*Original Article*

# Preliminary validation of a computerised psychomotor test

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**Psychomotor skills have been recognised as a pre-requisite for aircrew selection, in addition to information processing skills, intelligence and personality traits. A computerised psychomotor test (PMT) apparatus was fabricated at IAM, consisting of two tests which measure pursuit and compensatory tracking abilities. The present study is a validation of these tests with the psychomotor tests of the PABT. Thirty-six candidates for flying branch who reported to IAM for medical examination (after being selected at No. 2 Service Selection Board, Mysore) were administered this test. These test scores were transformed using Angular Transformation tables and then correlated with the standarised scores on the SMA and CVT tests of the PABT, using Pearson's product moment correlation method. The scores of the PMT showed correlation ranging between - 0.416 to + 0.320 with the PABT scores, depending on the type of error score and the type of tracking task. Further validation studies are required to enhance the utility of the PMT for application in either clinical or selection assessment.**

Keywords: **Psychomotor abilities, validation, pursuit tracking, compensatory tracking**

The rapid advances in technology have resulted in the aviation industry emerging as one of the most expensive industries today. Selection has proven to be the most cost-effective method for putting the right man within the cockpit. However, changes within the cockpit need to be mirrored in the selection procedures if attrition is to be minimised.

Psychomotor skills have been recognised as a pre-requisite for aircrew selection, in addition to information processing skills, intelligence and personality traits [1]. These maybe explained as the ability to perceive information, integrate it with either existing templates in the brain or with other inputs, make logical decisions and perform some motor activity on the basis of these conclusions. Psychomotor tasks include both pursuit and compensatory tracking abilities. Pursuit tracking tasks are defined as a series of movements that are adjusted and coordinated, so as to keep in accord with a series of changes of movements, acting as a stimulus or a series of stimuli. Compensatory tracking tasks are movements, often reflex, of one part of the body in order to restore equilibrium. The present sensory

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motor apparatus (SMA) in use in the Indian selection procedure is a measure of compensatory tracking abilities and has descended from the Reid apparatus used by the Royal Air Force (RAF) during WW-II. Pursuit tracking tests were developed as early as 1920 in England. This was the genesis of the Controlled Velocity Test (CVT) [2]. These two, SMA and CVT, are being used even today as part of the Pilot Aptitude Battery Test (PABT) being administered at various selection boards in India.

The United States Air Force (USAF) used psychomotor screening of aircrew for selection between 1942 and 1955, after which it was discontinued. This was done, as the electromechanical equipment being used was difficult to maintain and calibrate. Improved computer technology provided the opportunity to test more complex co-ordination tasks and psychomotor abilities in a reliable and retrievable manner. The USAF reintroduced psychomotor tests after a gap of forty years in the early nineties during which they were computerised [3]. The RAF computerised SMA and CVT successfully and followed it up with converting their complete selection system into a computer-based model.

Validity of a test is expressed as a co-efficient of correlation known as validity co-efficient, in which the test scores are correlated with some objective performance criterion or with qualitative measures. Thus, it is a method of determining the correspondence between two sets of scores [4]. A high correlation coefficient of validity indicates that test scores predict the success of the behaviour under consideration very accurately.

Metastudies have shown that the highest predictive validity results from work sample tests (e.g., simulation) and ability composites consisting of combined scores from cognitive and psychomotor tests [2]. Thus, psychomotor abilities determine success in a job. They maybe considered as those in which our sensory or motor apparatuses are used with great skill. These have been classified as reaction time, speed of limb movement, wrist-finger speed, finger dexterity, manual dexterity, rate control dexterity and control precision [5].

A number of validation studies have reported that these tracking tasks correlate well with a dichotomous pass/fail criterion of pilot performance [6]. Compensatory tracking scores and pursuit tracking scores augment the validity when used along with cognitive pencil and paper tests as well as intelligence and personality tests. In the USAF, the Pilot Candidate Selection Method (PCSM) has incorporated these two tracking tasks into the selection batteries [7].

Validity of psychomotor tests has been measured worldwide since the post WW II scenario. Most studies measured only predictive validity. One study found that the complex co-ordination test was the best single predictor of pilot training success with a correlation of 0.45 based on a sample of over 1000 pilot candidates [8]. Newer studies have considered the validity of test batteries that have psychomotor tests as a part of a larger battery. A recent study showed tracking error scores from the psychomotor tests of the Basic Attributes Tests (BAT) of the USAF to be related to success in training with an $r = 0.256$, $p < 0.0001$ [9]. Other authors worked on the development of the PCSM using the PORTA-BAT for the psychomotor testing [7]. They found a multiple correlation value of 0.178 for the tests highly significant and of predictive value. Newer studies have shown that most test batteries used for pilot selection are measures of general cognitive ability or "g". Cognitive ability measures are found to be good predictors of job training ($r = 0.43$) and job performance($r = 0.34$). Psychomotor abilities show incremental validity of 0.02 to 0.04 over and above that of "g" [10].

