VIENNA TEST SYSTEM

MANUAL

CORSI

Block-Tapping Test Forwards

Block-Tapping Test Backwards

Supra-Block Span Test

Version 24 – Revison 1

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1 SUMMARY

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Application

Measuring the storage capacity of spatial short-term memory and of learning in spatial working memory.

Main areas of application: clinical and health psychology, neuropsychology

Theoretical background

Key functions of working memory include the short-term storing and processing of information. The block-tapping test for measuring the immediate block span (German abbreviation: UBS) measures the storage capacity of spatial working memory. In addition to short-term spatial storage, the storage of assistive processes such as rehearsal and spatial binding and executive functions such as temporal encoding and reconstruction of a serial (temporal) sequence of stimuli are also operationalised in working memory. The immediate block span thus incorporates storage and executive processes of spatial working memory. The block span can be measured either forwards or backwards. Differences in performance between the two test forms are particularly relevant in the context of developmental psychology.
The supra-block span (SBS) measures learning processes of spatial working memory: sequence lengths are used that exceed the respondent's visual memory span and therefore require the application of learning processes. This learning should be regarded as an automation of cognitive processes and hence as a form of implicit learning.
The tests can also be used for symptom validity assessment: the UBS test results can be used to calculate the Reliable Spatial Span (RSS), and error clusters in the SBS can indicate whether the respondent's performance is authentic.

Administration

In the test of immediate block span nine irregularly distributed blocks are displayed on the screen. A pointer in the form of a hand "taps" on a certain number of blocks one after the other. The respondent's task is to tap the blocks either in the order shown or in reverse order. After three items the number of blocks increases by one. The test is terminated if the respondent answers three successive items incorrectly.
To calculate the supra-block span, the respondent's immediate block span is first determined. Items are then presented that contain the number of blocks in the immediate block span + 1 (SBS=UBS+1). The test contains 24 items and includes a sequence that is repeated eight times (the target sequence). The test ends when the respondent reproduces the target sequence correctly.

Test forms

For each of the three available tests – immediate block span forwards, immediate block span backwards and supra-block span – an adult form and a children's form are provided; CORSI thus consists of a total of six test forms (S1-S6).

Table 1: Tests, designations in the CORSI program, operationalisation

Test	Test forms Adults	Test forms Children	Operationalisation
UBS forwards	**S1**	**S2**	Spatial memory span forwards
UBS backwards	**S3**	**S4**	Spatial memory span backwards
SBS (+ UBS forwards)	**S5**	**S6**	Spatial supra-span(+ spatial memory span forwards)

Scoring

Immediate block span tests (forwards and backwards): immediate block span (longest sequence length that was correctly reproduced at least twice), number of correctly and incorrectly tapped sequences, sequencing errors, working time.
Supra-block span test: supra-block span (number of attempts made by the respondent before the target sequence was correctly reproduced), number of correctly tapped distractor items.

Reliability

The reliabilities for the immediate block span are consistently high; internal consistency on the basis of the norm sample assessed is r = .76.

Validity

The block-tapping test is regarded as the gold standard (Baddeley, 2001; Piccardi et al., 2008) for measurement of the spatial memory span. For more than three decades the validity of this test has been repeatedly confirmed in the neuropsychological literature and it has been widely used in clinical contexts.

Norms

A norm sample of N=300 healthy respondents is available. The norms reported are corrected for age and educational background. No significant gender differences have been found.

Time required for the test

Between 10 and 15 minutes (including instruction and practice phase), depending on test form.

2 DESCRIPTION OF THE TEST

2.1 Theoretical background: immediate block span (UBS)

2.1.1 Theoretical background: UBS forwards

Working memory has been extensively investigated and is a theoretically fruitful concept. Theoretical models of working memory overlap with theories of attention, executive functions and long-term memory – irrespective of whether they are predominantly process-oriented or structure-oriented (e.g. the embedded process model of Cowan (1995, 2005) or the multi-component model of Baddeley (1986, 2003)). With one exception, consistent distinctions between mnestic, attentional and executive processes have not been found. The exception is that in the standard models of working memory a distinction is made between its executive functions and its storage processes; a summary is provided by Miyake & Shah (1999), who surveyed representatives of ten influential and widely used models. This distinction is often described in more depth as an active/passive dichotomy: active procedures such as monitoring and upgrading of information in working memory are contrasted with the more passive processes of maintenance and mechanical rehearsal.
The storage component of working memory is usually measured by quoting its capacity limit – i.e. the maximum amount of information that can be stored in it. This function is also termed short-term memory; in this manual the term "short-term memory" is regarded as largely synonymous with the storage functions of working memory. Short-term memory is made up of a number of subsystems, whose capacity must be operationalised separately. Which subsystem is operationalised by the block-tapping test will be explained by reference to the following distinctions: a) verbal vs. visuo-spatial, b) spatial vs. visual and c) sequential vs. simultaneous. d) In addition, in calculating the capacity limits of short-term memory, it should be borne in mind that memory can be improved – and hence its capacity increased – through binding and in particular through rehearsal. In the final section (e) the encoding of a sequential array of stimuli is explored in order to explain the theoretical background to sequencing errors.

a) Verbal vs. visuo-spatial

It is nowadays beyond question that short-term retention involves separate visuo-spatial and verbal components (for a summary see Baddeley, 1990; Logie, 1995; Baddeley & Lieberman, 1980; Basso, Spinnler, Vallar, & Zanobio, 1982; Farmer, Berman, & Fletcher, 1986; Hanley, Young, & Pearson, 1991; Logie, Zucco, & Baddeley, 1990; Della Sala & Logie, 1993; Shallice & Warrington, 1970).
In most cases experimental design has involved using the dual-task technique. The verbal memory span is not impaired when it is combined with a visuo-spatial tracking task. By contrast, a visuo-spatial tracking task severely disrupts the retention of spatial information (Baddeley & Liebermann, 1980). The fact that one or other of these subsystems can be damaged in isolation by a brain injury provides further evidence that the two systems are largely independent. In a clinical study with the present block-tapping test it was found that in more than 40% of patients deficits were not observable if memory was tested only by means of the number memory span and not by means of the spatial memory span (Schellig & Hättig, 1993; see also De Renzi & Nichelli, 1975; Ross, 1980; Farah et al., 1988; Hanley et al., 1990). The number memory span is about one more than the block span (see e.g. WMS-III).

b) Spatial vs. visual (spatial coding vs. object coding)

The visuo-spatial working memory can store both object properties and position properties. The evidence that these two storage processes represent two separate sub-components of working memory again comes from a wide range of sources. In interference studies using a dual-task design Baddeley (1992) and his colleagues (e.g. Della Sala et al., 1999) found a double dissociation between "spatial" and "visual" memory spans: the block span (operationalised by the Block-Tapping Test) was disrupted by spatial activities, while the pattern span (operationalised by the Visual Pattern Test, VPT) was disrupted by the processing of visual stimuli. In other theoretical contexts this distinction is described in terms of spatial coding and object coding, i.e. as working memory for spatial and object information (Wilson et al., 1993; Smith et al., 1995). This distinction has been confirmed by clinical studies of specific lesions (Carlesimo et al., 2001; Hanley, Young, & Pearson, 1991) as well as by studies using imaging techniques (Haxby, Petit, Ungerleider, & Courtney, 2000; Munk et al., 2002).

c) Sequential vs. simultaneous

The contrast between the Block-Tapping Test and the Visual Patterns Test (VPT) illustrates another aspect of the tapping task. In sequential spatial tasks the position of each item is presented in sequence; this sequence must be remembered and then reproduced in the prescribed order. The paradigm for this type of task is the block-tapping task. By contrast, the items of the Visual Pattern Test (VPT) are presented in simultaneous spatial form (Mammarella et al., 2006): all the positions in a trial are presented simultaneously. The VPT consists of matrices of increasing complexity in which half the cells are filled and the other half are empty. Relying on their memory, respondents must tap on the filled cells – the order in which they do this is unimportant. The difference between the storage of spatial information and the storage of that information with the addition of a prescribed sequence can be observed in studies using imaging techniques (Smith & Jonides, 1995, 1998, Smith et al., 1995; review by Baddeley, 2003).

The Block-Tapping Test Forwards tests an important storage function of working memory: the short-term storage of a sequence of spatial details. Sequential presentation is regarded as the standard design (Baddeley, 2001) for testing spatial working memory, because simultaneous spatial presentation enables the individual objects to be combined into an overall object. This process, which is termed binding, goes beyond the spatial storing of locations; it is made much more difficult by sequential presentation. In sequential presentation the respondent must retain the position of each individual object within the context of a spatial reference system – in other words, he must remember their spatial allocation – irrespective of whether he uses an egocentric or an allocentric reference system (see Section 3.3). This means that sequential presentation operationalises the spatial components of working memory better than simultaneous presentation of the stimuli, in which the structure or figure has an additional, non-spatial influence on memory.

d) Rehearsal processes

The sequential aspect draws attention to the spatial rehearsal function. Logie (1995) identified within short-term visuo-spatial memory a "rehearsal mechanism" which became known as the "inner scribe". The Block-Tapping Test allows rehearsal of the information that needs to be stored. Spatial rehearsal requires a conscious, attention-based shift from one remembered location and its corresponding stimulus to the next one – analogous to the consecutive presentation of the stimuli. Spatial attention is the central process of spatial rehearsal – just as subvocal articulation is the key function in verbal rehearsal (Awh, Jonides & Reuter-Lorenz, 1998; Awh et al., 2006; Cavanna & Trimble, 2006; Jonides et al., 2008; Malhotra, Coulthard & Husain, 2009; Schellig, Schuri & Sturm, manual to the VISP training program, Mödling, 2010)). This attention-based spatial rehearsal assists the short-term storage of spatial information and extends the spatial span by an average value of between five and six. It can be assumed that the capacity of the spatial storage system is small. If rehearsal and other strategies (such as binding) that assist storage are blocked, the capacity limit of the subsystems of working memory – including the spatial subsystem – is about four items (Cowan, 2001, 2005; Vogel et al., 2001; Halford et al., 2005, 2007). The Block-Tapping Test operationalises not just the capacity of short-term sequential spatial storage but also the assistive rehearsal processes (as well as binding processes, see above).

e) Sequencing

How is information on the sequential ordering of stimuli encoded? An answer that is intuitively correct and has a long tradition in memory research (Lashley, 1951) is as follows: sequentially presented stimuli or events are represented in memory by an analogue serial array along a continuous time axis. In other words, there is a sequential array in memory that corresponds to the temporal sequence of events during encoding.

