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WORKING MEMORY, ATTENTIONAL REGULATION AND THE STAR COUNTING TEST*

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Summary—The Star Counting Test (SCT) has been developed to measure the regulatory function of attention. In a previous study it was shown that the SCT is suited for assessment of this attentional aspect with children. The present study concerns a more difficult version aimed at young adults. In the literature, the regulatory function of attention is increasingly stressed and it has been linked to working memory functioning. In order to further determine the validity of the SCT, performance was checked against two kinds of measures relating to working memory, i.e. Digit Span and Computational Span. These tasks both call for storage but differ in their claims on the processing component of working memory. Using confirmatory factor analysis substantial correlations were demonstrated with either of these measures. As expected, the correlations tended to rise with increasing demands on the processing component. Test scores were further compared with self-reported cognitive failures. No significant relation appeared to exist. The results are interpreted in terms of demands on the regulatory function of attention.

Attentional deficits are a topic of great concern and practical interest, especially in the educational and clinical field. Large scale assessment studies have shown that a considerable amount of children suffer from attentional problems, either or not accompanied by hyperactivity (e.g. Achenbach, Verhulst, Edelbrock, Baron & Akkerhuis, 1987). From clinical studies it appears that many types of brain dysfunction, such as schizophrenia, closed head injury, depression or dementia, are associated with disturbances of attentional function (e.g. Cooley & Morris, 1990). Also in normal aging, decrements in attentional abilities show up (Salthouse, Davenport, Rogan & Prill, 1984).

In view of the overall importance of the concept of attention, it is surprising that there has been relatively little work on its proper measurement. Handbooks of neuropsychological tests (e.g. Lezak, 1983; Spreen & Strauss, 1991) show that attention tests are rather scarce. They also often lack a sound theoretical background. In an attempt to improve this situation, a new test has recently been developed (de Jong & Das-Smaal, 1990; de Jong, 1991). This test, the Star Counting Test (SCT), is designed to measure attentional control. The test was administered to children in a large scale assessment study of attentional deficits in Dutch elementary schools (de Jong, 1991), and appeared to have good psychometric properties. As outlined in de Jong and Das-Smaal (1990), the test is based on a clear theoretical framework, i.e. Baddeley's (1986) Working Memory model in combination with the idea of a Supervisory Attentional System advanced by Norman and Shallice (1986). In a validation study it was shown that the SCT relates to other attention tests designed to measure working memory (de Jong, 1991). The main purpose of the present research is to examine further the relation between SCT performance and working memory functioning. Also, the connection with self-reported cognitive failures will be investigated. A more difficult version of the test is employed, which is suitable for young adults.

Attention is generally thought to be a multidimensional phenomenon, but knowledge of its dimensionality and structure is still incomplete. Correlational and factor analytic studies can give important information on this issue. Research of this kind may also provide a basis from which measures can be selected (Cunningham, 1986). Recently, de Jong (de Jong, 1991; de Jong & Das-Smaal, in preparation) reported on this subject. Based on both the available data from the

*This study is part of a research program on problems of attention and impulsiveness at school which is guided by a team of staff members from the departments of Cognitive, Physiological, Work & Organization, Neuro- and Developmental Psychology, and Special Education of the Vrije Universiteit Amsterdam, The Netherlands.

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literature and his own results, he concluded that either of two main factors seem to be implicated in attention tests. These are a (perceptual) speed and a working memory factor. Regarding the first factor, it is indeed the case that many attention tests demand just numerous repetitions of a relatively simple process like pattern detection (e.g. cancellation tasks). It is likely that regarding the transition between controlled and automatic processing, these tasks incline to the development of automaticity of performance. In contrast, the second factor relates primarily to the regulatory or control aspects of working memory, which have been associated by Baddeley (1986) with attention. Aspects like flexibility and planful behavior are important here. This factor is more in line with recent developments in the literature on attention, according to which the regulatory function of attention is increasingly stressed (Allport, 1989; Neumann, 1987).

