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Assessing tactile perception in limited visibility could be child's-play: developing the Tupperware Neuropsychological Task

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ABSTRACT

In task-environments with limited visibility (e.g. rescue workers in smoke), individuals rely on tactile perception as a primary mode of data acquisition. They need to translate tactile information into three-dimensional images, to solve problems mentally, before translating them into motor actions.

To assess this ability in an inexpensive, standardised way, the Tupperware Neuropsychological Task (TNT) was developed. It is a timed task using the Tupperware™ Shape O Toy. Participants completed the TNT blindfolded, and also completed standardised measures of spatial visualisation, tactile form perception and memory, and fine motor coordination.

Healthy adults (N=170) aged 19 to 30 completed the tasks on all tests on an individual basis. This paper reports normative data for the TNT, including mean completion time and standard deviations. It also reports small but significant correlations with other measures of tactile form perception, mental rotations, motor manipulation and tactile recall. This suggests that the TNT taps all these constructs in one task, which would make it an economical measure of the functions required to work effectively in low visibility environments.

Key words: tactile form perception; mental rotation; tactile memory

Introduction

Within the South African context, formal neuropsychological tests are expensive, and often require substantial infrastructure (tables/chairs, pen/paper, blocks/cards, etc.), as well as some level of educational attainment, which makes administration difficult under unusual circumstances (e.g. "field testing").

While education levels are improving generally, a large proportion of the South African population has limited education[1], but most of this section of the population are still intelligent and enthusiastic, often making ability tests for individuals with limited education either too simple or not interesting enough[2]. They often require more stimulating tasks to assess their abilities by practical means.

The author has been using the Tupperware™ *Shape O Toy* in practice as a playful way to assess psychomotor development and other fine motor skills of patients. It is easy to use, fun to do, and elicits much information through simple observation. The playful nature, three-dimensional form, and time challenge aspects of the task generates interest and stimulates. The robust plastic three-dimensional forms also make it appropriate for use with individuals with visual challenges (e.g. limited sight).

The author's experience suggested that this toy might provide information on a number of psychological functions, as the toy appeared sensitive to tactile form perception, visuo-spatial perception, and fine motor coordination. Furthermore, it appeared sensitive to the effect of anxiety on neuropsychological performance, concentration, and frustration tolerance, as well as eliciting information on logical processing (in problem-solving). As these were subjective observations made by the author, the thought was born to test them by correlating performance on the *Shape O Toy* with standard neuropsychological measures.

Apart from the general population, individuals who work in environments where there is limited visibility (for example, due to water or smoke), good sensory-motor coordination is essential. This would include groups such as rescue workers (e.g. firemen)[3], and military personnel (e.g. divers or bomb disposal operators)[4,5]. They often work where visibility is obscured by smoke, dirty water, or their protective clothing. In a task-environment where visibility has deteriorated, individuals rely on tactile perception as a primary mode of data acquisition[5]. They need to translate tactile information into three-dimensional images, and then solve the problem by mentally manipulating the image before translating it into motor actions, with tactile sensation acting as the feedback mechanism. Other occupational groups include technicians[6] who may need to work where they cannot see their hands, in particular when they work from a diagram or design with their hands out of their sight.

To assess this ability in an inexpensive, standardised way, the Tupperware Neuropsychological Task (TNT) was developed. In essence the TNT is a timed task using the Tupperware™ *Shape O Toy*, with a standard instruction sheet and scoring rules, formulated by the author. It is easy to transport, easy to administer, easy to interpret, and requires little formal education to complete. The TNT is in essence a 'home-made' task to assess performance in unusual circumstances such as limited visibility. For any task to be

successful in this context, it needs to meet certain requirements. It must be practical, standardised, meaningfully normed, and have adequate construct validity.

This study hypothesised that completion of the TNT taps a number of constructs, including:

a. anxiety, due to task novelty and performance pressure
b. tactile (form) perception of shapes
c. mental transformation or rotation of shapes
d. finer motor control to manipulate (or 'fit') shapes
f. tactile memory in recalling shapes
g. visuo-spatial perception in organisation of drawings

Thus, if this could be confirmed, the TNT could be a useful tool for assessing individuals who work in low visibility environments.

This study set the following aims:

1) To develop norms for the standardised TNT (e.g. mean, standard deviation, variations and ranges for the timed task);
2) To investigate the potential neuropsychological correlates of the TNT hypothesised above.

