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de Jong, P.F.; Das-Smaal, E.A.

published in
Personality and Individual Differences
1990

DOI (link to publisher)
10.1016/0191-8869(90)90043-Q

document version
Publisher's PDF, also known as Version of record

Link to publication in VU Research Portal

citation for published version (APA)
de Jong, P. F., & Das-Smaal, E. A. (1990). The Star Counting Test: An attention test for children. *Personality and Individual Differences*, *11*, 597-604. https://doi.org/10.1016/0191-8869(90)90043-Q

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Person. individ. Diff. Vol. 11, No. 6, pp. 597–604, 1990
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THE STAR COUNTING TEST: AN ATTENTION TEST FOR CHILDREN

P. F. DE JONG and E. A. DAS-SMAAL
Department of Cognitive Psychology, Free University, De Boelelaan 1111, 1081 HV Amsterdam, The Netherlands

(Received 2 October 1989)

Summary—The Star Counting Test (SCT), an attention test for children, is presented. The test is suitable for groupwise administration. It was developed within a clear theoretical framework and focuses, in contrast to many current attention tests, on accuracy rather than speed. The test requires the control and alternation of two simple processes: forward and backward counting. In a prestudy, the reliability of the test appeared satisfactory. Substantial correlations were found with the Hyperactivity scale of the Conners Teacher Rating Scale and with grades for language and arithmetic. For the main study, a large scale assessment study of attentional deficits in Dutch elementary schools, three versions of the test were constructed. All versions of the test appeared reliable and substantial correlations were observed with the Attentional Behavior Scale of the Amsterdam Child Behavior Scale, a rating scale for teachers. Furthermore, the test was able to discriminate between various childhood disorders as rated by teachers. It was concluded that the SCT exhibits some essential characteristics that are needed for the measurement of individual differences in attention. The test can be used in large scale assessment studies and might be useful as a first screening device for attentional deficits.

Attention is assumed to have a wide range of influence on many aspects of cognitive functioning. An efficient and successful course of the process of knowledge acquisition, for instance, is dependent on a proper functioning of attentional control processes like selectivity, flexibility, and planful behavior. Attention is a prerequisite for learning.

In schools, children with attention deficits are of great concern. According to teachers in The Netherlands, an increasing number of children suffer from attentional problems (Das-Smaal, de Leeuw & Orlebeke, 1987), and large scale assessment studies in different countries indicate that the incidence of attentional problems among children aged 6–12 is considerable (Achenbach, Verhulst, Edelbrock, Baron & Akkerhuis, 1987; McGee, Williams & Silva, 1985; Taylor & Sandberg, 1944; Verhulst & Akkerhuis, 1986; Vikan, 1985). Cross-cultural and cross-temporal comparisons of prevalence rates are, however, problematic because most of these epidemiological studies have heavily relied on teacher ratings of behavior. Often the items in the rating scales that are used, are not tied to precise behaviors, but require a judgment about the appropriateness of a behavioral category, like for instance 'impulsiveness' (Taylor, 1987). Variations in teacher ratings might therefore reflect systematic differences in the behaviors that are considered relevant to a behavioral category. Another point of concern with respect to the comparison of teacher ratings are norm differences. Taylor (1987) suggests that the 20-fold difference in the prevalence rate of hyperactivity in the U.K. and U.S.A. might be the result of a discrepancy in the thresholds of tolerance towards the behaviors that form the problem. Because of these difficulties, it seems desirable to use instruments that can be administered according to standardized procedures. In order to measure the prevalence of attention deficits at school and to make cross-cultural and cross-temporal comparisons possible, these should be used in addition to behavior ratings.

