Neuropsychological Assessment of Basic Planning Competence

J. Kohler, U. Beck, B. Hohnecker

INTRODUCTION

In 1982 the Tower of London (TOL) was developed by Shallice and Mc Carthy as a new method for detecting planning deficits in patients with neurological diseases. The task is to match a given arrangement of three colored balls stuck on three pegs of different lengths in a minimum number of moves. The advantage of TOL in comparison of the Tower of Hanoi (TOH) is a **graded-difficulty approach** instead of a somehow „dual situation“ in case of TOH because of a greater variety of different positions. The complexity of the TOL problems increases through the minimum number of moves necessary to match the starting position with the goal position.

To solve the task the subject must plan „by mentally testing sequences of moves before carrying out the appropriate solution“ (Dagher et al 1999) while anticipating and avoiding unnecessary and incorrect moves.

In the original study involving normal controls and patients with anterior and posterior lesions Shallice & Mc Carthy found that patients with left anterior lesions were impaired in the number of moves required to successfully complete the task in comparison with normal controls and patients with other localizations.

In a methodological-empirical analysis of the TOL paradigma Röhrenbach (1989) showed clearly that the minimum number of moves will only explain 41% of the variance of the task difficulty. Additional parameters (e.g. the number of possible moves from a given starting position, the fact if there are only one or more solutions possible, the fact if a part of the solution is already known through a prior task, the structure of the goal position etc.) are able to increase the variance up to 81%.

Owen et al (1990) presented a computerized version of TOL with a yoked motor control condition to substract the motoric component. They used the number of moves and additionally different time parameters („initial thinking/planning time“ and the „subsequent thinking time“) for scoring and found a significant effect with a „frontal patient group“ requiring more moves to complete the problems and spending more time thinking about the problem subsequent to the first move. In contrast no difference was found with regard to initial thinking/planning time.

In the meantime different authors developed various modifications on the procedure and the scoring of the TOL paradigma (Krikorian et al

1994). Overall these investigations support the diagnostical value of TOL for being sensitive to “frontal dysfunction” regarding planning aspects (Andreasen et al 1992, Lange et al 1992, Baker et al 1996, Dagher et al 1999 and 2001). However there is no standardized test form of the TOL available since yet although there even has been done some promising research on test-theoretical aspects (for reliability Schnirman et al 1998, for validity Culbertson & Zillmer 1998).

METHOD

For our study we used a modified, computerized version of TOL without motor execution through the subject who is instructed to just sit in front of the monitor, concentrate on the task and tell the examinator which move to do next. In order to control the difficulty level of the tasks and also to construct a design for “**testing the limit**” we analyzed the mathematical solution space regarding to the different parameters which has been known to influence the task difficulty (Röhrenbach 1989) and kept all parameters constant except the minimum number of moves (fig.1). Then we picked trials for 3, 4, 5, 6, 7 and 8 moves necessary to solve a given problem within the minimum number of moves to get two **parallel test forms** (fig. 2).

Subjects are told that only one response per trial is allowed and that they should not respond until quite sure of the correct sequence of moves. After two example trials (2 and 3 moves) the test trials are presented in a fix sequence starting with 3 and ending with 8 moves.

While “easy” problems require very minimal planning because the selection of the appropriate move is somehow „intuitively“ clear, the more difficult the TOL problem gets, the higher rises the anticipatory load and forces the subject to a more explicit mental planning.

Performance is scored by the number of correct trials within a test form (max. = 6), the number of moves and rule breaks for each trial and the times for each move.

The results of Owen et al (1990) that patients with frontal lobe damage do not spend more time thinking about the problem before making the first move, let us assume that patients with planning deficits very often do not analyse the problem in advance, but start with some moves and suddenly realize that there is more time necessary to think about the problem. So we decided to measure the initial "thinking/planning time" not only before making the first move but moreover to measure the times before every move in order to get a more differentiated "**time profile**" for each task and difficulty level.

Furthermore we computed a **planning coefficient** for each trial by considering the "thinking" time before the first move in relation to the total time needed to solve the problem. Patients who do not plan in advance while they make moves can then be identified by a lower planning coefficient.

Another aim was to develop a parallel form of the test for retesting patients with planning deficits after a therapeutic intervention. Therefore we tested 54 normal controls with both test forms in random sequence.

