INVESTIGATING THE FACTOR STRUCTURE OF A SELF-ESTIMATE APTITUDE SCALE (SEAS) FOR USE IN CAREER GUIDANCE IN SINGAPORE SECONDARY SCHOOLS: AN EXPLORATORY CUM CONFIRMATORY FACTOR ANALYTIC STUDY

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INTRODUCTION

Research on development and validation of self-estimates of aptitude (or ability) is sparse. The majority of the self-estimate scales of aptitudes (or abilities) are of the one-item type, where the respondent is required to indicate on a scale, the extent he/she possesses that aptitude in comparison to others in his/her age groups. The Holland's Self Directed Search (1985) has a subcomponent on ability that is of this type. As these scales are of the one-item type, the quality in terms of reliability and validity are to a certain extent questionable. Dupont[1] (1985) attempted to develop a self-estimate aptitude measure of the multi-item type. Her scale is now adapted for use in the CHOICES program for computerised career guidance. The present study adapted part of the Dupont's scale to form the Self-Estimate Aptitude Scale (SEAS). Out of a pool of 84 items, 52 were selected for the study. The study looked into the factor structure of the scale using exploratory and confirmatory factor analysis procedures. The SEAS was theorized to be multidimensional consisting of six specific factors (traits, constructs) that the items were written to measure. These were verbal aptitude (Verapt), numerical aptitude (Numapt), form perception (Fomapt), spatial aptitude (Spaapt), clerical aptitude (Cleapt) and mechanical reasoning aptitude (Mecapt). (Refer Appendix A: Sample items of SEAS).

Thompson (1989), in a meta-analytic study reviewed seven sets of factor structures involving the Bem Sex Role Inventory. The results indicated that the inventory's primary factors were reproduced in the studies. The results supported the validity of the androgyny measure across several variations of sample types. Thompson observed that most of the studies used designs and methods of the factor analytic type; some employing confirmatory factor analysis, factor analysis of the variance/covariance matrices and extraction of second-order factors. Marsh (1985) investigated the 20 items Masculine/Feminine (M/F) scale of the Comrey Personality Scales using confirmatory factor analysis for testing the factor structure as well as the factorial invariance across groups. Using first-order as well as second-order factor analyses techniques he found that the M/F scale was multifaceted. In a later study, Marsh and Hocevar (1985), used the same technique to examine the factor structure of a self-concept scale. Byrne and Shavelson (1986, 1987), and Bryne (1989) also studied the structure of adolescent self-concept using the same technique. Khattab, Hocevar and Michael (1987) reanalysed correlational data from selected variables in the Guilford Aptitudes Research Project, using confirmatory factor analytical techniques. They found the factors were well-differentiated and in part supported the Guilford's structure of the intellect (SOI) theory. Later, Ulosevich, Michael and Bachelor (1991) used both exploratory as well as confirmatory factor analytic techniques to further examine the structure of SOI. Keith (1990) investigated the factor structure of the Differential Ability Scale (DAS) using the same technique.

It seems that the-state-of-the-art in the study of factor structure of certain scales, invariably will involve exploratory or confirmatory factor analytical techniques or both. The present study used the same techniques in the study of the factor structure of a self-estimate aptitude scale.

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1 The author wishes to thank the Ministry of Education, Singapore, for permission to administer SEAS in schools, and is grateful to Assoc Prof P. Dupont for permission to partly adapt her scale.

METHOD

An initial pool of 84 items of a self-estimate aptitude scale purporting to be multidimensional and measuring specific aptitudes was administered to a group of 1568 Secondary 3 and Secondary 4 students from the express and normal streams. 52 items from the initial pool were selected after preliminary factor analysis showed their parsimonious representation of the scale. These 52 items of the SEAS were subjected to exploratory as well as confirmatory factor analyses to investigate its factor structure.

The maximum likelihood factor analysis (Lawley & Maxwell, 1971) procedure was used in the study. This factor analytic procedure estimates the population correlation matrix under the assumption that the variables come from a designated number of factors. An advantage is that this procedure provides a Bartlett's χ^2 statistical test of significance for the null hypothesis that all of the population covariance has been extracted by the hypothesized number of factors. This procedure also gives several fit indices for the sufficiency of factors, including the Tucker-Lewis coefficient.

