Arch. Psychiat. Nervenkr. 229, 45–52 (1980)

Archiv für Psychiatrie und Nervenkrankheiten
Archives of Psychiatry and Neurological Sciences

The Vigilance Scale: An Analysis of Elicited Behavioral Responses

Detlev von Cramon and Uwe Schuri

Max-Planck-Institut für Psychiatrie, Kraepelinstraße 10, D-8000 München 40, Federal Republic of Germany

Summary. The Vigilance Scale (VS) is a 12-step additive scale (Guttman scale) that allows assessment of the behavioral deficit in the unconscious state and the state of clouding of consciousness. Despite restrictions on its applicability, which are discussed in detail, the VS seems to be a useful measuring device that indicates the level of brain function a patient with a disturbance of consciousness can actually attain. There are two categories of scale errors to be found, the first being caused by various 'instrumental' disorders, i.e., severe motor deficits, the second resulting from the probabilistic approach of the VS to a Guttman scale.

Key words: Consciousness, disturbances of – Vigilance – Vigilance scale – Guttman scale.

Zusammenfassung. Die Vigilanz-Skala (VS) ist eine 12-stufige additive Skala (Guttman-Skala) zur Bestimmung des Verhaltensdefizits bei bewußtseinsgestörten Patienten. Die VS scheint, trotz Beschränkungen in ihrer Anwendbarkeit, die im Detail diskutiert werden, ein brauchbares Meßinstrument zu sein, mit dessen Hilfe das Niveau der Hirnfunktionen angezeigt werden kann, die ein bewußtseinsgestörter Patient jeweils noch erreichen kann. Dabei kommen zwei Fehlerkategorien vor; die erste ist durch „instrumentale" Störungen, z. B. schwere motorische Defizite bedingt, die zweite durch die probabilistische Annäherung der VS an eine Guttman-Skala.

Schlüsselwörter: Bewußtseinsstörungen – Vigilanz – Vigilanz-Skala – Guttman-Skala.

Offprint requests to: Priv.-Doz. Dr. D. v. Cramon, Max-Planck-Institut für Psychiatrie, Kraepelinstraße 10, D-8000 München 40, Federal Republic of Germany

0003-9373/80/0229/0045/$01.60

Introduction

Disturbed consciousness manifests itself in disturbed behavior. In the continuum from unrestricted consciousness to brain death, the cerebral responses to different kinds of stimuli are increasingly reduced, causing a growing deficit of intellectual and emotional performance as well as a loss of behavioral control mechanisms.

Psychic functions can only be detected as far as that brain state we arbitrarily call unconsciousness. That state is characterized by a suspension of verbal and nonverbal communicative behavior. As a consequence of the behavioral deficit there seems to be a 'threshold' of consciousness. Above this threshold, verbal and figural stimuli are behaviorally significant, whereas below it the physical intensity of a given stimulus dominates the behavioral efficiency.

To include the whole range of disturbances of consciousness a measuring device should allow assessment of stimulus-bound responses in the unconscious state as well as increasingly differentiated responses to verbal and figural stimuli in the state of clouding of consciousness.

With the vigilance scale (VS) such a measuring device is available. The scale allows assessment of the course of vigilance.[1] It can be used for the control of changes in vigilance due to therapeutic interventions. Furthermore, repeated measurements of vigilance can provide valuable prognostic information concerning the outcome of the disturbance of consciousness.

The Vigilance Scale (VS)

The VS is a 12-step Guttman scale. Such scales are based on the principle of additivity and permit the scaling of linear items along one dimension. Given several additively ordered behavioral responses, the presence of the highest ranking response implies the presence of all lower ranking ones. Every violation of this additive rule is regarded as scale error.

Evidence for the external validity and objectivity of the VS were provided in previous studies (von Cramon et al. 1975; Benz 1977; von Cramon 1979; Benz und Schulz 1980). As to the objectivity in judging the behavioral responses on steps 1–4, video recordings of the patients were done and evaluated by five raters (neurologists). The interrater reliability amounted to 93%.

To improve the economy of the VS in clinical use we recently revised the VS and compared the new form with the previous one in 80 patients with disturbances of consciousness (unpublished data). In comparison with its original form the number of stimuli for eliciting responses on steps 1–4 was reduced from 4 to 2; only a painful and a tickling stimulus were administered. There were no differences in the number of errors between both forms on steps 1–4.

The analysis of scale errors resulted in a concentration of errors on step 8, which could be diminished substantially by lowering the cutting point. In the revised form only one of two geometrical patterns has to be combined with the help of four colored blocks. By this procedure the coefficient of reproducibility of the scale was $r = 0.97$ (for the methods of scalogram analysis, refer to v. Cramon 1979). In Table 1 the revised form of the VS is shown.