In the past decade the multi component model of working memory developed by Baddeley and his colleagues (Baddeley & Hitch, 1974; Baddeley, 1986) has gained wide acceptance. In this model, working memory is conceptualized as a modular system for temporary storage and information manipulation. The model suggests that working memory comprises a controlling Central Executive (CE) system, which operates to guide and regulate the processing of material in working memory. The CE is assisted by a number of subsidiary "slave systems", that have a storage function. One of these, the articulatory loop, is assumed to be responsible for the maintenance and rehearsal of phonological material. The CE itself is closely associated with attention (Baddeley, 1986).

The SCT is aimed at measuring the regulatory function of attention. The test focuses on accuracy rather than speed and is suitable for groupwise administration. The SCT asks for the control of a simple process: counting. More specifically, the test requires, according to a certain procedure (see Method section), alternating forward and backward counting. This alternation is assumed to place demands on the CE, because an ongoing process has to be inhibited and another has to be activated. An essential characteristic of the test, therefore, pertains to the alternation procedure. A dysfunction in the CE should be manifested by an inability to alternate in a flexible way between counting directions.

The original test is suitable for children. The present investigation employs a more difficult version, meant to extend the domain of application to other age groups. A major aim of the present study is to amplify the information on the validity of the test. The performance on the SCT will be compared concurrently with two other measures of working memory, as well as with self-report measures of proneness to minor cognitive failures or absent-mindedness.

The justification for the selection of the criterion measures again rests upon Baddeley's working memory model, involving both storage and processing of information. Working memory functioning has traditionally been measured by tests of memory span. A well-known example is the digit span, defined by the longest list of digits which can be recalled in correct serial order. The task relies heavily on continuous attention, not only when the material is encoded or recalled, but also during retention (Morris & Baddeley, 1988). It has been shown that this task taps some of the important processes regarding the storage capacity of working memory (Baddeley, 1986). One criterion measure in this study, therefore, will be the digit span task.

However, as Daneman and Carpenter (1980) have pointed out, digit span may provide an incomplete picture of the working memory capacity. The digit span task measures mainly the storage component, and seems to have only minimum processing requirements. In terms of Baddeley's working memory model, the task relies heavily on the articulatory loop function. Daneman and Carpenter argue that a test of the efficiency of the total working memory system should measure processing functions as well. Daneman and Carpenter devised a measure of working memory capacity in which *Ss* are presented with a number of sentences and asked to recall, afterwards, the last word of each sentence in order. This span was shown to be strongly related to reading comprehension (Daneman & Carpenter, 1980). It can be argued that a point of weakness of this task resides in its complexity and involvement of too much language and comprehension skill to represent general working memory capacity (Baddeley, 1986). Therefore, as a second criterion task, we preferred to use a less complex task, the computational span task, which was developed in our own laboratory (Brand, *in preparation*). Like the Daneman and Carpenter measure, the computational span task requires both storage and processing. The idea of this task was borrowed from a dot counting task devised by Case, Kurland and Goldberg (1982), that has been used to measure individual and developmental differences in working memory capacity. This

task involves presenting sets of dots in two colors. Ss have to count the number of dots of a specified color for each presentation, and afterwards to report the numbers in correct order. Counting (processing) and retaining previous totals (storage) are combined in this task. However, this task also has a drawback. Individual differences in a process called subitizing, i.e. quantifying the number of dots in one glance instead of counting them (Klahr, 1973), could be a source of undesired variation regarding the processing demands on the Ss. With subitizing, no counting occurs. The processing aspect is different in that case, and it is doubtful whether it is sufficiently demanding. Our computational span task requires simple computations instead of counting dots. Like in the digit span task, Ss are presented with a series of digits. However, together with each digit goes an instruction to either add or subtract one from that digit. Instead of the given digits, the results of the computations have to be retained and reported in correct order following the last instruction. As in the normal span procedure, working memory capacity is measured here by the longest list of (computed) digits accurately recalled.