Seven criteria were used to determine the number of factors to be extracted for the factor solution: eigenvalues greater than one (Kaiser's criterion), Cattell's scree test, Bartlett's χ^2 test, Tucker-Lewis coefficient (Tucker & Lewis, 1973), the root mean square residues (RMSR, which denote the magnitude of the residue differences between the observed and reproduced correlation coefficients), the proportion of variance accounted for by the factors and the interpretability of the factor solution in relation to theory. Confirmatory factor analytic procedure using Lisrel, specifying *a priori* a certain factor structure was followed up to further ascertain the factor structure of the SEAS.

RESULTS

The 52 selected items were subjected to maximum likelihood factor analysis under the promax criterion and restricting the number of factors to six. In the case of the Secondary 3 sample, seven factors had eigen values greater than one, 'breaks' in the screeplot were observed between factors four and five, and between factors six and seven. The hypothesis of six factors being sufficient resulted in a significant χ^2 value of 1786.54 on 1029 degrees of freedom. The Tucker-Lewis coefficient was .93 and the root mean square residue was .026. The proportion of variance accounted for by the first six factors was as follows: F1=52.69%, F2=19.98%, F3=11.32%, F4=6.03%, F5=4.74% and F6=3.13%; making a total of 97.89%. The order of the factors under the promax criterion was Mecapt, Numapt, Verapt, Fomapt, Spaapt and Cleapt.

For the case of the Secondary 4 sample, eight factors had eigenvalues greater than one, 'breaks' in the screeplot again occurred between factors four and five, and between factors six and seven. The hypothesis of sufficiency of six factors resulted in a significant χ^2 value of 2285.77 on 1029 degrees of freedom. The Tucker-Lewis coefficient was .91 and the root mean square residue was .025. The proportion of the variance accounted for by the first six factors were as follows: F1=49.87%, F2=20.04%, F3=12.81%, F4=6.43%, F5=4.30% and F6=3.63%; making a total of 97.09%. The order of the factors generated after the promax criterion was Mecapt, Numapt, Fomapt, Verapt, Spaapt and Cleapt.

The above sets of figures showed that the six-factor structure characterized the data sufficiently well and can be taken to be parsimonious in explaining the item variance for the scale for both the Secondary 3 and 4 samples. Tables 1 and 2 give the comparative figures for criteria of sufficiency of factors for the cases of four, five, six and seven-factor models for the two samples. It can be seen that the six-factor model fitted the data very well and that the seven-factor model, in both the cases only offered marginal increments in all the fit statistics. Besides, the seventh factor in both cases was quite uninterpretable in the factor pattern analysis.

Table 1 Criteria for Sufficiency of Factors for Cases of 4, 5, 6 and 7-Factor Model for Sec. 3 Sample (N=739)

No. of Factors	Criteria: % of Variance Explained	χ^2	DF	Tucker-Lewis Coef.	RMSR*
4	90.02	2744.06	1124	.868	.038
5	94.76	2156.18	1076	.908	.031
6	97.89	1786.54	1029	.933	.026
7	100.19	1546.53	983	.948	.023

* Note: RMSR is the root mean square residue denoting the residue differences between the observed and reproduced correlation coefficients

Table 2 Criteria for Sufficiency of Factors for Cases of 4, 5, 6 and 7-Factor Model for Sec. 4 Sample (N=829)

No. of Factors	Criteria: % of Variance Explained	χ^2	DF	Tucker-Lewis Coef.	RMSR*
4	89.15	3452.59	1124	.840	.040
5	93.45	2821.40	1076	.875	.034
6	97.09	2285.77	1029	.906	.027
7	99.29	2018.17	983	.919	.025

* Note: RMSR is the root mean square residue denoting the residue differences between the observed and reproduced correlation coefficients

The results of the rotated six-factor pattern of the 52 SEAS items under the promax criterion for Secondary 3 was shown in Table 3. It can be seen that all the items loaded substantially and neatly on their respective target factors.

Table 4 shows the results of the rotated six-factor pattern of the 52 SEAS items under the promax criterion for the Secondary 4 sample. Here again, the factors loaded substantially and neatly on their respective target factors.

The several fit indices for the sufficiency of six factors were reasonably good, showing that in both instances, the six-factor structure of the SEAS was consistent across the samples. It was interesting to note that the orders the factors were generated for both the samples, were nearly the same except for the middle two, switching places.

