Correlative study of performance on mental rotation test and outcome of *ab initio* flying training

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Visuo-spatial abilities are considered important in the performance of navigational tasks during flying. This hypothesis was tested in 44 flight cadets with a mean age of 22.4 years. All the subjects were administered a standardized mental rotation test (flag test). Three scores were derived for this test, namely, FM (total score in first five minutes), FTT (total time taken for completing the test) and FRS (total raw score). Actual flying performance was obtained in respect of the trainees under 7 components from instructors and supervisors. Flight cadets obtained a mean score of 54.62 (19.63) on FM, 11.45 (3.35) on FTT and 114.41 (5.81) on FRS component of this test. Multiple regression analysis was carried out between scores on various scales of flag test and flying performance on various components. This analysis revealed that flag test scores had a significant correlation with scores on navigational sorties (pilot navigation training and low level navigation training) as well as performance during other phases of flying such as close formation training, Night flying training and total marks in flying subjects. On the basis of these results, it is concluded that the mental rotation test used in this study has a good predictive validity for training outcome during ab initio flying.

Keywords: Flag test; Pilot Navigation Training, Mental rotation, Visuo-spatial abilities

In our day-to-day life, there is a need to orient ourselves in various places and landmarks in a particular environment. People differ in their ability to find their way back to the starting point. Some people can do it with ease whereas others find it extremely difficult. An individual may readily give a self-assessment of his or her own sense of direction. The sense of direction that interests us is concerned with awareness of the location or orientation. Knowledge of one's own location in the environment is of primary functional significance. As such, environmental orientation skills are important for behavioural competence in navigation. People with a poor sense of direction are more likely to become disoriented spatially [1, 2]. Such people may perform poorly in navigational tasks.

Air navigation is the art of guiding an aircraft from one place to another and fixing its position when required. Aretz [3] has conceptualized navigation as a cognitive process by which the pilot maintains a congruent relationship between ego-centred reference frame (ERF) and world-centred reference frame (WRF). ERF is established by forward view outside the cockpit and WRF is established by aircraft location on the map. Aircraft navigation forms an important aspect of flying and is required in all phases of aircraft operations. Hence, the success of a flying mission depends on navigation to a large extent. There are several modern modes of navigation, e.g. celestial, radio, inertial, satellite. But the oldest mode, popularly known as 'pilotage', does not require any external aids and needs our own visual cues. In pilotage a course is typically plotted on a paper map and visual landmarks and check points bracketing this course are selected. During the flight, the pilot achieves and maintains awareness of aircraft position and heading by continuously comparing the position of the landmarks (as viewed in the outside world) with the position relative to the plotted course on the map [4]. Thus, he has to depend upon his visuo-spatial abilities. Navigation seems to depend upon spatial cognition, visuo-spatial memory, mental rotation and map-reading ability [3, 5, 6–9]. Since all these cognitive processes are related to visuo-spatial abilities, it appears that navigation, to a large extent, should depend upon such abilities and a person higher in such abilities is likely to be better in navigation.

In a study on flying trainees we observed that more than one-third of the successful candidates had difficulty in absorbing the navigation phase of training [10]. Therefore, it was felt that there is a need to develop a reliable screening measure for delineating navigational abilities of prospective aviators. It is possible that delineation and objective measurement of these abilities may provide important input in improving the psychological screening of aviators.

Eysenck and Kaene [11] postulate that mental rotation seems to demand the dynamic transformation of visual images. The task involving mental rotation has been used to study the nature of visual images. In a particular task where the test figure was presented in different orientations, it was found that the farther the test figure was rotated from the upright position, the more was the time taken by the subjects to make their decision. These results show that visual images have all the attributes of actual objects. They take up some mental space and are rotated mentally in a similar way that objects are manipulated in the world. But increasing the complexity of the imagined object introduces differences in the mental rotation effect as compared to real-time physical rotation.

Shepard and Metzler [12] published the first experiment demonstrating mental rotation. Their principal findings were that the time required by subjects to visually compare two stimuli increased linearly with the angular differences between their orientations. They concluded that mental rotation is a fundamental cognitive process.