Based on Baddeley's model, a relation is predicted between SCT performance and either of the criterion span measures. However, because the processing demands of the computational span task are higher, and therefore also the claims on the CE system, a stronger relationship is expected between SCT and computational span than between SCT and digit span.

For further validation of the SCT, a questionnaire will be administered regarding minor cognitive failures. The questionnaire concerns self-reported deficits in perception, memory and motor function. People appear to vary in their proneness to these failures (Broadbent, Cooper, FitzGerald & Parkes, 1982). Reports of failures in everyday functioning of memory and attention show that when attention is captured by something, slips or lapses may occur that reflect a lack of attentional monitoring, with strong habit intrusions as a result (Reason & Mycielska, 1982). The Cognitive Failures Questionnaire (CFQ), developed by Broadbent *et al.* (1982), will be used to measure these failures. It is hypothesized that a liability to cognitive failures is related to reduced attentional control as reflected in performance on the SCT.

METHOD

Subjects

Ss were 122 students (104 female and 18 male). All students were freshmen with a mean age of 20 years. One group of 39 students attended the Free University in Amsterdam; another group of 83 students were in a teachers college.

Measurements

The Star Counting Test (SCT). The original version of the SCT (de Jong & Das-Smaal, 1990) was developed for children in elementary school of 8 to 11 years of age. For this study the test was modified to increase its difficulty so that it would be suitable for young adults. An example of an item of the adult version is displayed in Fig. 1.

As in the children's version, the items of the test consisted of patterns of approx. 40 stars with plus and minus signs in between. Each item had a specified number in the top left corner, ranging

Fig. 1. An example of an item of the SCT.

from 14 to 78. Starting from that number the stars had to be counted row-wise from left to right, in the direction (forward or backward) indicated by the signs between the stars. Thus, the test required alternating forward and backward counting until the last star is reached. The number of the last star was the answer to the item.

To adapt the test to young adults, the difficulty of the original test was increased in two ways. First, the number of changes in the direction of counting per item was heightened. The number of alternations in an item of the present version was 4, 6 or 8. Second, items were devised which required counting by 2s either forward or backward. For each item an instruction was given how to count forward and backward. Thus, instruction 1 *forward*, 1 *backward* meant both forward and backward counting in steps of one, as in the original version (which goes without extra instruction). Instruction 2 *forward*, 1 *backward* indicated forward in steps of two, backwards in steps of one. And finally, instruction 1 *forward*, 2 *backward* stood for forward by one, and backwards by two.

As in the children's version, the adult version of the test had two parts which differed in the meaning of the signs. In the first part the signs had their normal meaning, i.e. forward counting following a plus, and backward following a minus sign. In the second part, the Ss were instructed to reverse that meaning, implying that they now had to count backwards following a plus sign, and forwards following a minus sign.

The test consisted of 24 items, 12 in part 1 and 12 in part 2, which means that the maximum score on the test was 24. Ss were given 15 min for each part of the SCT.

In a pilot study with young adults, the principles that were supposed to make a new version more difficult were tried out. Thus, increasing the number of changes in counting directions and adding instructions as mentioned above, were followed out in a tentative short form. This new form appeared to elicit errors, as such meeting the requirements of a power test.

Digit Span Test (DST). Digit spans from the WAIS (Wechsler, 1955), both forward and backward, were tested using the following procedure. For Span Forward, lists of three to eight digits, two for each list length, were recorded on audiotape with a one second inter-digit interval. The same was done for Span Backward with lists of two to seven digits. The test was presented groupwise and Ss were given all lists. They were asked to retain each sequence and to write them down following each presentation (in reversed order for Span Backward). They were scored for the total number of lists recalled correctly. The maximum score on the test was 24.