This model has turned out to be over-simple. It is true that temporal sequence is an important structuring factor for working memory (and for long-term memory). However, the representation in memory of a sequence of stimuli presented consecutively in time is frequently more complex: serial order encoding or sequence encoding is governed not only by the temporal order but also by criteria such as recency and familiarity, the degree of similarity or difference between the stimuli and the distance between the positions of the elements of a sequence. Also crucial is the form in which recall is required – for example, does the respondent need to decide whether two elements have changed places, or must the entire sequence be reproduced? Working memory has various strategies for encoding the serial order of presented stimuli. Different strategies are used depending on the task situation at the encoding stage and on the recall requirements. The literature contains two competing theoretical approaches to this: time-based models and event-based models (time-based: Burgess & Hitch, 1999; Brown, Preece & Hulme, 2000; Brown, Neath & Chater, 2007; event-based: Botvinick & Plaut, 2006; Farrell & Lewandowsky, 2002). Both models provide only limited explanation; they do, however, at least partially complement each other (Schellig, Schuri & Sturm, CODING, 2010). There is no need to explore them in more detail in the present context, since the only fact relevant to interpretation of the variable "Sequencing errors" is this: since working memory can process serial arrays in various ways, a larger than normal number of sequencing errors in the Block-Tapping Test cannot simply be regarded as indicating a general sequencing problem in working memory. Coding of the serial order is determined largely by rehearsal processes. The Block-Tapping Test allows complete rehearsal. Complete reproduction of the sequence is required: this means that the serial order that is rehearsed internally is identical to the sequence upon presentation and upon recall. The information on the consecutively presented item sequence in the Block-Tapping Test can therefore be represented in memory by a simple, primarily time-based, serial structure – especially if rehearsal processes are used. Sequencing errors in the Block-Tapping Test – if the sequences during presentation, rehearsal and full reproduction do not agree – are an indicator of deficits in this simple, direct encoding and reproduction of the presented sequences rather than deficits in the sometimes complex time- or event-based encoding processes.

2.1.2 Theoretical background: UBS backwards

There is a long tradition of clinical and experimental use of verbal and spatial span tasks in which the presented sequence is stored and must be reproduced in reverse sequence. Like the span test forwards it is included in the widely used Wechsler test batteries. The verbal components of working memory are often assessed by measuring the number memory span forwards and backwards; the Block-Tapping Test is regarded as the standard test for the assessment of spatial components (Baddeley, 2001). While the forward spans operationalise the storage components of working memory, the backward spans are intended to measure simultaneous retention and processing. There is a significant performance difference between the number memory spans forwards and backwards but not between the block spans forwards and backwards (Wilde & Strauss, 2002; Hester et al, 2004; Kessels et al., 2008; Ylioja et al, 2009). This has given rise to a number of theoretical hypotheses that can usefully be described in terms of Baddeley's structure model (for a summary see e.g. Baddeley, 2003). In verbal working memory the difference in performance between the forward and backward spans indicates that additional functions are involved in the number span backwards – functions of the supra-modal central executive. There is no performance difference between the block spans forwards and backwards; this can be interpreted as evidence that the same functions of working memory are involved in both span measures and that the block span backwards does not require any additional (amodal) executive functions of working memory. In verbal working memory storage and executive functions are clearly separated; in visuo-spatial working memory this separation is less marked. This implies that there is a difference between the architecture of verbal and spatial working memory (Cornoldi & Mammarella, 2008): in contrast to verbal short-term memory, spatial working memory is a system that can simultaneously store material and process it – in other words, it includes executive functions such as sequential encoding. This system can handle the requirements of both the Block-Tapping Test Forwards and the Block-Tapping Test Backwards. The Block-Tapping Test backwards is therefore not a spatial analogue of repeating numbers backwards.

There are nevertheless differences in the functions that are required in the Block-Tapping Test Forwards and Backwards. There are brain-damaged patients who perform worse on the Block-Tapping Test Backwards than on the Block-Tapping Test Forwards – and some who perform worse forwards rather than backwards. The Block-Tapping Test Backwards is better than the Block-Tapping Test Forwards at distinguishing between respondents with good and poor spatial ability (Cornoldi & Mammarella, 2008) and patients with pronounced visuo-spatial learning deficits (Mammarella et al, 2006). Differences between the two presentation forms are also found in studies in the field of developmental psychology (see Section 2.1.2) and in training: after metacognitive strategies had been practised the block span backwards improved significantly more than the block span forwards (Caviola et al., 2009), indicating a more marked executive component in the block span backwards. Even if the differences between the block span forwards and backwards are not yet sufficiently well explained in theoretical terms (Cornoldi & Mammarella, 2008), the studies indicate which of the two tests can most usefully be used in particular assessment contexts.

2.1.3 Neural networks: UBS forwards and backwards

Modern imaging techniques and lesion studies provide plenty of evidence for the neural correlates of short-term storage processes. Cerebral activities associated with spatial working memory take place primarily in a frontoparietal network in the right hemisphere – in the right inferior posterior parietal lobe (BA 40) and in the right lateral and inferior prefrontal cortex (for a summary see Wager & Smith, 2003; examples: Awh et al., 1996, Jonides et al., 1993, Smith & Jonides, 1998, 1999; Baddeley, 2003; Jonides et al., 2008).
Spatial rehearsal involves additional areas that are also activated for spatial attention (both overt and covert) and the associated eye movements. These additional areas are the right premotor cortex and the right superior posterior parietal cortex (BA 7) (Smyth & Scholey, 1994; Gathercole, 1999; Awh et al., 1998; Corbetta, 1998; Awh et al., 1999; Awh & Jonides, 2001; Corbetta & Shulman, 2002; Corbetta et al., 2002; Wager & Smith, 2003; Curtis & D´Esposito, 2003; Awh et al., 2006; Cavanna & Trimble, 2006; Jonides et al., 2008; Malhotra, Coulthard & Husain, 2009).

There is still uncertainty regarding the extent to which the separation between visual and spatial working memory continues in the frontal lobe (Ungerleider & Mishkin, 1982; Mishkin et al., 1983); the traditional view is that the dorsal pathway in the processing of visuo-spatial information ends in the parietal lobe. However, an extensive dissociation in the frontal cortex is unlikely (Owen et al., 1998; Wager & Smith, 2003).

The neural function circuits outlined above are not the only components involved in the memory functions that have been described: there are indications that in connection with unstructured spatial stimulus material, like that used in the Block-Tapping Test, inferior prefrontal areas in the left hemisphere are also activated (Bor et al., 2006). Furthermore, the central storage location of the frontoparietal network described above – the right inferior posterior parietal lobe – appears to be supported by structures in the anterior occipital lobe (BA 19). Also involved are subcortical structures such as the basal ganglia, which play an important part in the coordination of frontal and parietal areas and are crucial to the reciprocally arranged cortico-thalamic circuits.

It is not yet possible to state with precision what part the frontal areas play in the fronto-parietal network outlined above. They do not appear to be directly involved in storage and rehearsal functions (Carpenter et al., 2000). It is relatively rare for patients with lesions of the right hemisphere to display abnormal results in the Block-Tapping Test unless they have large-scale lesions of the right frontal lobe. On the other hand the frontal areas consistently show increased activation in studies with imaging techniques (for a summary see Bor et al, 2006). This would suggest that dorsolateral and ventrolateral frontal structures play an important part not in the storage of spatial information but in the processing of spatial tasks – i.e. in selecting and maintaining (defending against inhibition) spatial storage strategies. If the executive requirements of short-term memory tasks are increased – e.g. through highly structured presentation of the spatial material, which enables additional (including verbal) storage strategies to be used – activation of the dorsal areas increases (Morris et al., 1999; Jonides, 2008). On the other hand, performance in block-tapping forwards and backwards is at a similar level, which suggests that no additional executive functions need to be activated and that both tasks activate the same neural networks.

2.1.4 Areas of application: UBS forwards and backwards

If spatial working memory is seen as a system for the short-term storing and processing of information, the key role that it plays in our thinking will be immediately apparent. Working memory is regarded as the basis of many higher cognitive functions (Smith & Jonides, 1998; Wager & Smith, 2003; Kane et al., 2004; Unsworth & Engle, 2005), and the Block-Tapping Test as the standard procedure for assessment of its spatial components (Baddeley, 2003) is among the most widely used tests for the assessment of memory functions (De Lillo, 2004). Its applications are correspondingly diverse. As well as being useful in experimental psychology, the test is used to measure the immediate block span in neuropsychology, rehabilitation, psychiatry, pharmacopsychology, work psychology and developmental psychology, as well as in other fields.