1 A detailed discussion of the concept of vigilance was presented in 1979 by von Cramon

Table 1. The Vigilance Scale (VS)

Step	Stimulus/task	Required response
0		None
1	Painful stimulus: Brisk pressure on at least one nail bed on both sides with a squared pencil	Any body movement, movements of the head without clear-cut directional components in relation to stimulus or experimenter
2		Any orofacial movements, i.e., frowning, movements of lids, nasolabial furrows, lips, mouth, tongue, and larynx
3	Tactile stimulus: Tickling of the nose with a nylon hair (intra- and perinasal stimulation)	According to direction, definite turning of head to or away from stimulus. Opening of eyes (included the state of open eyes)
4		According to direction, definite looking at stimulus or experimenter. Verbal utterance with evident semantic content in native language of patient
5	Shake hands	Shaking hands
6	Tell your place of residence	Telling his/her place of residence
7	Tell your age	Telling his/her age
8	Copy two-colored (red and white) geometrical patterns with four multi-colored cubes (mod. Elizur test)	Combining one of two geometrical patterns
9	Read a line with 17 random ordered letters of A and B and spell B if A and A if B is written	Solving the task with no more than two errors
10	Point out one previously shown geometrical figure from a table with four similar figures (Benton test, form C)	Accomplishing six of ten Benton items
11	Draw previously shown geometrical figures from memory (mod. Elizur test)	Reproducing three of four Elizur figures

As a rule tasks 5–11 were presented verbally. The patients were instructed several times. To elicit responses to tasks 6, 7, and 10 despite severe motor deficits (i.e., in locked-in syndrome) the instruction was modified. A set of five cards was presented to the patient with one place of residence on each card, including the correct one. The same procedure was used to present task 7. The patient was supposed to indicate with an eye blink (= yes) if the card with his/her place of residence or age was shown to him/her. For task 10 he was to blink when the experimenter pointed to the correct geometrical figure on the table with four similar figures, all presented at random. In aphasic patients (with reading disorders) only tasks 8, 10, and 11 were given. The examiner elicited responses from these patients by demonstrating the task nonverbally. The aim of this study was to analyze the elicited responses in more detail including the errors in additivity.

Subjects

An ad hoc sample of 198 subjects (113 males, 85 females) was tested with the VS. The age distribution ranged from 10 to 78 years and was roughly bimodal with

Table 2. Distribution of the different etiological subgroups of the sample

Diagnostic group	No. of cases
Head trauma	52
Contusion	44
Chronic subdural hematoma	8
Intracranial nontraumatic hemorrhage	40
Subarachnoid hemorrhage	24
Intracerebral hemorrhage (cerebral hemispheres)	13
Intraventricular hemorrhage	3
Cerebral ischemia	32
Cerebral hemispheres	21
Brain stem and cerebellum	11
Brain tumor	27
Supratentorial	22
Infratentorial	5
Inflammatory cerebral process	19
Brain atrophy	11
Hydrostatic hydrocephalus	5
Diffuse cerebral hypoxy	4
Various	8
	Σ 198

Table 3. Distribution of 198 patients on the 12 steps of the VS

VS	0	1	2	3	4	5	6	7	8	9	10	11
N	2	2	5	16	7	18	11	35	14	23	40	25

one definite peak about the age of 18 caused by the great number of young male adults with head trauma. The second peak was not so sharp and lay about age 50.

Testing was done if the attending physician suspected disturbance of consciousness. It was done without any information of specific neurological or neuropsychological deficits. Afterwards we carefully noted every diagnostic report available.

Table 2 presents a survey of the different etiological subgroups in the sample. The five subgroups are: head trauma (26%), intracranial nontraumatic hemorrhage (20%), cerebral ischemia (16%), brain tumors (14%), and inflammatory processes (10%).