Shepard and Hurwitz [13] found that mental rotation may be used in navigation. Their data showed that subjects judge the direction of turns relative to movement in the forward direction. Thus, in order to determine whether the map indicated a left or right turn, subjects had to mentally rotate the visually presented map to track-up orientation. This implies that for egocentred tasks on a visually presented map, track-up orientation is better so that the requirement of mental rotation is minimized and the performance is not degraded.

From the above literature on mental rotation it is presumed that an individual who does mental rotation with ease and at a higher speed will be better in navigating the aircraft in particular and in piloting in general. The basic premise in this study is that mental rotation plays a significant role in the performance of navigational tasks in particular and in flying performance in general.

Material and methods

Forty-four flight cadets who were undergoing advanced phase of flying training constituted the group for this study. Their age varied between 21 and 26 years with a mean statistics of 22.38 ± 1.26.

Flag test is a test of spatial ability which has been standardized by Thurstone and Jeffrey [14] and is widely used in neuropsychology. It consists of 21 reference figures given on the left-hand side and for each reference figure there are six comparison figures placed in the horizontal row in front of the reference figures. This makes a maximum of 126 responses to be recorded on the response sheet. The comparison figures are derived by either rotating the reference figures by various degrees as it is, or by reversing and rotating. Comparison figures are labelled as same (s) or opposite (o) after comparison with reference figures.

Each subject was explained the procedure of the test with the help of a flag made up of cloth. This flag was 6 × 8" in size and had a pattern similar to the one used in the actual test figure. It was white in colour with a 2" black stripe along the right-hand edge and a black rectangle in the upper left-hand corner. This flag was used to explain the same or opposite side of the flag and various degrees of rotation. Each individual was shown three reference figures and an accompanying comparison figure for familiarization. The time was recorded with the help of a stop watch.

The following instructions were given to the subjects:

(a) Work as quickly and as accurately as possible but do not guess.

(b) The normal time alloted for this test is 5 min. You are not expected to finish the whole test within this time.

(c) At the end of 5 min you will be given the signal to mark the response number you are attempting at that time.

(d) After marking the response continue with the test at the same speed and accuracy.

(e) As soon as you finish all the responses give a call to the investigator immediately so that he can note the total time taken by you to complete the test.

(f) Wrong answers will count against you.

Three sub-scores were obtained from this test as follows:

(a) The correct score within the first five minutes, called as FM, measured the speed and accuracy.

(b) The total time taken to complete the test (FTT), which is predominantly the measure of the speed of performance.

(c) The total raw score, called the FRS, which mainly measures the accuracy of performance.

During the course of training, acquisition of flying skills is evaluated in various stages at frequent intervals. This assessment is carried out as a part of the training process and no special briefing/discussion with the flying supervisors was considered necessary. It is ensured that such an assessment is done carefully by independent examiners. All those flight cadets who do not form the grade are suspended from flying training at the respective stages. At the end of the advanced phase of training, their performance scores were obtained from the Headquarters Training Command under the following headings: Instrument Flying Training (IFT), Pilot Navigation Training (PNT), Low Level Navigation Training (LLNT), Close Formation Training (CFT), Night Flying Training (NFT), Aerobatics (Aeros), General Handling (GH).

All the cadets undergoing flying training at a flying training establishment were taken. They were administered these tests in batches of four. It was ensured that the subjects had a good night's sleep on the previous day and, to the extent possible, were free from any mental or physical problems. All the subjects were assured that the results of these tests would only be used for this study and would not, in any way, affect the outcome of their training.

The study generated data on spatial ability through the flag test. These were treated as independent variables whereas the performance scores were taken as dependent variables. The scores were subjected to statistical analysis, including descriptive statistics, correlation studies, multiple regression analysis and ANOVA using the advanced statistical programme SPSS-PC. The goal of the analysis was to determine the correlation between visuo-spatial abilities and navigation scores in particular and flying performance in general.