Indian validation studies are few. Most studies are old and deal with the PABT as a complete battery rather than the role of psychomotor tests specifically. In one follow up study of 2,345 candidates at selection stage and 470 candidates at training stage study, the PABT showed a positive and significant correlation of the order of 0.35 with the pilot training results [11]. Other studies analysed the weights to be attributed to different PABT components to give the best possible predictions of success in basic flying, intermediate flying and advanced flying. It was found that the Instrument-Battery (INS-B) and CVT required greater weightage as compared to SMA for best prediction in flying in a ratio of SMA: CVT: INS-B: 1: 2: 2 [12]. In another study, the PABT scores yielded correlations equal to 0.34 and 0.24 with flying training marks at the intermediate and advanced stages of training [13].

The PMT equipment was fabricated vide AFMRC Project No. 2054/95 at IAM [3]. Two tests, one each for Two-Hand Co-ordination (THC) and Multi-Limb Co-ordination (MLC), were developed on the model of the USAF tests. These tests measure eye-hand co-ordination during pursuit tracking and compensatory tracking tasks. The tests were administered to 102 novices and 23 aircrew. It was recommended in the report that this apparatus should be made available to Air Force Selection Boards (AFSBs) for carrying out large-scale trials on all pilot candidates along with the prevalent tests for correlational analysis. Before these recommendations were implemented, validation of these tests for the user population was required. Validation of any test apparatus is an exhaustive and time-consuming process. Due to time constraints, determining predictive validity was not feasible.

**Aim**

The aims of this study were:

(a) To carry out concurrent validation of individual's psychomotor scores (using the PMT) with the PABT scores in use in the AFSBs.

(b) To develop database of psychomotor scores on the testing equipment for the user population.

## MATERIAL AND METHOD

A concurrent validation method was chosen. The existing PABT as in use in the AFSBs was used as a standard and scores generated by the apparatus were correlated against the scores of the psychomotor components of the PABT.

### Subjects

The PMT was administered to a total number of 136 subjects. The mean age of this group was 22.71yrs (Range 17 to 25 yrs.) and the mean educational qualification was 14.36 yrs. (Range 12 to 17 yrs.) Of these, 45 were candidates, 49 were aircrew, 31 were airmen, 4 were medical officers and one was a civil pilot. The remaining six subjects were college students.

The study required PABT scores of subjects who had done the psychomotor test on the test apparatus. Since PABT scores were not available for all these subjects, 36 candidates, who reported to IAM after clearing the service selection board at No. 2 AFSB, Mysore served as the test population. This sub group had a mean age of 17.95 yrs (Range 17 - 21yrs.). Of these, 32 were male and 4 female candidates. Their average educational qualification was 12.47 yrs.

### Test Apparatus

The PMT equipment used consists of a simulated cockpit structure provided with a centrally placed joystick and two-foot operated rudder style pedals along with a right-sided lever simulating the side-stick and a left-sided one simulating the throttle. An adjustable seat is present with a provision for changing the height of the seat in order to accommodate subjects of various heights. A computer console is positioned at the eye design point. There are two cabinets provided on either side of the console to house the CPU and the keyboard of the computer.

The two psychomotor tests, THC and MLC, are each of ten minutes duration. THC is administered first and requires pursuit tracking while MLC requires compensatory tracking ability.

**THC :** In this test a white circular target is presented on the screen, moving along a fixed elliptical path. The target has different speeds in the four quadrants of the screen. The subject is required to move a similar circular piper, slightly smaller in size to overlap the target. This is done by using the central column for side to side movements and either of the side controls (as chosen before the test) for the up and down movement of the piper. For this protocol, the left-sided lever was used. Ten iterations, each of sixty seconds were given; ensuring the subjects took their hands off from the controls in between two iterations.

**MLC :** Two targets, one circular, in the centre of the screen and another, a vertical bar just below the circle are provided. The subject is required to move another circle and vertical bar to overlap the targets. These pipers attain new random positions on the screen at regular intervals. Using the central column both horizontal and vertical movements of the circular target are controlled, while that of the vertical bar is controlled by the rudder pedals. Ten iterations of sixty seconds each are given.

