	17.21
Vigilance / visual / moving bar / 20-69 years: Difference between the medians of RT of the intervals of the 1-5 AND 26-30 minutes.	15.09
Vigilance / visual / moving bar / 20-69 years: Difference between the medians of RT of the intervals of the 1-15 AND 16-30 minutes.	8.70
Vigilance / auditory / 20-69 years: Difference between the medians of RT of the intervals of the 1-5 AND 26-30 minutes.	10.81
Vigilance / auditory / 20-69 years: Difference between the medians of RT of the intervals of the 1-15 AND 16-30 minutes.	6.06
Visual Field Test / 20-69 years: Difference between the median of RT on left- AND right-sided stimuli	5.11
Neglect / 20-69 years: Difference between the median of RT on left- AND right-sided stimuli	7.07
Visual Scanning / 20-90 years: Difference between median of RT column 1 (outer left) AND median of RT column 5 (outer right)	3.45
Visual Scanning / 20-90 years: Difference between omissions column 1 (outer left) AND omissions column 5 (outer right)	12.79

Example (adults):

With reference to the odd-even reliability, the following T-value differences are significant at the 5% level:

- For the Visual Scanning test, the critical T-value difference between the medians of RT for critical stimuli in the far left and far right column of the stimulus matrix is 4
- For the Divided Attention test, the critical difference between the medians of RT for auditory targets in the dual task (cond. 3) and the simple condition (cond. 2) is 3.

In the test Visual Scanning, the respective differences in reaction time and omissions between columns 1 and 5 of the stimulus matrix has proven to be an especially good measure of potential attentional asymmetries with high diagnostic relevance (Fimm, 1997; Fimm et al., 2001a)

Tab. 7.2: Critical T-value profile differences at the 5% level for selected TAP variables (acc. to Lienert, 1969, S. 460, formula 162) for the normative sample of children and adolescents (6-19 Years)

	Critical difference of T-values
Divided Attention / 9-12 years: Difference between the medians of RT for visual stimuli in condition 3 (dual task) AND in condition 1 (single task)	5.205
Divided Attention / 9-12 years: Difference between the omissions for visual stimuli in condition 3 (dual task) AND in condition 1 (single task)	18.573
Divided Attention / 9-12 years: Difference between the medians of RT for sound-stimuli in condition 3 (dual task) AND of RT in condition 2 (single task)	3.472
Divided Attention / 9-12 years: Difference between the omissions for sound-stimuli in condition 3 (dual task) AND in condition 2 (single task)	19.134
Flexibility / 9-12 years: Difference between the medians of RT of the total test – verbal conditions 1 (letters) AND 3 (alternating)	1.288
Flexibility / 9-12 years: Difference between the medians of RT of the total test – verbal conditions 2 (numbers) AND 3 (alternating)	1.357
Flexibility / 9-12 years: Difference between the errors of the total test – verbal conditions 1 (letters) AND 3 (alternating)	20.491
Flexibility / 9-12 years: Difference between the errors of the total test – verbal conditions 2 (numbers) AND 3 (alternating)	18.810
Visual Scanning / 10-19 years: Difference between median of RT column 1 (outer left) AND median of RT column 5 (outer right)	5.655
Visual Scanning / 10-19 years: Difference between the omissions column 1 (outer left) AND omissions column 5 (outer right)	15.606

Example (children and adolescents):

With reference to the odd-even reliability, T-value differences are significant at the 5% level:

- In the Visual Scanning test, the difference of 6 between the medians of reaction time for targets in the far left and far right column of the stimulus matrix is significant.
- For the Divided Attention test, the critical difference between the medians of RT for auditory targets in the dual task (condition 3) and the simple condition (condition 2) is 4.

7.2.4 Retest-reliability

A provisional coefficient of retest-reliability has been computed based on a small sample of 35 healthy persons. Table 7.3 shows the composition of the sample with regard to the most important demographic variables[1].

Tab. 7.3: Composition of the re-test sample

Sex / Age	male		female		Total
	< 12 years of school	≥ 12 years of school	< 12 years of school	≥ 12 years of school	
20-29 years	3	13	1	6	23
30-39 years		6		2	8
40-49 years		1	1	1	3
50-59 years		1			1
Total	3	21	2	9	35

As can be seen in the table, younger individuals with higher school education predominate.

The product-moment correlation between first and second testing represents an index of retest-reliability. The average interval between both test sessions was 25 days in the presented investigation (SD = 5.75 days), with a range of 18 - 43 days (see Tab. 7.4).

The tests Alertness, Visual Field Test, Neglect, Flexibility, and to a limited degree Incompatibility and Working Memory demonstrate very high coefficients of between .60 and .83 for the median of RT (i.e. speed parameter). There were also high correlations for the number of errors in the tests Divided Attention, Go/Nogo (cond. 1) and Incompatibility. The retest-reliability of .67 was also relatively high for the number of omissions in the test Working Memory.

It was, however, surprising that low coefficients were seen in the tests Crossmodal Integration (all coefficients) and Visual Scanning (all parameters with the exception of the row correlation). There are also important interindividual differences in the index of phasic alertness, in omissions in Go/Nogo and the F-values of the variance analysis of the test Incompatibility (Visual field, Hand, Visual field × Hand). It cannot be judged conclusively whether these low values are attributable to a fluctuation in function or to low retest-reliability in a narrower sense.

It should be critically noted that the results for retest-reliability rest only on a small highly homogenous sample that inevitably results in a “restriction of range” and therefore (in view of the size of the sample) in an over-evaluation of even small interindividual (and intraindividual) variation. The result and re-test coefficients should therefore be understood as reflecting the lower boundary of the real reliability.

[1] We thank Prof. Dr. Heinze for providing the data.

Tab. 7.4: Provisional results for retest-reliability. Method: Product-Moment-Correlation and t-test for dependent samples. Average interval between pre- and post test: 25.06 days (SD=5.75 days; range=18 to 43)

Variable		Correlation	t-test
Alertness	total test: median of RT	0.81**	n.s.
Alertness	index of phasic alertness	-0.07	n.s.
Visual Field Test	total left visual field: median of RT	0.73**	n.s.
Visual Field Test	upper left 9 : median of RT	0.73**	n.s.
Visual Field Test	lower left quadrant : median of RT	0.67**	p<.05
Visual Field Test	total right visual field : median of RT	0.74**	p<.05
Visual Field Test	upper right quadrant : median of RT	0.65**	n.s.
Visual Field Test	lower right quadrant : median of RT	0.76**	p<.01
Divided Attention	dual task : median of RT	0.48*	n.s.
Divided Attention	dual task : errors	0.64**	n.s.
Divided Attention	dual task : omissions	0.44*	n.s.
Go/Nogo - condition "1 of 2"	median of RT	0.56**	n.s.
Go/Nogo - condition "1 of 2"	errors	0.73**	n.s.
Go/Nogo : condition "1 of 2"	omissions	-0.09	n.s.
Incompatibility	total test : median of RT	0.65	n.s.
Incompatibility	total test : errors	0.65	p<.01
Incompatibility	total test : F-value visual field	-0.12	
Incompatibility	total test : F-value hand	0.04	
Incompatibility	total test : F-value visual field x hand	0.32	
Crossmodal Integration	median of RT	0.42*	n.s.
Crossmodal Integration	errors	0.30	n.s.
Crossmodal Integration	omissions	-0.08	n.s.
Working Memory	median of RT	0.60**	n.s.
Working Memory	errors	0.11	p<.05
Working Memory	omissions	0.67**	p<.01
Visual Scanning	search time for the total matrix	0.40	n.s.
Visual Scanning	errors	-0.02	n.s.
Visual Scanning	omissions	0.20	n.s.
Visual Scanning	correlation RT x position of stimuli (row model)[a]	0.50*	p<.01
Neglect	total left visual field : median of RT	0.76**	n.s.
Neglect	total right visual field : median of RT	0.78**	n.s.
Flexibility - verbal	alternating : total : median of RT	0.83**	p<.01
Flexibility - verbal	alternating : total : errors	0.41*	p<.01

*: p < .01; **: p < .001

[a] The correlation measure was subject to Fisher Z transformation before calculation

The retest-reliability of the subtests Divided Attention and Go/Nogo II was established in a study of Bühner et al. (2006), based on a sample of 125 subjects. The aim of this study was the evaluation of potential training effects of fourfold test repetition of the TAP subtests on the d2 Attention Test (Brickenkamp & Zillmer, 1998). Four groups of 25 subjects (the fifth group served as control) first completed the d2, followed by four immediate repetitions of one of the TAP subtests and subsequent re-testing with the d2. The coefficients for the retest-reliability of the corresponding test values are presented in Tab. 7.5.

Tab. 7.5: Correlation matrix of the test values for the subtests Divided Attention and Go/Nogo (from Bühner et al., 2006)

Test	Median of RT [a]			Errors [b]			Omissions [b]		
	run 2	run 3	run 4	run 2	run 3	run 4	run 2	run 3	run 4
Divided Attention tone run 1	.90*	.84*	.83*	-.05	.24	-	.04	.33	.08
Divided Attention tone run 2		.91*	.89*		.33	-		.19	.09
Divided Attention tone run 3			.96*			-			.42*
Divided Attention square run 1	.47*	.60*	.72*	.17	.09	.30	.01	-.01	-.29
Divided Attention square run 2		.82*	.64*		-.15	-.16		.04	.35
Divided Attention square run 3			.70*			-.10			-.34
Divided Attention dual task run 1	.65*	.72*	.71*	.83	.18	.31	.55*	.52*	.42*
Divided Attention dual task run 2		.77*	.79*		.32	.23		.32	.33
Divided Attention dual task run 3			.90*			.19			.43*
Go/Nogo run 1	.83*	.73*	.60*	.51*	.36	.43*	-	-	-
Go/Nogo run 2		.79*	.80*		.30	.72*	-	-	
Go/Nogo run 3			.92*			.43*			-

*: p<.05

[a] Product-Moment-Correlation after Pearson; [b] Kendall-Tau-b

As can be seen from the Table 7.5, very high coefficients are evident for the consecutive test repetitions from first to the second testing, with the exception of the Divided Attention single task “square”. There are no high reliability coefficients for errors and omissions. This problem may be accounted for by their low frequency, as discussed in more detail in 7.2.1 “Odd-even-reliability”.

Zoccolotti et al. (2002) investigated a number of TAP-Tests in 62 brain-damaged patients, applying a re-test at an interval of one month. The results of the reliability measures for the TAP subtests Alertness, Divided Attention, Go/Nogo and Vigilance are presented in Tab.7.6.

Tab.7.6: Correlation matrix of the individual parameters of subtests (from Zoccolotti et al., 2002)

Variable		**Correlation**
Alertness	without warning: median of RT	0.87**
Alertness	with warning median: of RT	0.86**
Alertness	index of phasic alertness	0.15
Divided Attention	dual task: median of RT	0.33**
Divided Attention	dual task: errors	0.65**
Divided Attention	dual task: omissions	0.73**
Go/Nogo	condition “2 of 5”: median of RT	0.53**
Go/Nogo	condition “2 of 5”: errors	0.59**
Go/Nogo	condition “2 of 5”: omissions	0.16
Vigilance	visual / moving bar: median of RT	0.18
Vigilance	visual / moving bar: errors	0.4*
Vigilance	visual / moving bar: omissions	0.67**

*: p<.05¸**: p<.01

The correlations are on the whole significant. The reliabilities for Alertness are at .86 and .87, in a very stable range. Reliability is also moderate for Divided Attention, with the exception of the median of RT, and for the Go/Nogo Test. The index of phasic alertness proved to be less reliable, as was also the case for the number of omissions in the Go/Nogo test and the reaction time in the Visual Vigilance test, but these are parameters of less importance.

Földényi, Giovanoli, Tagwerker-Neuenschwander et al. (2000) determined the retest-reliability of several subtests of the TAP for a sample of seven to ten year-old children (52 girls, 43 boys), on the basis of a retest interval of 16-81 days (mean = 40 days; SD = 15 days). Both test sessions were conducted by the same examiner to ensure the best possible comparability between the two sessions. Table 7.7 shows the results of the analyses. Altogether, almost all subtests demonstrated moderate to high reliabilities for speed measures (exception: Divided Attention – median of RT). With respect to accuracy of performance, the tests Divided Attention and Visual Vigilance demonstrated moderate reliabilities, while the other sub-tests showed a somewhat low reliability for these parameters. As reported by Földényi and colleagues (2000), the latter finding was especially true for Go/Nogo and Incompatibility where the greater part of the children adopted a strategy of precision as reflected in the smaller number of errors and slower processing times.

It should be mentioned, however, that the tests Go/Nogo and Visual Scanning were administered with an altered number of stimuli (50 instead of 40 in Go/Nogo and 50 instead of 100 in Visual Scanning) and that the visual Vigilance test was performed for only 10 instead of 30 minutes. The reliabilities for the tests Visual Scanning and Vigilance are thus somewhat lower than for a complete test administration.

Tab. 7.7: Retest reliability and stability of selected TAP parameters of 7-10 year-old children (from Földényi et al., 2000)

Variable		Spearman-Rank-Correlation (age partialed out)
Alertness	median of RT without warning	0.78**
Alertness	median of RT with warning	0.68**
Alertness	index of phasic alertness	0.21
Divided Attention	dual task: median of RT	0.33*
Divided Attention	dual task: errors and omissions	0.60**
Flexibility, non-verbal	total test: median of RT	0.80**
Flexibility, non-verbal	total test: errors	0.22
Go/Nogo	condition “1 of 2”: median of RT	0.55*
Go/Nogo	condition “1 of 2”: errors and omissions	0.34*
Incompatibility	total test: median of RT	0.62**
Incompatibility	total test: errors	0.46**
Vigilance visual	median of RT	0.61**
Vigilance visual	errors and omissions	0.74**
Visual Scanning	scan time fort the total matrix	0.66
Visual Scanning	median of RT for critical trials	0.61
Visual Scanning	errors	0.27
Visual Scanning	omissions	0.55
Visual Scanning	row-correlation	0.48

*p<.01, **p<.001

See Földényi et al. (2000) for a detailed report of the results.

7.2.5 Test repetition and training effects

Bühner et al. (2006) investigated in the study mentioned above whether there are training effects in the subtests Divided Attention and Go/Nogo II associated with retesting, and whether there are transfer effects to the d2 Attentional Test resulting from training with the TAP-Tests. The experiment involved the initial completion of the d2, followed by four repetitions of the TAP-Tests and subsequent retesting with the d2. As can be seen in Table 7.8, there are low to moderate training effects of maximally seven per cent with the TAP subtests. Moreover, the training effects are evident only after several test repetitions. The gains made by training in the subtest Go/Nogo may possibly be influenced also by the number of stimuli being increased from 60 in the standard condition to 80 stimulus presentations. Training-based improvement of roughly 13 per cent was achieved in the d2 Test after repeated test administration. A performance transfer from the administered TAP subtest to the processing of the d2 could not be established.

Tab. 7.8: Percentage of training-related improvement in specific subtests compared with performance at first testing (from Bühner et al., 2006)

Variable		**Percentage of raining-related performance (%)**
Divided Attention I	tone: run 2	-1,86
Divided Attention I	tone: run 3	0,04
Divided Attention I	tone: run 4	2,77
Divided Attention I	square: run 2	0,81
Divided Attention I	square: run 3	6,55
Divided Attention I	square: run 4	6,62
Divided Attention I	tone and square: run 2	-0,39
Divided Attention I	tone and square: run 3	0,51
Divided Attention I	tone and square: run 4	2,86
Go/Nogo	condition “2 of 5”: run 2	0,43
Go/Nogo	condition “2 of 5”: run 3	3,06
Go/Nogo	condition “2 of 5”: run 4	5,58

In the context of their investigation on retest-reliability in children, Földényi et al. (2000) also calculated training effects by means of a pair-wise non-parametric rank comparison (Wilcoxon-Test) for the tests Alertness, Divided Attention, Flexibility, Go/Nogo, Incompatibility, Vigilance, and Visual Scanning. The reaction times improved in the second test in almost all tasks, with the exception of Alertness with warning and Go/Nogo. The errors and row correlations in the test Visual Scanning showed no training effect. With regard to omissions and errors, improvements in performance were evident in the tests Divided Attention, Go/Nogo, Incompatibility and for the omissions in Visual Scanning; no training effects on the accuracy measures could be found for Flexibility, Visual Vigilance and the errors in Visual Scanning. Tab.7.9 provides an overview of the rank comparisons and the significance of the training effects.

Tab. 7.9: Training effects in 7-10 year-old children (from Földényi et al., 2000). The Wilcoxon sign-rank test was applied for determining the training effects.

Variable		Wilcoxon sign-rank test Z-value	p
Alertness	without warning: median of RT	-2.81*	<0.1
Alertness	with warning: median of RT	-0.42	n.s.
Alertness	index of phasic alertness	-3.48**	<.001
Divided Attention I	dual task: median of RT	-3.36*	<.01
Divided Attention I	dual task: omissions and errors	-5.71**	<.001
Flexibility, non-verbal	median of RT	-7.81**	<.001
Flexibility, non-verbal	errors	-1.15	n.s.
Go/Nogo	median of RT	-0.22	n.s.
Go/Nogo	errors and omissions	-2.43	<.05
Incompatibility	median of RT	-3.68**	<.001
Incompatibility	errors	-2.92*	<.01
Visual Vigilance	median of RT	-4.36**	<.001
Visual Vigilance	omissions and errors	-0.07	n.s.
Visual Scanning	without target: median of RT	-6.90**	<.001
Visual Scanning	with target: median of RT	-6.80**	<.001
Visual Scanning	errors	-0.22	n.s.
Visual Scanning	omissions	-4.94**	<.001
Visual Scanning	row-correlation	-1.24	n.s.