Results

The results of the flag test are shown in Table 1. Here FM represents the speed and accuracy of performance in 5 min, FTT shows the speed, whereas FRS is a measure of accuracy. The score on FM has a mean value of 54.62 ± 19.63

Table 1. Descriptive statistics: psychological test score (n = 44)

Test	Mean	SD	Range Min. – Max.
FM	54.62	19.63	16.00 – 93.00
FTT	11.45	3.15	8.00 – 21.15
FRS	114.41	5.81	95.00 – 123.0

Table 2. Descriptive statistics: performance scores ($n = 44$)

Parameter	Max possible score	Mean ± SD	Min	Max
IFT	600	404.68 ± 26.60	364	448
PNT	175	118.43 ± 6.96	105	113
LLNT	175	120.43 ± 9.28	105	141
CFT	400	275.55 ± 22.47	240	332
NFT	400	296.82 ± 15.78	244	330
AEROS	675	459.05 ± 34.43	405	557
GH	775	541.91 ± 44.85	481	667
TOT-FC	3200	2185.20 ± 111.49	2018	2261

Table 3. Intercorrelations: performance scores

	IFT	PNT	LLNT	CFT	NFT	AEROS	GH
PNT	0.50*						
LLNT	0.39*	0.48**					
CFT	0.41*	0.32	0.25				
NFT	0.60**	0.56**	0.55**	0.32			
AEROS	0.57**	0.60**	0.27	0.51**	0.43		
GH	0.70**	0.56**	0.32	0.49**	0.44*	0.82*	
TOT-FC	0.78**	0.63**	0.45*	0.65*	0.62**	0.89**	0.87**

*p < 0.01
** < 0.001.

Similarly, FRS has a mean value of 114.41 ± 5.81. Flight cadets scores are found to be on the higher side of the normative population on which this test was standardized [14].

Table 2 depicts the actual values of performance scores and Table 3 the intercorrelation of performance scores. There is no negative correlation amongst any of the component parameters. The overall scores have shown good correlation with all the component scores. The individual parameters are also well correlated with each other. This means that the performance of flight cadets has been assessed in a consistent manner and there are no obvious incongruities in the intercorrelation of various performance scores in flight cadets.

Table 4 depicts the correlation matrix of PTS and PS of flight cadets. Their overall score is significantly correlated with FM ($r = 0.35$). FTT has shown significant negative correlation with PNT, LLNT and NFT ($r = -0.43$, -0.46 and -0.41, respectively). FM has shown correlation with two of the component performance ratings, viz. CFT and NFT, whereas NFT and FRS have shown similar significant positive correlation. Scores on PNT and LLNT have significant negative correlation with FTT. This shows that navigational ability is predominantly related to the speed of mental rotation. IFT, GH and AEROS have not shown any correlation with any of the scales of the flag test. The result of this correlational study unambiguously points out the importance of the flag test in predicting scores on performance parameters of navigational test (PNT and LLNT) as well as the overall performance score, CFT and NFT.

Table 5 shows the regression analysis between performance parameters and psychological test scores in respect of flight cadets. This shows that a significant correlation between PNT and LLNT with FTT explains the variance of 18.8% and 20.7%, respectively. A similar significant regression between CFT and NFT with FM explains the variance of 14.4% and 20.4%, respectively. Further, the overall score has shown significant regression with FM,

Table 4. Correlations performance score (PS) vs psychological test score (PTS)

	FM	FTT	FRS
ITT	0.23	0.22	0.08
PNT	0.34	**–0.43***	0.25
LLNT	0.35	**–0.46****	0.25
CFT	**0.38***	0.34	0.11
NFT	**0.45***	**–0.41***	**0.35***
AEROS	0.28	–0.21	0.19
GH	0.27	0.22	0.16
TOT	**0.35***	–0.32	0.21

*p < 0.01
** < 0.001

Table 5. Correlation regression performance score vs psychological test score

Variables				
Depend.	Independ.	R^2	*F* ratio	Significance
PNT	FTT	0.188	9.741	0.003***
LLNT	FTT	0.207	10.976	0.002***
CFT	FM	0.144	7.079	0.011**
NFT	FM	0.204	10.746	0.002***
TOT	FM	0.124	5.966	0.019*

* < 0.05
** < 0.01
*** < 0.001

explaining 12.4% variance. These results of regression analysis confirm the findings of correlation matrices and give further insight into these relationships.