Methodology

Measures

Tupperware™ 'Shape O Toy'

The toy is a round ball that has 10 different shapes cut out of it, and 10 slightly smaller shapes that correspond to the cut-out shapes. The different shapes are a triangle, pentagon, square, cross, circle, star, trapezoid, pie wedge, hexagon, and oval. The purpose is to find the right shapes for the corresponding cut-outs, and then fit them into the cut-out.

Permission was obtained from the Tupperware Company to use the *Shape O Toy* in this study, and there was no further involvement with them.

Tupperware Neuropsychological Task (TNT)

Participants were asked to complete the *Shape O Toy* blindfolded, without prior opportunity to see the ball or shapes. A standardised instruction set was developed for this study, and participants were asked to complete the task against time. Participants used both hands, in any way they preferred. Their score was the 'Total Time', which was recorded in seconds (TNTt).

On completion of the task, the shapes and blindfold were removed, and participants were requested to draw as many of the shapes they could remember on an A4 sheet of paper, to measure tactile memory. This provided for a 'Memory Score', which was the total of correctly recalled shapes (TNTm). Participants were not prompted before hand to remember the shapes. Visuo-spatial perception could be observed in the organisation of the drawings.

In order to guide later research on construct validity, apart from being tested on the TNT the participants also completed standardised measures of spatial visualisation, tactile form perception, tactile memory, fine motor coordination, and anxiety. These measures, described below, have proven validity and reliability. Correlating these measures to performance on the TNT would create a triangulation aimed at improving the validity of the study.

Differential Aptitude Test Spatial visualisation (3-D)[7]

Subtest 7 of the Differential Aptitude Test, Form K (DAT) measures three-dimensional spatial perception[7]. The test is based on the assumption that the ability of a person to mentally (i.e. in his/her mind) a) join two blocks together to form a cube; b) build a recognisable figure with objects of different shapes and sizes that are represented three-dimensionally; and c) manipulate two three-dimensional blocks in such a way that a recognisable figure is obtained after one of the blocks is rotated, is a valid criterion of three-dimensional spatial perceptual ability (i.e. mental transformations in space). The manual provides for a standardised administration. The score is the number of correct answers within the time limit. Different standardised scores are available for women and men. The norms for grade 12 learners were used.

Adapted Form Board (FB)[8]

The FB is based on the Tactile Performance Test of the Halstead-Reitan neuropsychological test battery (also called the Seguin-Goddard Formboard)[8], which taps tactile form perception and tactile memory (recall)[8]. It was adapted for this study by using a particular administration set. Participants were again blindfolded and asked to complete a 2-dimensional form board on a flat surface, by placing the differently shaped blocks in the right spaces. A standardised instruction set was used, and participants were asked to complete the task against time. The score was the 'Total Time', which was recorded in seconds (FBt). Participants used both hands, in any way they preferred. On completion of the task, shapes and blindfold were removed, and participants were requested to draw as many of the shapes as they could remember on an A4 sheet of paper. The number of correct shapes recalled made up the 'Memory Score' (FBm).

Grooved Pegboard (GP)[9]

The Grooved Pegboard is a manipulative dexterity test[9]. The board consists of 25 holes with randomly positioned slots. Pegs which have a key along one side must be rotated to match the hole before they can be inserted. The GP taps fine motor coordination and mental motor manipulation. The manual provides for a standardised administration. Scores were obtained for the total time to complete the task, with the dominant hand (GPd), and then both hands combined (GPb).

Anxiety Scale (AS)[10]

The IPAT Anxiety Scale (AS), SA version[10] is a self-report questionnaire that provides a reliable estimate of free-floating anxiety. South African norms are available[11], and it appears not to discriminate between SA race groups[12]. Different standardised scores are available for women. Norms for people with a grade 12 qualification were used.

Biographical sheet

Participants completed a biographical sheet to record information on their age, level and years of education, gender, and home-language.

The battery of measures were administered in English, in the following order, consecutively: Biographical sheet, AS, 3-D, TNT (time and memory), FB (time and memory), and GP.

Participants

One hundred and seventy volunteers between the ages of 19 and 30 completed the battery on an individual basis. All participants were employed in the public sector at the time of their participation, and were recruited to participate in the study during their employer mandated occupational health surveillance program. Participants came from 3 sites in the Western Cape.

Inclusion criteria were set to this age group, as entry into the occupations that would require work in low visibility usually occurs within this age period. Further criteria included 12 years of formal education, as well as some proficiency in English, again because most of these occupations would require that for entry into their respective training programs. Members of the study sample had to be neurologically and medically healthy at the time of their participation, as confirmed during their annual health surveillance. Candidates with a history of neurological or psychiatric difficulties were excluded from the study. None had any significant emotional complaints at the time, as determined by a psychologist.