Developmental psychology

Since the Block-Tapping Test has proved to be a good predictor of the development of cognitive functions and because there are specific differences between the block span backwards and forwards in this context, some of the findings from studies in the field of development psychology will now be described in more detail.
The educational achievements of children in their first years at school are focused on learning to read and acquiring basic arithmetical skills. Mathematical and reading skills are learned, crystallised abilities (aspects of Cattell's crystallised intelligence (Gc)). Acquisition of these skills is based on a number of factors, including basal, non-learned cognitive functions. The ability to learn – the cognitive capacity to learn – is fundamental to the learning of new skills. This fluid (in Cattell's terms (Gf)), non-learned cognitive capacity might therefore be a suitable predictor of achievement in school, especially achievement in mathematics and reading. In this context, therefore, the question of the connection between working memory and complex cognitive functions can be posed as follows: is working-memory performance in pre-school children a good predictor of the acquisition of mathematical and reading skills?

It is beyond dispute that spatial working memory plays a key role in the development of mathematical and reading abilities in childhood (McKenzie, Bull, & Gray, 2003; Holmes & Adams, 2006). The situation changes in the course of development. During the first years at school, spatial working memory (operationalised by the block span forwards) was found to be the best predictor of mathematical and reading abilities (Kyttala et al., 2003). Verbal short-term memory (repeating numbers forwards), verbal working memory (repeating numbers backwards), basal executive functions of working memory (e.g. inhibition) and executive skills such as planning (Tower of London) were also found to be important predictors, although with significantly lower predictive power (Bull, Espy & Wiebe, 2008). If pre-school performance in working memory is compared with learned educational skills in the third class (i.e. at the age of between seven and eight years), the picture changes: mathematical abilities are predicted best by the block span backwards, while reading ability is predicted equally well by the spatial and verbal memory spans (block span and number span). The important correlation between block span and mathematical abilities can also be demonstrated at the age of between 10 and 14 years (White, Moffitt, & Silva, 1992; McLean & Hitch, 1999; Maybery & Do, 2003; van der Sluis, van der Leij, & de Jong, 2005). The close link between complex cognitive abilities and working memory justifies the use of the Block-Tapping Test in the context of developmental psychology. Conversely, the findings from developmental psychology described above demonstrate the close correlation between working memory and complex cognitive abilities.

Symptom validity assessment

The investigation of symptoms described by patients is an important aspect of psychological assessment, especially when medical reports and expert opinions need to be compiled. Greiffenstein et al. (1994) developed an index that is now widely used to identify non-authentic symptom presentation. This index, based on the number memory spans in the WAIS-R, is the Reliable Digit Span (RDS). The RDS is calculated as the sum of the longest number sequence forwards and backwards for which the respondent correctly reproduced both the presented trials. Here is an example: a respondent correctly reproduced both sequences of three in repeating numbers forwards and both sequences of two in repeating numbers backwards. The fact that he correctly repeated one of the two sequences of four forwards is of no consequence for the calculation. The RDS for this respondent is five. The cut-off score for the RDS is between seven and eight – in other words, all scores up to and including seven are regarded as abnormal (for a summary see Babikian & Boone, 2007). For this sample respondent the results therefore suggest diminished willingness to make an effort. In parallel to this and using the same method of calculation, Ylioja, Baird and Podell (2009) developed the Reliable Spatial Span (RSS) using the Block-Tapping Test as a basis. The RSS is found to have greater specificity, sensitivity and predictive power than the RDS. At a cut-off score of between seven and eight this index correctly classifies around 70% of respondents with negative answer distortions (sensitivity). Around 20% of respondents are incorrectly classified as having negative answer distortions (specificity) even though their willingness to make an effort is adequate.

2.2 Theoretical background: Supra-block span (SBS)

The immediate block span (UBS) forwards corresponds to the longest sequence for which the respondent correctly reproduced at least two of the three trials presented. In this test the term supra-block span (SBS) is used to describe the block span that is one block above (supra) the respondent's immediate block span. If a respondent can correctly tap out five blocks, his supra-span is six blocks (UBS + 1 = SBS). However, the key variable in the Supra-Block Span Test is not the length of the sequences or the number of blocks (UBS + 1), but the number of repetitions that a respondent needs in order to correctly reproduce a block sequence that is one item longer than his immediate block span. Thus the Supra-Block Span

Test does not measure a memory span: it is a learning test. The term "supra-block span test" is therefore misleading but has nevertheless become the established name for the test.
Before the key theoretical aspects of this design are described, the structure of the test will once again be outlined. The respondent's immediate block span must first be measured. The respondent is then presented with sequences that are one block longer than the identified UBS (UBS + 1 = SBS). During calculation of the UBS he therefore failed on sequences of this length – he was unable to immediately retain at least two of them. The respondent is now required to learn one trial of this supra-sequence (UBS + 1) – the target sequence. The target sequence is repeated unannounced after every second trial until the respondent reproduces it correctly or until the task is terminated after eight presentations. The maximum number of trials presented to the respondent is therefore 24. The target sequence can appear up to eight times – always interrupted by two non-target sequences of the same length. The primary parameter measured is the number of repetitions that the respondent requires in order to reproduce the target sequence correctly.

The Supra-Block Span Test (SBS) is an incidental learning test: the respondent is not informed of the learning goal. Incidental learning is a form of learning in which no intention is directed towards the required goal; it is therefore distinct from intentional learning. It is also necessary to clarify whether the incidental learning of a supra-span occurs as implicit or explicit learning. The retention of a block sequence – such as is tested in the assessment of immediate block span – is a form of explicit memory. This would appear to imply that the learning of a supra-span is also a form of explicit learning and that the supra-span test assesses explicit learning in incidental form. This has not been confirmed: the Supra-Block Span Test assesses implicit learning. Before this can be explored in more detail, some terminological explanation is required, in particular with regard to the distinctions between incidental, intentional and implicit learning.

Incidental - intentional - implicit

Incidental learning involves learning processes that occur unintentionally and incidentally: e.g. the many images that are absorbed during a car journey, in the course of a shopping trip or while leafing through the newspaper. By contrast, deliberately learning vocabulary, learning a poem by heart or memorising a telephone number before dialling it are all intentional learning processes. All these examples of incidental and intentional learning relate to the area of explicit memory.
But implicit learning can also take place either incidentally or intentionally. It is thus not the absence of the intention to learn that distinguishes incidental from implicit learning. For example, I can deliberately and intentionally acquire skills such as swimming or speed reading, or I can improve my reading skills incidentally through frequent reading. Another example of international implicit memory: I can practise deliberately every day so that my tennis serve lands more frequently in the right part of the court. But the process of learning a skill (improving one's serve) does not thereby become more consciously accessible. There is no metacognitive knowledge of the structure of an ability, the improvement of a skill – when I have practised my tennis for an hour, I don't immediately know what has changed or by how much; I cannot describe it directly. I need to finish practising the activity and observe or test how much improvement has taken place. It is only in this indirect way that my learning progress becomes apparent to me; this is the only way in which I can become aware of it. Table 2 summarises the distinctions that have been described. In this table the Supra-Block Span Test is classed as an incidental implicit memory test. The incidental aspect has already been explained; the reasons for regarding it as an implicit memory test are put forward in the next section ("Theoretical background").

Table 2: Incidental and intentional learning – implicit and explicit material

	Explicit memory	Implicit memory
Intentional learning	Deliberately acquired knowledge: e.g. material for the next history assignment	Deliberately acquired skills: e.g. the backhand stroke during tennis coaching
Incidental learning	Incidentally acquired knowledge: e.g. images of landscapes and villages while driving a car	Incidentally acquired skills: e.g. learning to walk or the syntactic rules of one's native language; ***SUPRA-BLOCK SPAN TEST***

Theoretical background

The Supra-Block Span Test was developed in a specific research context, namely with patients who had undergone resection of the temporal lobe. The particular focus of interest was the function of the hippocampus. It was found that the immediate block span was not sensitive to lesions of the hippocampus (cf. the section on “Neural networks” in the UBS section). Corsi (1972) therefore designed the block board – modelled on a verbal learning task of Hebb (1961) – as a non-verbal task for measuring the so-called supra-block span (SBS). The present test is designed in the same way as that task.

Corsi (1972) used the SBS in an attempt to measure the functions of the right hippocampus. His results showed that he was successful in this, in that patients who had undergone resection of the right temporal lobe performed abnormally on the Supra-Block Span Test. However, others were unable to replicate these findings (Rausch & Ary, 1990; Gagnon et al., 2005). These more recent studies suggest that the hippocampus plays at most a subordinate role in learning recurring sequences on the block board. Doubt is cast on Corsi's hypothesis that the shift from the immediate block span to the supra-block span corresponds to the shift from short-term to long-term memory by the observation that the mesial temporal lobe is involved in explicit long-term memory (Squire & Knowloton, 2000).
Learning of the SBS target sequence takes place in working memory: it is learning in the sense of an automation of cognitive processes, resulting in faster execution with fewer errors. An important consequence of this is that pressure on the limited capacity of working memory is relived; this is convincingly demonstrated by the fact that a second, parallel task can be carried out more efficiently (Ramsey et al., 2004; Jansma et al., 2001). Ramsey et al. (2004) used a task involving the learning or training of verbal material. The learning process resulted in a reduction of activation in the anterior cingulate cortex (ACC) and in frontal regions, especially the dorsolateral area (BA 9/46). In other words, learning led – as is to be expected with the automation of a cognitive function – to reduced activity in the neural network of working memory (Ramsey et al., 2004).
Clinical studies provide further evidence that the learning that occurs in the Supra-Block Span Test takes place in working memory and not in long-term memory. For example, Gagnon et al. (2005) conducted a single-case study of an amnestic patient in whom the hippocampus and amygdala had degenerated bilaterally following an inflammatory process of unclear aetiology. A feature of the patient's memory was rapid forgetting. His measures of memory span, though, were in the average range, as was his supra-block span. The repeated practising of the target sequence led in this patient from a controlled to a more automated process, resulting in the retention of longer sequences.