*p<.01, **p<.001

7.3 Validity

Because of the large number of subtests and possible test conditions it is not possible to perform a comprehensive determination of validity (and reliability) of the subtests. The normative data stem from different studies in which different subsets of tests were applied. There is generally speaking only partial overlap between the studies as far as the psychometric procedures used are concerned. For this reason and for the sake of clarity the following factor analyses are presented.

7.3.1 Factor Validity

In this section, the results of main component analyses are presented on the basis of different normative samples of healthy subjects that comprise different age categories and a different selection of tests, respectively.

7.3.1.1 Factor analysis I: 20-72 years / N=54

Tab. 7.10 : Analysis of the tests Alertness, Divided Attention I, Flexibility - verbal, condition shift, Go/Nogo I and Visual Scanning for a group of subjects from 20 to 72 years (N = 54)

	Factor						
Variable	1	2	3	4	5	6	Communality
Alertness							
Median of RT without warning	,92						,89
Stand. dev. of RT without warning	,82						,87
Median of RT with warning	,84						,76
Divided Attention I							
Median of RT – visual target		,41		,48			,72
Omissions – visual target						-,66	,57
Median of RT – auditif target				,68			,55
Omissions – auditif target				,81			,72
Flexibility verbal, shift							
Median of RT – whole test		,93					,90
Stand. dev. of RT – whole test		,91					,88
Errors – whole test			,55				,60
Go/Nogo I							
Median of RT	,74						,71
Stand. dev. of RT	,59						,64
Errors			,88				,80
Visual Scanning							
Exploration time of the whole matrix		,48				,63	,75
Omissions of the target					,74		,66
Errors – trials without target					,75		,69

Factor 1: This concerns a pure speed factor: Median and standard deviation of reaction time of the tests Alterness and Go/Nogo.

Facotr 2: Factor of speed in the more complex tests, especially Flexibility, and to a lesser extent for exploration during Visual Scanning and the detection of the visual target stimulus in Divided Attention.

Factor 3: This factor represents the error particularly in the test Go/Nogo I and to a lesser degree in the test Flexibility; this constellation corresponds with the notion of “disturbed arbitrary actions” in the sense of Luria.

Factor 4: Represents performance in divided attention.

Factor 5: This factor stands for the parameter of performance quality in Visual Scanning (false alarms when target cue is absent and omissions when target cue is present)

Factor 6: This factor is best described as concerning the exploration time during visual scanning; it also represents the precision of target cue detection during divided attention. Common to both aspects is that they require spatial exploration: the shorter the exploration time during visual scanning, the greater the risk of omissions in divided attention, and vice versa. This corresponds largely to the idea of a « speed-accuracy trade-off » Factor.

It can be seen that a speed- and precision factor applies for the majority of the test procedures:

Alertness: This test is represented by a single factor that concerns both the median of the reaction times and that stability of the reactions (standard deviation of the RT) in both conditions, i.e., with and without the warning cue.

Divided Attention: This test does not reveal a cohesive factor structure. This may be explained by its construction, comprising two tasks in different modalities, a visual and an auditive task. One factor represents the speed and precision in the auditive visual task and in part the speed in the visual task. The other part is explained by a factor for processing speed in complex tasks (Factor 2). The reliability in detecting the critical visual cue depends however on the exploration speed in the test Visual Scanning (Factor 6)

Flexibility: The performance in this task is described by a factor of processing speed of complex tasks (Factor 2) and by a further factor that measures reaction control (Factor 3, together with the errors in Go/Nogo)

Go/Nogo: Two separate factors are found for this task, too. One is for the speed in simple tasks (Factor 1, together with Alertness) and one for precision, i.e., reaction control (Factor 3, together with the errors in Go/Nogo).

Visual Scanning: The structure of this task is described by a factor for speed of visual exploration (Factor 6) and by a second factor for precision of exploration (Factor 5).

7.3.1.2 Factor analysis II: 6-9 years / N=137

Tab. 7.11 : Analysis of the tests Alertness, Divided Attention I, Flexibility - nonverbal, condition shift, Go/Nogo I, Incompatibility and Visual Scanning for a group of subjects from 6 to 9 years (N = 137)

	Factor						
Variable	1	2	3	4	5	6	Communality
Alertness							
Median of RT without warning	,87						,84
Stand. dev. of RT without warning	,76						,67
Median of RT with warning	,81						,73
Divided Attention I							
Median of RT – visual target		,52					,41
Omissions – visual target					,59		,49
Median of RT – auditif target				-,53			,54
Omissions – auditif target	,68						,609
Flexibility nonverbal, shift							
Median of RT – whole test		,85					,82
Stand. dev. of RT – whole test		,75		,43			,81
Errors – whole test				,74			,66
Go/Nogo I							
Median of RT	,52					-,48	,60
Stand. dev. of RT						,54	,55
Errors						,84	,82
Incompatibility							
Median of RT – compatible trials		,69					,70
Errors – compatible trials			,81				,69
Median of RT – incompatible trials	,45	,69					,74
Errors – incompatible trials			,89				,78
Visual Scanning							
Exploration time of the whole matrix		,59					,58
Omissions of the target					,62		,51
Errors - trials without target					,75		,62

Factor 1: This concerns a pure speed factor in simple tasks: Median and standard deviation in the test Alertness and reaction time speed in Go/Nogo, as well as to a small degree the median reaction speed in incompatibility for incompatible tests.

Factor 2: This represents a factor that describes processing speed in more complex tasks (Flexibility, Incompatibility, Exploration speed in Visual Scanning and in visual tasks of Divided Attention).

Factor 3: This is a specific factor of the precision of reactions in incompatible conditions in the Incompatibility test.

Factor 4: Represents a lack of flexibility (false responses) and uncertainty in the test Flexibility. The meaning of this factor for the processing of auditive cues in divided attention is not clear.

Factor 5: This factor describes precision during scanning of spatial structures (Visual Scanning and the visual pattern during Divided Attention).

Factor 6: This factor clearly represents a speed-accuracy trade-off factor for the Go/Nogo task: the faster the responses, the greater the number of erroneous responses and vice versa.

For the age groups of 6-9 years there is also a structure with 6 factors and this independently of the fact that Incompatibility was entered in the analysis as an additional task. The analysis shows a factor structure that is principally consistent with that of the preceding analysis of the sample of 20-72 year olds,

Alertness: The aspect of speed and stability of reactions is described by a single factor (Factor 1) that also describes to a lesser degree the speed aspect of the Go/Nogo task and Incompatibility.

Divided Attention: As in the preceding analysis, the aspects of precision and speed may be differentiated depending on the visual and auditive task parts.

The speed in the visual task part is consistent with the exploration time in Visual Scanning as well as with the speed aspect in the test Flexibility. The precision is described by a factor that describes precision in Visual Scanning, too.

The speed in the auditive task of this test concurs with the precision in the test Flexibility, and the precision is associated with the speed in simple tasks. The meaning of this factor for the Divided Attention task is not clear.

Flexibility: This task is described by a factor for speed and stability of performance as well as a factor for precision. The speed factor is somewhat broader in as far as it describes also the speed aspect of the tests Divided Attention, Visual Scanning, and Incompatibility. The factor of precision for Flexibility describes also the reaction speed in the visual task of Divided Attention, for which there is no clear explanation.

Go/Nogo: A specific factor (Factor 6) describes the "speed-accuracy trade-off" between precision and speed in this test. In addition, the speed in Go/Nogo is in part described by a further factor of speed in simple response tasks.

Incompatibility: This task is clearly described by a speed (Factor 2) and a precision factor (Factor 3). The speed factor generally concerns more complex tasks (visual processing in Divided Attention, Flexibility, and Visual Scanning). The factor precision is specific for Incompatibility.

Visual Scanning: In this test there is also a clear structure for precision and speed. A factor for precision (Factor 5, as also applied for exploration performance in the visual task of Divided Attention) and a factor for processing speed in complex tasks (Factor 2, as also applied for visual processing in Divided Attention, Flexibility, and Incompatibility).

7.3.1.3 Factor analysis III: 20-72 years / N=99

Tab. 7.12 : Analysis of the tests Covert Shift of Attention, Eye Movement, Visual Field Examination and Visual Scanning for a group of subjects from 20 to 72 years (N = 99)

Variable	Factor 1	Factor 2	Factor 3	Communality
Covert Shift of Attention				
Median of RT – valid cue	,62	,60		,78
Median of RT – invalid cue	,57	,65		,78
Eye Movement				
Median of RT – GAP left	,97			,93
Median of RT – GAP right	,94			,95
Median of RT – OVERLAP left	,87			,93
Median of RT – OVERLAP right	,89			,90
Visual Field Examination				
Median of RT – left visual field		,89		,94
Median of RT – right visual field		,88		,89
Visual Scanning				
Exploration time of the whole matrix			-,90	,88
Omissions of the target			,92	,86
Errors – trials without target		,41	,62	,56

Factor 1: This factor concerns performance in the test Eye-Movement and at least in part for covert Shift of Attention

Factor 2: This factor describes the ability to shift attention, both intentionally (with warning cue in covert Shift of Attention) and reflexively (the detection of the blinking stimulus in Visual Field Examination).

Factor 3: This is a specific factor that reflects performance in the test Visual Scanning, showing a clear "speed-accuracy trade-off" effect.

The results of this analysis clearly meet the requirements of the different tests that were developed for assessing visual attention. In fact, with the exception of the test for Covert Shift of Attention, each test is represented to a great extent by a specific factor. The test Covert Shift of Attention can be explained on the one hand to involve a distinct behaviour and on the other hand to be a preparatory process for overt eye movements.

7.3.2 Effects of age on specific test performances

This section presents graphically the differential age effects of TAP Parameters. Linear trends without correction of outliers are primarily considered; therefore, these regressions do not correspond to the regression analyses underlying the normative standardisation

Tonic Alertness

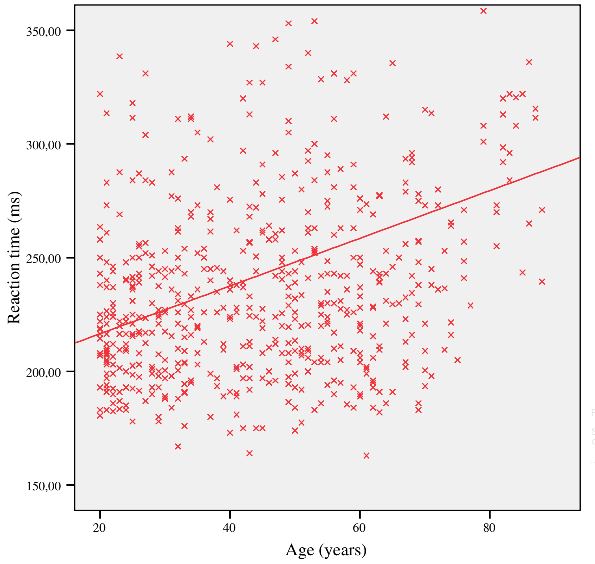


Fig. 7.1: Linear Regression of age on test performance for the reactions on trials without warning tone in the adults sample (age 20-89 Years).

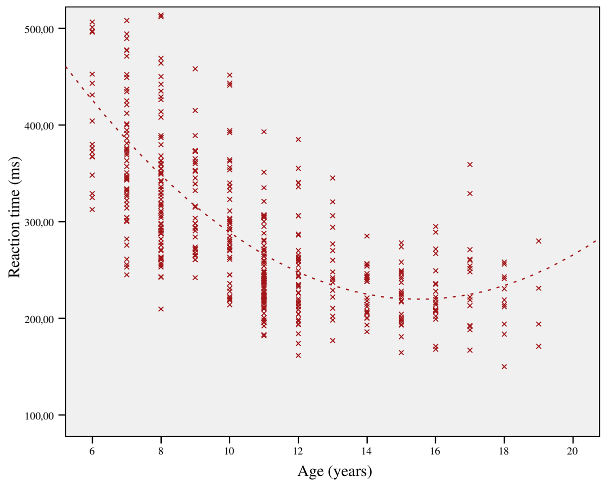


Fig. 7.2: Quadratic regression of age on test performance for the reactions on trials without warning tone in the child sample (age 6-19 years).

The Fig. 7.1 shows a linear age trend for adults in reactions to trials without warning tone, while Fig. 7.2 presents a quadratic age trend for children and adolescents between the ages of 6-19 years.

Divided Attention I

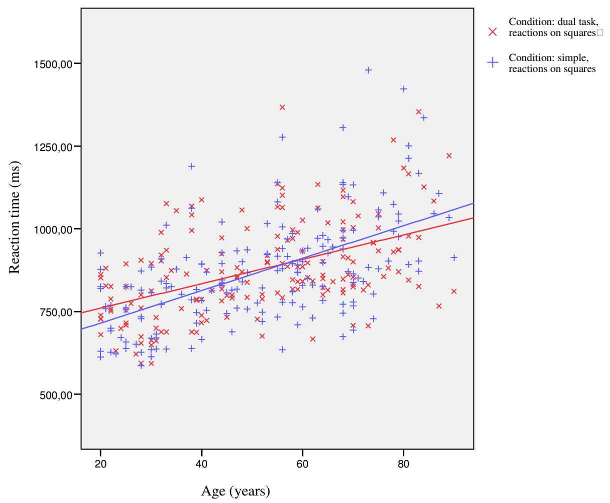


Fig. 7.3: Linear regression of age on test performance, shown separately for the medians of reaction time of the square-trials in the dual task condition of the test Divided Attention I and the medians of the RT of the simple condition square of Divided Attention I.

As may be discerned in Fig. 7.3, there is a marked age effect in visual information processing in the test Divided Attention I. It is in this case unimportant whether the response must be made exclusively to the square or in addition to the tones. With increasing age the reaction times to the visual critical stimulus become longer.

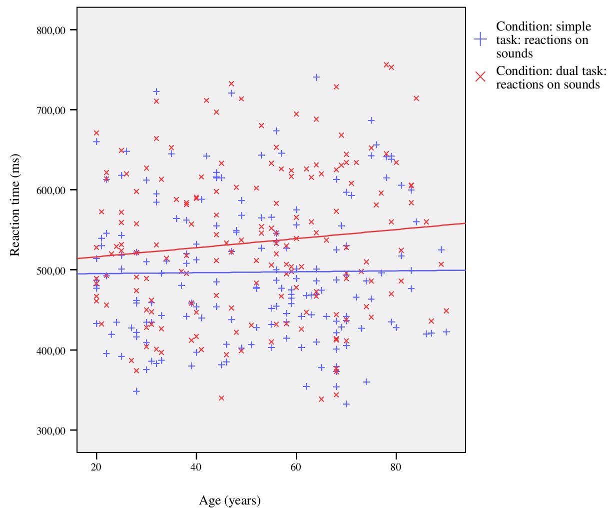


Fig. 7.4: Linear regression of age on test performance, shown separately for the medians of reaction time of the tone-trials in the dual task condition of the test Divided Attention I and the medians of the RT of the simple condition tone of Divided Attention I.

Fig. 7.4 clearly illustrates that no age effect is discernible in the normative sample in selective auditory attention, and correspondingly no trend correction has to be performed in determining the normative value. Somewhat slower reactions are however apparent (independent of age) to tones in the dual task condition than in single task processing.

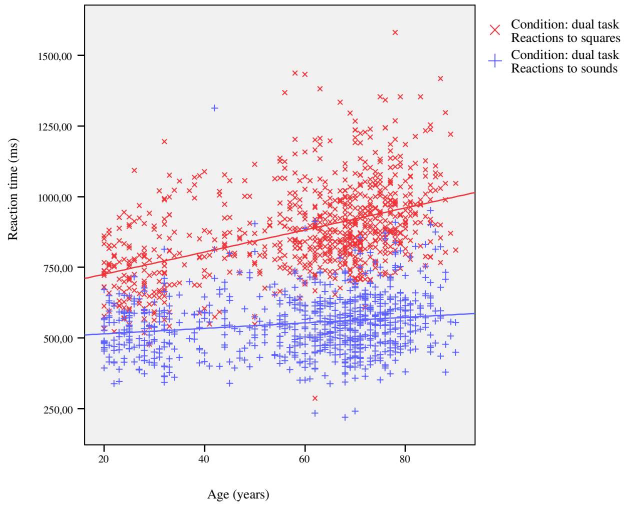


Fig. 7.5: Linear regression of age on test performance, shown separately for the medians of reaction time of the square trials and the tone trials in the dual task condition of the test Divided Attention I.

It is clear from Fig. 7.5 how differently the visual and auditory stimuli are processed in the dual task condition of Divided Attention I. On the one hand, the reactions to acoustic stimuli are much quicker, and on the other, the selective visual stimulus processing shows a marked age trend.

No analogous differential effects can be found in the omissions in the dual task conditions of the test Divided Attention I. There is, however, a positive age trend in the visual trials (possibly due to a more frequent accuracy-based strategy of older subjects).

Flexibility

A comparison of the verbal condition Numbers with the condition Alternating targets of the Flexibility test reveals distinct age effects that are especially marked in the alternating condition that requires permanent shifting of attentional focus. This appears to be much more difficult with increasing age (see Fig. 7.6). It should be emphasised, however, that some older individuals are definitely able to perform as well as much younger subjects. The age effect is essentially characterised by an increasing interindividual variance with increasing age. Performance in the non-verbal Shift condition does not increase as much with increasing age as it does in the verbal Shift condition (see Fig. 7.7).