For two reasons instruments that are to be used in large-scale studies in education should be suitable for groupwise administration. One reason is rather obvious: groupwise administration is efficient, and therefore more or less a prerequisite for large-scale assessment. The second reason is more theoretical. In the literature, it is more and more recognized that task and situation can be a crucial factor in experimental results. In many research areas, often weak relationships have been found between performance on laboratory tasks and behavior in real-life situations (e.g. Bennet-Levy & Powell, 1980; Magnusson, 1984). From an educational perspective, the novelty of the situation and the personal attention offered to the child in a laboratory setting, could temporarily optimize attentional behavior to a level that a child may not afford normally in the

classroom. This may apply especially to children with attentional deficits (Kinsbourne, 1983). Therefore, as the influence of the situation is potentially a source of systematic error, groupwise measurement in the classroom situation is to be preferred.

Most current instruments for the measurement of attention are not very suitable for groupwise administration. The tests often demand just numerous repetitions of a relatively simple perceptual process like pattern detection. As a consequence, hardly any error is made, and only speed remains as a measure of attention. This has the disadvantage of confounding attentional performance and general speed of processing. To meet the objections, the Star Counting Test (SCT) was designed, which will be described in this article. The SCT is meant as an attention test for children aged 8–11 yr old. The test is suitable for groupwise administration and focuses on accuracy rather than speed. The SCT is aimed at measuring attentional control, and has a specified theoretical basis.

The SCT was developed within the framework of the model of Working Memory advanced by Baddeley and Hitch, 1974; (Baddeley, 1986). Working memory refers to a system for the temporary storage and processing of information (Baddeley, 1986; Logie & Baddeley, 1987). The system is, up to now, subdivided into three components. The Central Executive (CE) system, of limited capacity, forms the control centre. It can be relieved of part of its functions by subsidiary slave systems, two of which are specified. These are a system to maintain verbal material, and one for spatial material. The CE is, as formulated by Morris and Baddeley (1988), "responsible for initiating and modulating the different mental processes associated with working memory" (p. 284). Manipulation of control processes is central to the system. The CE system is, as put forward by Baddeley (1986), virtually the same as the Supervisory Attentional System (SAS) in the information processing model of Norman and Shallice (1986).

The model of Norman and Shallice further specifies the role of attention in the model of Baddeley and Hitch. It concerns the attentional control of thinking and action, particularly the initiation and modulation of cognitions and activities. According to Norman and Shallice, a sequence of (mental) activities can be represented by a series of schemas, that are run off successively. Selection of schemas is accomplished by a process of activation and inhibition of relevant and irrelevant schemas, respectively. Two complementary systems are assumed to be involved in this process. One of them is a conflict resolution process, called contention scheduling, which is always active. It prevents disruption of behavior which could be caused by incompatible schemas. However, its activity alone is sufficient only in case of routine selection. In all other situations, an overall controller, the SAS, has to be active. It serves to bias the activation of schemas, to override the activating and inhibitory forces of the conflict resolution system. The SAS is a limited capacity system that is called upon in a variety of situations characterized by the need of nonroutine selection of schemas.

Whatever the system is named, CE or SAS, it is important to note that both Baddeley (Baddeley & Wilson, 1988) and Shallice (1982) agree that a dysfunction of this system leads to an impairment of the control function of attention. One implication of the view of Norman and Shallice is that despite a deficit in attentional control of the CE, routine behavior may continue to be executed in a normal way. Indeed, this pattern of behavior has been described by Luria (1973) to occur with frontal lobe patients. A proper test of attention, therefore, should focus on the deliberate control of activation and inhibition. This will especially be called upon when the task elicits a competition among incompatible schemas to control action. The SCT is aimed directly at the activation and inhibition function of the CE.

The SCT asks for the control of a very simple process: counting. More specifically, the test requires, according to a certain procedure, alternating forward and backward counting. The change from forward to backward and vice versa is supposed to place demands on the Central Executive, because an ongoing process has to be inhibited and another has to be activated. A dysfunction in the Central Executive should be manifested by an inability to alternate flexibly between counting directions.

The prime aim of the current study was to examine if it is possible to design a test, the SCT, which focuses on accuracy, is suitable for groupwise administration and is based on the view of attention as a control process. Some basic characteristics of the test that are required for the measurement of individual differences in attention will be reported here. A prestudy and a main

study investigated whether errors are made and if the test is reliable. Further, it was examined whether the SCT differentiates between various childhood disorders as rated by teachers.