For collecting normative data the test is integrated in a multi-centric study about neuropsychological tests in the german-speaking part of Switzerland. At the end of the project there will be a representative N of 600 with an age range from 15 to 65 years. Right now there are data from 241 control persons available, ranging from 16 to 65 years (mean = 36.7, sd = 13.2) with 137 females and 104 males.

For the comparison with neurological patients we also tested 95 patients with neuropsychological deficits from a rehabilitation center in Switzerland (66 ¯, 29 α; 59 CVI, 20 TBI, 6 Parkinson, 10 others). The age ranges from 15 to 83 years (mean = 50.9, sd = 17.8).

RESULTS

First empirical investigations on our modified TOL version with normal control subjects and neurological patients with neuropsychological deficits show that according to Krikorian et al (1994) it is necessary to fully use the difficulty variability to clearly get differences between normal subjects and neurological patients with planning deficits.

For the analysis of the two test forms we used a 2-factorial MANOVA design with the factors “test form” (A and B) and “test form sequence" (A-B and B-A). There were no differences found between form A and B ($F(1.53) = 0.46$; $p = 0.50$) and also no differences between the test form sequences ($F(1.53) = 1.08$; $p = 0.30$).

As mentioned before for the parameters of the test we used the number of correct trials ($0 \leq \mathbf{C} \leq 6$), the number of moves for each trial ($\mathbf{M_1} - \mathbf{M_6}$), the total number of moves ($\mathbf{M} \geq 33$) and the total number of rule breaks ($\mathbf{R} \geq 0$) over all 6 trials. Furthermore we completed the analysis with the times ($\mathbf{T_1} - \mathbf{T_6}$) and the planning coefficients ($\mathbf{PC_1} - \mathbf{PC_6} = T_{i1}/\sum T_{i1}\text{-}T_{in} * 100$) for each trial.

For the control subjects ($N = 241$) we only found a slight correlation of age with M ($p < .05$). For the patients there were higher correlations of age with M ($p < .0001$) and also with C ($p < .01$) but not with R. Sex did not play a significant role for control subjects. Only patients differ slightly for M (mean($\overline{\ }$) = 41.8, mean (α) = 38.5, $p < .05$).

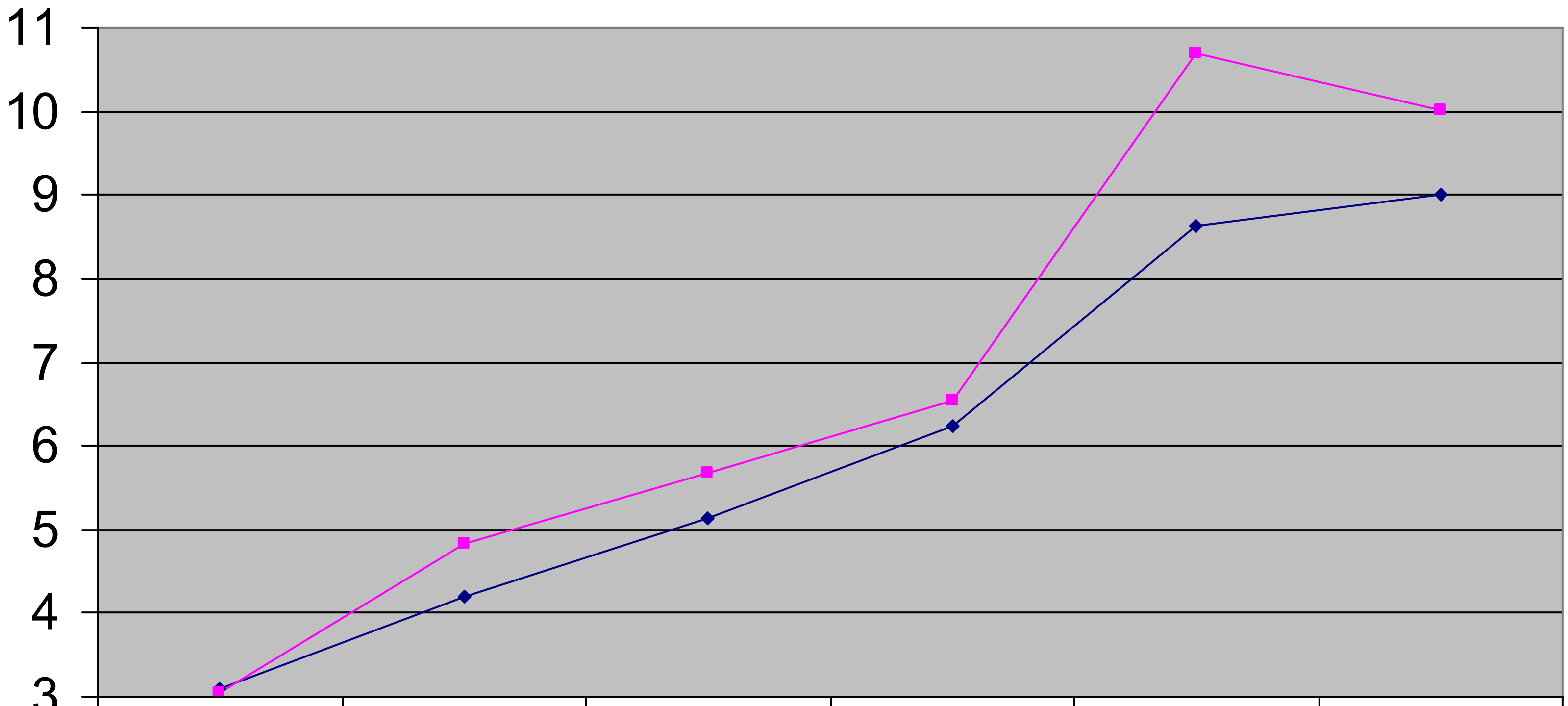
The comparison of controls versus patients revealed highly significant differences of almost all test parameters (C, M, R, M_2 – M_6). Only trial 1 (3 moves) did not differ between controls and patients (see fig. 3).