Participants completed the measures and tasks after being briefed on the study, and completing a consent form. Ethical approval was obtained from the Surgeon General Health Research Ethics committee.

Data analyses

The analysis of the data provided descriptive statistics for the TNT timed task, from which normative data could be presented. Where appropriate, the same was provided for the other measures (AS, 3-D, TNT memory, FB time and memory, and GP).

The relationship between TNT time and memory scores, and age, years of education, and anxiety was calculated using Pearson's correlations, and the relationship with gender calculated using the t-test for independent groups. To further investigate the potential neuropsychological correlates of the TNT, Pearson's correlations between the TNT and other standardised measures (3-D, FB, GP) were also calculated.

Results

The sample consisted of 170 volunteers, aged 19-30, with a mean of 22.1 years (±2.3 years). It comprised 95 men (55.9%) and 75 women (44.1%). There were no significant gender differences in the demographic data. They had a mean of 12.3 years (±0.7) of formal education. Their education and language distribution is presented in *Table I*.

Table I: Descriptive statistics of sample

	N	%
Education		
Senior certificate: academic ("matric")	134	78.8
Senior certificate: technical ("N3/N4")	22	12.9
Post matric certificate	11	6.5
National diploma	3	1.8
Language		
English	23	13.5
SeTswana	12	7.1
SeSotho	14	8.2
SePedi	23	13.5
isiXhosa	15	8.8
TsiVenda	8	4.7
Tsonga	7	4.1
isiZulu	22	12.9
Afrikaans	38	22.4
Ndebele	4	2.4
SiSwati	4	2.4

The total sample completed the TNT in a mean time of 7 min 48 seconds (468 seconds, ±227), ranging from 118 to 1326 seconds. Women and men did not differ significantly in their timed performance. The total sample mean memory score was 7 (±1.5), ranging from 2 to 10. Men had significantly better recall than women (7.15 vs. 6.67, $p<0.05$).

The total sample had a mean sten[a] score of 4 (±2) on the AS. Women and men differed on their raw scores, but this difference disappeared when using the standardised scores from the manual. Anxiety was negatively correlated to age ($r=-.25$, $p<0.001$). On the 3-D task, the total sample had a mean stanine[b] score of 7 (±2). Women and men differed on their raw scores, but this difference again disappeared when using the standardised scores from the manual.

The total sample completed the FB in a mean time of 7 min 3 seconds (423 seconds, ±228 seconds). The total sample mean memory score was 7 (±1.5), ranging from 3 to 10 (out of 11). Women and men did not differ significantly in their timed performance or recall.

The total sample completed the GP dominant hand task in a mean time of 65 seconds (±9). Women were significantly faster than men (63 vs. 66 seconds, $p<0.05$). The task with both hands took 56 seconds (±9) and no significant gender differences were noted.

The TNT timed task showed no significant correlation with age, education, or anxiety. Small but significant correlations were noted between the TNT timed and memory task ($r=-.3$, $p<0.0001$), and the FN timed and memory tasks ($r=-.3$, $p<0.0001$). Further, small but significant correlations were noted between the TNT timed task and the FB timed task ($r=.39$, $p<0.0001$), GP-dominant hand ($r=.32$, $p<0.0001$), GP-both hands ($r=.31$, $p<0.0001$), and the 3-D task ($r=-.36$, $p<0.001$).

The TNT memory task showed no significant correlation with age, education, or anxiety either. A small but significant correlation was noted between the memory score and the FB memory task ($r=.38$, $p<0.0001$), as well as the 3-D task ($r=.32$, $p<0.0001$). Performance on the 3-D and GP tasks did not correlate significantly. The correlation matrix is presented in *Table II*.

Table II: Correlations between measurements

	Age	Edu	AS	TNTt	TNTm	FBt	FBm	GPd	GPb	3-D
Age	1.00	0.09	0.25	0.03	0.00	0.06	0.05	0.01	0.02	-0.13
Edu		1.00	0.05	-0.06	-0.03	-0.06	-0.08	0.07	0.0	-0.01
AS			1.00	-0.02	-0.08	-0.02	-0.13	0.00	0.05	-0.08
TNTt				1.00	-0.30*	0.39*	-0.20	0.32*	0.32*	-0.36*
TNTm					1.00	-0.30*	0.38*	-0.15	-0.21	0.32*
FBt						1.00	-0.30*	0.31*	0.32*	-0.34*
FBm							1.00	-0.11	-0.15	0.22
GPd								1.00	0.68	-0.03
GPb									1.00	-0.08
3-D										1.00