Computational Span Test (CST). Computational spans, both forward and backward, were determined. The test was composed of lists of simple arithmetic problems. Each arithmetic problem consisted of a digit to which either 1 had to be subtracted or added. For example, a list length of three could look as follows: $8 - 1$, $2 - 1$, $3 + 1$. The problems were recorded on tape, with a 1 sec inter-problem interval. Each problem had to be solved, and the result had to be retained. In the example above, the numbers 7, 1, and 4 had to be saved. Procedure and scoring were further identical to Digit Span. That is, at the end of each presented problem list, Ss had to write down the sequence in order (reversed for Span Backward), and their scores were the total number correctly recalled. The maximum score on the CST was 24.

Self-reported cognitive failures. The questionnaire for cognitive failures consisted of the 25 items of the CFQ developed by Broadbent *et al.* (1982). Apart from a general factor of overall cognitive lapses, no other stable dimensions were found by Broadbent *et al.* In order to see whether an extension of the questionnaire would lead to a further structuring of the list, the CFQ was supplemented by another 10 items on perception, memory and action slips (further to be denoted as the Extended CFQ). These were 4 items regarding memory slips from the Inventory of Everyday Memory Experiences (Hermann & Neisser, 1978), and 6 items on perception and action slips from the Error Proneness Questionnaire (Reason & Mycielska, 1982). Ratings were on a 5-point scale, ranging from 'never' (0) to 'very often' (4). The Extended CFQ consisted of 35 items with a maximum score of 140.

Procedure

Tests and questionnaire were administered by the same experimenter to groups of 15–25 Ss at a time. The order of presentation was as follows: SCT part 1, DST (Forward and Backward), a period of 5 min rest, SCT part 2, Extended CFQ, and CST (Forward and Backward). The total session, instructions included, took 1 hr 30 min.

Table 1. Mean (M), standard deviation (SD) and the reliability (Cronbach's α) of the tests and inter-correlations between the tests

Test	M	SD	α	Correlations		
				SCT	DST	CST
SCT	20.36	2.73	0.62	1.00		
DST	18.02	2.78	0.68	0.39**	1.00	
CST	15.87	3.97	0.83	0.65**	0.62**	1.00

SCT = Star Counting Test; DST = Digit Span Test; CST = Computational Span Test. For the SCT and the DST n is 119, for the CST n is 39. ** $P < 0.01$.

RESULTS

Due to a restricted testing time the CST Backward could not be administered to the group of 83 students from the teachers college. On the other tests 2 S s had incomplete data, and 1 S was considered as an outlier. Thus, 119 S s were available for the data analysis, with the exception of the CST Backward for which 39 S s took part in the analysis.

The means, standard deviations and reliabilities of the total scores of the tests are presented in Table 1. From this table it can be seen that the reliability of the SCT is moderate. This might in part be due to the fact that the mean score on the test is high. Several items were solved correctly by over 90% of the S s, thus adding little to differentiate S s of different ability. It is also of note, however, that the reliability of the SCT is very similar to the reliability of the DST. The reliability of the CST is good. However, this result should be considered with caution, because it is based on a small number of S s.

Table 1 also shows the inter-correlations among the SCT, the DST and the CST. The correlations between the SCT and the span measures turn out to be substantial. As predicted, the SCT correlates higher with the CST, which is supposed to depend more heavily on the CE than with the DST. However, the comparison of these correlations is not without problems. First, the correlation between the SCT and the DST is based on all S s whereas the correlation between the SCT and the CST is computed in one group of S s only. Thus, both correlations are based only partly on the same S s which severely hampers their comparison. Second, the differences between the correlations should be tested (e.g. Steiger, 1980). Testing is complicated here again by the fact that the CST Backward was administered only to part of the S s. The group that completed all the tests is quite small (i.e. 39 S s) and a test between the two correlations in this group will have a low power. Third, the DST and the CST have unequal reliabilities (see Table 1). The difference between the correlation of the SCT with the DST and the CST might therefore reflect differences in the reliability of these tests instead of being a consequence of the different abilities that are supposed to be involved (cf. Lord & Novick, 1968).