PRESTUDY

Method

Subjects

The *S*s were 109 Dutch-speaking children (46 boys and 63 girls) from grade 5, coming from 7 elementary schools in the neighbourhood of Amsterdam. The mean age of the children was 9.13 yr. For practical reasons one school could not be visited for a second time, leaving 83 children for the second administration of the test.

Materials

The Star Counting Test. Each item of the test (see Fig. 1) consists of a pattern of stars with plus and minus signs in between and a number in the left top corner. The task is to count the stars row-wise from left to right starting from the number. Each item has a different starting number, which can range from 7 to 72.

The open spaces have no meaning and are only there to prevent counting by fives. The signs denote the direction (forward or backward) in which subsequent stars have to be counted. Thus the test requires alternating forward and backward counting until the last star is reached. The number of changes in the direction of counting ranges from 2 to 6. Every item always starts with forward counting. The number of the last star is the answer.

The test has two parts. In the first part the signs have their normal meaning, which implies that following a plus counting has to go forward, and following a minus counting has to go backward. In the second part of the test the meaning of the signs is reversed, implying backwards counting following a plus, and forwards counting following a minus sign. The first part of the test contains 12 items and has to be finished in 12 min, the second part consists of 10 items and has to be completed in 10 min. The score on the test is the total number correct on both parts together.

Teacher ratings. All children were rated by their teacher on items from the Hyperactivity and the Anxiety subscale of the Dutch translation of the Conners Teacher Rating Scale (CTRS) (Blöte & Curfs, 1986). The Dutch version of the CTRS consists of 5 factors which were labeled as Acting-out behavior, Anti-social behavior, Hyperactivity, Anxiety and Social isolation. The Hyperactivity and Anxiety factor are fairly similar to respectively the Hyperkinetic and Shy-inept factor found by Arnold, Barnebey and Smeltzer (1981) and the Hyperactivity-inattention and Anxiety factors of Taylor and Sandberg (1984).

The Hyperactivity scale consists of 5 items: fidgeting, humming and other odd noises, restless or overactive, inattentive/easily distracted and short attention span. From the Anxiety scale 4 items were taken: fearful, overly serious or sad, sensitive, and shy.

The teachers had to indicate how often the behavior to which an item referred, was manifested in the classroom. The ratings were on a 4-point scale ranging from 'never' (1) to 'often' (4).

Performance in school. In addition to the teacher ratings, the grades of the second trimester for Dutch-language, including reading, spelling and writing, and arithmetic were registered.

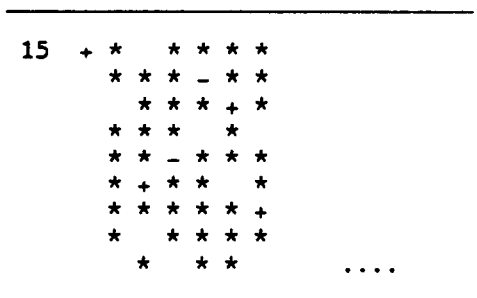

Fig. 1. An example of an item of the SCT.

Procedure

The SCT was administered twice within 3 weeks. In both sessions the test was given to whole classes by a test-assistant. At the beginning of the morning part 1 of the test was held. Following the administration of another test, which took about 45 min, part 2 was given. The behavior ratings by the teachers were done during the first session.

Results and Discussion

The means, standard deviations and reliabilities of the total score of the SCT for the first (SCT-t1) and for the second (SCT-t2) administration are presented in the top half of Table 1. One outlier was removed.

As the maximum score is 22, it is clear from the mean scores on SCT-t1 and SCT-t2 that errors are made. Because most of the participants finished the test in time, the SCT can, to a large extent, be considered as a power rather than a speed test.

The reliability (Cronbach's α) of the test for both administrations is satisfactory. The test–retest reliability is acceptable.

In Table 2 the correlations between the total scores of the SCT and the various criterion measures (teacher ratings and school grades) are shown. Note here, that for the behavior ratings a higher score indicates less behavior problems.