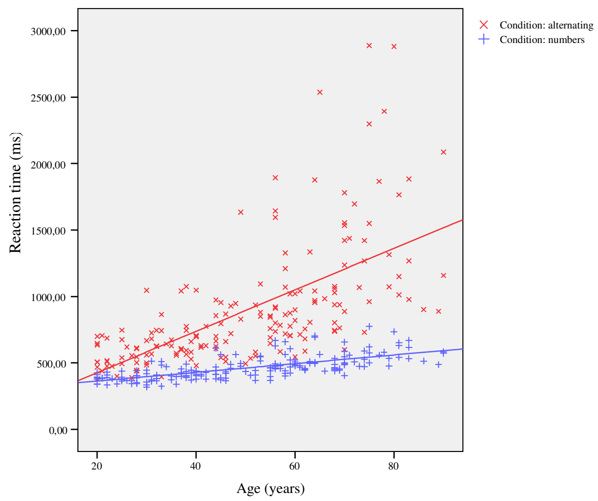


Fig. 7.6: Scattergram of age and raw values as well as the corresponding linear regression of age on test performance, shown separately for the medians of reaction time for the conditions Numbers and Shift/Letters and Numbers of the test Flexibility.

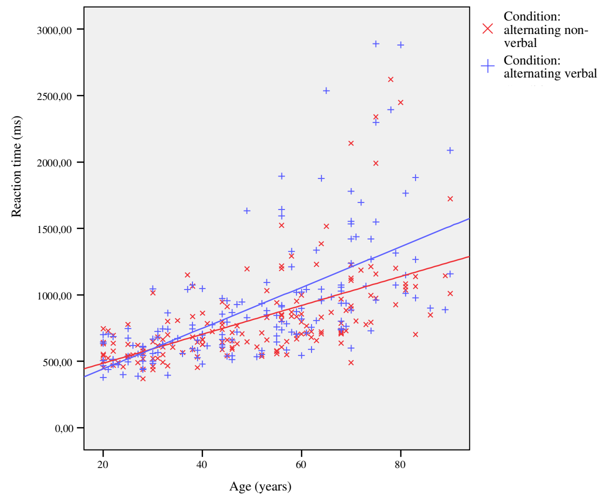


Fig. 7.7: Scattergram of age and raw values as well as the corresponding linear regression of age on test performance, shown separately for the medians of reaction time for the non-verbal and verbal Shift condition of the test Flexibility.

Incompatibility

A further indication that interference with increasing age leads to delayed reaction time may be obtained from Fig. 7.8 and Fig. 7.9. In the trials with stimulus-reaction incompatibility, there is a much stronger increase in RT and errors with increasing age.

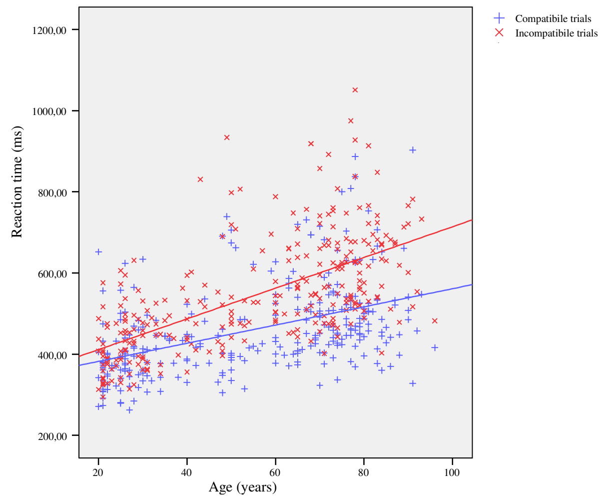


Fig. 7.8: Linear regression of age on test performance, shown separately for the medians of reaction time in the compatible and incompatible trials.

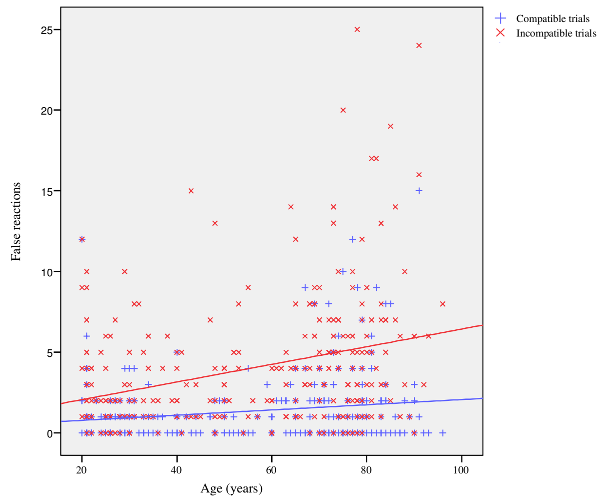


Fig. 7.9: Linear regression of age on test performance, shown separately for the errors in the compatible and incompatible trials.

Visual Scanning

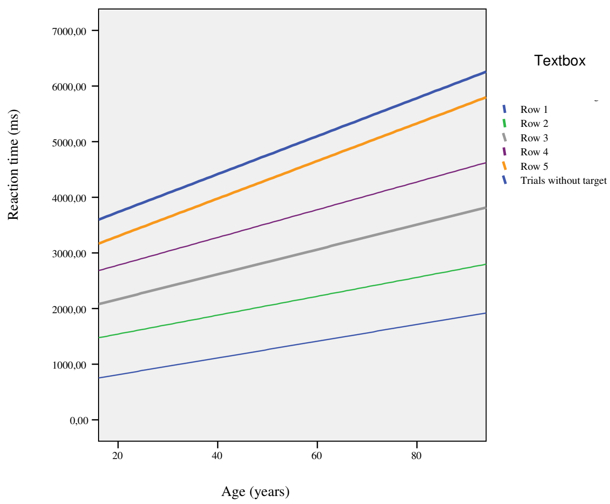


Fig. 7.10: Linear regression of age on test performance, shown separately for the medians of RT for the 5 rows as well as the total search time of the stimulus matrix in the test Visual Scanning. These regressions form the basis for the trend correction for the determination of norm values (see Normative Tables in Part 2 of the manual).

The age effect on visual search increases with the duration of the search process, as illustrated in Fig. 7.10. The subjects were instructed to scan the stimulus matrix for the target stimulus systematically, that is, row for row from top to bottom (i.e. from the 1st to 5th row). The detention times increase from row to row with increasing age.

7.3.3 Illustration of the search strategy in Visual Scanning

The test Visual Scanning provides important diagnostic information concerning the use of strategy in searching the stimulus matrix. The results output (and the Test-specific graph) of this test procedure display two correlation coefficients, “row correlation” and “column correlation”. (See 2.12 “Visual Scanning” and 6.1 “Test parameters” for details on the computation of these coefficients.) The higher the row correlation the more closely the subject follows the instruction “search the matrix row for row”. In analogy to this, the column correlations increase when these are searched on a column-by-column basis. As the test is to be administered in general with the instruction “search row by row”, the row correlations are diagnostically most important. To investigate the question whether different instructions and search strategies are really reflected in these test values, the test was administered twice to 98 healthy subjects, once with the instruction to search the stimulus matrix for the target stimulus on a row-by-row basis “as one might do when reading” and once with the instruction to inspect column-by-column.

Fig. 7.11 shows the results of these subjects in the case of row-by-row processing. The curve “in rows” shows the reaction medians of target stimuli in the 1st, 2nd, 3rd, 4th, and 5th row and also for the inspection of the entire matrix (= without target). The curve “in columns” plots the medians of RT to stimuli in the columns 1-5 during row-wise scanning. A linear increase in reaction times from row to row is clearly discernible, whereas the detection times for the targets in the different columns remain largely constant. Row-wise scanning, as per instruction, manifests a clearly linear increase in the detection time of the targets in the rows.

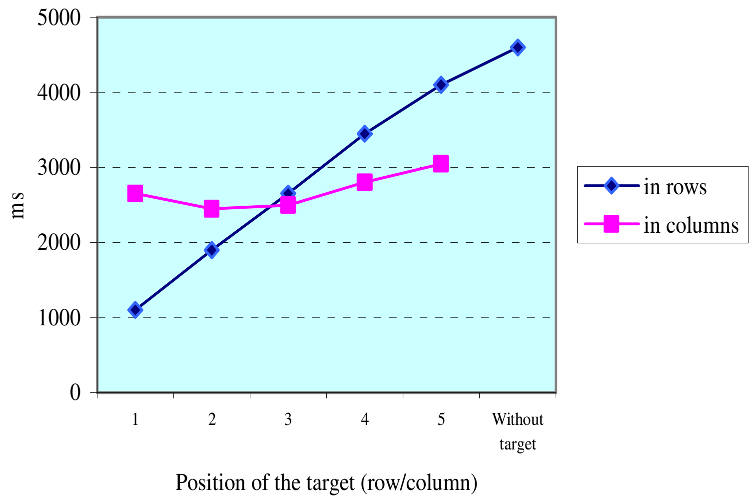


Fig. 7.111: Reaction times for targets in rows or columns for row-wise scanning in the test Visual Scanning (N=98)

There is a similar pattern with the instruction to inspect “column by column”: As can be seen in Fig. 7.12, the time for detecting the target in the columns1 to 5 increased linearly, but the detection times for target stimuli in the rows did not.

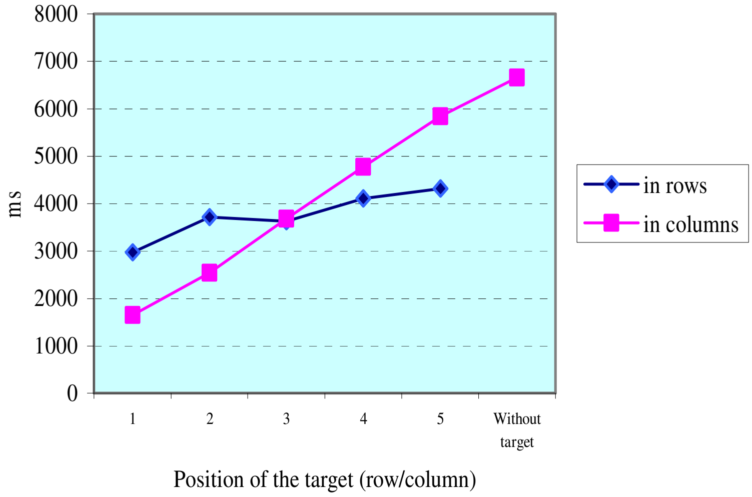


Fig. 7.12: Reaction times for targets in rows or columns for column-wise scanning in the test Visual Scanning (N=98)

Fig. 7.12 and Fig. 7.13 show that the test instruction is highly objective. The increase in detection times across the rows when instructed to “scan row by row” or across the columns when instructed to “scan column by column” is linear. It is noteworthy that the scan times for the column-wise search are longer than the row-wise inspection of the matrix, and this has some plausibility given the over-learned row-by-row scan behaviour shown when reading.

7.3.4 Information on validity from the literature

7.3.4.1 Neurological patients

The diagnosis and therapy of attention deficits in neurological patients is still the largest field of application for the TAP. The test validity has been confirmed in numerous studies on genetic disease, degenerative disease, as well as brain damage following stroke or traumatic brain injury.

Stroke patients frequently report difficulties with concentration or increased fatigue. These reports correlate generally with deficits in various areas of attention. In a validation of a questionnaire on impairments of attention in brain-damaged patients as well as in a group of students, Bühner et al. (2002) found test performance to be correlated with reported complaints. For this, the TAP-Tests Alertness, Go/Nogo, Divided Attention, Flexibility and Visual Scanning were administered as criteria of validity for attentional deficits. The parameters in Alertness correlated significantly with the frequency of the patient's reports.

The training of attention deficits in patients with neurological damage has benefited greatly from the opportunities provided by computer-supported training programmes. The TAP has been implemented frequently to evaluate training outcome. Plohmann et al. (1998) conducted computer-based training of different functions of attention in patients with multiple sclerosis. With the help of the TAP tests Alertness, Flexibility, Divided Attention, Go/Nogo, Incompatibility and Vigilance, it was possible to allocate the patients to subgroups with different patterns of attention deficits. Specific training effects were evident depending on the group, and these effects were also discernible in the TAP results of the patients.

Sturm et al. (2003, 2004a, 2004b) also found specific training effects using a computer supported training of attention in patients with traumatic brain injury or lesions after stroke. These studies also used the objective measures provided by the TAP tests Alertness, Vigilance, Visual Scanning, Go/Nogo and Divided Attention.

The TAP has frequently been utilised for re-test measurements, for example, in the investigation on the long-term impact of brain-damage. Zoccolotti et al. (2000) found in a group of patients with closed traumatic brain injury that at re-testing after five months the components of selective attention (in the sense of van Zomeren & Brouwer, 1994; TAP tests: Divided Attention, Go/Nogo) were still affected, whereas the intensity dimension (in the sense of van Zomeren & Brouwer, 1994; TAP tests: Alertness, Vigilance) showed hardly any impairment.

The utility of TAP for visual neglect is well established. Hildebrandt, Gießelmann & Sachsenheimer (1999) compared the performance of three patient groups with a control group in different visual search paradigms: patients with neglect, patients with hemianopsia and patients with right hemispheric lesions without neglect or hemianopsia. The TAP tests Neglect and Visual Scanning were administered for the visual search. Significant differences in the horizontal search in Visual Scanning were found: Neglect patients demonstrated many more omissions of target stimuli in the most peripheral contralesional column than either of the other two patient groups.

The TAP test Neglect has proven to be especially sensitive for the measurement of post-chiasma visual field defects in a study of 50 patients by Hildebrandt (2006). The test was compared with the Goldmann-Perimetry, which is often applied for visual field examination. For the so-called small marker of the Goldmann Perimeter (small stimulus size and intensity of luminance), the Neglect test achieved a comparable sensitivity in its allocation of patients to the groups “visual field defect” vs. “no visual field defect”. In comparison to the larger marker of the Goldmann-Perimetry, the TAP tests achieved a significantly higher sensitivity. In contrast to the Goldmann-Perimetry, the Neglect test tended to diagnose more frequently a partial field defect instead of a complete hemianopsia. Hildebrandt points out that the instruction in the Neglect test was altered for this study in such a way that the patients were not required to name the central letter. Instead of this, they were instructed to fixate the square in the middle; this was emphasised as an important aspect of the study. In addition, fixation was guaranteed by observation of the experimenter and by prompting the patient accordingly whenever the eyes drifted from the point of fixation.

In a group of patients with Chorea Huntington, Müller et al. (2002) found impairments in the intensity dimension of attention in particular, but also in functions of selected attention. The TAP-Tests Alertness, Go/Nogo and Divided Attention were used as part of the detailed neuropsychological assessment.

Thiel et al. (2003) found deficits in patients with idiopathic Parkinson’s disease in the Go/Nogo test of the TAP and interpreted these as confirming the hypothesis of a dysexecutive syndrome in these patients.

In a study by Böttger et al. (1998) with patients who had suffered an aneurysm of the arteria communicans anterior, the patients were shown to not only to have the previously established memory deficits but also different impairments of attention functions. These impairments were found with the TAP tests Go/Nogo, Divided Attention and Vigilance.

The diagnosis of dementia is very challenging for neuropsychological assessment. In a study by Kutz et al. (2001), the TAP tests Alertness, Go/Nogo and Flexibility were administered to patients who had been diagnosed as having dementia according to the diagnostic criteria of the DSM-IV. Deficits in attention and executive functions were found in all subgroups of different dementia syndromes.

The role played by the basal ganglia and the thalamus in visual orientation of attention was investigated by Fimm et al. (2001a) in patients with subcortical lesions. Using the tests Neglect and Visual Scanning from the TAP, patients with right or left hemispheric thalamic lesions showed slowed reactions to the contralesional side in the Neglect test. In the test Visual Scanning, only patients with right hemispheric lesions showed impairment in the processing of contralesional visual information (measured by the difference between median of RT and omissions in the 1^{st} and 5^{th} columns of the stimulus matrix).

Cognitive impairments, especially deficits in memory functions, concentration and orientation performance, have been described in patients with brain tumours in frontal brain regions in several case studies. Indeed, the risks following operative tumour removal are discussed in connection with possible damage of cognitive functions, in addition to the general risk of complications. Tucha et al. (2001) showed that no significant worsening of cognitive functions occurred after surgical removal of tumours in patients of 60 to 80 years. In the area of attention functions, a pre- and post surgical comparison with the TAP test Flexibility demonstrated improvement in the form of shorter reaction times. The comparison with a healthy control group showed that the patients had much longer reaction times before the operation.

7.3.4.2 Psychiatric patients

A relationship between neuropsychological deficits and schizophrenia has been shown in several studies. Impairments in working memory appear here to be of special importance.

Huguelet, Zanello and Nicastro (2000) reported significant differences in working memory performance in a comparison of healthy and schizophrenic subjects. Thus, the subtest working memory revealed a higher rate of error in schizophrenic patients.

Daban et al. (2002) showed strongly attenuated reaction times and increased rates of error in working memory performance in schizophrenics compared with healthy individuals. Impairments in processes of divided attention were found by Lauer et al. (1999) in patients with Anorexia Nervosa and Bulimia Nervosa. Attentional performance was measured four times: that is, before, during, and after therapeutic treatment. Distinct improvements were demonstrated over the course of treatment in divided attention performance (TAP test: Divided Attention).

7.3.4.3 Pharmacological studies

Psychiatric patients

The impact of addictive substances on attention functions has been proven in numerous studies.

In a study on the effect of alcohol, Schreckenberger et al. (2004) showed that processes of attention are differentially affected during different phases of alcohol consumption. The tests Divided Attention I, single task, auditory, Divided Attention I, single task, visual, Divided Attention I, dual task and the subtest Flexibility, verbal, shift condition were used. Significant differences were found in attention performance between the time point of acute ethanol intake (influx phase), the time point at which the blood alcohol level reached its maximum (elimination phase), and the placebo condition. Only in Divided Attention, single task, visual could no difference be established between the influx and elimination phase.