To overcome these problems, a structural modeling approach was applied. This approach makes it possible to examine correlations between latent variables that are, by definition, free of measurement error (cf. Bollen, 1989). Differences between correlations can therefore not be caused by unequal reliabilities. Furthermore, in the structural modeling approach missing data can be handled elegantly by partitioning the data in groups with different patterns of missing data and subsequently conducting a multiple sample analysis (Bentler, 1989, 1990).

In the present study a two group confirmatory factor analysis was performed. Two covariance-matrices were computed: one for the group with complete data (the university students) and one for the group with the missing variable CST Backward (the students from the teachers college). For both groups a highly similar factor model was formulated. For each test (SCT, DST, and CST) a latent variable was postulated. Every latent variable had two indicators, namely the first and the second part of the test. However, in the group with incomplete data the CST Backward was omitted from the model. Further, it was assumed that the estimates of the parameters (i.e. factor loadings, factor inter-correlations and error variances) that were present in the models for both groups would be equal.

The two group confirmatory factor analysis was conducted with EQS (Bentler, 1989). This program computes maximum likelihood estimates for the parameters in both groups simultaneously. The fit of the model can be tested with a statistic that is asymptotically chi-square distributed. The model appeared to fit the data ($\chi^2 = 16.61$, $df = 21$, $P = 0.73$). The standardized

Table 2. Standardized solution of the 2-group factor model

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Test	Factors			Unique variance
	SCT	DST	CST	
Factor loadings				
SCT-N	0.61	—	—	0.63
SCT-R	0.79	—	—	0.38
DST-F	—	0.77	—	0.41
DST-B	—	0.61	—	0.63
CST-F	—	—	0.67	0.55
CST-B	—	—	0.93	0.13
Factor inter-correlations				
SCT	1.00			
DST	0.53	1.00		
CST	0.77	0.72	1.00	

SCT-N = SCT Normal (part 1); SCT-R = SCT Reversed (part 2);
DST-F = DST Forward; DST-B = DST Backward; CST-
F = CST Forward; CST-B = CST Backward. —, parameter
constrained to zero.

parameter estimates of the model are presented in Table 2. Note that the parameter estimates were constrained to be equal in both groups. Only the factor loading and the unique variance of CST Backward is solely based on one group.

In the structural modeling approach hierarchical tests can be performed when one model is a special case of the other. In the present study the crucial test is between the original 2-group factor model (see Table 2) and a model in which the correlation between the SCT-factor and the DST-factor is constrained to be equal to the correlation of the SCT-factor with the CST-factor. The difference between the chi-square of the original model and the model with this restriction has also a chi-square distribution (Bollen, 1989). The degrees of freedom of this chi-square difference are the degrees of freedom of the original model minus the degrees of freedom of the restricted model, i.e. one. The restricted model also appeared to fit the data well ($\chi^2 = 19.77$, $df = 22$, $P = 0.60$). However, the chi-square difference between the original model and the restricted model turned out to be marginally significant ($\Delta\chi^2 = 3.16$, $df = 1$, $P = 0.08$). The extra constraint led to an almost significant decline of the fit of the model. Therefore, the original model in which both correlations are unequal is to be preferred. From the parameter estimates of the original model it can be seen that, as was predicted, the SCT has a higher correlation with the CST than with the DST (see Table 2).

The correlations of the three working memory tests with the (unextended) CFQ are reported in Table 3. The correlations are uniformly low and none of the correlations deviates significantly from zero. However, the reliability of the CFQ (see Table 3) is rather low for a scale of 25 items. The reliability of the Extended CFQ is higher, but nevertheless none of the correlations with the working memory tests reaches significance. It is possible however, that the Extended CFQ is multidimensional and it is worth pursuing whether there are significant relations between the tests and the separate dimensions that might be involved.

The Extended CFQ was subjected to a principal component analysis. According to the Scree criterion (Zwick & Velicer, 1986) three factors would be appropriate to describe these data. However, the third factor could not be interpreted and therefore two factors were preferred. These factors explained 27% of the variance and appeared, after oblimin rotation, fairly easy to interpret.