PABT consists of three sub tests, two of which are psychomotor; SMA and CVT. SMA is a compensatory tracking task, which is a console-based test. Each candidate is given three chances, each of ninety seconds duration and the best score of the three is recorded. Two squares are marked on the screen, the smaller central black square and a blue coloured larger, the outer square. The candidate is required to try and keep a randomly moving target inside the inner square using the rudder pedals for horizontal movement and the central joystick for the up and down movements. An auditory signal is presented randomly to the candidates via headphones five times during one ninety-seconds test and is to be switched off with the help of a switch on the joystick. Two lights, one red and one white are on the left side of the console and are switched on intermittently seven and eight times in ninety seconds respectively. The red light is switched off by the forward movement of the throttle and the white light by the backward movement. Bringing the target in the inner square gives one mark, while half a mark is awarded for the outer square, as well as for switching off the audio signal or lights within three seconds.

Pursuit tracking is tested by the CVT. This is a rotating drum with serial, concentric paths, rotating at four rpm with the help of a motor. It is covered with 250 dots arranged in a non-linear fashion. A vertical pointer is available mounted on a horizontally moving bar which can be controlled by clockwise and anti-clockwise movements of a rotating lever. The pointer is to be made to overlap the dots to complete an electrical circuit. This causes a counter to move and the score is directly read off the counter.

Scoring

The scoring of the PMT is done in the form of a ratio between the maximum and minimum error scores. The first sixty seconds were used for the maximum error score without the subject operating the controls. The computer calculated the error score in millimeters twenty-five times a second for each iteration after the initial sixteen seconds, which are used for familiarisation. These values were then added to yield the error score for each of the ten iterations. The final score is a ratio between the maximum error score and the minimum error score calculated by using the mathematical average of the errors in the $x_1$- and the $y_1$-axis. Thus, a lower ratio signifies a larger error and a poorer performance while a higher ratio means a better performance.

For the second test, three ratios are generated - one for the circular target calculated with the averages of the errors on the $x_2$ and $y_2$ axis (i.e. the upper limb component), the second, for the vertical bar using error scores of displacement in the x axis only (called the $z_2$ scores or the rudder component) and the third, a composite value using a mathematical average of all the three error scores ($x_2y_2z_2$).

## PABT Scoring

The raw scores obtained from CVT and SMA of PABT are converted using normative tables. These are then added to the scores of the INS-B using a predetermined weightage to yield the summed equivalent scores (SUMMED EQ) of the PABT.

## Procedure and Statistical Analysis

The PABT scores of the 36 candidates were procured from SSB Mysore and the correlation was computed.

The PABT scores for both SMA and CVT are converted, using normative tables for standardisation, developed for the candidate population (SMA C and CVT C). The test scores using the PMT were converted using angular transformation tables, as these scores were in the form of ratios between the maximum error score and the minimum error score in ten iterations ($Tx_1y_1$, $Tx_2y_2z_2$, $Tx_2y_2$ and $Tz_2$). Unconverted minimum error scores were also used to find the correlation with the PABT scores ($x_1y_1$MIN, $x_2y_2z_2$MIN, $x_2y_2$MIN and $z_2$MIN ). In this case a low value of 'r' meant a better performance as error scores were used.

Pearson's product moment correlations were carried out using the Windows based Statistical Package for Social Sciences programme. These were calculated between the converted scores from PABT and the PMT for the 36 candidates. Correlations were computed between the scores of THC and MLC of PMT and CVT and SMA of PABT. The upper limb and rudder components of MLC were correlated separately with SMA and the summed equivalent scores (SUMMED EQ) of the PABT. A second set of correlations were computed using the minimum error scores instead of the ratio scores generated by dividing the maximum error scores and the minimum error scores. Finally, correlations between each of the scores and educational qualification was also done.

## RESULTS

Descriptive statistical values of both the general and the test groups are shown in Table 1.

**Table 1.**
**Descriptive statistics of untransformed ratio scores on PMT for general and test populations**

| Population | Statistics / Score | Min | Max | Mean | SD |
|---|---|---|---|---|---|
| General Population n = 100 | $x_1y_1$ | 1.19 | 10.47 | 4.58 | 2.01 |
| | $x_2y_2z_2$ | 1.39 | 4.31 | 2.56 | 0.64 |
| | $x_2y_2$ | 1.29 | 4.78 | 2.78 | 0.76 |
| | $z_2$ | 0.92 | 5.25 | 2.27 | 0.62 |
| Test Population n = 36 | $x_1y_1$ | 1.00 | 10.88 | 3.60 | 1.99 |
| | $x_2y_2z_2$ | 1.11 | 9.96 | 2.74 | 1.73 |
| | $x_2y_2$ | 0.90 | 4.19 | 2.45 | 0.67 |
| | $z_2$ | 0.88 | 9.18 | 2.58 | 1.73 |

**Correlation values**

**Inter-test correlations**: Three correlations were computed for the pursuit-tracking test of PMT with that of PABT. The final score of PABT was used for another two correlations. None of these were significant The correlation between THC and CVT as well as MLC and SMA were not significant. However, the value was higher for the pursuit tracking task than for the compensatory tracking task.