This shows that the Supra-Block Span Test measures implicit learning in spatial working memory – using an incidental task design. The fact that the respondent attempts during each learning process – whether or not it involves the target item – to organise the material and employ deliberate rehearsal processes does not vitiate the incidental nature of the task. Learning success depends to a significant extent on automation of these processes in respect of the recurring target item. If the test were not presented in incidental form – i.e. if the respondent were informed that one sequence recurs repeatedly – greater involvement of long-term memory would be expected. The respondent could attempt to memorise the target sequence using an explicit learning strategy. For example, he could set out to memorise just the first half of the sequence at the first presentation and progressively extend it, or develop more complex verbalisations of the verbal gestalt. These are strategies that encourage longer-term storage and hence involvement of long-term memory.

Test construction

The test in the form developed by Corsi meets with some problems in use. For this reason a partially redesigned task variant for measuring the supra-block span (SBS) is presented here.

The trials of the supra-block span (SBS) involve sequence lengths that exceed the respondent's spatial memory span. The respondent is thus required to do something at which he has previously (during calculation of the immediate block span) failed. Because of this the test is frequently terminated by the respondent. This motivational problem would appear to be a major reason why the test was not widely used in clinical assessment. The redesigned material attempts to circumvent this problem. The difficulty of a trial depends on the length of the path (Smirni et al., 1983) and in particular on the figural complexity of the tapping path (Schellig & Hättig, 1993). With this in mind it is possible to design items of equal sequence length but varying difficulty. The sequences used as distractors (non-target trials) in the present test are selected as having a level of difficulty that is lower than that of the target trial and roughly equivalent to the respondent's UBS. For example: a respondent achieves a UBS of seven. The sequence length for the SBS trial must therefore be eight. The 16 non-target trials with a sequence length of eight have roughly the same level of difficulty as the sequences of seven; in the majority of cases, therefore, the respondent will be able to solve them.

The selection of the target sequences took account of the sum of the angles in the tapping path but was based primarily on difficulty indices calculated from the test results of the two available control groups (Schellig & Hättig, 1993; Smirni et al., 1983). Table 3 below shows a) the percentage of patients who correctly reproduced the three UBS items at the level in question (column 2) and b) how many respondents correctly reproduced the selected SBS target item at the first presentation (column 3). Thus 38% of control group members correctly reproduced the sequences of six in the UBS test; 36.9% correctly reproduced at the first attempt the SBS target trial selected for this level.

Table 3: Item reproduction frequency

Sequence length	Item reproduction frequency for UBS items (%)	Item reproduction frequency for SBS items (%)
4	76.9	76.9
5	58.5	59.2
6	38.0	36.9
7	14.9	7.2
8	9.6	4.8
9	0.8	0.0

2.2.1 Neuronal networks: Supra-block span (SBS)

The attempt by Rausch & Ary (1990) to confirm Corsi's results (1972; see Section 2.2.) with patients who had undergone resection of the right anterior temporal lobe was unsuccessful. Thereafter attention tended to focus on frontal structures thought to be involved in measurement of the visuo-spatial supra-block span. These structures were interpreted as the anatomical correlate of the central executive system (Daigneault & Braun, 1993; Carlesimo et al., 1994). Unlike patients with posterior brain damage, patients with frontal brain damage only achieved below-average results (on a modified form of the task) if they had to set intermediate goals for themselves. If the supra-block span was realised in the "classical" manner – as it is in the present computerised version – no deficits were apparent (Vilki & Holst, 1989). These findings could be interpreted as indicating that the poor performance on spatial working memory was caused by the need to use additional executive functions in searching for and organising intermediate steps in action plans.
No definitive answer can yet be given to the question of the form in which frontal structures are involved in supra-block span learning. However, the fact that these structures play only a subordinate role when the test is realised in the classical manner, combined with the fact that patients with posterior – especially parietal – brain damage perform less well (Vilki & Holst, 1989) supports the thesis that the learning involved takes place in spatial working memory and thus utilises the same neural correlates (outlined above) as the short-term retention of spatial material. It would appear that the neural correlates involved in working the Block-Tapping Test are largely identical for UBS and SBS. However, there is a need for studies with modern imaging techniques and further lesion studies with patients.

2.2.2 Areas of application: Supra-block span (SBS)

Spatial working memory plays an important role in many complex cognitive functions (see Section 2.1.4.: "Areas of application of the UBS"). The supra-block span test assesses the learning capacity of this system. The areas of application of the Supra-Block Span Test are therefore largely the same as those of the two immediate block span tests. It can also be used for symptom validity assessment, although in this case a different variable is used than – the so-called reliable spatial span (RSS).

Symptom validity assessment

The authenticity of symptoms described and displayed by patients is an important part of psychological assessment, in the context of report writing as well as elsewhere. Tests designed especially to assess the authenticity of symptoms usually use the alternative choice method or the principle of "hidden easiness" (Slick, Sherman & Iverson, 1999; Merten & Dettenborn, 2009). By contrast, the reliable spatial span (RSS) and reliable digit span (RDS) are used for symptom validity assessment within standard tests. Their use renders administration of a special test unnecessary. The Supra-Block Span Test is one such standard test. To assess symptom validity it uses an incidental learning program intended to reveal suboptimal performance behaviour in situatins in which the respondent is motivated to present his symptoms inauthentically.
To gauge the supra-block span the respondent's immediate block span (UBS) is first measured. The respondent is then presented with sequences that are one block longer than his UBS (UBS + 1 = SBS). While the difficulty of the target trial that is to be learned is indeed greater than the difficulty of the trails successfully completed at UBS level, the non-target trials (distractor items) are designed to be of the same difficult as the successfully achieved UBS level. In other words, the respondent should in the majority of cases be able to complete the non-target trials. The respondent, however, sees himself as being presented with a sequence length that he failed to master during testing of the immediate block span (UBS). Respondents with non-authentic symptom presentation are therefore likely to assume that they should not be able to correctly complete these tasks – although these non-target trials, despite having the same sequence length as the unsolved UBS sequences, are in fact

significantly easier. The number of errors in the non-target trials, which can serve as an indication of a tendency to exaggerate symptoms, is reported; norm scores are available.

2.3 Test structure

Procedure

On the screen the respondent sees nine irregularly positioned blocks. A mouse cursor in the shape of a hand moves about the screen and points to a block, which briefly lights up (see Figure 1 below).

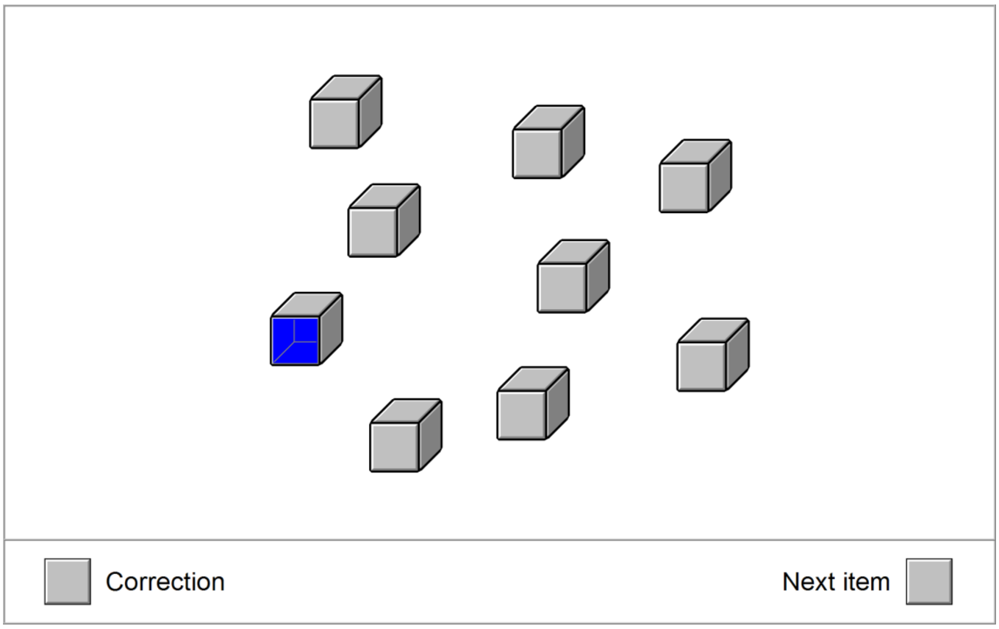

Figure 1: Client monitor

Note: The numbers in brackets indicate how the blocks are numbered. The numbers are only relevant to scoring and do not appear on the client's screen.

After the block has lit up, the “hand” points to another block and then to another and so on, resulting in a particular sequence of blocks that have been pointed to. Each sequence concludes with a signal tone. The respondent must then tap on the same blocks, adhering to the order in which they were originally pointed out. The mouse or light pen can be used as the input device.

Material

In selecting the tapping sequences, reference was made to studies by Schellig & Hättig (1993) and Smirni et al. (1983) in which the item characteristics were defined. The difficulty index was used to ensure that the tapping sequences used to determine the UBS contain no sequences with a higher number of blocks that are easier to reproduce than any of those with a lower number of blocks. Only if the sequences with a larger number of blocks are actually more difficult is it possible to calculate the UBS and classify the respondent as having a particular visual memory span.