Ehrenreich et al. (1999) investigated specific functions of attention in subjects with early onset and late onset consumption of cannabis. The following subtests from the TAP were applied: Alertness, Visual Scanning, Divided Attention, Flexibility and Working Memory. No significant differences were found in Visual Scanning between early and late users of cannabis. Processes of phasic alertness and divided attention were clearly impaired in those consuming cannabis compared with a control group. In the tests Flexibility and Working Memory, no significant group differences were to be found. Gouzoulis-Mayfrank et al. (2000) also demonstrated cognitive impairments in former users of ecstasy. They compared users of cannabis who at the time abstained from concomitant use of ecstasy with those who only consumed cannabis and with drug free subjects. In the subtests Alertness, Go Nogo, Divided Attention and Crossmodal Integration there were much longer reaction times in the groups consuming ecstasy, but the groups were not significantly different in the number of errors.

Processes of working memory appear however to be less influenced by the consumption of ecstasy. Daumann et al. (2003) investigated in an fMRI-based study the brain activity of 22 abstinent users of ecstasy during a working memory task. A modified variant of the Working Memory subtest at all three levels of difficulty was applied for fMRI data acquisition. No significant differences between the subjects with previously high ecstasy consumption, with moderate ecstasy consumption, and a control group of healthy drug-free subjects could be found. A tendency toward longer reaction times in the group with very high consumption was found but only at the third level of difficulty.

The extent to which benzodiazepines have an influence on processes of attention was investigated by Röttgers et al. (2003). In a placebo-controlled double-blind study, the influence of the benzodiazepine Lorazepam on different aspects of attention was examined. Divided Attention and the ability to shift attention (Flexibility) were examined with the TAP. An attenuation of reaction or processing speed under the influence of Lorazepam was demonstrated, but only for the auditory stimuli on the Divided Attention test. The visual task and the general accuracy of attention performance in both test procedures were however unimpaired. The authors concluded that benzodiazepine intake tends to lead to a general attenuation of processing speed.

7.3.4.4 Neurological Patients

Müller-Vahl et al. (2003), examined the hypothesis that the administration of cannabis would alleviate behavioural problems and tics in patients with Tourette syndrom. Given the indications of impaired memory and attention performance in cannabis users, the performance in different memory and attention tests was measured in patients receiving either medication or placebo. The subtest Divided Attention from the TAP was conducted. Attention performance did not change significantly depending on the administration of medication.

The influence of the catecholaminergic stimulating medication L-Dopa on memory and attention performance was investigated by Golz and Erdfelder (2004) in a double-blind study with stroke patients. In the test Alertness no differences were seen between the placebo and the medication group; in this study, the medication L-Dopa only had an impact on memory performance.

7.3.4.5 Healthy Subjects

Lautenbacher, Roscher & Krieg (2002) investigated the effect of hormones of the *Hypothalamus-Hypophyse-Adrenulla-Axis* (HHDA) released under stress on processes of attention. Cognitive deficits are frequently observed in longer-term hyperactivity of the

HHDA, which occurs, for example, in certain forms of depression. The administration of corticotropin-releasing-hormones with the aim of a short-term stress-related activation of the HHDA however had no impact on processes of selective attention. No effects of the stress hormone could be proven on information processing speed or accuracy in the simple verbal condition of the subtest Flexibility.

In contrast, nicotine appears to have a positive impact on information processing. Mancuso et al. (1999) investigated the effect of nicotine on the intensity and selectivity aspects of attention. The TAP subtest Flexibility was applied to operationalise the aspect of selectivity. While there was an improvement in simple speed of information processing under the influence of nicotine, there was no change in flexibility. The results suggest therefore that nicotine mainly influences the aspect of intensity and less so the aspect of selectivity of attention.

7.3.4.6 Functional Imaging studies

Neuroanatomical localisation studies of differentiable functions of attention have gained in importance in recent years. The TAP has been frequently applied in these imaging studies, either online during imaging or as an additional behavioural test.

In a SPECT study, Slosman et al. (2001) investigated the distribution of global cerebral blood flow (gCBF) in terms of age and gender and correlated these data with neuropsychological findings. The neuropsychological assessment comprised, amongst others, of the TAP tests Flexibility and Working Memory. Changes in the form of a reaction attenuation and reduced gCBF were found in the behavioural data and in gCBF in relation to age.

Patients with multiple sclerosis show different patterns of activation in attention performance than healthy subjects. Penner et al. (2001) found in an fMRI-based study found differences in activation during performance of different TAP tests: during Alertness, the contralateral motor cortex and the supplementary motor area (SMA) and the ipsilateral cerebellum were more strongly activated in the MS patients than in the control group. In the test Working Memory, MS patients were distinguishable from the controls on the basis of reduced activations in frontal cortex and precuneus. The authors conclude that MS patients exert more effort in simple reaction tasks, whereas higher cognitive functions such as working memory cannot be compensated for by application of additional effort.

The effect of the specific stimulus material on working memory was investigated by Fimm et al. (2001b) in an fMRI-based study. For this, a modified version of the TAP test Working Memory was used: the critical stimuli were either letters or numbers. Imaging showed that the letters activated the left hemisphere more strongly, especially in the left frontal gyrus, whereas numbers resulted in right hemispheric activations, especially in the superior temporal, mid-frontal and parietal cortex.

Visual stimulus material is frequently used in fMRI-based studies. Increasingly, therefore the question has been asked whether the observed networks of attention relate simply to a stimulus modality or may be transferred to other modalities (especially acoustic). Sturm et al. (2004) studied activations in a modified auditory Alertness test ("Acoustic Alertness"). They found an extensive overlap of functional networks for the auditory and visual tasks.

Selective and divided attention can also be separated into different functional networks. Loose et al. (2000) found stronger prefrontal activations during divided attention compared with selective attention in a modified version of the TAP test Divided Attention.

7.3.4.7 Studies with children

Attention performance of children is highly important in both the areas of schooling and rehabilitation.

Földenyi, Imhof and Steinhausen (2000) carried out a clinical validation study with the TAP on children who had been diagnosed with Attention Hyperactivity Disorder on the basis of structured clinical interview. On the basis of the variance in reaction times in the test Go/Nogo, of the number of errors in Flexibility (non-verbal shift condition) and of age at testing, 90% of the children were correctly allocated to the "control" group and the "ADHS" group. In addition, parent and teacher assessments measured with standardised questionnaire were used for the criterion validity of attention performance. Significant correlations were found between these assessments and the test results of Go/Nogo, Incompatibility, Divided Attention and Flexibility.

Children with the diagnosis "ADHS" do not necessarily exhibit worse attentional performance than healthy children. This was demonstrated in the study by Koschack et al. (2003), who carried out the TAP tests Visual Scanning, Go/Nogo, Flexibility and Divided Attention. The ADHS children showed quicker reactions than the control group but showed many more incorrect responses. Koschack et al. interpreted this as an impulsive pattern of responses typical of hyperactive children.

Tucha et al. (2005) compared healthy children with ADHS children, and found that the latter showed much worse attention performance. The subtests Alertness, Vigilance, Divided Attention, Visual Scanning, Incompatibility and Flexibility were used. With the exception of Alertness, in all other areas ADHS children showed strongly attenuated reaction times, greater instability in processing the tasks and higher numbers of errors. Furthermore, treatment with Methylphenidate (MPH) did not lead to an improvement in attention performance in all areas. The reaction times did improve but the accuracy of performance compared with healthy children was still relatively poor.

The diagnosis of attentional deficits is an essential aspect in the ambulant neuropsychological treatment of children. Heubrock & Petermann (2001) investigated service utilisation of a Neuropsychological Out-patient Department for Children, amongst others in terms of diagnosis at referral and correlated this with neuropsychological findings. As criterion for deficits of attention, the TAP tests Divided Attention, Go/Nogo and Visual Scanning were selected. Most of the children with deficits of attention were allocated to the group with the referral diagnosis "partial performance deficit".

To determine the factor validity of the TAP, Kunert, Derichs & Irle (1996) carried out a factor analysis with the parameters reaction speed in all TAP subtests. Three factors were extracted that together explained 67.5% of the variance. In contrast to the factor analysis of the adult sample, the structure does not lend itself to easy interpretation. The authors explanation is that a differentiation in "frontal" attention performance is possible only at a late point in brain maturation, and that at the age of the normative sample (9-12 years) these functions are also controlled by subcortical structures that have already matured.

7.3.4.8 Studies with older subjects

In addition to the question of the development of specific attention functions in children, it is also important to consider attention performance in those in old age. Klein et al. (2000) compared optomotoric and neuropsychological function of three age groups of healthy subjects aged 20-35, 59-73 and 74-88 years, respectively. The measurement of attention-related performance was achieved with the TAP subtests Alertness, Working Memory, Go/Nogo and Incompatibility. Significant differences were evident between all three age groups in all of the subtests used. A precise statistical analysis by pair-wise group comparison showed in particular significantly longer reaction times for the age group of 59-73 years compared with the younger subjects. A comparison between the senior groups did not show any significant differences in the test Go/Nogo and Incompatibility. The incompatibility effect in relation with the median of RT was much clearer for the 59-73 year-old subjects compared with the younger age groups. This effect appears to show no considerable increase with increasing age.

8 Case examples

8.1 Patient 1 (28 years, female)

Diagnosis:

- Carrier of the Huntington allele (42 CAG repeat)
- Crohn's disease

Complaints :

- Patient has no complaints

Neuropsychological diagnosis:

- LPS 1+2: T= 50, LPS 3: T=65; LPS 6: T=55
- WMS-R Digit Span: 6 (PR=14)
- HAWIE-Digit Span backwards: 5 (inconspicuous)
- Corsi-Block-Tapping test: 6 (PR=65)
- RWT- Formal lexical verbal fluency (2 minutes duration, respectively): 22 (PR=50); RWT-
- Formal lexical categorical shift: 26 (PR=25); RWT- semantic categorical verbal fluency: 48 (PR=50); RWT- semantic categorical shift: 30 (PR=84)
- Trail-Making-Test: Part A: 18 (T=51); Part B: 48 (T=46)
- Beck Depression Inventory: 2 (clinically inconspicuous)

TAP

- Alertness: Without warning: 182 ms (PR=99); With warning tone: 179 ms (PR=96)
- Go/No-Go Condition 1 from 2: 391 ms (PR=50); errors: 2 (PR<34); omissions: 0 (PR>14)
- Divided Attention I/ aud.-vis.: Squares: 820 ms (PR=27); Tones: 660 ms (PR=10); Tones omissions: 1 (PR<31); total omissions tones: 1 (PR<46); errors: 5 (PR=7)
  Divided Attention I/auditory: 425 ms (PR= 79); errors: 1 (PR<46)
- Working Memory / level of difficulty 3: 683 ms (PR=18); omissions: 3 (PR<24); errors: 4 (PR=21)
- Flexibility/Numbers: 411 ms (PR=34); errors: 1 (PR=42)
  Flexibility/Shift, verbal: 844 ms (PR=18); errors: 1 (PR<82)
- Visual Scanning: Search time of entire stimulus matrix: 3,8 s (PR=50); omissions: 4 (PR=50); correlation-RT × row position: 0,93 (PR=76)

Assessment:

The patient has an average vocabulary at her disposal, an average two above average performance in verbal fluency and an above average ability in logical abstraction. Both verbal learning and longer-term verbal retention are unaffected. Spatial constructed processing is distinctly above average. Visual-spatial memory span is unaffected, with only the verbal memory span being below average. For the functions of attention an above average general level of activation, as well as intact selective visual attention functions and unimpaired visual search processes are revealed. Evidence is simply a mildly reduced performance in working memory under permanent control of the flow of information within the short term memory as well as a mild reduction in attention capacity (exclusive attention to tones is achieved much more quickly than with the additional processing of visual stimuli).

Besides these mild deficits, the patient shows an unimpaired level of performance which is reflected in the patient's subjective report of feeling healthy. Because of the age at which the disease becomes manifest - as a rule between 30 and 50 years – a neuropsychological follow-up should take place in due course. Distinct deficits of attention mostly appear at a later point in the course of a disease that together with diverse cognitive deficits culminate in a dementia.

8.2 Patient 2 (43 years, female)

Diagnosis:
- Dystyhmia
- Mostly selective visual disorders of attention
- Unremarkable neurological diagnosis
- Unremarkable EEG
- MRT: a single large lesion right frontally; partially low-grade, increasing small focus after four year interval; no indication of territorial infarction; no reduction in brain volume in excess of the age norm; no recognisable gait disorder.

Complaints:
- Patient complains of cognitive impairments also after anti-depressive treatment
- Persistent stomach and intestinal problems for several years
- Forgetfulness, especially names and appointments
- Always feels not to have slept enough
- Hazy feeling in their head as if “packed in cotton wool”
- Family burden on account of Anorexia/Bulimia illness of the daughter

Neuropsychological diagnosis:
- LPS 1+2: T= 45; LPS 3: T= 45
- WMS-R Digit Span: 7 (PR=22)
- HAWIE-Digit Span: 5 (unremarkable)
- Corsi-Block-Tapping test: 5 (PR=37)
- RWT- Formal lexical verbal fluency (2 minutes duration, respectively): 11 (PR=13); RWT- Formal lexical categorical shift: 16 (PR=9); RWT-Semantic categorical verbal fluency : 21 (PR=2); RWT- Semantic category shift: 18 (PR=12)

TAP:
- Alertness – beginning of examination: Without warning: 234 ms (PR=58); with warning tone: 212 ms (PR=66)
- Alertness – end of examination: Without warning: 240 ms (PR=54); with warning tone: 237 ms (PR=38)
- Divided Attention I/ aud.-vis.: Squares: 1060 ms (PR= 5); Tones: 544 ms (PR=46); omissions - visual: 6 (PR=1); omissions - auditory: 1 (PR<31)
  Divided Attention I/visual: 913 ms (PR= 21); omissions: 6 (PR=1)
- Working Memory/ level of difficulty 3: 662 ms (PR=42); omissions: 3 (PR<27); errors: 6 (PR=10)
- Visual field-Neglect with central task: left visual field: 537 ms (PR=8); right visual field: 509 ms (PR=10); omissions: 0
- Visual Scanning: search time for whole stimulus matrix: 7,1 (PR=7); omissions: 0 (PR>92); correlation-RT × row position: 0,773 (PR=27); 1. column: 4790 ms (PR=4); 5. column: 3683 ms (PR=27) Indication of an attentional asymmetry to the detriment of the left visual field

Assessment:

The patient exhibits an above average vocabulary as well as an average ability in logical abstraction. Both the visual-spatial as well as the verbal memory span show themselves to be largely intact. Alone in verbal working memory is there a mild reduction in performance upon complex demands. Verbal and non-verbal learning are unimpaired. An impairment of the phonetic and semantic verbal fluency that may be graded as intermediate is apparent. For functions of attention, there is an average level of general activation without indication of increased fluctuations in attention. Increased tiring during the course of examination cannot be determined. Because of apparent deficits during the examination of visual-spatial attention performance, this cognitive domain received careful attention. No attention asymmetries were hereby found between the right and left visual field in tasks that do not require systematic eye-movements. However, deficits can be shown as soon as these must be applied for successful processing of a task. Here with, a clear tendency toward delayed reactions to left side-positioned stimuli is seen. In addition, the patient obviously experiences difficulties in reacting to quickly changing stimuli that are embedded in a correspondingly complex stimulus display (see 2.4 “Divided Attention”). The mentioned asymmetry to the detriment of left-sided stimuli could be a correlate of the right frontal lesion found in the MRT. It cannot be excluded that voluntary eye-movements to the left may be affected hereby.

8.3 Patient 3 (51 years, male)

Diagnosis:
- State after astrocytoma WHO Grade II, left thalamus region

Complaints:
- Sporadic headaches
- Increased forgetfulness, especially for conversational content
- Buzzing in the ears on both sides

Neuropsychological diagnosis:
- LPS 50+: 1+2 T=41; 3 T=58
- RWT (2 minutes duration, respectively): Formal lexical verbal fluency PR 4, Formal lexical categorical shift PR 2, Semantic categorical fluency PR <1, Semantic categorical shift PR 2
- WMS-R Digit Span: PR 67
- HAWIE-Digit Span backwards: RW=5
- Corsi-Block-Tapping Test: PR 65
- TMT A1: T=49; B1: T=42

TAP
- Alertness: without warning signal 252 ms (PR 21), with warning signal 231 ms (PR 34)
- Go/Nogo condition 1: MDN 375 ms (PR 73), no omissions, 2 errors (PR=34)
- Divided Attention /auditory-visual: reactions to critical visual stimuli 872 ms (PR=34), reactions to critical auditory stimuli 475 (PR=73), 3 omissions (PR=18).
- Working Memory / level of difficulty 3: MDN 649 ms (PR=50), 2 omissions (PR=38), 9 errors (PR=4)
- Flexibility / numbers: MDN 440 ms (PR=62); 3 errors (PR=4)
- Flexibility / shift verbal: MDN 2 s (PR=3); 18 errors (PR=3)
- Visual Scanning: Total search time 7,9 s (PR=4); 1 omission (PR=82), no errors (PR>24); 1. column: 3760 ms (PR=16); 5. column: 5562 ms (PR=3) Indication of an attention asymmetry to the detriment of the right visual field

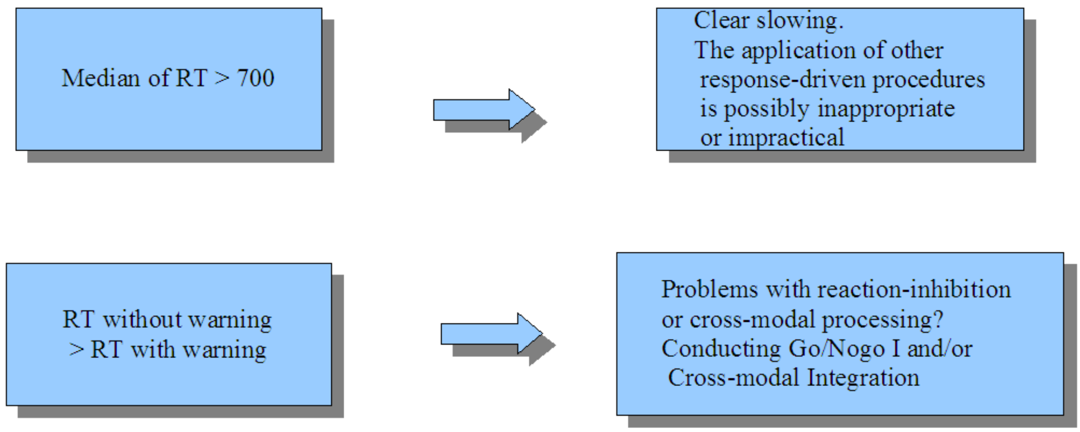
Assessment:

The patient shows a just average vocabulary, as well as an above average ability in logical abstraction. The verbal and visual spatial memory spans as well as simple working memory processes are unimpaired. Recognition of numerously repeated verbal and non-verbal information is average. Spatial-constructive processing as well as basal processes of attention is also average. There are however distinct phonetic and semantic deficits of verbal fluency as well as a partially associated distinct difficulty in learning and recognition of semantically structured verbal information. This deficit in learning a word list is however attributable not only to a pure problem of recall but it is indicative of an impairment of verbal learning. Furthermore, there is indication of attention asymmetries to the detriment of the right visual field during visual search which is correlated with the left hemispheric localisation of the astrozytoma. There is also a marked deficit in cognitive flexibility that manifests itself in the shift condition of the test Flexibility.