Table 3 Promax (after Varimax) Factor Pattern, Six-Factor Model from Responses of Sec. 3 Students to 52 SEAS Items (N=739)

ITEM	FACTORS					
	F1	F2	F3	F4	F5	F6
SEAS73	85					(-25)
SEAS74	83					
SEAS76	82					
SEAS75	81					
SEAS83	76					
SEAS84	76					
SEAS77	74					
SEAS82	71					
SEAS78	70					(25)
SEAS81	62					
SEAS26		85	(-21)			
SEAS27		81				
SEAS31		79				
SEAS25		74				
SEAS28		68	(-21)			
SEAS29		62				
SEAS35		58				
SEAS30		57	(27)			
SEAS32		54				
SEAS36		46				
SEAS22			65			
SEAS23			65			
SEAS19			60			
SEAS14			58			
SEAS17			56			(24)
SEAS20			47			
SEAS12			47			
SEAS5			42			
SEAS13			42			
SEAS11			32			
SEAS41				70		
SEAS38				64		
SEAS39				63		
SEAS42				61		
SEAS44				61		
SEAS45			(20)	55		
SEAS43			(21)	50		
SEAS37				49	(25)	
SEAS46				46		
SEAS47				30		
SEAS58					70	
SEAS60					64	(29)
SEAS59					56	
SEAS51					51	
SEAS57					50	
SEAS54					31	
SEAS68						66
SEAS69						57
SEAS67						53
SEAS64			(25)			33
SEAS66				(27)		33
SEAS65				(20)		24

N.B. Figures denote loadings on factors, decimals omitted.
F1 = Mecapt, F2 = Numapt, F3 = Verapt, F4 = Fomapt, F5 = Spaapt, F6 = Cleapt.
(Only loadings | .20 | and above shown)

Table 4 Promax (after Varimax) Factor Pattern, Six-Factor Model for Responses of Sec. 4 Students to 52 SEAS Items (N=829)

ITEM	FACTORS					
	F1	F2	F3	F4	F5	F6
SEAS76	81					
SEAS74	80					
SEAS73	80					
SEAS77	79					
SEAS83	76					
SEAS75	75					
SEAS82	75					
SEAS84	75					
SEAS78	75					
SEAS81	64					
SEAS31		85				
SEAS27		83				(-20)
SEAS26		81				
SEAS25		72				
SEAS28		70		(20)		
SEAS29		67				
SEAS30		64				
SEAS35		58				
SEAS32		58				(22)
SEAS36		41	(22)			
SEAS41			74			
SEAS44			69			
SEAS45			65			
SEAS39			65			
SEAS42			62			
SEAS38			57			
SEAS37			53			
SEAS46			48			(25)
SEAS43			44			
SEAS47			36			
SEAS19				65		
SEAS17				58		
SEAS23				53		
SEAS14				51		
SEAS22				48		
SEAS10				46		
SEAS13				46		
SEAS5				44		(24)
SEAS12				43		
SEAS11				42		
SEAS60					75	
SEAS58					74	
SEAS59					66	
SEAS51					62	
SEAS57					54	
SEAS54					34	
SEAS68						64
SEAS67						62
SEAS69				(22)		60
SEAS66		(25)				40
SEAS65						36
SEAS64				(21)		34

N.B. Figures denote loadings on factors, decimals omitted.
F1 = Mecapt, F2 = Numapt, F3 = Fomapt, F4 = Verapt, F5 = Spaapt, F6 = Cleapt.
(Only loadings | .20 | and above shown).

All the items loaded substantially on their respective target factors except item SEAS65: Find hidden words in a text?, which had a loading of .24 on its target factor, Cleapt, in the Secondary 3 sample. This item, however, loaded substantially on its target factor in the Secondary 4 sample.

The rotation of factors under the varimax (orthogonal) criterion was first examined and compared to the results under the promax (oblique) criterion. It was found that for both the samples, the oblique solution was superior. The six factors although distinct were correlated to a certain extent (Median inter-factor correlation was .33 for both the samples).

To further investigate and ascertain the relationship of the items with their respective latent traits (factors), the 52 items of the SEAS were next subjected to confirmatory factor analysis (CFA), specifying **a priori** a six-factor model, allowing the factors to correlate (oblique model) as well as treating them as independent to each other (orthogonal model).