The test consists of 6 trials. The number of correct trials for the controls were 4.57 (sd = .85). Patients did only solve 3.87 trials correct (sd = .89, $p < .0001$). To solve the test optimal a person needs a total amount of 33 moves. The control subjects needed 36.31 moves (sd = .28) whereas patients needed significant more moves (40.82, sd = .45, $p = .0000$).

We also scored the number of **rule breaks** during the testing when subjects told the instructor to make a move which is not permitted. For control subjects the amount of rule breaks has been very small (R

= .20, sd = .12) while patients make significant more rule breaks (1.23, sd = 0.19, $p < .0001$).

Fig. 3: Number of moves (mean) for each trial



	M1	M2	M3	M4	M5	M6
controls	3,09	4,20	5,14	6,24	8,62	9,00
patients	3,04	4,83	5,68	6,54	10,69	10,02
p	.3374	.0039	.0008	.0077	.0000	.0001

Furthermore we analyzed the times subjects needed for each move and each trial. Our hypothesis was, that patients with planning deficits do not plan ahead but begin with some moves and start planning when they encounter a problem during the task.

For all 6 trials patients needed significant more time to finish the tasks than control subjects (fig. 4). Additionally we compared the planning coefficients (PC_{1-6}): for the first trial patients had a significant higher PC than controls. When the complexity of the task increased the PCs between patients and controls turned around and control subjects had a higher PC than patients (fig. 5).