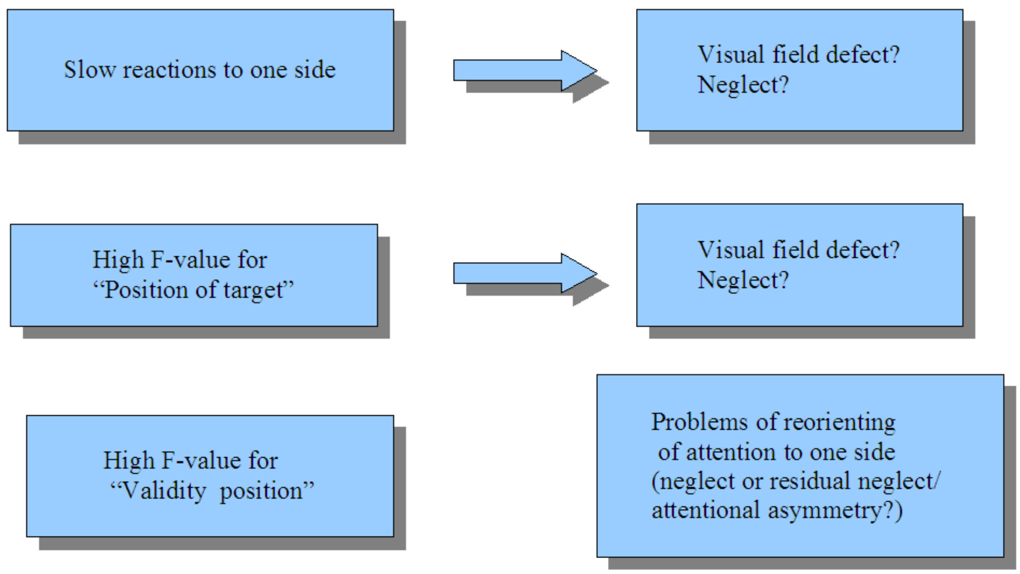
9 Diagnostic strategies

The following graphs show possible strategies and possible explanations for the application or the interpretation of subtests of the TAP. As a rule, not all test procedures are administered within the context of a routine examination. As a minimal selection of tests with sufficient meaningfulness, the tests Alertness, Go/Nogo, Divided Attention and Flexibility should be mentioned. These should, however, depending on the problem, be complemented by other procedures.

