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Trail Making Test and Visual Search

Walter H. Ehrenstein*, Gabriele Heister, and Rudolf Cohen

Fachgruppe Psychologie, Universität Konstanz,
D-7750 Konstanz, Federal Republic of Germany

Summary. The performance in the Trail Making Test (Form A) was correlated with a variety of verbal and nonverbal tests in 5 groups of patients: Broca's aphasics ($N=18$), Wernicke's aphasics ($N=19$) and nonaphasic patients with right hemisphere ($N=20$), left hemisphere ($N=17$) or diffuse ($N=18$) lesions. Correlations with the Trail Making Test were found for two tests, both requiring visual search. The "Objects Finding Test" in which the target varies from item to item showed high correlations for all groups of patients. The "Hidden Patterns Test", in which the target is kept constant, correlated only on the groups of nonaphasic patients. It is concluded (1) that visual search, as tested here, is not restricted to lateralized cortical functions, and (2) that the performance in the Trail Making Test depends largely upon processes involved in visual search of varying targets.

Key words: Trail Making Test – Severity of brain damage – Visual search – Lateralization of cortical function – Aphasia

Zusammenfassung. Der Trail Making Test (Form A) dient gewöhnlich der Diagnose des allgemeinen Schweregrads von Hirnschädigungen verschiedenster Lokalisation und Genese. Der Patient hat dabei 25 unregelmäßig über ein Blatt verteilte Kreise in numerisch angegebener Reihenfolge so schnell wie möglich durch Bleistiftstriche miteinander zu verbinden. Mittels Korrelationen wurde die Beziehung verschiedener verbaler wie nonverbaler Tests zur Testleistung im Trail Making Test bei fünf Patientengruppen untersucht: Broca-Aphasiker ($N=18$), Wernicke-Aphasiker ($N=19$) und Hirngeschädigte ohne Aphasie mit rechtshemisphärischen ($N=20$), linkshemisphärischen ($N=17$) oder diffusen ($N=18$) Läsionen. Zwei Tests, bei denen visuelle Suchleistungen gefordert waren, korrelierten mit dem Trail Making Test. Beim Test „Objekte Finden", der die Suchleistung anhand wechselnder Suchobjekte prüft, ergaben sich Korrelationen bei allen Patientengruppen.

* *Present address:* Neurologische Klinik, Universität Freiburg, Hansastrasse 9, D-7800 Freiburg i. Br., Federal Republic of Germany

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Der „Hidden Patterns Test", bei dem das Suchobjekt konstant bleibt, korrelierte nur bei nichtaphasischen Patientengruppen mit den Leistungen im Trail Making Test. Nach der vorliegenden Untersuchung scheinen visuelle Suchleistungen, insbesondere bei variablen Suchobjekten, weitgehend unabhängig von der Lokalisation der Hirnschädigung zu sein und eng mit den Leistungen im Trail Making Test zusammenzuhängen.

Schlüsselwörter: Trail Making Test - Schwere des Hirnschadens - Visuelle Suchleistung - Lateralisierung corticaler Funktionen - Aphasie

Introduction

The Trail Making Test (TMT) [2, 18] has become popular for testing the general severity of impairment caused by brain damage, regardless of its etiology or location [3, 4, 10, 17]. Form A of this test consists of 25 circles, numbered from 1 to 25, randomly distributed on a white sheet of paper. The subjects' task is to connect the circles in numerical order as rapidly as possible, correcting errors, if they occur, before continuing the sequence. Errors, therefore, add to the overall time necessary to complete the task, which is the criterion of test performance. In Form B of the TMT the patient has to alternate between numbers and letters. This form thus requires more complex symbolic processes and may be biased against patients with left cerebral lesions [4, 19, 20].

What are the processes involved in performing Form A of the Trail Making Test that makes it so sensitive to the general severity of brain damage and at the same time so insensitive to the localization of the lesion? The present investigation attempts to contribute to this question by looking at the factor of visual search from data which were obtained as part of a more extensive investigation concerned with aphasia [6].

Subjects and Methods

The subjects were 92 male patients with aphasic and nonaphasic disorders caused by cortical lesions as shown in Table 1. They were selected from a total of 106 patients tested in 14 different hospitals in the Federal Republic of Germany. The selection was done in such a way that the 5 groups of patients were comparable with respect to age ($42.5 \leqq \bar{x} \leqq 46.9$; $F(4,88) = 0.45$; $P > 0.10$) and a combined index for level of education and occupation ($2.08 \leqq \bar{x} \leqq 2.44$; $F(4,88) = 1.08$; $P > 0.10$).

Diagnoses were taken from hospital records consisting of clinical examinations together with angiogram, CAT scan and EEG information. Subjects who were either left-handed or ambidextrous according to a German adaptation of the Edinburgh Inventory [13] were not included in the sample, nor were patients, whose records mentioned any form of "agnosia". The performance on Form A of the Trail Making Test was used as a criterion to match the groups with respect to the overall severity of performance impairment due to cortical damage, irrespective of location and etiology ($1.87 \leqq \bar{x}_{\log.s} \leqq 1.91$; $F(4,88) = 0.08$; $P > 0.10$). All patients were native German speakers.

The patients were tested on a variety of verbal and nonverbal tasks including the Token Test, a German version of the Peabody Picture Vocabulary Test, Picture Naming, the Hidden Patterns Test, and the Objects Finding Test (see [6] for detailed description).