Table 3. Number of items (K), Cronbach's α and scale inter-correlations for the CFQ and the subscales of the Extended CFQ, and the correlations of the CFQ, the Extended CFQ and the subscales of the Extended CFQ with the three working memory tests

Scale	K	α	Scale inter-correlations		Correlations		
			MAS	AM	SCT	DST	CST
CFQ	25	0.80			0.03	0.12	-0.12
E-CFQ	35	0.88			-0.01	0.10	-0.18
MAS	24	0.87	1.00		0.02	0.10	-0.23†
AM	7	0.65	0.40**	1.00	-0.06	0.10	0.11

CFQ = Cognitive Failures Questionnaire; E-CFQ = Extended Cognitive Failures Questionnaire;

MAS = Memory and Action Slips; AM = Absent-Mindedness. †0.10 < P < 0.05. * P < 0.05.

** P < 0.01.

The first factor could be characterized as reflecting memory and action slips, or more specifically as rote memory failures and slips during habitual actions. The second factor was formed by items on absent-mindedness. Items and factor loadings are presented in the Appendix.

On the basis of the item loadings on both factors, two scales were formed. To be included in a scale, the loading of an item on its main factor had to be at least 0.35. This main loading should differ also more than 0.10 from the loading on the other factor. The latter loadings, in addition, should not exceed 0.30. Thus, two scales were constructed: a memory and action slips scale (MAS, 24 items), and an absent-mindedness scale (AM, 7 items). According to the criteria, items 7, 14, 28 and 35 of the list were excluded from the scales. The reliabilities of and inter-correlations between the scales are given in Table 3. The reliability is good for the MAS scale, but somewhat lower for the AM scale. The correlation between the scales is just moderate, which corroborates the supposed multidimensionality of the Extended CFQ.

For both scales the correlations with the working memory tests were computed. From Table 3 it is clear that again none of the correlations are significant, although there is a tendency for a correlation between the MAS scale and the CST, in the expected direction ($r = -0.23$; $P = 0.08$).

DISCUSSION

In a previous study it was shown that the SCT is suitable for children (de Jong & Das-Smaal, 1990). The psychometric properties of the test appeared to be robust. The SCT version employed in the present study was a more difficult one, aimed at young adults. The results show that the test procedure, i.e. alternation between forward and backward counting, again elicits errors. However, several test items turned out to be too easy. Perhaps as a result, the reliability of the test was just moderate. On the positive side, it should be noted that the *Ss* in this study were all college students, who can be expected to have a good quality of working memory functioning. The fact that many test items did elicit errors even among this group means that in principle the test can be adjusted for a broad range of target groups.

In order to test the validity of the SCT, in the present study performance on the test was checked against two other measures relating to working memory functioning. These were the CST and the DST. According to Baddeley's working memory model, performance on the SCT should be related to either of these measures. However, the CST poses heavier demands on the CE in Baddeley's model than the DST. The CST taxes the regulation of processing and storage functions in working memory, whereas the DST measures primarily a storage function. The alternation procedure in the SCT was also aimed at placing demands on the CE. Therefore, the relationship between SCT performance and computational span was expected to be stronger than the relationship between SCT performance and digit span. In the analysis of the present study, problems of unequal reliabilities or missing data were avoided by applying a structural modeling approach. The results appeared to fit nicely to the variation in processing demands on working memory. The correlations between the SCT and both span measures turned out to be substantial. In addition, the correlation tended to rise with increasing demands on the processing component. Besides validating the SCT, these results add to the evidence on the usefulness of the theoretical concepts on which the test is based, i.e. Baddeley's working memory model. Recently, comparable evidence was also provided by Babcock and Salthouse (1990). Part of their study was aimed at examining whether an increase in processing demands of different task types would alter demands on a central, domain-independent executive component of working memory. To answer this question, they employed two verbal span tasks just slightly different from the span tasks in the present study. In addition, they used a comparable set of spatial span tasks. The idea was that in the verbal and spatial tasks measuring primarily storage, performance would depend mostly on different "slave systems", as hypothesized by Baddeley. However, more processing demands would lead to more reliance on one CE for both the verbal and the spatial tasks. As predicted, a stronger relationship was found between the storage plus processing tasks than between the storage tasks. This supports the notion of an increased involvement of one CE with more processing requirements in working memory span tasks. As both the storage and processing aspects of their verbal storage and processing task appear to be very similar to the ones in our computational span task (i.e. ordered recall of digits and simple calculations), it is not unlikely that our task too makes demands on a domain-independent CE.