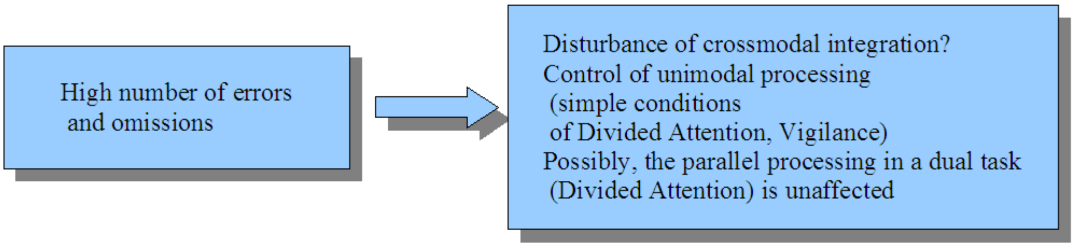
Alertness



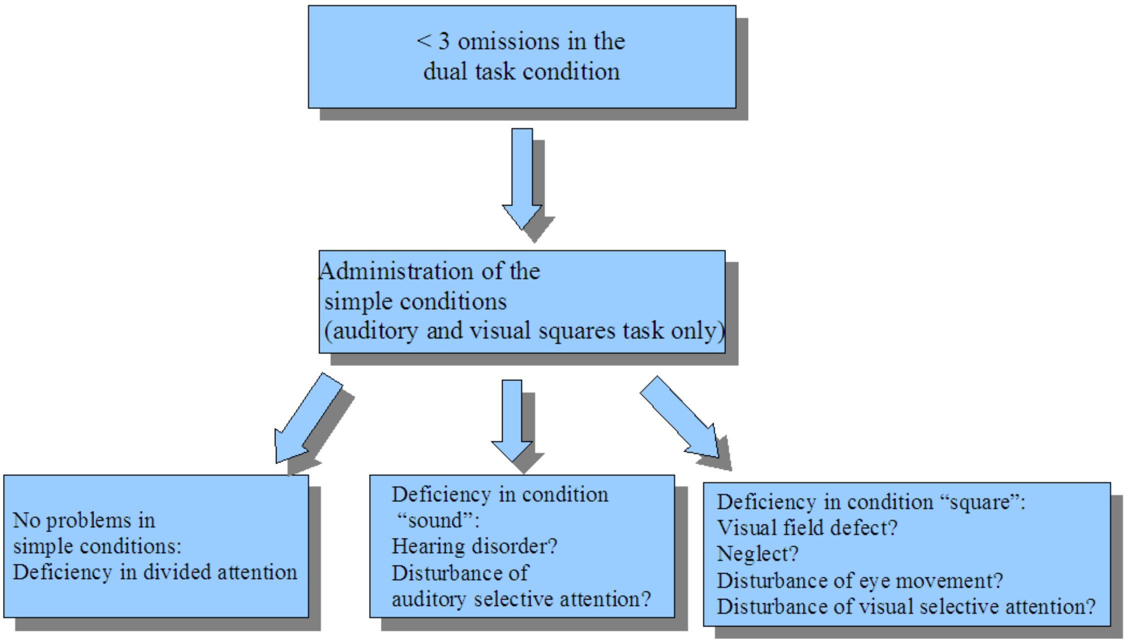
Covert Attention Shift



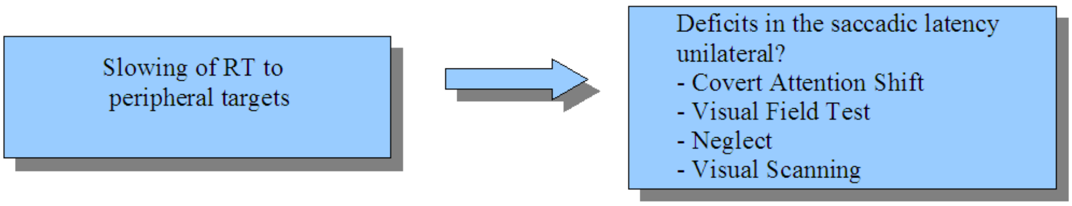
Crossmodal Integration



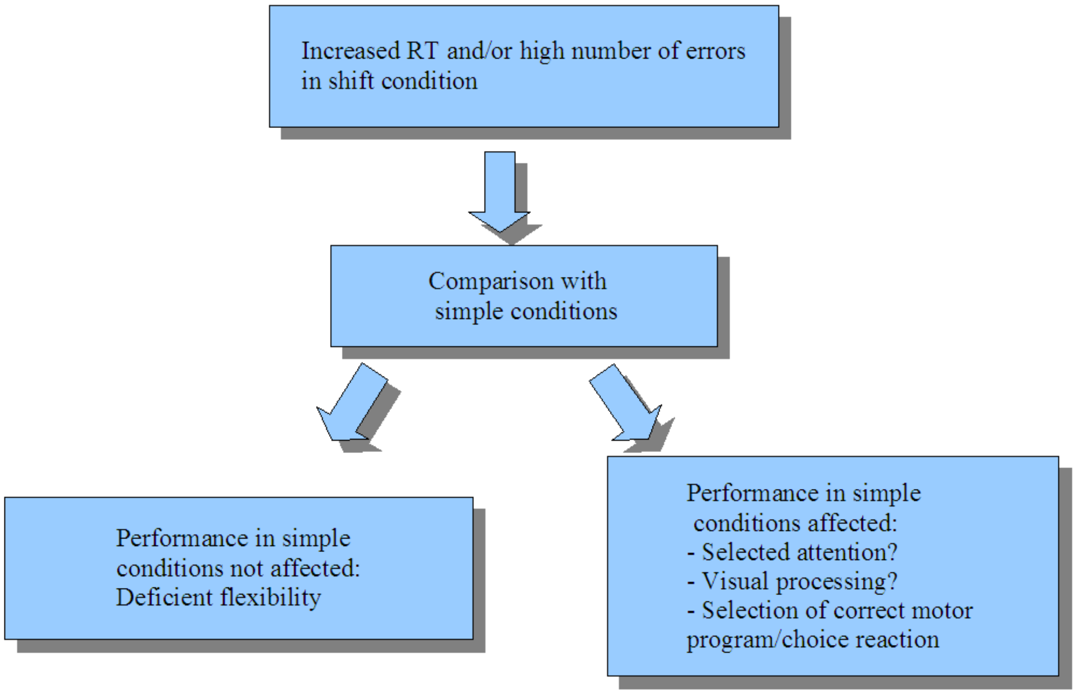
Divided Attention



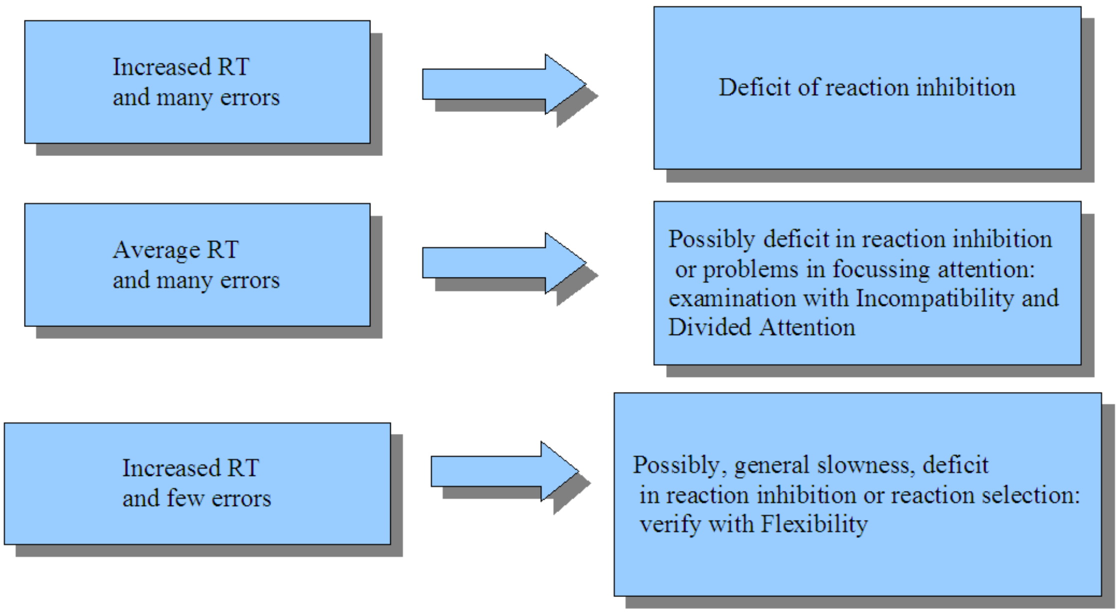
Eye Movement



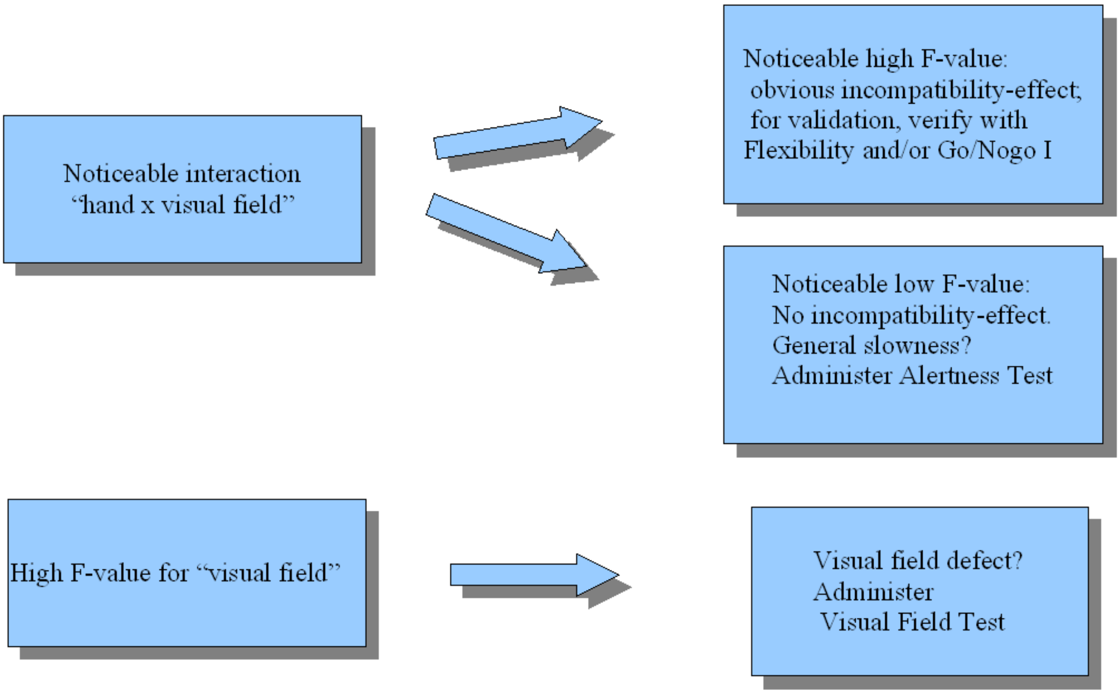
Flexibility



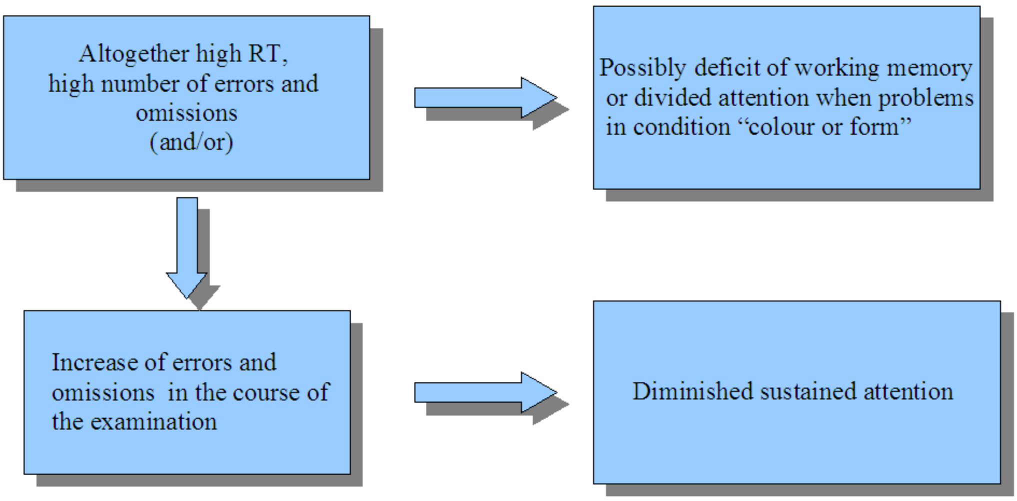
Go/Nogo I



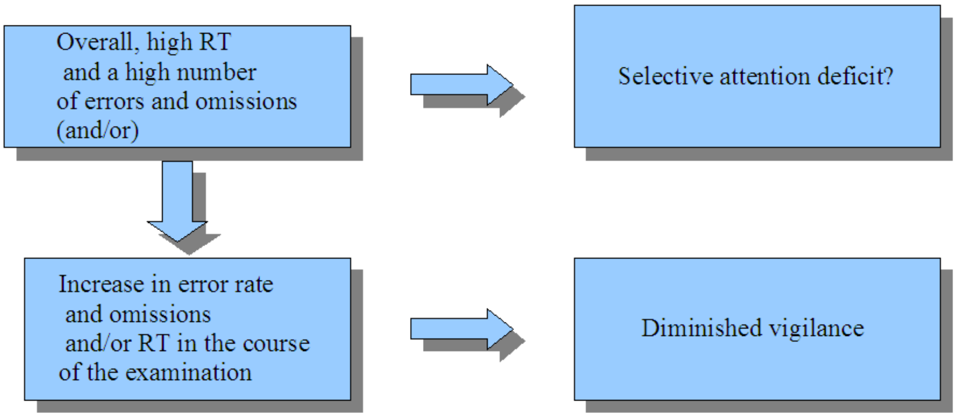
Incompatbility



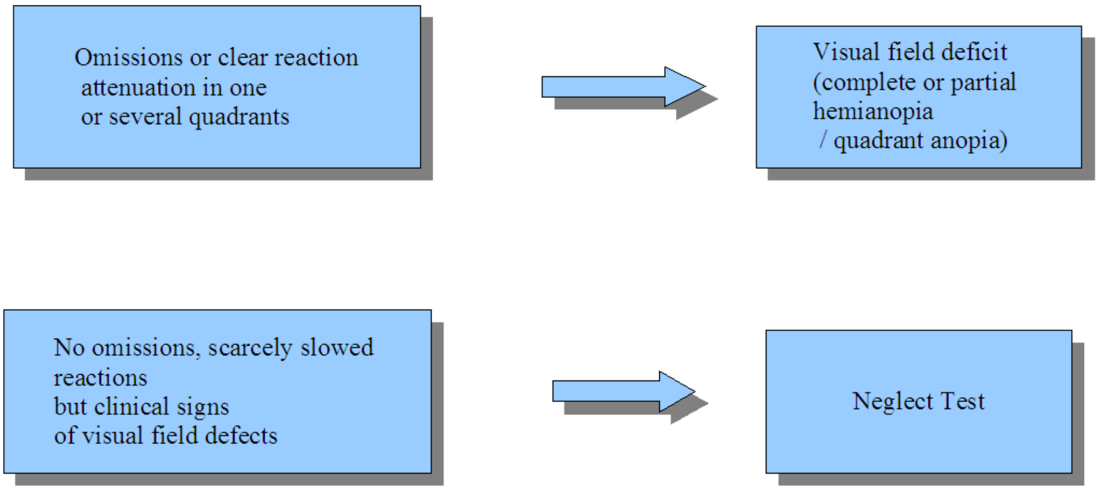
Sustained Attention



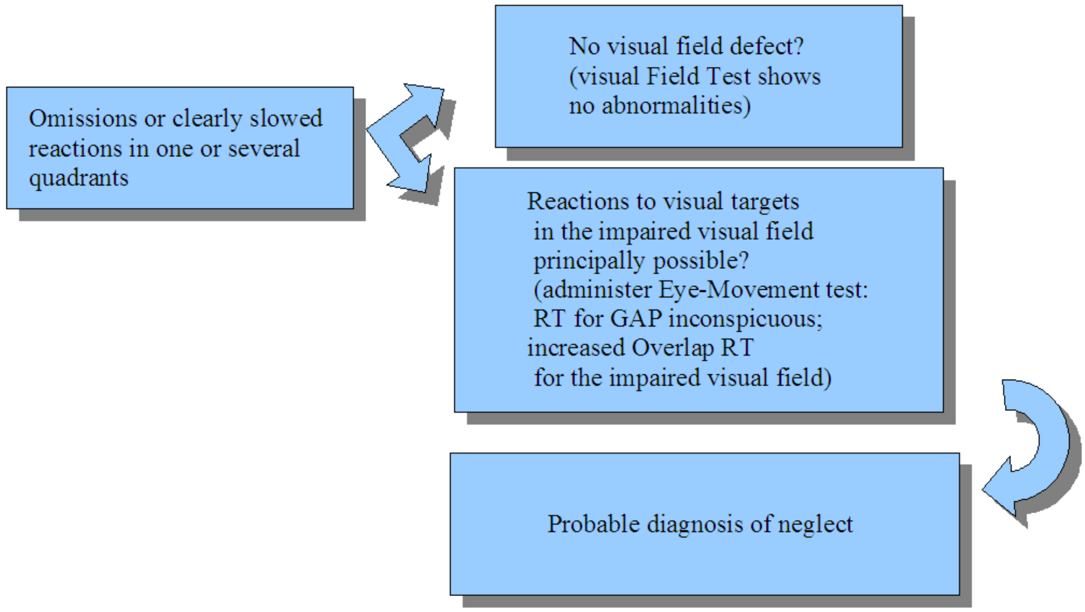
Vigilance



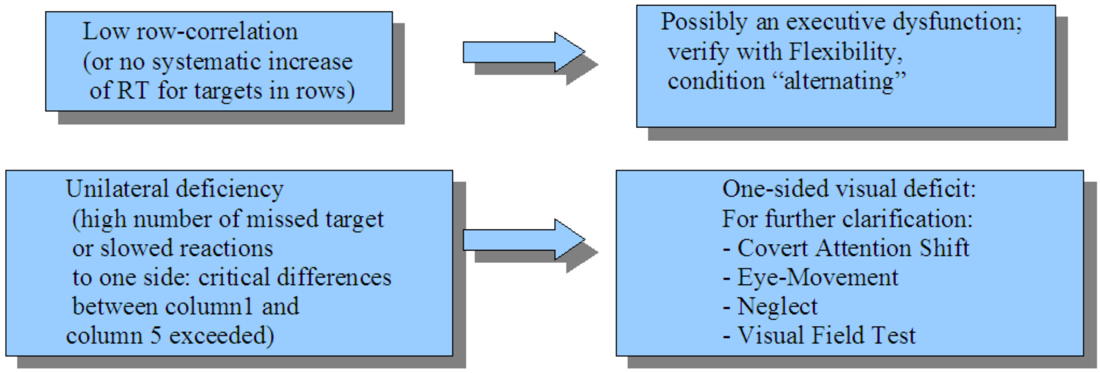
Visual Field Test



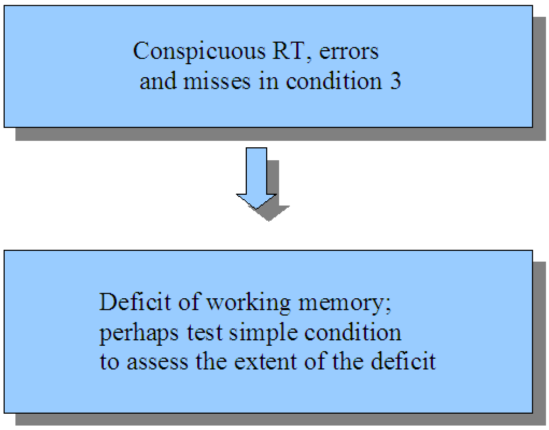
Neglect



Visual Scanning



Working Memory



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You will find further publications concerning the TAP on the website www.psytest.net

Subject Index

Appendix A

A1: Test parameters

Alertness

	Duration: 5’00“
Runs without warning	
Number of stimuli per run:	20 (to max. 25 stimuli, with omissions)
Stimulus presentation time:	till reaction, max. 2000 ms
Interval reaction-stimulus:	1800…2700 ms
Runs with warning tone	
Number of stimuli per run:	20 (to max. 25 stimuli, with omissions)
Presentation time des warning cue	400 ms
ISI warning cue – target stimulus	SOA: 600…1500
Presentation time of target stimulus:	till reaction, max. 2000 ms
Interval reaction - warning cue	1800…2700 ms

Covert Shift of Attention:

Duration:	4’30“
Number of stimuli:	100
Number of valid cues:	80
Number of invalid cues:	20
Presentation time of cue stimuli:	100 ms
Presentation time of target stimuli:	maximal 5000 ms
ISI cue – target stimulus, variable:	230…680 ms
Interval reaction – cue stimulus, variable:	1800…2700 ms

Crossmodal Integration

Duration:	2’50“
Number of stimuli:	40
Number of target stimuli:	18
Presentation time of auditory stimuli:	500 ms
Presentation time of visual stimuli:	1000 ms
ISI of auditory stimulus – visual stimulus	750 ms
SOA auditory stimuli	3550 ms

Divided Attention:

synchronous: auditory task	
Duration:	3’25“
Number of stimuli:	200
Number of target stimuli:	16
Stimulus presentation time:	433ms
SOA	1000 ms
synchronous: visual task	
Duration:	3’25“
Number of stimuli:	100
Number of target stimuli:	17
Stimulus presentation time:	2000 ms
SOA	2000 ms
synchronous: dual task	
Duration:	3’25“
Number of auditory stimuli:	200
Number of auditory target stimuli:	16
Presentation time of auditory stimuli:	433 ms
SOA of auditory stimuli:	1000 ms
Number of visual stimuli:	100

Number of visual target stimuli:	17
Presentation time of visual stimuli:	2000 ms
SOA of visual stimuli:	2000 ms
SOA auditory – visual stimulus:	5 ms
asynchronous: auditory task	
Duration:	2’25“
Number of auditory stimuli:	267
Number of auditory target stimuli:	20
Presentation time of auditory stimuli:	110 ms
SOA of auditory stimuli, variable:	825 – 1650 ms
asynchronous: visual task	
Duration:	2’25“
Number of visual stimuli:	155
Number of visual target stimuli:	20
Presentation time of visual stimuli:	500 ms
SOA of visual stimuli:	2000 ms
asynchronous: dual task	
Duration:	5’45“
Number of auditory stimuli:	267
Number of auditory target stimuli:	20
Presentation time of auditory stimuli:	110 ms
SOA of auditory stimuli, variable:	825 – 1650 ms
Number of visual stimuli:	155
Number of visual target stimuli:	20
Presentation time of visual stimuli:	500 ms
SOA of visual stimuli:	2000 ms
SOA auditory – visual stimulus:	variable

Eye-Movement:

Duration:	7’40“
Number of stimuli:	110
Number of target stimuli	60 (Gap & Overlap: left, middle, right: 10 each)
Stimulus presentation time:	2000 ms
SOA variable:	800…3700 ms

Flexibility: Simple Conditions (numbers, letters, angular form, round form)

Duration:	ca. 1’45“ and longer
Number of stimuli:	50
Stimulus presentation time:	reaction-driven
Interval reaction-stimulus	700ms

Flexibility: Complex conditions (numbers and letters alternating, shapes alternating)

Duration:	ca. 3’00“ and longer
Number of stimuli:	100
Stimulus presentation time:	reaction-driven
Interval reaction - stimulus	700ms

Go/Nogo

1 from 2

Duration:	2’00“
Number of stimuli:	40
Number of targetl stimuli:	20
Stimulus presentation time:	200 ms
SOA variable:	2150…3350 ms

2 from 5

Duration:	2’45“
Number of stimuli:	60
Number of target stimuli:	24
Stimulus presentation time:	1000 ms
SOA variable:	2150…3350 ms

Incompatibility

Duration:	2’50“
Number of stimuli:	60
Number of compatible stimuli:	30
Number of incompatible stimuli:	30
Stimulus presentation time:	100 ms
ISI warning signal - stimulus:	200 ms
SOA variable:	1800…2700ms

Neglect:

Neglect

Duration:	5’10“
Number of peripheral target stimuli:	44
Stimulus presentation time:	max. 3000 ms
ISI variable:	1600…2900ms

Neglect with central task

Duration:	5’10“
Number of peripheral target stimuli:	44
Presentation time of peripheral stimuli:	max. 3000 ms
ISI of peripheral stimuli, variable:	2400…3400ms
Number of central target stimuli:	18
Presentation time of central target stimuli:	400 ms
SOA of central stimuli	Onset ca. 600 ms after reaction to last peripheral stimulus

Sustained Attention: All conditions

Duration:	15’
Number of stimuli:	450
Number of target stimuli	54
Stimulus presentation time:	500 ms
SOA	2000 ms

Vigilance

auditory

Duration:	30’
Number of stimuli:	1200
Number of target stimuli:	36
Stimulus presentation time:	167 ms
SOA	1500 ms

visual (jumping square)

Duration:	30’
Number of stimuli:	1200
Number of target stimuli:	36
Stimulus presentation time:	167 ms
SOA	1500 ms

visual (moving bar)

Duration:	30’
Number of stimuli:	2800
Number of target stimuli:	36
SOA (per up & down movement), variable:	~ 1250 ms

Visual Field:

short (48 Trials)

Duration:	5’35“
Number of peripheral target stimuli:	48
Stimulus presentation time:	max. 3000 ms
ISI variable:	1600…2900ms

long (92 Trials)

Duration:	10’45“
Number of peripheral target stimuli:	92
Stimulus presentation time:	max. 3000 ms
ISI variable:	1600…2900ms

with central task

Duration:	5’35“
Number of peripheral target stimuli:	48
Presentation time of peripheral stimuli:	max. 3000 ms
ISI of peripheral stimuli, variable:	2400…3400ms
Number of central target stimuli	15
Presentation time of central target stimuli	400 ms
SOA of central stimuli	Onset ca. 600 ms after reaction to last peripheral stimulus

Visual Scanning

Duration:	5’ and longer
Number of stimuli:	100
Number of target stimuli:	50 (10 per row / per column)
Presentation time of stimuli:	reaction-driven

Working Memory: All levels of difficulty

Duration:	5’00“
Number of stimuli:	100
Number of target stimuli	15
Stimulus presentation time:	1500 ms
SOA	3000 ms

A2: Saving Data

Each investigator's and each subject's test data are filed in the investigator's and subject's directory, respectively.

Example: C:\MY DOCUMENTS\TAP\EXAMINER.VL\CHARLES\.....

The data recorded from each test is automatically saved after each test performance (even if that test is aborted). Empty or incomplete files should be deleted.

The raw data recorded in a test is saved in the directories of subjects. The file name contains information about the respective test (as an extension) and the number of that particular test run, reflecting how often the test has been carried out in total: *name[148]001.al* means that the subject has performed the test Alertness for the second time (the first time is coded *name000.al*!).

The tests can be recognized by the following extensions

1. Alertness .... name000.al[1]
2. Covert Shift of Attention name000.cs
3. Crossmodal Integration name000.ci
4. Eye-Movement name000.em
5. Divided Attention
   Conditon: "synchronous: auditory task" name000.ds1
   "synchronous: visual task" name000.ds2
   "synchronous: dual task" name000.ds3
   "synchronous: auditory task" name000.da1
   "asynchronous: visual task" name000.da2
   "asynchronous: dual task" name000.da3
6. Flexibility
   Condition: "letter" name000.fv1
   "number" name000.fv2
   "letter and number alternating" name000.fv3
   "angular shape" name000.fn1
   "round shape" name000.fn2
   "shapes alternating" name000.fn3
7. Go/Nogo
   Condition: "1 of 2" name000.go1
   "2 of 5" name000.go2
8. Incompatibility name000.ic
9. Neglect:
   Condition: "letter naming " name000.ne1
   "with central task" name000.ne2
10. Sustained attention
    Condition: "form" name000.sa1
    "colour or form" name000.sa2
11. Vigilance
    Condition: "auditory" name000.vi1
    "square" name000.vi2
    "moving bar" name000.vi3
12. Visual Field Test
    Condition: "short" name000.vf1

[148] „name" stands for the first five letters of the subject's identification code

“long” name000.vf2
“with central task”..................................... name000.vf3

13. Visual Scanning name000.sc
14. Working Memory
Condition: “level of difficulty 1” name000.wm1
“level of difficulty 2” name000.wm2
“level of difficulty 3” name000.wm3

The file “name.pdt” contains the social data of the respective subject.

A3: Variable names in the result files (ASCII-files; SPSS-files)

Variable names of subjects and investigator:

subject	identification of subject
number	number of the line in the SPSS-list
exam	identification of examiner
sex	gender of subject
birth	date of birth
test[149]-date	date of testing
test[1]-time	time of testing

The names of the test parameters are constructed according to the following scheme.

"aaa_bbbx"

In which:

aaa	stands for the test
bbb	stands for the parameter
x	stands for the line in the list of results (from "1" upwards)

The identification of the tests:

al	Alertness
cs	Covert Shift of Attention
ci	Crossmodal Integration
em	Eye-Movement
da1	Divided Attention “asynchronous: auditory task“
da2	Divided Attention “asynchronous: visual task”
da3	Divided Attention “asynchronous: dual task”
ds1	Divided Attention “synchronous: auditory task”
ds2	Divided Attention “synchronous: visual task”
ds3	Divided Attention “synchronous: dual task”
fn1	Flexibility “angular shape”
fn2	Flexibility “round shape”
fn3	Flexibility “shapes alternating”
fv1	Flexibility “letter”
fv2	Flexibility “number”
fv3	Flexibility “letter and number alternating”
go1	Go/Nogo “1 of 2”
go2	Go/Nogo “2 of 5”
ic	Incompatibility
ne1	Neglect “letter naming ”
ne2	Neglect “with central task”
sa1	Sustained attention “form”
sa2	Sustained attention “colour or form”
sc	Visual Scanning
vf1	Visual Field Test “short”
vf2	Visual Field Test “long”
vf3	Visual Field Test “with central task”

149 “*test*” stands for the ID of the test; see “The identification of the tests”

vi1	Vigilance “auditory”
vi2	Vigilance “square”
vi3	Vigilance “moving bar”
wm1	Working Memory “level of difficulty 1”
wm2	Working Memory “level of difficulty 2”
wm3	Working Memory “level of difficulty 3”

The name of the parameters:

cor	Correct reactions
err	False alarms / errors
ert	T value for false alarms / errors (if established)
omi	Misses
omt	T value for misses (as far as available)
lap	Outlier ("lapses of attention"; if established)
mea	Mean of RT
mdn	Median of RT
mdt	T value of the median of RT (if established)
std	Standard deviation of RT
stt	T value of the standard deviation of RT (if established)

Example: the variable

"sa1_mdn4"

stands for the test Sustained Attention, condition "form", and the median of RT for the whole test (4. line of the list of results).

A4: Installation of the TAP on a notebook without parallel port

The connection of the response keys requires a parallel port for a precise measure of the reaction time.

Notebooks don't have any longer a parallel port but there are cards with a parallel port that can be introduced in a slot provided for such cards.

There are two norms for these cards: a PCMCIA card or an ExpressCard. The difference between these cards concerns the dimension of the slot. To identify the card you need, you have to remove the protection card of plastic and to *measure the end of this card*. If the slot is previewed for a PCMCIA card the width should be 5,5 cm and 3,4 cm for an ExpressCard.