The SCT correlates significantly with the Hyperactivity-scale and shows a low or insignificant correlation with the Anxiety-scale. Furthermore, the test has a substantial correlation with the grade for Dutch-language and a smaller, but significant, correlation with arithmetic.

Using a procedure outlined by Steiger (1980) for the comparison of two correlation coefficients which are computed on the same sample, it appears that the correlation of SCT-t1 with the Hyperactivity scale is higher than with the Anxiety scale ($z = 2.97$, $P < 0.01$). The same difference is found with respect to SCT-t2 ($z = 2.04$, $P < 0.05$). These results suggest that the SCT is able, as it should, to differentiate between an externalizing (hyperactivity) and an internalizing (anxiety) disorder.

However, the Hyperactivity scale of the CTRS contains two types of items. One type of item refers to attention, the other is concerned with (motor) restlessness. Therefore, it is not completely clear what is responsible for the observed relationship between the SCT and the Hyperactivity scale. As the SCT is supposed to measure attentional deficits, in the main study a rating scale was used with which attentional behavior can be differentiated from the activity part of hyperactivity.

Table 1. Mean (M), standard deviation (SD) and reliability (Cronbach's α and r_{tt}) of the SCT for the prestudy and for the main study

Test	*n*	M	SD	α	r_{tt}
Prestudy					
SCT-t1	108	12.01	5.26	0.85	
SCT-t2	82	12.97	5.44	0.88	0.77
Main study					
SCT1	716	12.40	5.08	0.84	
SCT2	710	12.80	4.90	0.83	
SCT3	727	12.88	4.92	0.83	

r_{tt} = test–retest correlation; SCT-t1 = SCT first administration; SCT-t2 = SCT second administration; SCT1 version 1; SCT2 = version 2; SCT3 = version 3.

Table 2. Correlations of the SCT with teacher ratings: prestudy

Test	*n*	HYP	ANX	GL	GA
SCT-t1	108	0.48**	0.12	0.51**	0.34**
SCT-t2	82	0.46**	0.16*	0.51**	0.28**

For SCT-t1 and SCT-t2, see Table 1; HYP = Hyperactivity; ANX = Anxiety-scale; GL = Grade Language; GA = Grade Arithmetic.
*$P < 0.05$; **$P < 0.01$.

MAIN STUDY

Method

Subjects

The *S*s were 2157 Dutch grade 6 elementary school children from the Dutch National Assessment Study of Attentional Deficits in Elementary Schools. The characteristics of the sample of this study have been described in de Jong and Das-Smaal (1989a). In short, 2588 children, mostly from grade 6, of a national sample of 111 elementary schools in The Netherlands participated in the study. Of these 2588 children, 366 had at least one parent that was born outside The Netherlands and/or were in grade 5. Of the remaining 2222 children, 2157 (1088 boys and 1059 girls) made both parts of the SCT.

Materials

The SCT. Three versions of the SCT were constructed. The design of the test was essentially the same as in the prestudy.

An item pool of 24 items for part 1 of the test and of 20 items for part 2 was constructed. Both itempools contained items with a starting number from 14 to 78. Items required either 2, 4 or 6 changes in counting direction. From the item pools three versions of the SCT were constructed. The usage of several versions of the same test makes cross-validation possible and so the robustness of the results can be evaluated. The first and the third version did not overlap. The second version consisted of items that were either in the first or in the third version.

Teacher ratings. All children were rated by their teachers on the Amsterdam Child Behavior Scale (de Jong & Das-Smaal, 1989a). Each item in the list contained a description of a behavior. The teacher had to indicate the appropriateness of the description for a particular child on a 4-point scale from 'does not fit' (1) to 'fits (nearly) completely' (4).

The scale was especially made to differentiate between various externalizing disorders (Hinshaw, 1987). Items were selected from a range of current behavior checklists for children. The original scale contained 33 items, 11 of which were dismissed. The remaining 22 items could be described by four factors accounting for 67.6% of the variance. On the basis of this factor solution four scales were constructed (see Appendix): Attentional Behavior (ATB), Restlessness (RES), Antisocial Behavior (ASB) and Fear/Uncertainty (F/U).