* $p<0.0001$

Legend

Edu	= education
AS	= Anxiety Scale
TNTt	= TNT time task
TNTm	= TNT memory task
FBt	= Formboard time task
FBm	= Formboard memory task
GPd	= Grooved Pegboard dominant hand
GPb	= Grooved Pegboard both hands
3-D	= Three-dimensional spatial visualisation

Discussion

It has been suggested that one standard deviation from the mean is used as cut-off point between normal range and outlier scores, to be consistent with the international use of other psychological measures[13]. This would put individuals who score below 4 min on the TNT in the above average range, and those who score above 11½ min in the below average rage. A score between 5 and 9 on the TNT memory task would fall within the average range. Future studies will need to confirm whether this cut-off point leads to adequate sensitivity and specificity figures.

No gender differences were noted on the TNT timed task. The TNT seemed resilient to the effects of anxiety in the current test context. No age or educational effects were found either. Small correlations between similar tasks and age and education have previously been reported[14], whereas the variance in the present study was too limited to detect such effects.

Time spent on task completion was consistently negatively correlated with tactile memory on both the TNT and FB. Faster times were associated with better recall. This

[a]A sten score refers to a standardised score on a scale from 1 to 10.

[b]A stanine score refers to a standardised score on a scale from 1 to 9

study did not explore the nature of this correlation, but it could be hypothesised that the correlation is based on both tasks tapping some underlying construct of general ability.

The small but significant correlations between the TNT and FB timed tasks suggest that they both tap the same construct. In the same way, the small but significant correlations between the TNT and FB memory tasks suggest that they also both tap the same construct. FB does measure tactile form perception and tactile memory[8], and it is thus suggested that the TNT does the same. The small but significant correlations between the TNT timed task and the GP suggest that the TNT also taps into fine motor manipulation.

The consistent small but significant negative correlations between the TNT timed task and the task of three-dimensional spatial perceptual ability (i.e. better spatial visualisation = shorter completion time) suggests that the TNT also measures some ability for mental transformation in space. The DAT purports to measure aptitude, and the TNT might be measuring the practical implementation or execution of that mental ability.

Thus, the hypothesised list of constructs tapped by the TNT is mostly supported: anxiety did not seem to be clearly involved, but tactile (form) perception, mental transformation of shapes, fine motor manipulation, and tactile recall memory are implicated by the TNT correlates. Given these findings, the value of the TNT lies in its economy – one task that could tap the same constructs as three other tests – and a task that seems to reflect many of the functions required to work effectively in low visibility environments.

This paper thus presents a first step towards creating meaningful normative data for the South African population. The TNT is practical, easily transported, and administered easily according to a standardised instruction set. Further research is needed to create different norms for different groups. In particular studies on samples with greater age, educational, and health status variability could further explore the possible effects of these constructs on performance.

Studies involving patients with brain injury completing the TNT may further our understanding of the underlying constructs being measured. For example, performance deficits on tests involving mental rotations have been associated with parietal lobe lesions[15], and if the same associations are found with the TNT, may give further direction for its use. According to Butters[15], patients with hemispheric lesions have difficulty with the use of different mental strategies – patients with left hemisphere lesions show a deficit as a consequence of their manual activity, whereas patients with right hemisphere lesions are impaired by means of a visual strategy[16].

There is a question whether blindfolded testing would increase anxiety, and so affect performance. To address this, a study comparing blindfolded testing and testing with the task behind a screen (thus retaining visual awareness) is currently underway. The type of work environment that individuals come from may also affect their performance, and needs to be included in future studies.

A number of uses of the TNT in practice seems promising, for example the assessment at entry - of the tactile perception, mental rotation, and fine motor manipulation - in individuals that may be exposed to limited visibility in the execution of their duties. The TNT further has application in the subsequent training of these workers. Using the instrument to identify limitations can lead to specific mental visualisation or tactile perception training.

In conclusion, the TNT offers a simple and inexpensive alternative for assessing tactile form perception, mental rotation, and motor manipulation in individuals who work in limited visibility environment. It's advantage lies in its economy, as no substantial infrastructure or expensive proprietary material is required, and it measures a number of constructs in one task; it is easy to administer, and creates stimulation through it's playful nature and time challenge; there are meaningful correlations to established measures; and the initial local normative data provides opportunity for use in different spheres of occupational and clinical applications. Assessing tactile perception in limited visibility could indeed be child's play!

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Acknowledgements

I would like to thank my colleagues Goudine Gaum, Chesray Hans-Arendse, and Devasham Naidoo for their assistance in administering the tasks.

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