The slot

Warning: *There are cards of low cost that are proposed as parallel port card that are actually an adapter for an USB port (often announced as "parallel port for printers"). The TAP doesn't function with these cards!*

The cards of Exsys (PCMCIA card: model Ex-1356; ExpressCard: model Ex-1376) or Delock (PCMCIA card: model Nr. 61624; ExpressCard. model Nr. 66220) are known to function.

To make running the TAP battery with the new parallel port, it is necessary that the system recognizes the address of the parallel port. This address is to specify when installing the battery. If the TAP was installed before, it will be necessary to reinstall the TAP and to repeat the installation.

Procedure:

- Introduce the parallel port card in the slot.

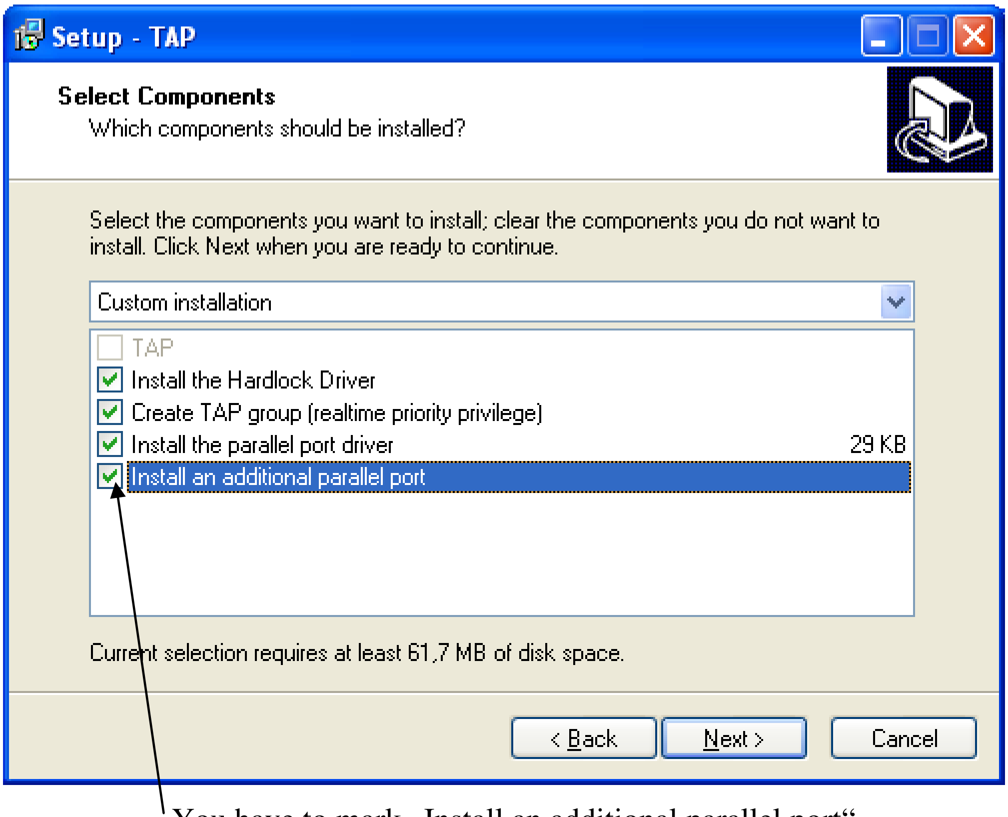
Search for the address of the parallel port in the following way:

- Open „*Start*" and then „ *Settings* ".
- Click on the icon „ *Control Panel* ".
- In the window that opens, select „ *Management* ".
- Click on the bottom „ *Computer Management* ".
- In the window that follows, open the list „*Ports (COM and LPT)*".
- Click two times on port LPT1.
- In the window that opens, select „*Resources*".
- Under „*Resource settings* ", there will be recorded in the first line e.g. „*IO Range* ***0378***-*037F*".

In this example, the address of the parallel port would be the here bold typed number, this is 0378.

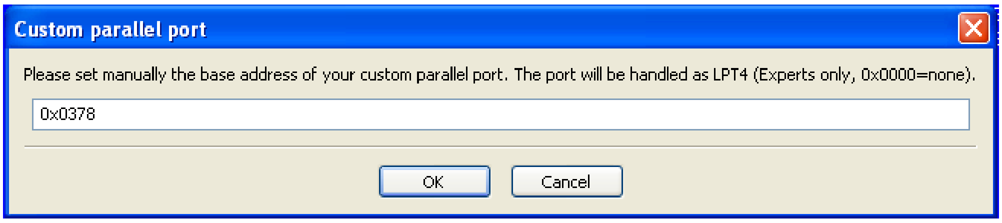
Install the TAP

- During the installation, a window will open:



You have to mark „Install an additional parallel port"

- At the end of installation, the following window will open where the address of the parallel port must be introduced (see the example above, the bold typed number ***0378***).



As can be seen in the figure, it is necessary to write "0x" before the address of the parallel port.

Warning: The address must be entered correctly. In the event of an error, a severe system failure may result!

So that the TAP will recognise the port where the keys are connected, it is necessary to open the menu "Options", and "Reaction key", to mark "LPT4" and to confirm with "ok".

A5: Changing language settings

The TAP is available in the following language versions. The appropriate version must be selected on installation:

English
French
German
Italian
Netherlands

After selecting a language all menu texts and all result lists will be displayed in that language.

The language setting of TAP can also be changed after installation. To do this, use the mouse to place the cursor on the TAP icon and press the right mouse key. A window will open in which the command “Properties” should be selected. The following path can be found in the directory Links under path.

C:\PROGRAMME\TAP\tap.exe -locale=en

The language is determined by the abbreviation following “-locale=…” (in this case: en for English).

The corresponding abbreviation for the language setting may be changed as follows:

English	= „en“
French	= „fr“
Finnish	= „fi“
German	= „de“
Italian	= „it
Netherlands	= „nl“

Language setting will remain active until it is changed.

A6: Error messages and error corrections

Description	Troubleshooting
General messages	
Message: “Can't open the TVicHW32 driver”	This message indicates, that the drivers for the reaction keys can't be accessed **1.** Ensure that the program was installed with administrative rights. **2.** A restart has to be carried out after installation. **3.** Check the entries in the registry. Root: HKEY_LOCAL-MACHINE => SYSTEM => CurrentControlSet => Services => TVICH32 Set Start to a value of 2.
Message on startup of a subtest: "Keep your finger off the key, please! “	**1.** Check the reaction keys under "Options>Reaction keys" in the menu bar. **2.** If using a notebook, ensure that the power supply is plugged in. If using battery, the voltage may be insufficient for the operation of the reaction keys.
Norms are not displayed	**1.** Establish from the normative tables whether the age of the subject is within the normed range. **2.** Ensure the subtest is passed completely. **3.** Ensure that the subjects name is not abbreviated with a point at the end, e.g. Doe, J. **4.** In the menu "Options>Norms" choose "All" and confirm with "OK". **5.** Ensure that an up-to-date HASP/Hardlock driver is installed. Contact us so that we can provide you with the latest driver. **6.** Sometimes antivirus background scanners can cause trouble with the access to the norm data files. Please adjust the scanner for full access to the norm data (by default C:\Program files\TAP: norms + subtest ending).
Message: „Error 7 - Hardlock not found"	**1.** Ensure that the USB dongle is plugged in. **2.** If this is the case, the dongle will appear to be incompatible with the Installation-CD. If you have several licences, ensure that the correct USB dongle is plugged in.

<table>
<tr><th>Sound output</th><th></th></tr>
<tr><td>Tones are distorted</td><td rowspan="4">1st Step: Check the audio properties:
In the properties of "Sounds and audio" go the audio tab and choose "Advanced…" under Sound output. If – on the "System performance" tab - "hardware acceleration" is set to maximum change it to standard.
If the problem persists:
2nd Step: From the main menu choose "Options>Real-time priority" and check "For all tests without acoustic stimuli". Please take care, that no other program is running in the background while conducting a subtest.
If the problem still persists:
3rd Step: Check your sound card:
Open in Windows under “Start” the command "Execute" and enter the word "dxdiag" in the box. The DirectX Diagnosis Program will open. Under the register card "Sound" you can than test the DirectSound. Some of the components of your sound card may be defect.</td></tr>
<tr><td>Sound sequences are rendered too slow</td></tr>
<tr><td>Despite working reaction keys a "No reaction" notification is shown while pressing a key</td></tr>
<tr><td>Conducting a subtest with sound output (e.g. alertness) the instruction site is still shown but moving further on the computer seems to be "frozen" and has to be restarted</td></tr>
<tr><td>No sounds are played while testing, but sounds can be heard using "Options>Adjust volume" from the main menu</td><td>Please check your sound card using the DirectX Diagnostic Tool (s. 3rd Step right above)</td></tr>
<tr><td>Video output</td><td></td></tr>
<tr><td>Message: „…cannot set video mode“, at the start of a subtest</td><td>Choose "Options>Screen specification" from the menu and select another screen resolution</td></tr>
<tr><td>The subtests are not displayed – the screen stays black</td><td>Check the monitor settings:
1. Right click on Desktop/Properties/Advanced and choose tab "Monitor" The "monitor Type" shouldn't be set to "Default monitor". If so please install the specific monitor driver.
2. The box "Hide modes that this monitor cannot display" should be checked</td></tr>
<tr><td>The subtests are not displayed – the TAP user interface is still shown</td><td>Check your graphics card:
Within Windows go to "Start>Run" and type "dxdiag" into the upcoming window. The "DirectX Diagnostic Tool" will open. On the "Display" tab you can test DirectDraw. Ensure that a proper display driver is installed and that DirectDraw acceleration is activated.</td></tr>
<tr><td>The Instruction sites are not shown completely – they are truncated at the bottom</td><td>Ensure that the Windows font size is set to standard.</td></tr>
</table>

A7: Odd-even-reliability, standard error of measurement, critical difference (adults)

	Standard deviation of raw values	Odd –even - Reliability	Standard error (based on odd-even reliability)	critical difference of raw values (5 % - level)	Critical T-value difference (5 % - level)
Alertness [20-89 Years; N=308]					
Median RT – Series 1	69.799	0.998	2.884	7.995	1.145
Median RT – Series 2	66.693	0.998	3.189	8.840	1.325
Median RT – Series 3	72.412	0.997	3.662	10.149	1.402
Median RT – Series 4	83.800	0.999	3.140	8.704	1.039
Median RT – Trials without warning tone	70.705	0.999	1.601	4.439	0.628
Median RT – Trials with warning tone	64.941	0.999	2.054	5.692	0.877
Covert Shift of Attention [20-90 Years; N=135]					
Median RT –arrow to left – target left	82.716	0.999	2.616	7.250	0.877
Median RT – arrow to left – target right	94.267	0.998	4.041	11.201	1.188
Median RT – arrow to right – target left	86.685	0.995	6.076	16.841	1.943
Median RT – arrow to right – target right	80.042	0.999	2.531	7.016	0.877
Crossmodale Integration [20-69 Years; N=236]					
Median RT	91.33	0.918	26.153	72.492	7.937
Errors	1.45	No details; distribution too skewed!			
Omissions	1.38	No details; distribution too skewed!			
Divided Attention / synchronous / condition 1 (visual) [20-90 Years; N=161]					
Median RT	142.208	0.982	18.883	52.341	3.681
Errors	0.791	0.186	0.714	1.979	25.012
Omissions	1.568	0.529	1.076	2.983	19.027
Divided Attention / synchronous / condition 2 (auditory) [20-90 Years; N=161]					
Median RT	87.591	0.994	6.533	18.110	2.068
Errors	5.213	0.953	1.136	3.149	6.040
Omissions	0.600	0.259	0.517	1.432	23.857
Divided Attention / synchronous / condition 3 (auditory-visual) [20-90 Years; N=537]					
Errors - total test	4.701	0.928	1.263	3.500	7.444
Omissions – total test	2.797	0.785	1.298	3.597	12.860
Median RT – visual	132.164	0.982	17.736	49.161	3.720
Omissions – visual	1.816	0.651	1.072	2.971	16.364
Median RT – auditory	94.708	0.987	10.801	29.939	3.161
Omissions - auditory	1.657	0.779	0.778	2.157	13.016
Divided Attention / asynchronous / condition 1 (visual) [20-90 Years; N=157]					
Median RT	63.380	0.998	3.072	8,516	1.344
Errors	0.745	No details; distribution too skewed!			
Omissions	0.819	No details; frequency too low!			
Divided Attention / asynchronous / condition 2 (auditory) [20-90 Years; N=157]					
Median RT	79.937	0.997	4.689	12.997	1.626
Errors	2.967	0.947	0.685	1.898	6.397
Omissions	0.812	0.087	0.776	2.150	26.491
Divided Attention / asynchronous / condition 3 (auditory-visual) [20-90 Years; N=157]					
Errors - total test	5.125	0.904	1.591	4.410	8.605
Omissions - total test	2.896	0.914	0.851	2.360	8.149
Median RT – visual	66.285	0.998	3.102	8.598	1.297
Omissions – visual	1.148	0.911	0.342	0.948	8.260
Median RT – auditory	79.109	0.992	7.177	19.893	2.515
Omissions – auditory	2.049	0.780	0.960	2.661	12.988

	Standard deviation of raw values	Odd –even - Reliability	Standard error (based on odd-even reliability)	critical difference of raw values (5 % - level)	Critical T-value difference (5 % - level)
Eye-Movement [20-89 Years; N=116]					
Median RT – GAP - left	96.049	0.999	3.037	8.419	Not normed!
Omissions – GAP – left	No details; no omissions!				
Median RT – GAP - middle	80.924	0.999	2.900	8.039	Not normed!
Omissions – GAP - middle	No details; no omissions!				
Median RT – GAP – right	99.776	0.998	4.633	12.841	Not normed!
Omissions – GAP – right	No details; no omissions!				
Median RT – OVERLAP - left	92.071	0.997	5.072	14.059	Not normed!
Omissions – OVERLAP – left	No details; only 1 x 1 omissions!				
Median RT – OVERLAP - middle	92.880	0.994	7.104	19.692	Not normed!
Omissions – OVERLAP - middle	No details; frequency too low!				
Median RT – OVERLAP – right	99.033	0.999	2.707	7.504	Not normed!
Omissions – OVERLAP – right	No details; only 2 x 1 omissions!				
Flexibility / nonverbal / condition 1 (angular shape) [20-90 Years; N=158]					
Median RT - total test	136.514	0.999	3.849	10.669	0.782
Errors - total test	1.184	No details; frequency too low!			
Median RT – trials with hand change	137.630	0.999	3.917	10.859	Not normed!
Errors – trials with hand change	0804	No details; distribution too skewed!			Not normed!
Median RT – trials without hand change	140.118	0.998	6.426	17.812	Not normed!
Errors – trials without hand change	0802	No details; distribution too skewed!			Not normed!
Flexibility / nonverbal / condition 2 (round shape) [20-90 Years; N=158]					
Median RT - total test	129.307	0.999	4.089	11.334	0.877
Errors – total test	1.236	No details; distribution too skewed!			
Median RT – trials with hand change	135.870	0.998	6.536	18.117	Not normed!
Errors – trials without hand change	0855	No details; distribution too skewed!			Not normed!
Median RT – trials without hand change	124.725	0.996	8.364	23.184	Not normed!
Errors – trials without hand change	0738	No details; distribution too skewed!			Not normed!
Flexibility / nonverbal / condition 3 (angular and round shape) [20-90 Years; N=158]					
Median RT - total test	332.607	0.999	10.518	29.154	0.877
Errors - total test	3.760	0.752	1.872	5.189	13.802
Median RT – trials with hand change	290.997	0.996	18.920	52.443	Not normed!
Errors – trials with hand change	1.214	0.641	0.727	2.016	Not normed!
Median RT – trials without hand change	373.549	1.000	4.058	11.249	Not normed!
Errors – trials without hand change	2.938	0.622	1.806	5.006	Not normed!
Flexibility / verbal /Condition 1 (letter) [20-90 Years; N=159]					
Median RT - total test	106.721	0.999	3.375	9.355	0.877
Errors - total test	0.898	No details; distribution too skewed!			
Median RT – trials with hand change	107.404	0.999	2.761	7.652	Not normed!
Errors – trials with hand change	0.550	No details; distribution too skewed!			Not normed!
Median RT – trials without hand change	107.651	0.998	4.336	12.017	Not normed!
Errors – trials without hand change	0.629	No details; distribution too skewed!			Not normed!
Flexibility / verbal /condition 2 (number) [20-90 Years; N=172]					
Median RT - total test	84.479	0.999	2.671	7.405	0.877
Errors - total test	0.899	No details; distribution too skewed!			
Median RT – trials with hand change	82.700	0.999	2.062	5.716	Not normed!
Errors – trials without hand change	0.449	No details; distribution too skewed!			Not normed!
Median RT – trials without hand change	94.152	0.998	3.996	11.077	Not normed!
Errors – trials without hand change	0.688	No details; distribution too skewed!			Not normed!
Flexibility / verbal / condition 3 (letters and number) [20-90 Years; N=588]					
Median RT - total test	629.632	0.999	19.911	55.190	0.877
Errors - total test	4.238	0.728	2.212	6.131	14.467
Median RT – trials with hand change	524.699	0.998	22.103	61.265	Not normed!
Errors – trials with hand change	1.247	0.684	0.701	1.943	Not normed!
Median RT – trials without hand change	763.469	0.999	21.745	60.275	Not normed!
Errors – trials without hand change	3.373	0.737	1.731	4.797	Not normed!