Procedure

The SCT was administered to whole classes by 10 test-assistants. The three versions of the test were, within classes, randomized over three groups. The first part of the SCT was given at the beginning of the morning, and the second part at the beginning of the afternoon. The teacher ratings were usually done during the test administration, but in some cases 1–3 weeks after the school was visited.

Table 3. Correlations of the SCT with the Amsterdam Child Behavior Scale

Test	*n*	ATB	RES	ASB	F/U
SCT1	709	0.41**	0.22**	0.12**	0.19**
SCT2	706	0.32**	0.19**	0.10*	0.18**
SCT3	725	0.34**	0.17**	0.08	0.19**
*z*1		—	6.36**	7.17**	5.34**
*z*2		—	4.12**	5.22**	3.46**
*z*3		—	5.34**	6.51**	3.78**

For SCT1, SCT2, SCT3, see Table 1; ATB = Attentional Behavior; RES = Restlessness; ASB = Anti-social Behavior; F/U = Fear/Uncertainty; *z*1, *z*2 and *z*3 are *z*-statistics for respectively SCT1, SCT2 and SCT3 to test differences (pair-wise) between the correlation of the SCT with the ATB-scale and the correlation with successively the RES, ASB and F/U scales.

*$P < 0.05$; **$P < 0.01$.

Results

The means, standard deviations and reliabilities of the total score of the SCT for each version (SCT1, SCT2, SCT3) are presented in the lower half of Table 1. The three versions of the SCT have nearly equal means and standard deviations. Their reliabilities are satisfactory and highly similar as well.

The correlations of the SCT with the Amsterdam Child Behavior Scale (ACBS) are shown in Table 3. Note, that a higher score on a scale indicates less behavior problems.

Each version of the SCT has a substantial correlation with the ATB scale. Moreover, the correlation with the ATB scale is, for all versions, significantly higher than the correlation with any other scale (see z-statistics in lower part of Table 3). This is even more striking if it is realized that the correlation between the ATB scale and the REST scale, which more or less constituted the Hyperactivity scale in the prestudy, is 0.60.

The score distributions of the RES, ASB and F/U scales are skewed, which can lead to an underestimation of the (true) correlation in the population (Carroll, 1961). Therefore, as a measure of control, all behavior variables were dichotomized, and polyserial correlations (Jöreskog & Sörbom, 1986) with the SCT were computed. The pattern of correlations was virtually the same, indicating that the SCT can differentiate fairly well between attention deficts and related childhood disorders.

GENERAL DISCUSSION

The SCT requires the control of relatively simple processes: forward and backward counting. However, the essential characteristic of the test is that, according to a certain procedure, alternation of these processes is required. As the results show, this specific procedure elicits many errors.

The SCT is, in contrast to most of the current attention tests, not a speed test. This makes the test suitable for groupwise administration. Of course speed is not entirely unimportant. Some children were not able to finish the test in time, but in this respect the test does not differ from many school aptitude tests. Moreover, oral reports of children suggest that they start anew whenever the number of the last start encountered is lost. It is to be expected that especially children with attention deficits often fail to keep track of the last number, start anew and thus have not enough time to complete all items of the test.

The results concerning the psychometric characteristics of the SCT appear to be robust. Several versions of the test were administered to different groups of persons. Despite these differences, the mean total scores and the standard deviations of the various versions are highly similar. Moreover, in both prestudy and main study the reliability of the SCT is satisfactory.

With respect to the validity of the test, in the prestudy a substantial relation with the hyperactivity-factor of the Conners Teacher Rating Scale was found, whereas the correlation with ratings of anxiety was significantly lower. In the main study, a further differentiation was made between attentional behavior and hyperactivity without attention deficit. This revealed, as expected, a fair relation of the SCT with ratings of attention. In addition, the SCT correlated higher with the attentional behavior scale than with any other behavior scale, despite the fact that all scales are correlated. It seems that the SCT is able to differentiate between attentional behavior and several related externalizing and internalizing childhood disorders as rated by teachers.