Results

The distribution of the 198 patients on the 12 steps of the VS is shown in Table 3. Of the patients tested, 84% made no errors, 14% made one, and 2% two

Table 4. Distribution of scale errors on the single steps of the VS with regard to the number of possible correct responses

	Steps of the VS										
	1	2	3	4	5	6	7	8	9	10	11
N	196	194	189	173	166	148	137	102	88	65	25
Error (in %)	1	< 1	0	< 1	3	1	7	6	3	2	0

Table 5. Relative frequency of responses to tasks 5-11 on steps 3-11 of the VS

Tasks No.	Steps of the VS								
	3	4	5	6	7	8	9	10	11
5	0	0	100						
6	0	0	33	100					
7	0	0	17	55	100				
8	0	0	0	0	23	100			
9	0	0	0	0	23	57	100		
10	0	0	0	0	26	64	83	100	
11	0	0	0	0	17	64	70	100	100

errors. Of all 32 errors in 198 patients, 13 were caused by tetraplegia, severe ataxia, obstruction of phonation, or speech motor disorder. Only two patients who actually had global aphasia were misjudged as having disturbance of consciousness. The occurrence of these categories of 'errors', however, depends on the sample. Even in these aphasic patients tasks 8, 10, and 11 were performed in a correct manner. Table 4 shows the percentage of errors on each step of the VS with regard to the number of expected correct responses. Only on step 7 and 8 did the errors exceed 5% of the overall observed responses.

The responses on steps 1-5 could only be noted as present or not present. The responses on steps 6–9, however, may also be evaluated as right or wrong. On steps 10 and 11, a varying number of correct responses below the defined cutting points could be expected.

In Table 5 the relative frequency of response (irrespective if right or wrong) to tasks 5-11 on steps 3-11 of the VS is summarized. There is a decreasing tendency of patients on the lower steps of the VS to make an approach to tasks above their level of performance. On step 5 some patients started tackling tasks 6 and 7; on step 7 patients started with tasks 8-11.

Summary and Analysis of Errors in Response

Step 1 to 4. On these steps only 4 errors were observed altogether. A more detailed analysis of these errors seemed to be dispensable.

VS	No. of correct responses						
	1	2	3	4	5	6	Σ
6	0	0	0	0	0	0	0
7	9	3	3	0	0	0	15
8	14	36	7	0	7	0	64
9	13	17	22	17	9	0	78
10	0	0	0	0	0	100	100

Table 6. Relative frequency of correctly solved Benton items (1–6) on steps 6–10 of the VS

Step 5. A correct response could not be obtained in patients with severe paresis of the upper extremities. This was the case in 3% of the patients who made a response to the command to shake hands.

Step 6. Of the patients, 5% responded incorrectly to the question regarding their place of residence. The majority of them indicated a former place of residence.

Step 7. Of the patients who responded to the question about their age, 14% answered wrong. There were six patients who gave an age (up to 10 years) above that of their actual age, whereas eleven indicated a younger age (up to 30 years).

Step 8. Of the patients who responded to this task (Copying two 2-colored geometrical patterns with four multicolored blocks; Elizur 1959), 11% did not reach the criterion of one correctly copied geometrical pattern. Six patients were found busy turning the blocks around and piling them up; five patients were not able to perform the task because of severe paresis or ataxia of the upper extremities.

Step 9. Of the patients who responded to this task (reading a line of letters, spelling B if A and A if B is written), 19% could not read the line with less than two errors. Seven patients simply read the line off; five did the same after a varying period of time (3–11 s); and all these patients forgot the instruction afterwards. Five patients could not perform the task because they had either a motor speech disorder or they were hindered from phonation by a tracheostoma.

Step 10. Of the patients who responded to this task (choosing a previously shown geometrical figure from a table of four similar figures; Benton and Spreen 1968), 37% did not reach the criterion of six of ten correct items.

Table 6 shows the relative frequency of correctly solved items (1–6) on steps 6–10. There is a marked increase in the number of correct responses (up to five) on steps 8 and 9, whereas correct responses are still sparse on step 7 and missing on step 6.

Step 11. Of the patients who responded to this task (drawing three of four previously shown geometrical figures; Elizur 1959), 74% did not reach the criterion of three correct drawings. Table 7 shows the relative frequency of correct Elizur drawings (1–3) on steps 6–11. Whereas no correct drawing could be obtained on steps 6 and 7, an approximately equal number of patients on steps 8, 9, and 10 made at least one correct drawing. There is a marked increase in the percentage of patients from steps 8 to 10 who accomplished two correct drawings.

Table 7. Relative frequency of correct Elizur drawings (1–3) on steps 6–11

VS	No. of correct responses			
	1	2	3	Σ
6	0	0	0	0
7	0	0	0	0
8	42	17	0	59
9	37	30	0	67
10	44	44	0	88
11	0	0	100	100

Discussion

The various scales for the assessment of disturbances of consciousness are all based on the concept of a one-dimensional order of brain functions along the continuum from brain death to unrestricted consciousness. They depend on this concept whether they measure behavioral responses or physiological parameters. Despite the implicit concept there has been no experimental approach so far to test it adequately.