Design

The test uses sequences of increasing length and starts by presenting sequences of three (sequences of two for children). The sequences of four, five, six, seven and finally eight then follow. The test terminates automatically after the third item of the sequence of eight, i.e. the 18th trial. The test also terminates if the respondent works three successive trials incorrectly. A reversal of this item presentation order involving a progression from longer to shorter sequences has no assessment advantages (Cornoldi & Mammarella, 2008) and is therefore not implemented in this program.

To illustrate the course of the test, all the items of the immediate block span forwards and backwards (item nos. 1-24) are listed in Table A1 in the appendix. The items in the two tests are identical.

Table A2 in the appendix contains the target items and the non-target items for the supra-block span (SBS). The items are shown in the table in the order in which they are presented in the test: two non-target items appear first, followed by the first presentation of the target item. Another two non-target items are then presented, followed by the first repetition of the target item. If the respondent succeeds in correctly reproducing the target item after this first repetition, he receives an SBS of one; correct reproduction after the second repetition results in an SBS of two and so on. (If the sequence is correctly reproduced at the first presentation the SBS = 0.)

2.4 Test forms and description of variables

Table 4 shows the three tests of the CORSI program: Immediate Block Span Forwards, Immediate Block Span Backwards and Supra-Block Span, each of which is available in an adult form and a children's form. The last column shows the variables that are measured and reported for each of the three tests. They are described in more detail in the two sections that follow. The main variables are shown in italics.

Table 4: Test forms

Test	Test forms Adults	Test forms Children	Variables
UBS forwards	**S1**	**S2**	*Immediate block span forwards* Correct Incorrect Sequencing errors Working time
UBS backwards	**S5**	**S6**	*Immediate block span backwards* Correct Incorrect Sequencing errors Working time
SBS (+ UBS forwards)	**S3**	**S4**	*Supra block span (Number of repetitions)* Distractor items correct *plus the 5 variables of the UBS forwards (see above)*

2.4.1 Description of variables UBS forwards (S1-S4) and backwards (S5-S6)

The same variables are reported for the block span forwards as for the block span backwards.

Main variable

Immediate block spans forwards / immediate block span backwards

The variable "immediate block span" operationalises the short-term visual memory span and hence the storage capacity of spatial working memory. The variable corresponds to the longest sequence that was correctly reproduced in at least two of the three trials presented.

Additional variables

Correct (UBS)
The number of correctly reproduced sequences

Incorrect (UBS)
The number of incorrectly reproduced sequences

Sequencing errors (UBS)
The number of sequences for which the positions of all the blocks in a sequence were correctly tapped but the order in which this was done was incorrect.

Working time
The number of sequences presented and hence the test length are determined by the respondent's memory performance. Among the control group working time fluctuates between 4 and 11 minutes.

2.4.2 Description of variables: Supra-block span (SBS) (S3-S4)

Before the Supra-Block Span Test can be administered, the respondent's immediate block span must first be determined. The results of this calculation of the UBS are reported in the same way as for the UBS test (see Section 2.4.1).

Main variable

Supra-block span (SBS)
The variable "supra-block span" operationalises short-term visuo-spatial learning. It reports the number of repetitions needed by the respondent before the target sequence was tapped correctly (max. 8).

Additional variable

Distractor items correct (SBS)
The number of correctly reproduced non-target items (distractor items) – i.e. the number of sequences that were presented only once. This variable provides an indication of non-authentic symptom presentation.

Before the supra-block span test can be administered, the respondent's immediate block span must first be determined. The results of this calculation of the UBS are reported in the same way as for the UBS test (see Section 2.4.1).

3 EVALUATION

3.1 Objectivity

Administration objectivity

Test administrator independence exists when the respondent's test behaviour, and thus his test score, is independent of variations (either accidental or systematic) in the behaviour of the test administrator (Kubinger, 2003).
Since administration of the CORSI program is computerised, all respondents receive the same information, presented in the same way, about the test. These instructions are independent of the test administrator. Similarly, administration of the test itself is identical for all respondents.

Scoring objectivity

The recording of data and calculation of the respondent's variables is automatic and does not involve a scorer. Computational errors are therefore excluded.

Interpretation objectivity

Since the test has been normed, interpretation objectivity is given (Lienert & Raatz, 1994). Interpretation objectivity does, however, also depend on the care with which the guidelines on interpretation given in the chapter "Interpretation of Test Results" are followed.

3.2 Reliability

Reliability aims at formal exactness of the trait measurement (measurement precision) – that is, a score obtained in testing should be correct in the sense of being exact (see Kubinger, 2003).

Using the internal consistency (Cronbach's Alpha) of the correctness of the items it is possible to calculate the reliability of the test variable "Number correct" and at least estimate the reliability of the test variable UBS. The calculation is made on the basis of the results of the norm sample.

For the norm sample as a whole this reliability index is r= 0.760. If internal consistency is calculated separately for educational levels 1-3 and 4-5, a reliability of 0.774 is obtained for the first group and a reliability of 0.727 for the second. For the three age groups of respondents aged up to 39, 40-54 and 55+, the following reliabilities are obtained: for the group aged up to 39 the internal consistency is 0.777; for the group aged 40-54 it is 0.802 and for the group aged 55+ it is 0.609.

3.3 Validity

3.3.1 Validity: UBS forwards

Construct validity

Working memory can be defined as the ability to store and process information in the short term. The Block-Tapping Test operationalises functions of working memory.
The block span measures the (maximum) immediate spatial memory span. A crucial aspect of this memory span is the capacity of the short-term spatial store. The test allows for spatial binding and rehearsal processes, the efficiency of which contributes to the spatial memory span. In addition, the sequential presentation of the stimuli requires both encoding and the reconstruction of a serial order during recall. Without these processes that go beyond "pure" recall the spatial span would be around four items. The theoretical background to these differences and hence to the construct validity of the test has already been outlined in Section 2.
Working memory has emerged as a theoretically fruitful concept and one that has been extensively researched in recent decades. Within this theoretical context the Block-Tapping Test has become the standard procedure for assessing spatial working memory. Baddeley sees the block-tapping task as a test that gets closest to the concept of spatial working memory and operationalises it almost in a pure form (Baddeley, 2001, p. 88). Studies of the test's validity are usually also interpreted from the theoretical perspective of working memory; conversely, the theoretical studies of spatial working memory can be regarded as validity studies of the Block-Tapping Test. For example, studies based on the dual-task design provide evidence of the distinction between verbal and spatial memory and can at the same time be read as studies of the divergent validity of the Block-Tapping Test. It is not necessary to describe these studies again here. The following section explores studies of the convergent validity of the test that do not focus on working memory as a construct but instead consider individual aspects of the block-tapping task in more detail.

Convergent validity

A number of dual-task studies have investigated the influence on spatial span of spatial tasks such as spatial tapping, eye movements in response to irrelevant stimuli or spatial attention shifts. All these functions, which are also involved in the Block-Tapping Test, lead to interference (Smyth & Scholey, 1994; Smyth, 1996; Pearson & Sahrie, 2003; Lawrence et al., 2001). It is consistently the case that the second task distracts attention from the block board.
A second group of validation studies varies the parameters of the spatial sequence and hence the tapping path that needs to be remembered during and beyond sequential presentation of the blocks. In summary it can be said that, as would be expected, simple and redundant paths are more easily remembered (Kemps, 2001; Schumann-Hengsteler, Strobl, & Zoelch, 2004; Parmentier, Elford, & Mayberry, 2005). The difficulty parameters of the path can be at least partially operationalised by the complexity of the tapping path, or more specifically through the size of the angles it covers (Schellig & Hättig, 1993).
A third group explores the influence on the spatial span task of the spatial clustering of the block sequence or the temporal clustering of the sequence. Again, these factors affect the retention of sequentially presented spatial localisations (Smyth & Scholey, 1994, 1996; De Lillo, 2004; however, the findings are sometimes confounded with the path length (Parmentier et al., 2006)).
Fourthly, studies discuss various reference systems for the storage of the positions. It is generally assumed that such a frame of reference must exist for each saved spatial representation. In the board versions of the Block-Tapping Test the stimuli are presented as fixed blocks on a board; in the computer version the board is replaced by a screen on which the blocks are usually shown as 3D drawings. The block board and the computer monitor

remain fixed – relative to the position of the respondent and the environment – throughout the test, enabling the respondent to use various frames of reference for storage. For example, he can use an egocentric frame of reference – relative to his eyes or body axis or relative to the hand that he uses for tapping. Or he can use the board on which the blocks are placed as a frame of reference and describe the path that needs to be remembered by means of directional instructions such as "up", "right" etc. in relation to this rectangular reference frame. Or he can develop an allocentric frame of reference relative to features of the environment (landmarks) such as a brand name on the screen, an object lying on the table alongside the block board etc. There is as yet no convincing evidence as to which frame of reference is most efficient in coding the block positions. In general there is a tendency for respondents to use an allocentric frame of reference rather than an egocentric one, and to use internal allocentric landmarks rather than external ones. In other words, encoding is carried out within the block board – relative to the rectangular board that provides the frame for unambiguous descriptions of direction and to local "landmarks", which in this context are other blocks (Avons, 2007).