	Standard deviation of raw values	Odd –even - Reliability	Standard error (based on odd-even reliability)	critical difference of raw values (5 % - level)	Critical T-value difference (5 % - level)
Go/Nogo – condition 1 – 40 Trials [20-90 Years; N=371]					
Median RT	87.713	0.998	3.536	9.800	1.117
Errors	2.302	0.708	1.244	3.447	14.976
Omissions	0.924	0.757	0.456	1.263	13.665
Go/Nogo – condition 2 – 60 Trials [20-90 Years; N=214]					
Median RT	88.876	0.997	4.641	12.864	1.447
Errors	2.124	0.860	0.794	2.201	10.363
Omissions	2.286	0.959	0.466	1.291	5.645
Incompatibility [20-90 Years; N=457]					
Median RT - total test	116.151	0.999	2.808	7.783	0.670
Errors - total test	5.244	0.867	1.911	5.297	10.099
Median RT – arrow left – direction left	124.369	0.994	9.777	27.100	2.179
Errors – arrow left – Direction left	1.327	0.690	0.739	2.048	15.433
Median RT – arrow left – direction right	143.903	0.985	17.420	48.286	3.355
Errors – arrow left –direction right	2.159	0.680	1.221	3.385	15.679
Median RT – arrow right – direction left	159.792	0.987	17.923	49.681	3.109
Errors – arrow right – direction left	2.075	0.750	1.037	2.874	13.847
Median RT – arrow right – direction right	120.297	0.992	10.739	29.768	2.475
Errors – arrow right – direction right	1.050	0.626	0.643	1.781	16.957
Neglect I [20-69 Years; N=200]					
Median RT – left total	84.46	0.946	19.627	54.403	6.441
Median RT – right total	84.33	0.924	23.248	64.441	7.641
Neglect II (with central task) [20-70 Years; N=98]					
Median RT – central task	118.128	0.999	3.736	10.354	Not normed!
Errors – central task	1.151	0.229	1.011	2.801	Not normed!
Omissions – central task	3.104	0.784	1.442	3.996	Not normed!
Median RT – left total	140.725	0.999	4.208	11.665	Not normed!
Median RT – right total	148.558	0.997	8.215	22.772	Not normed!
Vigilance test / acoustic / long ISI / low target stimulus frequency / 30 minutes [20-69 Years; N=200]					
Median RT - total test	139.53	0.971*	23.761*	65.862	4.720
Median RT 1.-15. minute	133.35	0.955*	28.445*	78.844	5.913
Median RT 16.-30. minute	162.10	0.950*	36.283*	100.571	6.204
Median RT 1.-5. minute	117.52	0.833*	48.025*	133.119	11.327
Median RT 6.-10. minute	148.28	0.873*	52.843*	146.472	9.878
Median RT 11.-15. minute	151.63	0.866*	55.506*	153.854	10.147
Median RT 16.-20. minute	176.06	0.830*	72.591*	201.213	11.429
Median RT 21.-25. minute	169.31	0.831*	69.603*	192.929	11.395
Median RT 26.-30. minute	181.52	0.863*	67.187*	65.862	4.720
Vigilance test / optic / bars / low target stimulus frequency / 30 minutes [20-69 Years; N=200]					
Median RT - total test	220.82	0.949*	49.868*	138.228	6.260
Median RT 1.-15. minute	198.48	0.907*	60.528*	167.776	8.453
Median RT 16.-30. minute	253.70	0.896*	81.973*	227.218	8.956
Median RT 1.-5. minute	142.28	0.650*	84.174*	233.318	16.399
Median RT 6.-10. minute	224.08	0.796*	101.209*	280.536	12.519
Median RT 11.-15. minute	257.73	0.709*	139.031*	385.374	14.953
Median RT 16.-20. minute	248.30	0.556*	165.451*	458.606	18.470
Median RT 21.-25. minute	268.54	0.791*	122.767*	340.293	12.672
Median RT 26.-30. minute	290.02	0.757*	142.965*	138.228	6.260

	Standard deviation of raw values	Odd –even - Reliability	Standard error (based on odd-even reliability)	critical difference of raw values (5 % - level)	Critical T-value difference (5 % - level)
Visual Field test I [20-69 Years; N=200]					
Median RT – left total	96.73	0.965	18.097	50.161	5.186
Median RT – left below	98.81	0.938	24.603	68.197	6.902
Median RT – left above	96.72	0.929	25.772	71.436	7.386
Median RT – right total	94.51	0.967	17.169	47.589	5.035
Median RT – right below	102.31	0.951	22.647	62.775	6.136
Median RT – right above	93.07	0.933	24.091	66.776	7.175
Visual Field test II (with central task) [20-70 Years; N=111]					
Median RT – central task	138.694	0.999	4.386	12.157	Not normed!
Errors – central task	0.807	No details; distribution too skewed!			
Omissions – central task	2.661	0.792	1.213	3.363	Not normed!
Median RT – left total	152.769	0.999	4.698	13.022	Not normed!
Median RT – left below	143.559	0.998	6.895	19.113	Not normed!
Median RT – left above	159.765	0.997	8.760	24.281	Not normed!
Median RT – right total	164.524	0.998	7.497	20.782	Not normed!
Median RT – right below	172.470	0.998	6.694	18.554	Not normed!
Median RT – right above	155.089	0.997	8.058	22.336	Not normed!
Visual Scanning – 100 Trials [20-90 Years; N=163]					
Median RT – noncritical stimulus	1702.490	0.999	53.837	149.230	0.877
Errors – total test		No details; frequency too low!			
Omissions - total test	6.688	0.894	2.174	6.025	9.008
Median RT - row 1	543.109	0.983	69.989	194.001	3.572
Omissions - row 1	1.347	0.789	0.618	1.714	12.726
Median RT - row 2	796.371	0.992	72.201	200.132	2.513
Omissions - row 2	1.886	0.759	0.926	2.565	13.600
Median RT - row 3	975.003	0.996	65.277	180.938	1.856
Omissions - row 3	1.700	0.639	1.021	2.831	16.651
Median RT - row 4	1264.271	0.978	186.332	516.485	4.085
Omissions - row 4	1.431	0.535	0.975	2.703	18.897
Median RT - row 5	1692.502	0.987	189.779	526.042	3.108
Omissions - row 5	1.630	0.596	1.037	2.873	17.627
Median RT - column 1	1006.112	0.991	94.590	262.189	2.606
Omissions - column 1	1.878	0.752	0.936	2.595	13.813
Median RT - column 2	913.844	0.995	63.519	176.065	1.927
Omissions - column 2	1.438	0.584	0.927	2.569	17.872
Median RT - column 3	986.359	0.988	107.240	297.254	3.014
Omissions - column 3	1.451	0.681	0.819	2.270	15.649
Median RT - column 4	1096.909	0.986	131.455	364.376	3.322
Omissions - column 4	1.365	0.651	0.807	2.237	16.384
Median RZ - column 5	1203.635	0.978	177.780	492.782	4.094
Omissions - column 5	2.113	0.822	0.891	2.469	11.688
Working Memory / level of difficulty 3 [20-89 Years; N=160]					
Median RT	221.872	0.995	15.027	41.654	1.877
Errors	5.016	0.907	1.533	4.249	8.471
Omissions	2.683	0.708	1.451	4.021	14.985

* The reliability and the standard error of measurement are based on Cronbach alpha

A8: Odd-even reliability, standard error of measurement, critical difference (children and adolescents)

	Standard deviation of raw values	Odd –even - Reliability	Standard error (based on odd-even reliability)	critical difference of raw values (5 % - level)	Critical T-value difference (5 % - level)
Alertness [6-19 Years; N=381]					
Median RT – series 1	86.300	0.996	5.470	15.161	1.757
Median RT – series 2	79.068	0.992	7.248	20.091	2.541
Median RT – series 3	85.105	0.995	5.855	16.229	1.907
Median RT – series 4	101.543	0.996	6.192	17.162	1.690
Median RT – trials without warning tone	88.737	0.999	2.655	7.360	0.829
Median RT – trials with warning tone	79.973	0.998	3.332	9.236	1.155
Crossmodal Integration [11-12 Years; N=94]					
Median RT	98.296	0.991	9.420	26.110	2.656
Errors	2.000	0.744	1.012	2.805	14.025
Omissions	1.190	0.706	0.645	1.789	15.030
Covert Shift of Attention [11-12 Years; N=60]					
Median RT – arrow to left – target stimulus left	54.029	0.997	2.807	7.779	Not normed!
Median RT – arrow to left – target stimulus right	89.637	0.986	10.458	28.988	Not normed!
Median RT – arrow to right – target stimulus left	89.595	0.953	19.399	53.771	Not normed!
Median RT – arrow to right – target stimulus right	55.540	0.988	6.021	16.690	Not normed!
Divided Attention / synchronous / condition 1 (visual) [9-12 Years; N=187]					
Median RT	186.030	0.963	35.650	98.818	5.312
Errors	2.350	0.827	0.977	2.709	11.529
Omissions	1.940	0.472	1.410	3.907	20.141
Divided Attention / synchronous / condition 2 (auditory) [9-12 Years; N=186]					
Median RT	88.860	0.985	10.807	29.956	3.371
Errors	1.720	0.655	1.010	2.800	16.281
Omissions	1.250	0.717	0.665	1.843	14.746
Divided Attention / synchronous / condition 3 (auditory-visual) [6-19 Years; N=327]					
Errors - total test	2.930	0.775	1.390	3.852	13.148
Omissions - total test	3.930	0.597	2.495	6.915	17.596
Median RT – visual	213.063	0.966	39.174	108.584	5.096
Omissions – visual	2.730	0.63	1.661	4.603	16.861
Median RT – auditory	123.175	0.983	15.862	43.966	3.569
Omissions - auditory	2.120	0.33	1.735	4.810	22.689
Eye-Movement [11-12 Years; N=94]					
Median RT – GAP - left	115.934	1.000	0.000	0.000	Not normed!
Omissions – GAP – left	No details; no omissions in the sample!				
Median RT – GAP - middle	112.215	0.755	55.599	154.114	Not normed!
Omissions – GAP - middle	No details; no omissions in the sample!				
Median RT – GAP – right	111.149	0.876	39.121	108.439	Not normed!
Omissions – GAP – right	No details; no omissions in the sample!				
Median RT – OVERLAP - left	110.049	0.840	43.963	121.858	Not normed!
Omissions – OVERLAP – left	No details; only 1x1 omissions in the sample!				
Median RT – OVERLAP - middle	140.130	0.783	65.287	180.968	Not normed!
Omissions – OVERLAP - middle	.340	No details; frequency too low			
Median RT – OVERLAP – right	113.750	0.959	23.027	63.829	Not normed!
Omissions – OVERLAP – right	No details; only 2x1 omissions in the sample!				

	Standard deviation of raw values	Odd –even - Reliability	Standard error (based on odd-even reliability)	critical difference of raw values (5 % - level)	Critical T-value difference (5 % - level)
Flexibility / nonverbal / condition 1 (angular shape) [9-12 Years; N=86]					
Median RT - total test	119.109	0.999	4.574	12.679	1.064
Errors - total test	.920	No details; frequency too low			
Median RT – trials with hand change	113.131	0.997	6.567	18.203	Not normed!
Errors – trials with hand change	.450	No details; distribution too skewed!			Not normed!
Median RT – trials without hand change	129.856	0.985	15.987	44.314	Not normed!
Errors – trials without hand change	.650	No details; distribution too skewed!			Not normed!
Flexibility / nonverbal / condition 2 (round shape) [9-12 Years; N=86]					
Median RT - total test	124.296	0.998	4.962	13.755	1.107
Errors – total test	1.580	0.532	1.081	2.996	18.962
Median RT – trials with hand change	127.429	0.998	6.154	17.058	Not normed!
Errors – trials with hand change	.790	No details; distribution too skewed!			Not normed!
Median RT – trials without hand change	127.560	0.993	10.885	30.172	Not normed!
Errors – trials without hand change	1.120	No details; distribution too skewed!			Not normed!
Flexibility / nonverbal / condition 3 (angular and round shape) [6-12 Years; N=86]					
Median RT - total test	438.223	0.997	24.840	68.852	1.571
Errors - total test	3.020	0.634	1.827	5.064	16.769
Median RT – trials with hand change	367.588	0.982	49.400	136.931	Not normed!
Errors – trials with hand change	.890	No details; distribution too skewed!			Not normed!
Median RT – trials without hand change	498.250	0.995	35.601	98.680	Not normed!
Errors – trials without hand change	2.650	0.75	1.325	3.673	Not normed!
Flexibility / verbal / condition 1 (letter) [9-12 Years; N=187]					
Median RT - total test	111.886	0.998	4.818	13.356	1.194
Errors - total test	1.640	0.375	1.297	3.594	21.913
Median RT – trials with hand change	108.962	0.998	4.978	13.798	Not normed!
Errors – trials with hand change	.910	No details; distribution too skewed!			Not normed!
Median RT – trials without hand change	122.531	0.993	9.978	27.659	Not normed!
Errors – trials without hand change	1.110	No details; distribution too skewed!			Not normed!
Flexibility / verbal / condition 2 (number) [9-12 Years; N=186]					
Median RT - total test	118.669	0.998	5.725	15.868	1.337
Errors - total test	1.640	0.547	1.104	3.060	18.656
Median RT – trials with hand change	118.332	0.998	5.098	14.131	Not normed!
Errors – trials with hand change	.950	No details; distribution too skewed!			Not normed!
Median RT – trials without hand change	130.384	0.980	18.271	50.646	Not normed!
Errors – trials without hand change	1.070	No details; distribution too skewed!			Not normed!
Flexibility / verbal / condition 3 (letter and number) [9-12 Years; N=187]					
Median RT - total test	268.712	0.998	13.339	36.973	1.376
Errors - total test	3.740	0.532	2.559	7.092	18.962
Median RT – trials with hand change	237.619	0.986	27.901	77.337	Not normed!
Errors – trials with hand change	.940	No details; distribution too skewed!			Not normed!
Median RT – trials without hand change	314.646	0.986	37.636	104.320	Not normed!
Errors – trials without hand change	3.250	0.593	2.073	5.747	Not normed!
Go/Nogo – condition 1 – 40 Trials [6-19 Years; N=184]					
Median RT	124.668	0.995	8.443	23.402	1.877
Errors	2.220	0.588	1.425	3.950	17.792
Omissions	1.180	0.69	0.657	1.821	15.433
Go/Nogo – condition 2 [9-19 Years; N=323]					
Median RT	90.037	0.996	5.808	16.098	1.788
Errors	2.450	0.756	1.210	3.355	13.692
Omissions	.990	0.856	0.376	1.041	10.518

	Standard deviation of raw values	Odd –even - Reliability	Standard error (based on odd-even reliability)	critical difference of raw values (5 % - level)	Critical T-value difference (5 % - level)
Incompatibility [6-19 Years; N=354]					
Median RT - total test	163.093	0.998	6.862	19.020	1.166
Errors - total test	6.380	0.878	2.228	6.177	9.682
Median RT – arrow left – direction left	169.195	0.981	23.113	64.067	3.787
Errors – arrow left – Direction left	1.690	0.62	1.042	2.888	17.087
Median RT – arrow left – direction right	174.026	0.981	23.846	66.097	3.798
Errors – arrow left –direction right	2.280	0.629	1.389	3.849	16.883
Median RT – arrow right – direction left	188.345	0.964	35.805	99.247	5.269
Errors – arrow right – direction left	2.250	0.68	1.273	3.528	15.680
Median RT – arrow right – direction right	164.098	0.964	31.177	86.419	5.266
Errors – arrow right – direction right	1.490	0.676	0.848	2.351	15.778
Visual Scanning – 100 Trials [10-19 Years; N=133]					
Median RT – noncritical stimulus	1981.492	1.000	40.237	111.531	0.563
Errors – Total test	.750	No details; frequency too low			
Omissions - Total test	5.560	0.877	1.950	5.405	9.721
Median RT - row 1	999.183	0.989	106.931	296.398	2.966
Omissions - row 1	.810	0.335	0.661	1.831	22.604
Median RT - row 2	1148.213	0.968	204.654	567.273	4.940
Omissions - row 2	1.670	0.675	0.952	2.639	15.802
Median RT - row 3	1424.459	0.993	120.871	335.037	2.352
Omissions - row 3	1.540	0.591	0.985	2.730	17.727
Median RT - row 4	1616.314	0.975	254.399	705.157	4.363
Omissions - row 4	1.420	0.394	1.105	3.064	21.578
Median RT - row 5	1960.280	0.975	311.782	864.216	4.409
Omissions - row 5	1.800	0.554	1.202	3.332	18.511
Median RT - column 1	1354.498	0.956	284.740	789.260	5.827
Omissions - column 1	1.740	0.71	0.937	2.597	14.927
Median RT - column 2	1221.761	0.986	144.474	400.462	3.278
Omissions - column 2	1.330	0.563	0.879	2.437	18.324
Median RT - column 3	1364.815	0.976	210.674	583.958	4.279
Omissions - column 3	1.390	0.583	0.898	2.488	17.899
Median RT - column 4	1411.053	0.964	268.452	744.112	5.273
Omissions - column 4	1.200	0.521	0.831	2.302	19.184
Median RZ - column 5	1386.597	0.961	274.059	759.654	5.479
Omissions - column 5	1.790	0.656	1.050	2.910	16.257
Working Memory / level of difficulty 1 [10-11 Years; N=53]					
Median RT	130.790	0.964	24.706	68.482	Not normed!
Errors	4.800	0.998	0.215	0.595	Not normed!
Omissions	.660	No details; frequency too low			
Working Memory / level of difficulty 2 [10-12 Years; N=108]					
Median RT	240.945	0.942	57.955	160.642	6.667
Errors	4.320	0.836	1.749	4.849	11.225
Omissions	2.510	0.466	1.834	5.084	20.255
Working Memory / level of difficulty 3 [11-19 Years; N=160]					
Median RT	188.181	0.980	26.780	74.231	3.945
Errors	3.730	0.795	1.689	4.681	12.550
Omissions	2.000	0.466	1.462	4.051	20.255

* The reliability and the standard error of measurement are based on Cronbach alpha