Concerning the validity, some additional points are worthy of note. First, in the prestudy a fairly high association between the score on the SCT and the grade for language was found, and a moderate relation with the grade of arithmetic. The former relation suggests that the test has a large verbal component. The correlation with the grade for arithmetic might also be explained by a verbal component as some parts of arithmetic require, inevitably, reading comprehension. The size of the relation with language grades is even more striking if it is realized that counting can be considered as a very simple everyday cognitive task, whereas the grades are based on very complex tasks such as reading comprehension, spelling and writing. This suggests that counting, and especially the aspect of alternation between forward and backward counting, refers to a very central ability.

A second point that should be mentioned in this regard is that the SCT was, in contrast to many current attention tests, developed within a clear theoretical framework: Baddeley and Hitch's Working Memory Model (Baddeley & Hitch, 1974; Baddeley, 1986) in conjunction with a model of Norman and Shallice (Norman & Shallice, 1986) for the automatic and controlled regulation of behavior. The test was especially designed to tap the functioning of the Central Executive or SAS, which, as specified by Norman and Shallice, is supposed to be the part of the system that is responsible for the activation and inhibition of mental processes in Working Memory. It is of concern here that several studies show that counting is, at least to a certain extent, dependent on working memory (Logie & Baddeley, 1987; Nairne & Healy, 1983; Healy & Nairne, 1985). The requirement to alternate forward and backward counting was intended to place extra demands on the Central Executive System. As a consequence, errors on the task are to be expected when a change in the direction of counting is encountered. The results of a study by Slot (1989) give some support to this idea. Children who took the test with the requirement to count aloud, made 22–32% of their errors on the star directly following a sign to change counting direction. Taking into account that there are only 2–6 stars that follow a sign, in a pattern of 40 stars per item, this percentage can be considered as high.

However, in Slot's study errors were also made in other places in an item. Thus, besides the flexibility to change, other factors are also involved in a score on the SCT. One of the factors that might be reflected in the score of the SCT, besides flexibility, is probably the ability to count. With respect to the role of this ability, however, two points can be made. First, by the age of 5, children already have fairly good numerical understandings (Siegler & Robinson, 1982). In a study by de Jong and Das-Smaal (1989b) it appeared that many children aged 9–10 yr old hardly made errors when, on similar items as those of the SCT, backward counting was the only requirement. This means that the ability to count as such is of little use to discriminate between children at these ages. Second, if the ability to count is of influence, it need not do harm to the validity of the SCT. Both counting and the flexibility to change the direction of counting might reflect the same trait. From a Working Memory point of view, it can be argued that errors in counting, and especially backward counting, are also due to a lack of attentional control.

In sum, the SCT has several characteristics that are needed to measure individual differences in attention. The test is reliable and appears to be able to discriminate between attention deficits and various other childhood disorders as rated by teachers. The test was developed within a clear theoretical framework. Finally, the SCT focuses, in contrast to many current attention tests, on accuracy. This makes the test suitable for groupwise administration. The SCT can be used in large scale assessment studies and might be useful as a first screening device of attentional deficits.

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APPENDIX

Items of the Amsterdam Child Behavior Scale

Attentional Behavior (ATB)
(1) Is able to concentrate well
(2) Is able to work on a task for a long time
(3) Can work well on his/her own
(4) Has little difficulty to follow instructions
(5) Thinks before doing
(6) Not easily distracted

Restlessness (REST)
(1) Fiddles often
(2) Excessive motoractivity
(3) Has difficulty waiting his/her turn
(4) Blurts out unthoughtful events fairly often

Anti-social Behavior (ASB)
(1) Cruelty, bullying, or meanness to others
(2) Destroys
(3) Hot-tempered
(4) Picks a quarrel
(5) Seldom speaks up

Fear/Uncertainty (F/U)
(1) Fearful
(2) Shy, timid
(3) Nervous, tense
(4) Quickly thinks he/she will fail