In addition to those studies that explore aspects of the Block-Tapping Test in more detail and those that consider the test from the point of view of theories of working memory, there is a third angle from which questions are asked. This involves regarding the functions of spatial working memory operationalised by the test as the basis for complex cognitive functions ranging from mental spatial operations, visualisation as a memory technique, topographical orientation and the planning and monitoring of movement to fluid intelligence itself. The list could be continued almost indefinitely; it serves merely to indicate the central importance of spatial working memory within complex cognitive functions. As has already been outlined in the section on the applications of the block span, this becomes particularly clear in the development of cognitive functions. At this point, therefore, a brief summary will suffice. Spatial working memory plays a key role in the development of mathematical abilities and also in learning to read in childhood (McKenzie et al, 2003; Holmes & Adams, 2006; Bull et al., 2008). It correlates strongly with performance in counting in early childhood (Kyttala et al., 2003), with the acquisition of mathematical and reading skills in the early years of schooling (Bull et al., 2008) and with the mathematical abilities of children aged 10-14 (Maybery & Do, 2003; Jarvis & Gathercole, 2003). Children who have problems with mathematics have shorter spatial spans (McLean & Hitch, 1999; van der Sluis et al., 2005; White, Moffitt, & Silva, 1992). Overall the Block-Tapping Test has been found to be a good predictor of these aspects of educational performance – and hence also demonstrates the close correlations between spatial working memory and complex cognitive functions.

3.3.2 Validity: UBS backwards

In the block span forwards the serial presentation of the stimuli must be reproduced in the order in which the stimuli were presented. In the block span backwards the serial order must be rearranged; the stimuli must be memorised in the presented order and then revised. This difference in task requirement between the spans forwards and backwards leads to significant differences in performance in the verbal field but not in the spatial one.

This is demonstrated by a clinical study with an unselected sample of patients from the Hegau Jugendwerk neurological rehabilitation hospital in Gailingen, Germany. Patients were excluded if they had motor disabilities that prevented them taking the test. More than half of the 86 patients had suffered cranio-cerebral trauma (N = 49). Of the 37 men and 49 women aged between 15 and 30 (M = 20.16 years, s = 3.62 years), four had no school-leaving qualification, 20 had complete basic secondary schooling, 21 had completed intermediate secondary schooling, 31 had completed advanced secondary schooling and 5 had attended university.

38 patients had the same span forwards and backwards, 28 had a higher span forwards than backwards and 22 had a higher span backwards than forwards. Of the 48 patients who had different block spans forwards and backwards, the difference between the spans was one for

35 of the patients and more than one for 13 of them (Table 5). The mean memory span forwards was 4.88 (s = 1.13); the mean memory span backwards was 4.75 (s = 1.39). The t-test shows that this difference is not significant (t = 0.662; p = 0.509). Similar results were obtained for the variable "Number of correctly reproduced sequences": mean forwards = 8.50 (s = 3.17), mean backwards = 7.72 (s = 3.71); t-score = 1.48, p = 0.141.

Table 5: Differences between the immediate block span forwards and backwards for 86 patients with brain damage

	No difference	Difference of				
		1	2	3	4	Total
UBS forwards longer	38	17	5	3	1	26
UBS backwards longer		18	3	0	1	22

These findings contrast with those of studies in which the block span forwards and the block span backwards diverge. Performance in the block span backwards can be significantly improved through metacognitive training of sequential-spatial working memory (especially more in-depth processing of the series presented in spatial sequence); the improvement that can be achieved in the block span forwards is much less marked. No effects were found for the visual pattern test that was administered at the same time, nor for the number memory spans forwards and backwards (Caviola et al., 2009).
The relationship between the verbal memory spans forwards and backwards differs from that between the spatial memory spans forwards and backwards. The spatial memory spans forwards and backwards lie as it were closer together; they activate similar neural areas (in contrast to the verbal area, see above), but that does not mean that processing them involves exactly the same functions. The present state of research does not yet enable these functions to be differentiated in more detail.

3.4 Economy

Being a computerised test, the CORSI program is very *economical* to administer and score. The administrator’s time is saved because the instructions at the beginning of the test are standardised and raw and norm values are calculated automatically. Another aspect of the tests' economy is the short administration time.

3.5 Usefulness

The quality criterion of usefulness is met if, firstly, a test measures a relevant trait and, secondly, this trait cannot be measured by other tests that meet all the other quality criteria to at least the same extent. (Kubinger, 2003).
The tests in the CORSI program can be considered useful: measuring the spatial memory span is a standard procedure in memory assessment (Schellig, Drechsler, Heinemann & Sturm, 2009, p. 348) and the Block-Tapping Test is regarded as the standard test for measuring the short-term spatial memory store (Baddeley, 2001).

3.6 Reasonableness

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

Since respondents are not put under mental or physiological stress and the test takes only a short time to complete, the CORSI program fulfils the criterion of reasonableness.

3.7 Resistance to falsification

A test that meets the meets the quality criterion of *resistance to falsification* is one that can prevent a respondent answering questions in a manner deliberately intended to influence or control his test score (see Kubinger, 2003).
The tests in the CORSI program can be described as meeting the quality criterion of resistance to falsification: the tests include features for assessing falsification tendencies. If non-authentic symptom presentation is suspected, this can be checked using the supra-span task or by calculating the reliable spatial span (RSS). This is called for primarily in connection with tests for medical reports and expert opinions. In traffic psychology and clinical neuropsychological assessment – two of the main areas in which the test is typically used – there is less reason to assume that respondents will deliberately underachieve.

3.8 Fairness

If tests are to meet the quality criterion of *fairness*, they must not systematically discriminate against particular groups of respondents on the grounds of their sociocultural background (Kubinger, 2003).
As far as can be judged from findings to date, there are no indications that the tests in the CORSI program are unfair – that is, that they discriminate against particular respondents. In particular there is not reason to think that respondents who lack computer experience are disadvantaged – no specific computer knowledge is required to complete the test.

4 NORMS

4.1 Norms: UBS forwards and backwards

The influence of the demographic factors of gender, age and education was examined by means of covariance analysis using the factors of gender and education and the covariate age. The control sample comprises the data of 300 healthy patients aged between 15 and 89 (M = 44.84; s = 17.853). Of the 125 male and 175 female respondents, 54 had completed basic or intermediate secondary schooling, 147 had attended a technical school or completed vocational training, 68 had a school-leaving qualification at university entrance level and 31 had a university degree.
The groups were found to be homogenous in terms of error variance; the p value of the Levene test was 0.221. The results of the covariance analysis are shown in Table 6.
Gender has no significant influence on the test results. By contrast, educational level and age show significant effects: test performance improved with rising educational level and deteriorated with increasing age.

Table 6: Immediate block span forwards, covariance analysis with the factors gender and education and the covariate age.

	SS	FG	MQ	F	P
GENDER	0.063	1	0.063	0.059	0.808
AGE	55.435	1	55.435	52.144	0.000
EDUCATION	10.637	3	3.546	3.335	0.020
GENDER x EDUCATION	1.244	3	0.415	0.390	0.760

Influence of gender

The findings with regard to the existence of gender differences in the Block-Tapping Test are ambivalent. Gender differences have been found in a number of studies (Piccardi et al., 2008; Orsini et al., 1986; Orsini et al., 1987; Capitani et al., 1991) but not in others (Pagulayan et al., 2006; Kessels et al., 2002; Nichelli et al., 2001; Smirni et al., 1983). This ambivalence cannot be explained by the differing scope of the samples or by differences in age structure within the samples (Piccardi et al., 2008).
In the present computer version of the test, men tended to perform slightly better than women but the differences were not significant. The women achieved an average block span of 5.03 (s = 1.106); the average block span for men was 5.19 (s = 1.209).
Separate gender-based norms have not been drawn up.

Influence of age

Age has a significant influence on the storage and executive functions of working memory; the effect on the executive functions is more marked than that on the storage processes operationalised by memory spans (Park & Payer, 2006). This age effect seems to impact in the same way on both visual and visuo-spatial tasks (Park et al., 2002), although this finding has not been consistently confirmed (Jenkins et al., 1999, 2000). If visual and spatial tasks are considered separately, the influence of age is found to be greater on visual working memory than on spatial working memory (Beigneux, Plaie and Insingrini (2007), Myerson et al., 2003; Hartley et al., 2001) – although Chen et al. (2002, 2003) find the reverse to be true.
It is undisputed that the performance of working memory declines with age, irrespective of whether the focus is on storage capacity or on process capacity (Salthouse, 1990, 1994; Kausler, 1994; Hartley et al., 2001; Waters & Caplan, 2003). This is also the case in the present version of the Block-Tapping Test, which covers the age range from 15 to 89 years

(M = 44,84; s = 17,853). Age groups were formed, each spanning five years. Figure 2 suggested that these should be combined into three broader age groups: 15-39, 40-54 and 55-89. Within these age groups there is no longer any significant correlation with age.