The compensatory tracking task of PMT was correlated with that of PABT to give six values, one each for the composite score (transformed and minimum error score) and two each for the upper limb and rudder component. The correlation using the composite minimum error score and the upper limb minimum error score were significant When the compensatory tracking task of PMT, i.e., MLC, was divided into its upper limb and rudder components, and inter-test relationship computed for each component with SMA, the result remained non-significant at the chosen level.

The same correlation, when computed using the minimum error scores instead of the ratio scores of PMT gave a higher value of r for the compensatory tracking task than for the pursuit-tracking task. The calculated value of r for $x_2y_2z_2$MIN and scores on SMA was –0.407 ($p<0.014$) which was a significant result. The components of MLC, when correlated with scores of SMA gave values that were not significant at the chosen level.

Inter test correlations were calculated between the ratio scores of each test of PMT with the final outcome of PABT (SUMMED EQ). The correlation of both the tests of PMT with the summed equivalent scores of PABT showed a non-significant result. The upper limb component of MLC showed a significant correlation with the summed equivalent scores resulting in an r of 0.393 ($p < 0.018$). The rudder component on the other hand, showed a negative r. When the minimum error scores were used, both correlations were non-significant. The relationship of the components of MLC against the summed equivalent score yielded values of $r = -0.379$ ($p < 0.023$) for the upper limb component which showed a significant relationship. However for the rudder component of MLC, the correlation was not significant.

Thus, out of the eight correlations carried out between the final score of PABT and the scores of PMT, only two (the transformed as well as the minimum error score for the upper limb component of MLC) were significant. Using the generated ratio scores, the THC test showed a higher correlation with CVT than MLC did with SMA, though both the values remained non-significant. When the minimum error scores were used, MLC showed a significant correlation with SMA, which was higher than the value obtained for two tests for pursuit tracking. However, all the results showed the upper limb component of SMA to be contributory to the final correlation while the rudder component showed the least correlation.

These results are summarised in Table 2.

**Table 2**

**Summary of inter-test correlations between PABT and PMT scores**

| PABT / PMT | CVT C | SMA C | SUMMED EQ |
|---|---|---|---|
| $Tx_1y_1$ | 0.303 ($p<0.072$) | - | 0.320 ($p<0.057$) |
| $Tx_2y_2z_2$ | - | 0.154 ($p<0.369$) | 0.210 ($p<0.220$) |
| $Tx_2y_2$ | - | 0.256 ($p<0.132$) | 0.393* ($p<0.018$) |
| $Tz_2$ | - | -0.014 ($p<0.936$) | -0.048 ($p<0.781$) |
| $x_1y_1$ (min) | -0.205 ($p<0.231$) | - | -0.233 ($p<0.172$) |
| $x_2y_2z_2$ (min) | - | -0.407 * ($p<0.014$) | -0.288 ($p<0.089$) |
| $x_2y_2$ (min) | - | -0.416 * ($p<0.012$) | -0.379 * ($p<0.023$) |
| $z_2$ (min) | - | -0.154 ($p<0.369$) | -0.006 ($p<0.970$) |

Levels of significance * $p < 0.05$

** $p < 0.01$

**Intra-test correlations**

The intra-test correlations for the PABT gave a significant value of $r = 0.78$ ($p < 0.01$) for the relationship between CVT and SMA. Similar correlations for PMT between THC and MLC yielded a much lower, non-significant value. Intra-test correlations were done between each of the two components of PABT with the summed equivalent score. For the pursuit tracking task, CVT, the value of r was 0.630 ($p < 0.01$) while for the compensatory tracking task, SMA, r was 0.915 ($p < 0.01$). The values for the correlation between educational status and the two tracking tests of PMT separately were also calculated and results showed a significant correlation with the ratio scores of THC with r=0.372 ($p<0.025$). The value for MLC was –0.051 ($p<0.769$). The correlations between the educational status and the summed equivalent score of PABT was a high 0.868 ($p=0.01$).

The results of the correlations using the summed equivalent scores were higher for the pursuit tracking tests than the compensatory tracking tests of PMT when the ratio scores were used, while those for the compensatory tracking task were higher when the minimum error scores were used. Educational qualification correlated significantly with the scores of the THC test indicating the role of psychometric 'g'.