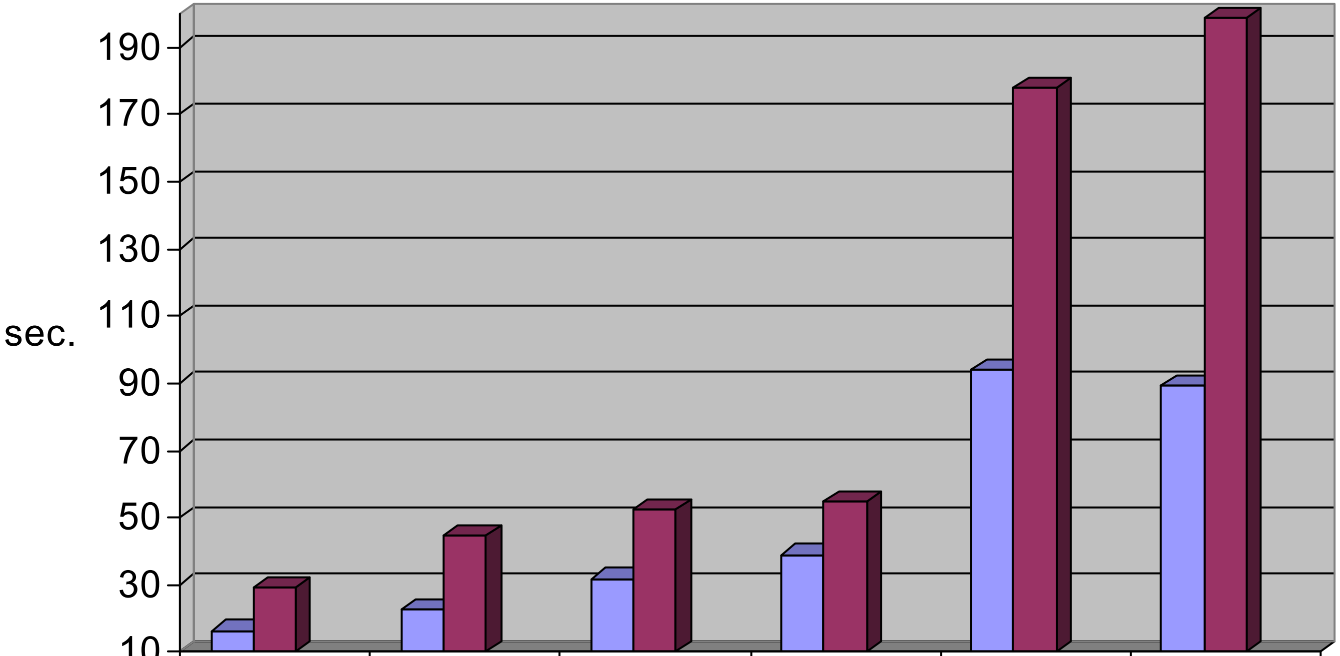
We assume that for easy problems patients overviewed the complete problem and did what they have been told, to plan ahead. When the problems got more difficult they ignored the instruction and just started to make some moves until they realized, that it was not possible to solve the problem within the minimum number of moves.

Discussion

In a first empirical study the data showed promising results for the modified TOL-test being used as a standard test for detecting planning deficits in neurological patients. It provides two parallel test forms for re-evaluating planning competence after a therapeutic intervention. The next step will be to investigate in a closer analysis of different patient groups to differentiate between patients with specific executive dysfunctions and others. There will also be more research to do for the validity of the test, especially in combination with ADL.

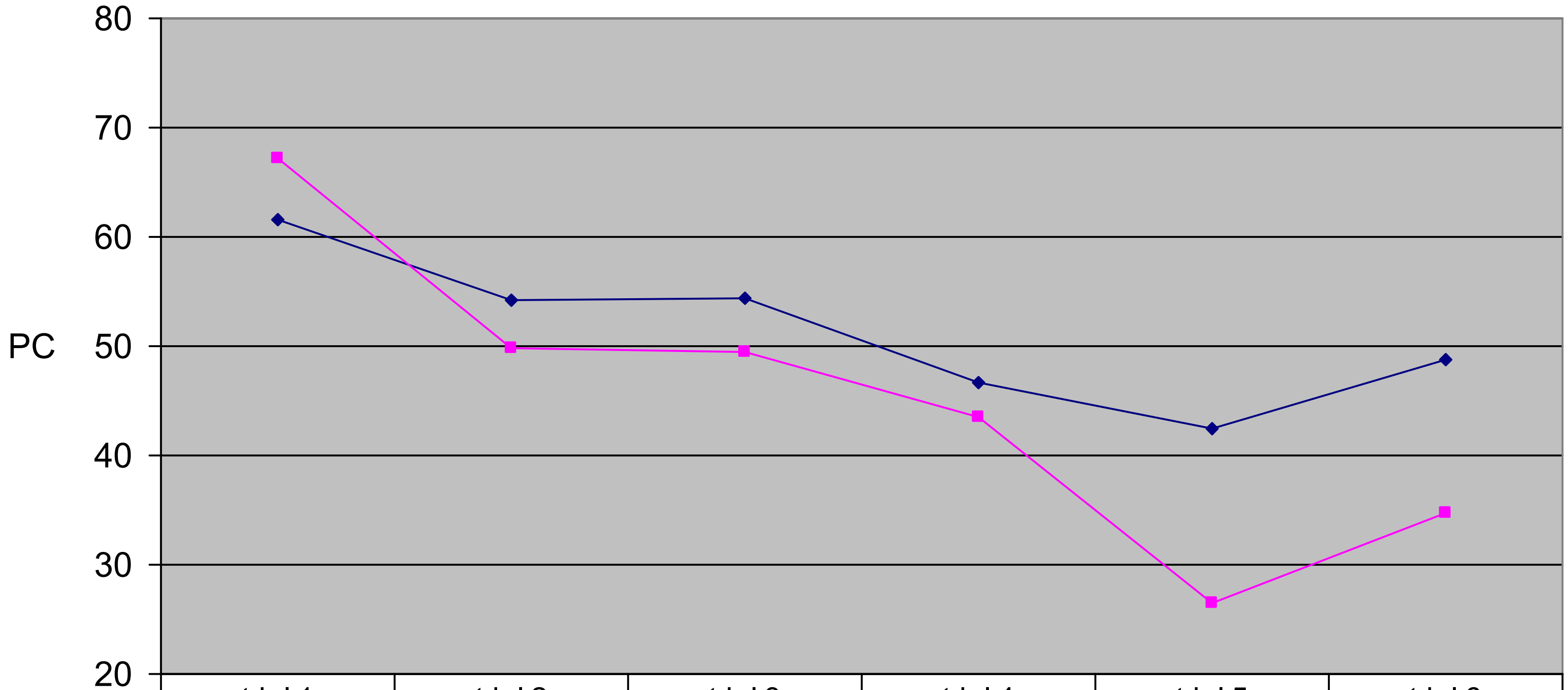
For more information please visit www.planungstest.de