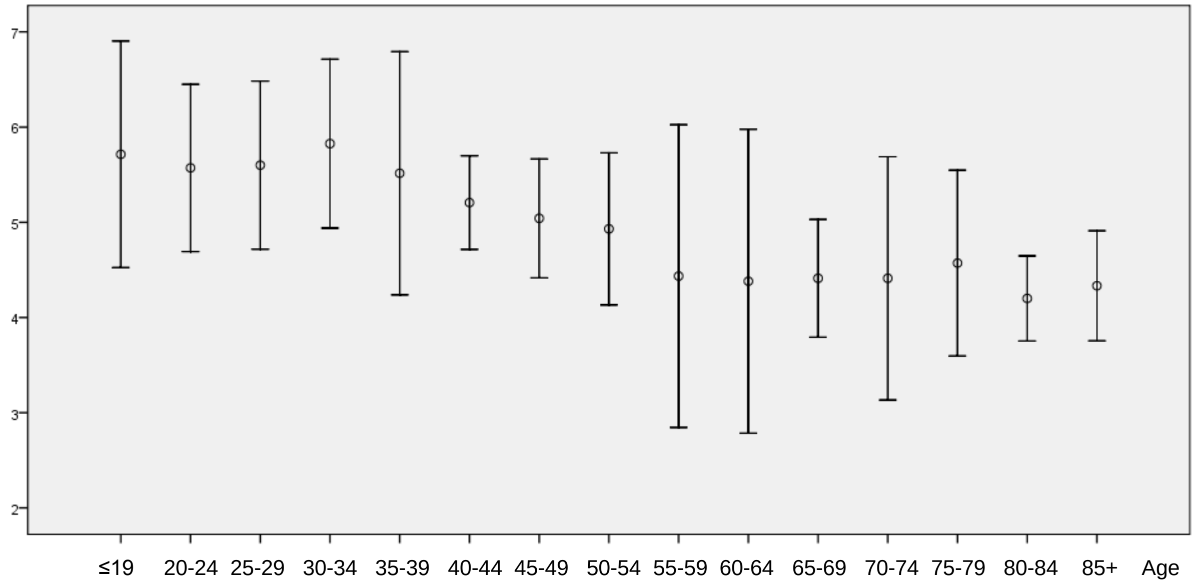

Figure 2: Immediate block span forwards. Mean scores and standard deviations of the age groups

Influence of education

Education level was gauged by vocational qualifications and the highest level of educational institution attended. Table 7 gives the definitions of the educational groups and their average block span. In the analysis of variance there was no significant difference between the first two and the last two educational groups. They were combined, which means that norms are reported for two different educational groups (see Figure 3).

Table 7: Immediate block span forwards: educational groups.

Education level	**Definition**	**Block span Mean and standard deviations**
2	Compulsory schooling or immediate secondary school completed (9-10 years of schooling)	5.17 (1.129)
3	Technical school or vocational training completed (10-12 years of education)	4.82 (1.163)
4	Advanced secondary school with leaving qualification at university entrance level completed (12-13 years of education)	5.37 (1.078)
5	University degree (>13 years of education)	5.48 (0.945)

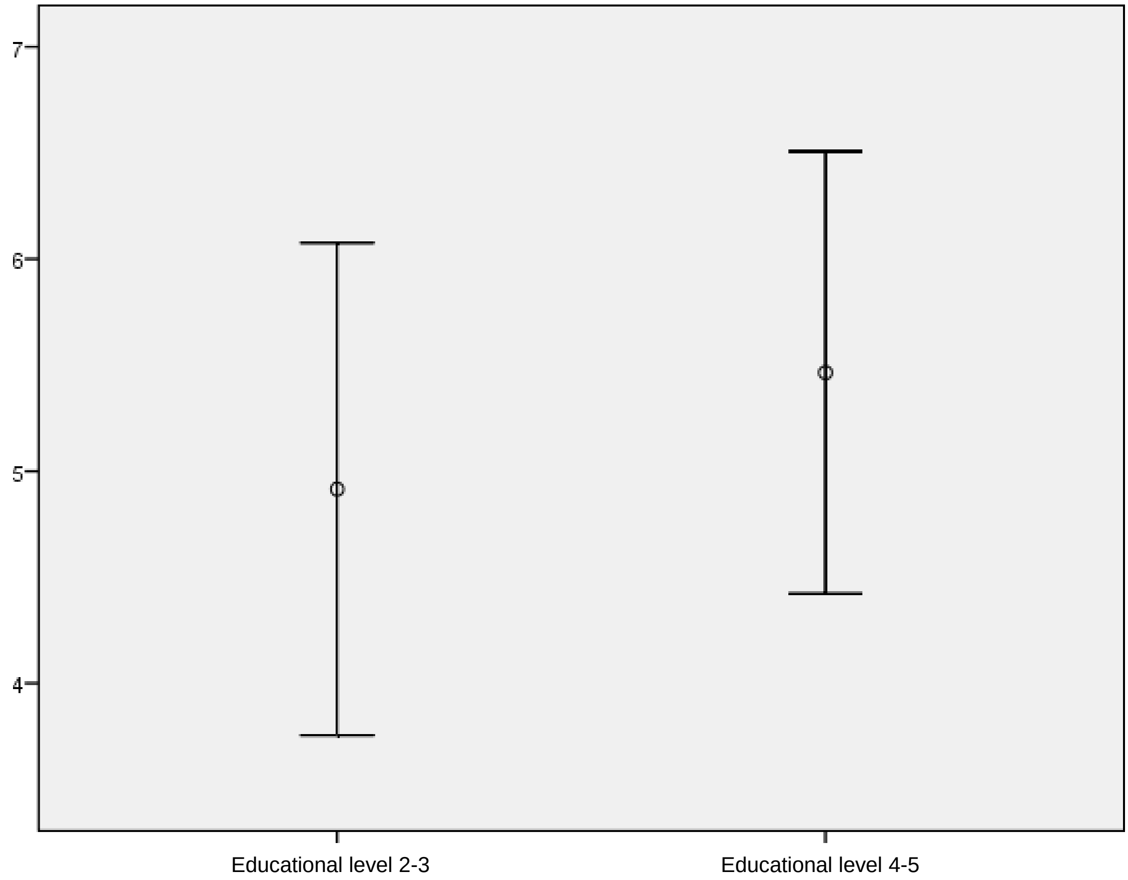

Figure 3: Immediate block span forwards. Mean scores and standard deviations of the educational groups.

Age and education effects

The important influence of the factors of age and education on test performance is illustrated in Figure 4. The performance of the two educational groups (education levels 2 and 3 (blue) vs. education levels 4 and 5 (green) is shown separately. The age effect is significantly more marked than the effect of education. The age-related decline in performance is similar in the two educational groups; there is no significant interaction.

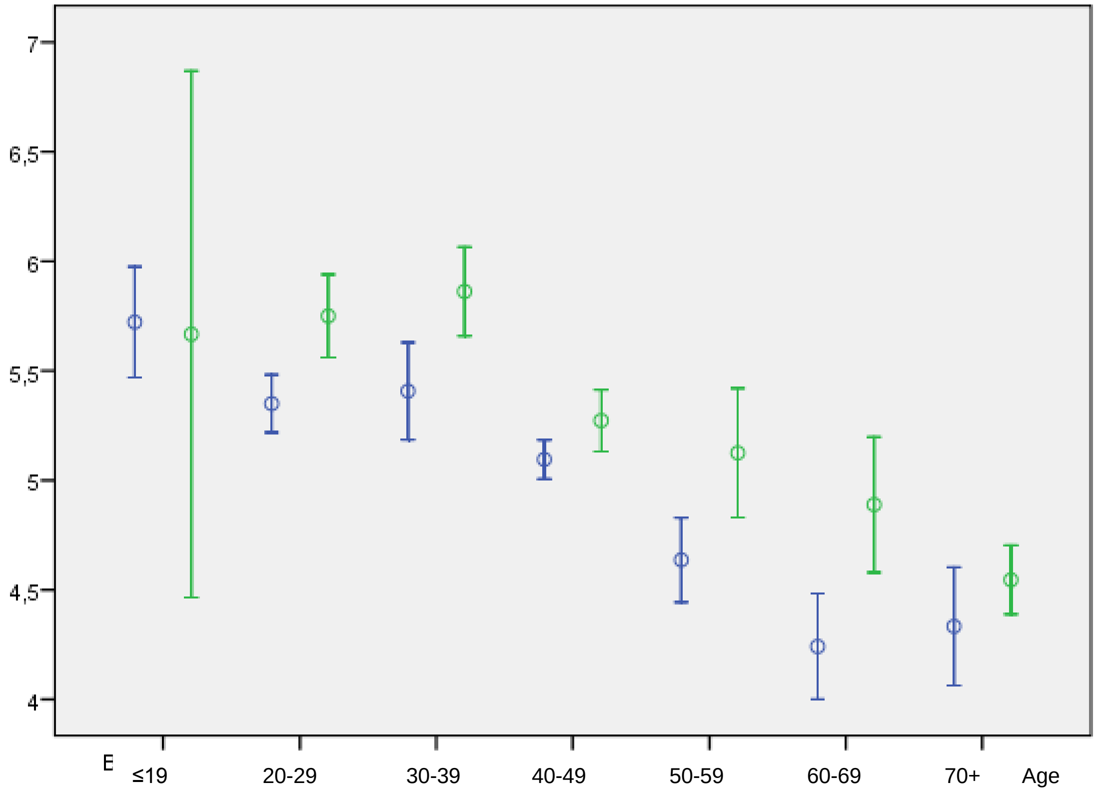

Figure 4: Immediate block span forwards, influence of age and education: means, vertical bars indicate standard deviations

Norms

Statistical analysis of the norm sample showed that gender does not influence performance in the Block-Tapping Test Forwards. Education, on the other hand, has a significant but small effect and age has a marked effect, with the decline in performance in the fifth decade of life being particularly noticeable.

The individual respondent can be assigned only a whole-number score on the test variable "block span". Scores in the norm group varied between four and nine. This small variation in scores suggests that a cut-off score might be applied. Because of the age effect this cut-off score is not uniform. If a cut-off score of five is used for respondents between the ages of 15 and 54 (i.e. respondents with a block span of five or more are regarded as normal), 88.41% are classified as normal. For respondents aged 55 and over a cut-off score of four should be used: 91.4% of the norm group are then classified as normal. For all other variables percentile ranks corrected for age and educational level are reported.

4.2 Norms: Supra-block span (SBS)

It is particularly difficult to norm the SBS on healthy respondents. Very little norm data for the sequences of 3, 4 and 9 can be expected, since healthy respondents with a UBS of 8 are very rare, and ones with a UBS of 3 are non-existent (see information on UBS cut-off scores above). A similar consideration applies to the sequence of 5 in relation to the SBS: this assumes that there are healthy respondents with a UBS of four – which occurs in the main only with older respondents (>55 years). In this group an age-related decline in performance in learning the supra-span is also to be expected (Turcotte et al., 2005). It is likely that for the foreseeable future a control group of non-brain-damaged individuals will be available only for an average UBS of between five and seven. For performance at a lower level than that the data of brain-damaged patients must be used for comparison purposes.