In the case of the Secondary 3 sample, a significant χ^2 value of 3459.51 was obtained on 1259 degrees of freedom for the oblique case. Ideally, one would expect to get a non-significant χ^2 value, indicating non-rejection of the hypothesis of fit of the model to the data. But, for sample sizes of this study, almost always, the χ^2 value would be significant. Hence we need also to look into the other indices of fit (Bentler & Bonnet, 1980; Joreskog & Sorbom, 1985). The goodness of fit index (GFI) was .818 and the adjusted goodness of fit index (AGFI) was .801, with the root mean square residual (RMSR) of .062. Here the GFI and the AGFI need to approach the value 1.00 and the RMSR should be small to indicate good fit. Examining the other indices like the standard errors, the modification indices and the Q-plot of standardised residuals, this set of figures suggested that the CFA of the six-factor model fitted the data reasonably well. For the orthogonal case, corresponding fit statistics were as follows: χ^2=4893.88 on 1274 degrees of freedom, GFI=.747, AGFI=.726 and RMSR=.184. Clearly, the oblique six-factor model is a better fit to the data than the orthogonal model. Table 4 shows the Lisrel estimates of factor loadings (lambda values) for each of the factors of the 52 SEAS items for the Secondary 3 sample. It can be seen here that all the loadings are significant and substantially high on their respective target factors.

Similarly, the 52 SEAS items for the Secondary 4 sample were submitted for confirmatory factor analysis, specifying **a priori** the same six-factor model, once again, allowing the factors to correlate as well as treating them orthogonal. Here a significant χ^2 value of 3821.15 was obtained on 1259 degrees of freedom for the oblique case (GFI=.826, AGFI=.810 and the RMSR=.062). Corresponding fit indices for the orthogonal case were as follows: χ^2=5064.34 on 1274 degrees of freedom (GFI=.769, AGFI=.750 and RMSR=.149). Again examining all the other indices of fit, the results showed that the six-factor oblique model fitted the data for the Secondary 4 sample reasonably well. Table 6 shows the factor loadings (lambda values) for each of the factors. Again, without exceptions, the items loaded significantly and substantially on their respective target factors. It can be seen from Tables 5 and 6, that item SEAS65 loaded significantly and substantially on its target factor. Relative to the rest, items SEAS14: Speak in front of others? and SEAS19: Explain something to others? in the Verapt subscale, seemed to have a little lower loadings, but still significant.

DISCUSSION AND CONCLUSION

The foregoing exploratory and confirmatory factor analyses show that a six-factor structure form a parsimonious solution for the 52 SEAS items. The results show that the SEAS is a multi-dimensional scale possessing six distinguishable subscales (although correlated to a certain extent), each purporting to measure a specific latent trait (aptitude) that the items were written to measure. There is strong evidence of construct validity in the factor structure of the SEAS. The well-ordered six-factor structure of the SEAS across the two samples show that this scale has consistent structure across groups. These items are students' self-estimates of their aptitudes. The SEAS then has the potential of being used in the career guidance situations and merit further investigation and study.

Table 5 Lisrel Estimates of Factor Loadings (Lambda) of Six-Factor Model under CFA of SEAS 52 Items for Sec. 3 Sample (N=739)

ITEM	FACTORS					
	F1	F2	F3	F4	F5	F6
SEAS5	513					
SEAS11	590					
SEAS12	539					
SEAS13	517					
SEAS14	485					
SEAS17	626					
SEAS19	493					
SEAS20	551					
SEAS22	552					
SEAS23	549					
SEAS25		637				
SEAS26		671				
SEAS27		754				
SEAS28		702				
SEAS29		714				
SEAS30		670				
SEAS31		724				
SEAS32		534				
SEAS35		642				
SEAS36		574				
SEAS37			607			
SEAS38			624			
SEAS39			648			
SEAS41			634			
SEAS42			634			
SEAS43			521			
SEAS44			635			
SEAS45			573			
SEAS46			575			
SEAS47			616			
SEAS51				669		
SEAS54				569		
SEAS57				662		
SEAS58				585		
SEAS59				665		
SEAS60				670		
SEAS64					600	
SEAS65					535	
SEAS66					614	
SEAS67					641	
SEAS68					592	
SEAS69					567	
SEAS73						739
SEAS74						805
SEAS75						762
SEAS76						799
SEAS77						769
SEAS78						710
SEAS81						725
SEAS82						738
SEAS83						781
SEAS84						639

N.B. Figures denote loadings on factors, decimals omitted.
F1 = Verapt, F2 = Numapt, F3 = Fomapt, F4 = Spaapt, F5 = Cleapt, F6 = Mecapt.