**Discussion**

PMT developed for assessing pursuit and compensatory tracking abilities showed a positive but non-significant correlation with PABT. This result is corroborated by other studies done in the USAF (14).

In this study, the pursuit tracking tasks of the two tests had a higher correlation than the compensatory tracking tasks, though neither of these attained significance at the chosen level. The relationship between the upper limb component of MLC and SMA were also non-significant. The rudder component gave a negative correlation. However, when minimum error scores were used, the correlation between the two compensatory tasks was significant. THC and MLC were separately correlated with the final outcome of PABT. The greater contribution of the upper limb component was seen when both ratio scores as well as minimum error scores were used with both the values being significant at the chosen level. A previous study on this equipment found a significant correlation between the THC scores and the experience of the pilots as compared to novices [3].

The intra-test correlation within the two types of tracking tasks of PABT gave a highly significant value. This value is much lower and not significant for the two tasks of PMT. This suggests that both CVT and SMA possibly assess similar psychomotor functions whereas THC and MLC test more varied psychomotor abilities [14]. This can also explain the low values of r obtained between the two tests which maybe testing different specific abilities.

These results showed that the pursuit-tracking task had a low positive correlation significant at $p<0.05$ with CVT as well as with the summed equivalent scores, while MLC was not significantly correlated to SMA or the summed equivalent scores. Whether the vertical or the horizontal component of the first test contributed to this correlation cannot be deduced. In the MLC test, the vertical and the horizontal components together for the upper limb controls could be differentiated from the rudder controls. These scores ($tx_2,y_2$) showed a low positive correlation with both SMA as well as the summed equivalent score. Since the further components of the upper limb controls were not known, the contribution of $x_2$ and $y_2$ separately to this validity cannot be commented upon. However, from the quoted literature, it would seem reasonable to assume that these correlation values could be due to $x_1$ and $y_2$ components of the scores [2].

The lower r values in this study could be because of a number of reasons. Firstly, the sample size was extremely small and range restricted [15]. Secondly, the reported low predictive r-value of the PABT itself would decrease the values of the experimental tests in a concurrent validation [13]. A meta-analysis of sixty-six independent samples from fifty studies found validities ranging from 0.14 to 0.37 [16]. Psychomotor tasks, in combination with cognitive tests and information processing skills showed validities of 0.24. Since all values available in literature are either for predictive validity studies or for construct validation, they are higher than concurrent validation values in this study.

Another reason, which could contribute to this result is the fact that the psychomotor tests of PABT in their electromechanical form may not have a significant correlation with the dichotomous pass/fail criteria of training. The differential weightage for the psychomotor tests in the PABT may contribute to the low values of r obtained in this study. Another possible reason could be the difference in the methodology in that the scores of PABT are positive scores while those of the experimental tests are error scores. Also, since the scores generated by these two tests in our experimental setup are composite scores, i.e., arithmetic mean of the error scores in the x and y axis which are then used to derive a ratio, equal weightage is assigned to both the vertical and horizontal axes. This averaging will also cause lowering of the r value.

The present study had a number of limitations. Firstly, the sample size was small for the design of the study. Also, the test group was a biased population comprising of those candidates who had already passed PABT. This gave rise to the range restriction in the samples. The reliability and validity of PABT that was used as the standard for this study is itself not very high.

## Conclusion

Psychomotor skills have been recognised as a pre-requisite for aircrew selection, in addition to information skills, intelligence and personality traits. A computerised psychomotor testing apparatus was fabricated at IAM, consisting of two tests that measure pursuit and compensatory tracking abilities. This was administered to 136 subjects. PABT scores of 36 of these subjects were procured from AFSB, Mysore, and a cross-validation carried out between the two sets of scores. A large number of correlations were calculated between the two sets of scores to find a relationship between performance on PMT and PABT.

To summarise, the correlative relationship between PMT and PABT appear to be influenced by two factors. These are the *type of tracking task* and the *type of error scores* used for the correlations. The correlations for the pursuit-tracking task were higher when the ratio error scores were used while minimum error scores resulted in higher values for the compensatory tracking tasks. The cause for this difference can be determined by a detailed analysis of the components of the two tests to find out the contribution of each of them in the two scoring methods.

Psychomotor tests are also a good measure of general cognitive ability. Factor analysis has been able to identify a higher order "psychometric g" to which psychomotor test scores show a high correlation. Thus this computerised test maybe used as an indicator tool for assessment of psychomotor abilities in conditions like neuropathies and learning and cognitive dysfunctions in other neurological conditions. It may also prove to be of some merit in objectively assessing the efficacy of drugs in such conditions.

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