5 TEST ADMINISTRATION

CORSI consists of a combined instruction and practice phase and the test phase itself.

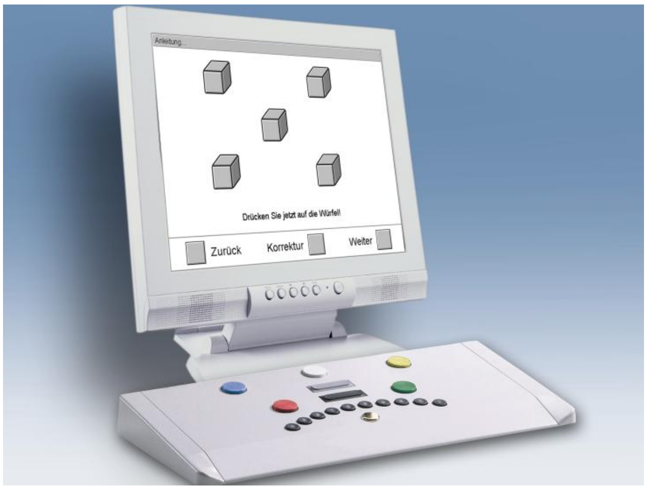

Figure 5: Practice item

5.1 Instructions and practice phase

At the start the aim of the test and the method of answering the items are explained, as are the options for making corrections. Two examples are then provided; each contains five blocks, of which three must be tapped in a particular order. The respondent must then tap on the blocks in the same order and confirm this by selecting “Next”. The answers are entered using a light pen or mouse. The respondent can correct his answer by selecting “Correction” and then entering the whole sequence in the right order. Feedback is given after the answer is entered. If a sample item is answered incorrectly it must be repeated. It is not possible to omit an example.

After the respondent has successfully worked the practice phase, the information is repeated and final instructions are given before he moves on to the test phase. The respondent selects “Next” to start the test phase.

5.2 Test phase

The blocks are presented in succession: the "cursor hand" moves from one block of the sequence being presented to the next. To complete a trial, he respondent must press the blocks in the correct order and then press the "Next" button. The next trial then appears. In contrast to the instruction phase, no feedback is given in this phase.
Before the respondent presses “Next”, he can make as many corrections as he wishes by pressing “Correction”. Doing this deletes his last answer; the new answer sequence must then be entered from the start. Once the “Next” box has been pressed it is no longer possible to correct an answer.

The test continues until the respondent answers three successive items incorrectly. If this termination criterion is not reached, the test continues until the last item – the third item of the group of eight – has been answered. The test is then terminated automatically.

There is no time limit on the working of the items.

5.3 Equivalence of input media

Classical presentation of the Block-Tapping Test on the computer involves using the light pen as the input medium. This is principally because the pointing movement made with the light pen is very similar to the pointing movement made with the hand when block tapping and high equivalence with older, non-computerised versions can therefore be expected.

This equivalence cannot be automatically assumed for other input media. A study was therefore conducted with a sample of N=196 individuals (51% men, 49% women) in the age range 17 to 80 (m=40.5, sd=14.7) from EU educational groups 2 to 5. Half of the group worked CORSI using a light pen while half used the computer mouse. The data was collected in the research laboratory of SCHUHFRIED GmbH in 2008.

There were no non-random differences between the different input media with regard to either immediate block span (t=-0.669; df=193; p=0.504) or working time (t=-1.125; df=194; p=0.262). It can therefore be concluded that – at least for normal individuals – block-tapping using the computer mouse is equivalent to block-tapping with the light pen.

6 INTERPRETATION OF TEST RESULTS

6.1 Interpretation: UBS forwards and backwards

The immediate block span describes the (maximum) visuo-spatial memory span. The capacity of short-term memory is limited. Measuring the spatial memory span aims to identify this limit for visuo-spatial material. The Block-Tapping Test for measuring the immediate block span (UBS forwards and backwards) thus measures the capacity limit of the spatial subsystem within short-term memory or (which amounts to the same thing) the capacity limit of the spatial storage system in working memory.

Tests for measuring the memory span aim to operationalise the storage capacity of working memory. However, the maximum memory span as measured by the Block-Tapping test goes beyond storage: it also includes binding processes and spatial, attention-based rehearsal process, and as well as involving retention of the position of objects it also calls for storage of the sequence shown. The test thus measures short-term spatial storage and the storage of assistive processes such as rehearsal and spatial binding as well as executive functions such as the temporal encoding and reconstruction of a serial (temporal) sequence of stimuli.
Measurement can involve either the block span forwards or the block span backwards. Differences in performance between the two test forms are particularly relevant in the context of developmental psychology. Both test forms should be administered if the Block-Tapping Test is used for symptom validity assessment.

6.2 Interpretation: Supra-block span (SBS)

The supra-block span (SBS) measures learning processes of spatial working memory. The target sequences of the supra-block span exceed the respondent's individual immediate block span and must therefore be learned. This learning takes place in short-term storage and processing systems: it has not been convincingly demonstrated that long-term memory structures are also involved. Learning should be understood in this context as an automation of cognitive processes. This automation reduces pressure on the limited capacity of working memory and thus enables additional spatial information to be stored. The learning of the supra-block-span sequences is thus to be interpreted as implicit learning that takes place in working memory.
The test is designed as an incidental test: the respondent is not explicitly informed that learning processes are being tested.

The learning paradigm used to measure the supra-block span can also be used for symptom validity assessment. The sequence length of the non-target items is the same as the length of the sequences at which the respondent failed during the preceding assessment of the immediate block span.

However, the non-target items of the supra-block span test are easier than the target items. Despite their longer length, they are of the same difficulty as the immediate block span items that the respondent previously reproduced correctly. This is intended to mislead respondents with non-authentic symptom presentation to make a large number of errors to highlight their disability at this apparently higher performance level – irrespective of the effective difficulty level of the sequences. Clustering of errors on the non-target items may indicate whether the respondent's performance is non-authentic.

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8 APPENDIX

Tabelle A1: Items of the UBS forwards and backwards

Item sequences	Item number	1	2	3	4 (replacement items)
Sequences of 2**		21*	65	38	*71*
Sequences of 3	1-4	479	319	425	*586*
Sequences of 4	5-8	3417	6158	5832	*6439*
Sequences of 5	9-12	52186	42731	97583	*69154*
Sequences of 6	13-16	392487	378294	927619	*389174*
Sequences of 7	17-20	5917428	5792846	1962791	*9852163*
Sequences of 8	21-24	58192647	59367243	36519127	*29763154*

* The numbers indicates the numbers of the blocks in the sequences in question (in accordance with Figure 1). For example, item 14 (see line 13-16 of the sequences of 6 and column 2) consists of the blocks 3, 7, 8, 2, 9 and 4.

** Sequences of 2 occur only in the test forms for children (S2 and S4)

*** The fourth sequence at each level is a replacement for a "missed" trial. Once per level respondents can press the "Next" button to be presented with the replacement trial.

Table A2: Target and non-target items of the supra-block span (SBS)

SBS – Sequences of four			
Item number	**Non-target items (distractor items)**		**Target items**
1-3	7953	9413	8134
4-6	8547	5496	8134
7-9	6359	1974	8134
10-12	5984	4219	8134
13-15	5421	6745	8134
16-18	9631	1796	8134
19-21	7894	8534	8134
22-24	2495	2851	8134
SBS – Sequences of five			
Item number	**Non-target items (distractor items)**		**Target items**
1-3	**24953**	**19743**	**52713**
4-6	85479	79536	52713
7-9	63597	59841	52713
10-12	94136	42198	52713
13-15	54216	67453	52713
16-18	96318	17965	52713
19-21	78941	85379	52713
22-24	54963	28514	52713
SBS – Sequences of six			
Item number	**Non-target items (distractor items)**		**Target items**
1-3	941368	598413	412795
4-6	854796	795368	412795
7-9	635974	197435	412795
10-12	549631	421987	412795
13-15	542169	674531	412795
16-18	963187	179654	412795
19-21	789413	853796	412795
22-24	249531	285147	412795412795

SBS – Sequences of seven			
Item number	**Non-target items (distractor items)**		**Target items**
1-3	9413685	5984137	4179386
4-6	8547962	7953681	4179386
7-9	6359748	1974356	4179386
10-12	5496316	4219876	4179386
13-15	5421693	6745316	4179386
16-18	9631875	1796543	4179386
19-21	7894132	8537964	4179386
22-24	2495316	2851473	4179386
SBS – Sequences of eight			
Item number	**Non-target items (distractor items)**		**Target items**
1-3	24953162	59841376	38295174
4-6	85479623	79536819	38295174
7-9	63597482	19743562	38295174
10-12	94136857	42198765	38295174
13-15	54216938	67453162	38295174
16-18	96318754	17965432	38295174
19-21	78941326	85379641	38295174
22-24	54963167	28514739	38295174
SBS – Sequences of nine			
Item number	**Non-target items (distractor items)**		**Target items**
1-3	963187542	941368572	426917835
4-6	854796231	795368194	426917835
7-9	635974821	197435628	426917835
10-12	598413762	421987653	426917835
13-15	542169387	674531628	426917835
16-18	549631678	179654328	426917835
19-21	789413265	853796412	426917835
22-24	249531628	285147396	426917835