Nevertheless, it remains possible that the higher relation between the SCT and the CST (as compared to the relation of the SCT with the DST) is not based on their demands on the CE but on some particular specialized slave system that both tasks have in common and is not tapped by the DST. This would imply the addition of another slave system to Baddeley's model of working memory. Before such an extension should be considered, however, much more evidence is needed and the proposition of a new slave system is certainly not warranted when the current model can, as in this study, explain the results.

Regarding the relationship between SCT performance and cognitive failures, the results are not quite as expected. Factor-analysis of the Extended CFQ showed that the failures seem to concern two moderately related factors. These are characterized by memory and action slips, and by absent-mindedness. Regarding the first factor, here by far most items contain the words *forget* or *don't remember*, although action slips are also concerned. The factor can be more specifically described as rote memory failures and slips during habitual actions. In contrast, items from the second factor seem to point to absent-mindedness, associated with a low activation for what has to be done (e.g. daydreaming, attending but not taking in). Neither the MAS scale, nor the AM scale showed a relationship with one of the working memory tests, except for memory and action slips, which tended to a relationship with CST performance. More slips tended to go together with a lower computational span.

Whereas no relationship turned up between SCT performance and cognitive failures, it should be mentioned here that in a former study (de Jong & Das-Smaal, 1990) a substantial correlation was obtained between SCT performance and teacher ratings of children's attentional behavior at school. The test was also able to discriminate between various childhood disorders as rated by teachers. Why, then, the lack of relationship with cognitive failures? Obviously, one would expect such a relationship, as both the tasks and the Extended CFQ were designed to measure attentional or cognitive control. The question seems the more relevant if one realizes that the present study is not the only one to report a lack of relation between cognitive failures and cognitive task performance. Broadbent *et al.* (1982) notice the same negative results, and Rabbitt and Abson (1990) signalled it too in various studies. Both Broadbent *et al.* and Rabbitt and Abson mention the limitations of laboratory paradigms as tools for understanding everyday cognitive competence. However, in light of the relation between SCT performance and teacher ratings of attention, this argument is not enough to explain our results. Rabbitt and Abson also put forward the fact that subjective self-ratings cannot reflect absolute levels of efficiency. People have no means of assessing their own efficiency in absolute terms, and this makes comparisons among individuals problematic. This argument is weakened by the fact that Broadbent *et al.* were able to show that the opinions of the persons themselves are shared by others who know them.

With hindsight, other considerations may be put forward in the interpretation of the lack of positive results. Reason and Mycielska (1982) have discussed why some people are consistently more prone than others to these types of minor cognitive failures. They suggest that this could be due to differences in the amount of attentional resources available to monitor and control routine processes at critical moments. They further propose that a reduced amount of attentional reserve could result from relatively persistent additional demands upon attention (e.g. intellectual or emotional), leaving less free to cope with nonconscious, lower-level control activities. Thus, the monitoring of routine processes is described by Reason and Mycielska as a matter of nonconscious, lower-level control activities. The situations and activities specified in the questionnaire indeed are all relatively routine and effortless. In contrast, the SCT explicitly calls upon higher-level control in a task that is experienced as demanding very much effort. The same may yield for the other cognitive (mostly memory) tasks that were examined in vain both by Broadbent *et al.* and by Rabbitt and Abson as an objective measure of level of cognitive failure. Individual differences in nonconscious lower-level control of attention regarding routine behavior need not necessarily be related to differences in higher-level control in nonroutine tasks. It will be a matter of future research to reveal the relationship between monitoring routine processes and the higher-level aspect of attentional regulation in demanding tasks.