The Vigilance scale represents a definite order of different brain functions along the measured continuum. With a coefficient of reproducibility of > 0.90 (see above), the VS meets the criteria for an additive scale like that proposed by Guttman (1944).

There are at least two categories of error. The first category implies errors which are caused by 'instrumental' deficits such as severe *motor disturbances* (i.e., tetraplegia, ataxia, motor aphasia). These motor disturbances hinder the patients from accomplishing tasks 5, 8, and 11. With a global motor deficit including lid-motor and oculomotor activity by additional curarization, proper assessment of the behavioral deficit as reflection of the disturbed consciousness is entirely impossible. A patient with severe *sensory aphasia* also presents a problem for the experimenter. Tasks 8, 10, and 11, however, were correctly 'understood' by these patients if they were *shown* how to do these tasks. In some patients an *obstruction of phonation,* i.e., by a tracheostoma, hindered them from accomplishing task 9. In this sample, 13 of 32 errors belonged to that first category of 'instrumental' errors.

The second category consists of errors resulting from the probabilistic approach to a Guttman scale. Such errors in additivity have to be expected. The question about the patients' age yielded the highest amount of errors with regard to the number of possible correct responses. Patients whose calculation was disordered failed in this task as well as disoriented patients. By a ratio of 2:1, patients tended to give an age below that of their actual age rather than above. Tasks 8 also contributed to errors in the second category. Patients not only had to respond to a *verbal* stimulus (the instruction), but also to a *figural* stimulus (the two-colored geometrical pattern). In addition, the rather complex motor performance of turning the Elizur blocks and putting them together was required. The frequently observed helpless manoeuvers with the blocks prove the patients had difficulty in managing the complex stimulus condition rather than insufficient motor control.

As shown in Table 5, patients tended to tackle a task even below the step of the VS which is determined by that very task. The responses left of the main diagonal are altogether incorrect; they were either wrong or insufficient, as defined by the cutting points. On step 5 some patients still responded to tasks 6 and 7, but no patient on step 3 and 4 even tried. Patients had to have reached a certain level of performance before they could respond reliably to a *verbal* stimulus.

On step 7 patients eventually started tackling tasks 8 to 11. It has been said before that patients at this level of vigilance learn to respond to figural stimuli, as they are used in all these tasks. While on step 7 still less than 30% of the patients responded to the tasks, approximately 60% did so on the next step of the scale. Thus, there is a steep rise in handling figural stimuli from step 7 to 8.

Six correctly solved Benton items was the criterion level to reach step 10. The frequency of several correct responses, whether there were one or several, increased from 0% on step 6 to 78% on step 9. On this step, however, less than 10 % of the patients made five correct responses, proving the difference in attainment level for step 10.

To reach step 11, the patients were required to draw three of four Elizur drawings from memory. Again the frequency of correct responses—one or two—increased from 0% on step 7 to 88% on step 10. No patient could make a correct drawing on step 7, but about 60% did so on step 8, underlining the rise of competence in dealing with complex visuomotor tasks from step 7 to 8.

It is beyond the scope of this paper to discuss the implications of these results for the organization of brain functions along the vigilance continuum. What should be achieved is a discussion of the advantages and disadvantages of this additive VS. Despite several restrictions on its applicability, the VS seems to be a valid, objective, and economical measuring device which allows assessment of the level of brain function a patient with a disturbance of consciousness can actually attain.

References

Benton AL, Spreen O (1968) Der Benton-Test (Handbuch). Huber, Bern

Benz R (1977) Skalierung von Aufmerksamkeitsstörungen bei neurologischen Patienten und Patienten mit Intoxikationen. Diplomarbeit, München

Benz R, Schulz H (1980) A scale for the measurement of cognitive performance deficit in neurological patients. (Submitted to Neuropsychologia)

Cramon D v (1979) Quantitative Bestimmung des Verhaltensdefizits bei Störungen des skalaren Bewußtseins. Thieme Copythek. Georg Thieme, Stuttgart

Cramon D v, Brinkmann R, Schulz H (1975) Entwicklung eines Meßinstrumentes zur Bestimmung der Aufmerksamkeit bei Patienten mit cerebralen Läsionen und Funktionsstörungen. J Neurol 208:241–256

Elizur A (1959) A combined test used for the diagnosis of organic brain condition. Arch Neurol Psychiat (Chic) 81:776–784

Guttman L (1966) The basis for scalogram analysis. In: Stouffer SA, Guttman L, Suchman EA, Lazarsfeld PF (eds) Measurement and prediction. J. Wiley, New York

Received June 20, 1980