Table 1. Groups of patients

		Aphasics		Brain damaged patients without aphasia		
		Broca's ($N=18$)	Wernicke's ($N=19$)	Right hemisphere ($N=20$)	Left hemisphere ($N=17$)	Diffuse brain lesions ($N=18$)
Etiology	Vascular	16	14	11	4	3
	Traumatic	2	4	7	11	12
	Neoplastic	–	1	2	2	1
	Other	–	–	–	–	2
Duration of illness	Median in months	30.5	11.9	12.5	55.0	95.5
	Range	3–115	3–109	2–408	5–468	2–444

The Objects Finding Test (OFT) was taken from the German adaptation [1] of the Illinois Test of Psycholinguistic Abilities [12]. It consists of 5 picture-strips in which the subject must look for a given class of objects (dogs, fishes, bottles, shoes, hammer and saw). The first strip (dogs) is a practice trial. Before presenting an item, the experimenter names the object the subjects have to find by showing its representation on the first part of the strip. Afterwards, the whole strip is presented. The number of objects to be found varies from item to item, as does the size, shape and orientation of the objects. The subject has a maximal search time of 30 s. The number of correct identifications is scored.

The Hidden Patterns Test (HPT) was adapted from the "Kit of Reference Tests for Cognitive Factors" [8]. This test, suggested by Thurstone's "Designs" and Gottschaldt's Figures, was used here in a shortened version. It consisted of two out of four pages each with 100 geometric patterns in some of which a single configuration is embedded. The task of the subject is to mark for each pattern whether or not it comprises this configuration. The number of correct identifications within a time limit of 90 s for each page is scored.

Results

The groups of patients did not differ in their mean performance level in either the Objects Finding Test ($21.2 \leqq \bar{x} \leqq 24.8$; $F(4,88)=1.07$; $P>0.10$) or the Hidden Patterns Test ($29.4 \leqq \bar{x} \leqq 31.0$; $F(4,88)=0.63$; $P>0.10$). The correlations between the Trail Making Test and the two tests for visual search (OFT, HPT) are shown in Table 2.

In contrast to these two tests the correlations with the Token Test, the Peabody Picture Vocabulary Test, and the Picture Naming task were insignificant throughout ($0.02 \leqq \rho \leqq 0.34$). The time necessary to complete Form A of the Trail Making Test (i.e. poorer performance) is negatively correlated with performance (number of correct responses) on the Objects Finding Test ($-0.41 \leqq \rho \leqq -0.93$) and, for the brain damaged patients without aphasia, also with performance in the Hidden Patterns Test ($-0.54 \leqq \rho \leqq -0.61$).

While the correlations between the Trail Making Test and the Objects Finding Test are significant for all five groups of patients, the correlation is higher for Wernicke's aphasics than for Broca's aphasics ($\chi^2=11.59$; $P<0.01$).

Table 2. Correlations between Trail Making Test (TMT), Objects Finding Test (OFT), and Hidden Patterns Test (HPT)

	Aphasics		Brain damaged patients without aphasia		
	Broca's ($N=18$)	Wernicke's ($N=19$)	Right hemisphere ($N=20$)	Left hemisphere ($N=17$)	Diffuse ($N=18$)
TMT/OFT	−0.41*	−0.93**	−0.68**	−0.60**	−0.70**
TMT/HPT	−0.36	−0.27	−0.61**	−0.58**	−0.54*

* $=P<0.05$
** $=P<0.01$

The correlations between the Trail Making Test and the Hidden Patterns Test are significant only for the nonaphasic patients. Note however, that both, aphasic and nonaphasic patients do not differ with respect to their mean performance level.

Discussion

The results show consistent correlations between the performances in the Trail Making Test and visual search abilities as required by the Objects Finding Test and the Hidden Patterns Test.

While the Objects Finding Test shows correlations with the Trail Making Test for all groups of brain damaged patients, the correlation between the Hidden Patterns Test and the Trail Making Test is restricted to the group of nonaphasic patients. This difference might indicate that it is of crucial importance only for the aphasics as to whether the target varies from item to item, as in the TMT and OFT, or remains the same, as in the HPT. Possibly, aphasic patients are more likely to use different cognitive strategies for these tasks than brain damaged patients without aphasia. Since the mean performance level was about the same for all groups of patients in all these three tests, one might speculate whether covert naming supports the internal representation of visual targets for all these three tests only in the nonaphasic patients whereas aphasics shift to other, nonverbal modes of representation whenever feasable. The higher correlation between TMT- and OFT-performances in Wernicke's as compared to Broca's aphasics suggests, in addition, that the strength of this association is particularly related to processes of language comprehension.

Our results with the Hidden Patterns Test are in accordance with the classical study of Teuber and Weinstein [22] who noted "a striking absence of localization" in the deficit of brain-damaged patients to discover hidden figures, although the group of aphasics showed lower performance which the authors attributed to "greater impairment rather than to their language defects as such" [22, p. 375]. Apparently, our aphasics (that were matched with respect to general severity of impairment) do not differ from brain damaged patients without aphasia in their

mean performance, but tend to rely on different strategies than nonaphasic patients. Similar conclusions were drawn by Corkin [7], Hartje et al. [11], Pizzamiglo and Carli [14] and Russo and Vignolo [21].

At first glance it may be surprising that visual search is highly related to a test that is generally used as a tool for diagnosing general severity of brain damage irrespective of location. In contrast to other visual spatial tasks, e.g. the Poppelreuter Test or the Gestalt Completion Test by Street [cf. 11], and in spite of all the findings about unilateral inattention [5, 9], the relative efficacy of visual search as measured in these three tasks seems to be rather independent of the site of the brain lesion. Through specific combinations of perceptual and cognitive demands (e.g. visual discrimination, sequential and selective searching, control of search by memory representations, or concepts of single features [cf. 15, 16]), it remains to be delineated what it is in the visual search tasks that makes them so closely related to Form A of the Trail Making Test.

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