Fig. 4: Times (means) for each trial



	T1	T2	T3	T4	T5	T6
controls	16,4	22,8	31,9	38,9	94,1	89,3
patients	29,1	44,5	52,3	54,7	177,7	198,5
p	.0000	.0001	.0002	.0001	.0000	.0001

Fig. 5: Planning Coefficients (means) for each trial



	trial 1	trial 2	trial 3	trial 4	trial 5	trial 6
controls	61,57	54,15	54,4	46,71	42,48	48,83
patients	67,11	49,79	49,42	43,51	26,57	34,68
p	.0001	.0185	.0173	.1257	.0001	.0001

LITERATURE

Andreasen, N., Rezai, K., Alliger, R., Swayze, V., Flaum, M., Kirchner, P., Cohen, G. & O´Leary, D. (1992). Hypofrontality in neuroleptic-naive patients and in patients with chronic schiziphrenia. *Archives of General Psychiatry, 49, 943 - 958.*

Baker, S.C., Rogers, R.D., Owen, A.M., Frith, C.D., Dolan, R.J., Frackowiak, R.S.J., Robbins, T.W. (1996). Neural systems engaged by planning: a PET study of the Tower of London task. *Neuropsychologia 34 (6), 515 –526.*

Culbertson, W.C. & Zillmer, E.A. (1998). The construct validity of the Tower of London DX as a measure of the executive functioning of ADHD children. *Assessment 5 (3), 215 – 226.*

Dagher, A., Owen, A., Boecker, H. & Brooks, D. (2001). The role of the striatum and hippocampus in planning: a PET activation study in Parkinson´s disease. *Brain, 124, 1020 -1032.*

Dagher, A., Owen, A., Boecker, H. & Brooks, D. (1999). Mapping the network for planning: a correlational PET activation study with the Tower of London task. *Brain, 122, 1973 -1987.*

Hohnecker, B. (2003). Testdiagnostik zur Planungsfähigkeit bei neurologischen Patienten. *Unpublished Diploma Thesis. Universitiy of Constance.*

Krikorian, R., Bartok, J. & Gay, N. (1994). Tower of London Procedure: A Standard Method and Developmental Data. *Journal of Clinical and Experimental Neuropsychology, 16, 840 - 850.*

Lange, K. Robbins, T. Marsden, C., James, M., Qwen, A. & Paul, G. (1992). L-Dopa withdrawal in Parkinson´s disease selectively impairs cognitive performance in tests sensitive to frontal lobe dysfunction. *Psychopharmacology, 107, 394 -404.*

Owen, A., Downes, J., Sahakian, B., Polkey, C. & Robbins, T. (1990). Planning and spatial working memory following frontal lobe lesions in man. *Neuropsychologia, 28, 1021 -1034.*

Röhrenbach, C. (1989). Der Turm von London als Verfahren zur Prüfung präfrontaler Funktionen. *Unpublished Diploma Thesis. University of Constance.*

Schnirman, G.M., Welsh, M.C., Retzlaff, P.D. (1998). Development of the Tower of London-Revised. *Assessment 5(4),355 –360.*

Shallice, T. (1982). Specific impairments of planning. Philosophical *Transactions of the Royal Society of London, 298, 199 - 209.*