Discussion

In this study on comparison of visuo-spatial abilities and navigation score in flying training, actual flying performance has been used as a dependent variable. The independent variables are the three scores on the flag test, which form an index of mental rotation ability and are considered to be good predictors of performance.

Performance scores on various parameters of flying trainees form the most important index of this study. These parameters reflect a very crucial assessment of the aspirants for flying. The assessment is carried out by highly responsible staff in a proficient training environment of IAF responsible for the safety of Indian skies. The assessment resulted in a wastage of 27.18 – 36.43% in the last four batches and generally maintains the same trend. The scatter in the performance score of flight cadets endorses the consistency and robustness of the assessment technique.

Flag test was constructed by Thurstone and Jeffrey [14]. The authors have prescribed only 5 min time for the conducting of this test. The correct responses obtained in these 5 min constitute its score. In this study the method of administration has been modified in order to augment its versatility. The subjects were allowed to continue the test after 5 min in order to complete the test. As a result, three scores were obtained: (a) FM – flag test main score, which is in the order prescribed by the author; (b) FTT – total time taken to complete the test; and (c) FRS – total score obtained. The test scores measure the speed and accuracy in performance of this spatial orientation task in different combinations. FM measures both speed and accuracy; FTT measures predominantly speed and FRS is indicative of accuracy in the performance of this test.

Edward [15] has provided control data on flag test. He found a mean score of 51.7 ± 14.2 in 21 male subjects in the age group of 65–75 yr in the British population. In this study the score on FM is found to be close to this value. This shows that the results are comparable to those provided by Edward. However, there is one very glaring difference between the sample taken for this study and Edward's sample, i.e. age group. It is tempting to conclude that spatial orientation does not get affected by age. This aspect will have to be verified by future studies.

The score on FTT subscale predicts the performance of flying training on PNT and LLNT. This significant relationship explains 18.8% and 20.7% variance, respectively. FM is useful in predicting the performance in CFT and NFT and the overall performance of flying cadets. The general impression from this finding is that the speed of mental rotation (FTT) is more important during the initial stages than speed and accuracy.

Shepard and Herwitz [13] have surmised that mental rotation may be used to predict navigational ability. In this study the mental rotation task devised by Thurstone and Jeffrey [14] has been used due to the simplicity in its structure and administration. The task devised by Shepard and Herwitz [13] is much more complex and probably has greater sensitivity. The present study has shown that an old and simple test of mental rotation, i.e. the flag test, has an acceptable sensitivity in predicting flying performance and proficiency in the tasks which have good navigational elements. Moreover, the change in administration of the flag test adopted for this study has augmented its value for the objectives of this study. Findings in this study are also in agreement with those of Aretz [3], who concluded that mental rotation is the fundamental cognitive process in navigational task.

Logie and Baddeley [6] are conducting a study in which visuo-spatial ability is sought to be correlated with the space fortress task. The performance of the space fortress test is designed to be akin to flying performance. They have found good initial results on the relationship between visuo-spatial abilities and space fortress task. They have also highlighted that the relationship becomes weaker as automaticity is gained in the performance of the space fortress task. They have also highlighted that the relationship becomes weaker as automaticity is gained in the performance of the space fortress test. In the present study the performance is measured in actual flying conditions by time-tested methods in vogue at various flying training establishments of IAF. As such, the constraints of laboratory assessment of performance do not apply to this study. Keeping in mind this fundamental difference between this study and that of Logie and Baddeley [6], we could say that our findings endorse the findings of Logie and Baddeley.

Conclusion

In the light of the above discussion it can be concluded that this test is capable of predicting training performance on navigational and related tasks in flying. As such, this test can form a part of any psychological assessment in screening the candidates for flying training.

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