Table 6 Lisrel Estimates of Factor Loadings (Lambda) of Six-Factor Model under CFA of SEAS 52 Items for Sec. 4 Sample (N=829)

ITEM	FACTORS					
	F1	F2	F3	F4	F5	F6
SEAS5	568					
SEAS11	511					
SEAS12	515					
SEAS13	510					
SEAS14	489					
SEAS17	585					
SEAS19	470					
SEAS20	527					
SEAS22	523					
SEAS23	523					
SEAS25		648				
SEAS26		704				
SEAS27		786				
SEAS28		698				
SEAS29		695				
SEAS30		661				
SEAS31		772				
SEAS32		604				
SEAS35		640				
SEAS36		540				
SEAS37			613			
SEAS38			555			
SEAS39			627			
SEAS41			668			
SEAS42			637			
SEAS43			575			
SEAS44			674			
SEAS45			613			
SEAS46			560			
SEAS47			565			
SEAS51				727		
SEAS54				586		
SEAS57				696		
SEAS58				678		
SEAS59				734		
SEAS60				688		
SEAS64					588	
SEAS65					564	
SEAS66					604	
SEAS67					650	
SEAS68					536	
SEAS69					597	
SEAS73						749
SEAS74						795
SEAS75						776
SEAS76						802
SEAS77						804
SEAS78						775
SEAS81						723
SEAS82						772
SEAS83						771
SEAS84						614

N.B. Figures denote loadings on factors, decimals omitted.
F1 = Verapt, F2 = Numapt, F3 = Fomapt, F4 = Spaapt, F5 = Cleapt, F6 = Mecapt.

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Appendix A Self-Estimate Aptitude Scale (SEAS) (Sample items in compressed form)

The accuracy of this instrument depends upon how honestly and correctly you rate yourself in comparison to others in your own age group. Please answer the questions frankly by giving yourself a rating according to the rating scheme below:

			Rating
Top	10%	Very High	5
Next	20%	High	4
Middle	40%	Average	3
Next	20%	Low	2
Bottom	10%	Very Low	1

You will answer the questions in each aptitude. Rate yourself as accurately as possible according to the rating scheme. Record this rating in the separate answer sheet provided. A rating of 5 means your aptitude for that activity is very high, 4 means high and .... 1 means very low. Read the definition of each aptitude carefully and comparing yourself to others your own age group, rate yourself accordingly in the answer sheet provided for each of the questions from 1 to 84.

Verbal Aptitude: Verbal aptitude is defined as the ability to express oneself in words or in writing. Comparing yourself with others your own age group, how do you rate your ability to:

1. Respond sensibly in a discussion?
2. Understand ideas that are presented verbally or otherwise?
3. Give clear and precise information?

Numerical Aptitude: Numerical aptitude is defined as the ability to work with numbers quickly and accurately. Comparing yourself with others your own age group, how do you rate your ability to:

11. Work with numbers?
12. Do mathematical calculations quickly and accurately?
13. Add and subtract numbers quickly and accurately?

Form Perception: Form perception is defined as the ability to perceive slight differences in shapes, match things that are similar and distinguish things that are dissimilar. Comparing yourself with others your own age group, how do you rate your ability to:

21. See slight differences in shapes in drawings?
22. Notice minor scratches or imperfections?
23. Inspect objects for flaws, grains and texture?

Spatial Aptitude: Spatial aptitude is defined as the ability to perceive geometrical forms or objects in three-dimensional space. Comparing yourself with others your own age group, how do you rate your ability to:

31. Create well-balanced drawings?
32. Imagine how a box would look like when unfolded?
33. Picture a finished object from a sketch?

Clerical Aptitude: Clerical aptitude is defined as the ability to respond to perceptual tasks routinely. Comparing yourself with others your own age group, how do you rate your ability to:

37. Use a filing system to sort information?
38. Find hidden words in a text?
39. See details in a table of figures?

Mechanical reasoning aptitude: Mechanical reasoning aptitude is defined as the ability to understand the mechanical principles and laws of Physics. Comparing yourself with others your own age group, how do you rate your ability to:

43. Repair broken mechanical toys?
44. Reason out the direction of movement of certain gears in a system of gears?
45. Understand the working principle of a machine?