In sum, in the present study an adult version of the SCT was validated. The original version of the test could be made more difficult and thus made suitable for adults. The results support the

hypothesis that the SCT makes demands on the CE-component of working memory. The performance on the SCT appeared not to be related to self-reported cognitive failures.

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(Appendix overleaf)

APPENDIX

	Item	Factor loading	
		I	II
29.	Do you find you must look up a number, that you had called several times before, because you don't remember it?	0.67	0.01
13.	Do you fail to see what you want in a supermarket (although it's there)?	0.63	-0.08
6.	Do you find you forget whether you've turned off a light or a fire or locked the door?	0.62	-0.10
27.	Do you find you discover, when you have just gone out, that you must return for something you had intended to bring but accidentally left behind?	0.60	0.13
18.	Do you find you accidentally throw away the thing you want and keep what you meant to throw away—as in the example of throwing away the matchbox and putting the used match in your pocket?	0.59	-0.11
31.	Do you find yourself searching for something that you are actually carrying around with you?	0.59	0.09
16.	Do you find you forget appointments?	0.58	-0.10
32.	Do you find you are struck by the feeling that you should be doing something, either at the present or in the near future, but you can't remember what it is?	0.56	0.17
12.	Do you find you forget which way to turn on a road you know well but rarely use?	0.53	-0.04
21.	Do you start doing one thing at home and get distracted into doing something else (unintentionally)?	0.52	0.02
33.	Do you find you leave some necessary step out of a sequence of intended actions?	0.52	0.10
17.	Do you forget where you put something like a newspaper or a book?	0.49	0.20
2.	Do you find you forget why you went from one part of the house to the other?	0.49	0.07
26.	Does it happen when you have looked up a local number in the phonebook, you have to look back at it again in order to finish dialing?	0.47	0.28
3.	Do you fail to notice signposts on the road?	0.44	-0.27
11.	Do you leave important letters unanswered for days?	0.43	-0.18
5.	Do you bump into people?	0.43	0.12
23.	Do you find you forget what you came to the shops to buy?	0.41	0.20
24.	Do you drop things?	0.39	0.10
22.	Do you find you can't quite remember something although it's 'on the tip of your tongue'?	0.37	0.16
34.	Do you find yourself not having done something you intended after having dealt with some unexpected interruption?	0.36	0.25
20.	Do you find you forget people's names?	0.35	0.04
28.	Do you forget where you have put something away when you look for it a week later?	0.34	0.27
4.	Do you find you confuse right and left when giving directions?	0.34	-0.10
35.	Does it happen that during the course of some routine activity, something happens that requires a modification of your usual actions, you note the need for change, but go on doing the same thing automatically?	0.32	0.26
8.	Do you say something and realize afterwards that it might be taken as insulting?	0.31	0.14
7.	Do you fail to listen to people's names when you are meeting them?	0.29	-0.07
14.	Do you find yourself suddenly wondering whether you've used a word correctly?	0.19	0.07
25.	Do you find you can't think of anything to say?	-0.26	0.66
19.	Do you daydream when you ought to be listening to something?	0.13	0.63
30.	Do you find yourself watching TV but not actually taking anything in?	0.13	0.59
10.	Do you lose your temper and regret it?	0.03	0.53
15.	Do you have trouble making up your mind?	0.11	0.46
9.	Do you fail to hear people speaking to you when you are doing something else?	-0.00	0.38
1.	Do you read something and find you haven't been thinking about it and must read it again?	0.19	0.38
Factor 1		1.00	
Factor 2		0.27	1.00

Note 1. Items 1–25 from CFQ of Broadbent *et al.* (1982); items 26–29 from Hermann Neisser (1978); items 30–35 from Reason and Mycielska (1982).

Note 2. In items 31, 32 and 35 an example was given.