(The correct APA citation for this paper is: Fogarty, G., & Stankov, L. (1982). Competing tasks as an index of intelligence. *Personality and Individual Differences, 3*, 407-422)

COMPETING TASKS AS AN INDEX OF INTELLIGENCE

GERARD FOGARTY and LAZAR STANKOV

Psychology Department, University of Sydney, N.S.W. 2006, Australia

(*Received* 31 *December* 1981)

Summary—Most studies involving competing (or dual) tasks have been concerned with the investigation of models of attention and have stressed the importance of task characteristics in determining competing-task performance. The relatively few studies which have looked at individual differences in competing-task performance suggest that measures of this performance could reflect operations which are central to cognitive functioning. This paper examines two key questions which stem from this research: is there a separate ability involved in competing-task performance'? Is competing-task performance more indicative of general intellectual functioning'?

A battery composed of both single and competing tasks was presented to 91 Ss. Two sets of scores, primary and `secondary', were obtained from the competing tasks. The results indicate that `single' and `primary' scores are basically measuring the same thing but that secondary' scores measure what is perhaps a time-sharing factor. There is also some evidence that primary and secondary scores are more indicative of the general factor, as measured by this battery, than their single counterparts.

INTRODUCTION

The ability to perform intellectual tasks of non-trivial difficulty simultaneously has traditionally been considered a sign of superior capacity. Napoleon Bonaparte was, reportedly, able to dictate several letters at the same time in order to overcome the lag caused by his secretaries' motoric limitations. In the past and in our modern world as well, this capacity must have had great survival value. Hunters and warriors, businessmen, people working in the media, airline pilots and, in general, anyone forced to cope with a large amount of information must benefit from the possession of such a capacity. In this paper the term `competing task' is used to represent measurement operations intended to simulate these high-pressured situations. Other terms commonly used by researchers in this area include `multiple (or dual/concurrent) task', `time-sharing' and `divided attention'. These terms are often used interchangeably although it could be argued that they are associated with slightly different experimental paradigms. We prefer the term 'competing task' since it emphasizes the notion of competition between inputs without implying that we favour one attentional theory over another.* Our concern is more with individual differences in competing-task performance than with the microstructure of this performance.

Studies of competing-task performance go back many years. Introspectionísts were using rather difficult competing task combinations towards the end of the last century in their attempts to explore the limits of consciousness (e.g. Paulhan, 1887; Solomons and Stein, 1896; Downey and Anderson, 1915). Some early attempts were also made to explore individual differences in performance under these conditions. Binet (1890), for example, reported a study intended to measure the hypothetical general ability to divide attention. Broadbent and Heron (1962), and later Broadbent and Gregory (1965), studied age differences in the ability to perform two tasks simultaneously. Horn *et al*. (1981) used the Broadbent and Heron task to study the possibility that a decline in ability to divide attention is involved in the well-known decline in fluid intelligence with age.

Underlying most of these studies is the implicit assumption that a separate ability is involved in competing-task performance and that this ability can be tapped by any task combination. Even supposing this assumption to be correct, the problem of defining the nature of this ability would be great: the mechanics of competing-task performance are

* It should be noted, however, that a restricted range of competing tasks is used in the present study--only those involving auditory markers for primary abilities.

still uncertain. For many years cognitive psychologists have debated whether or not it is possible to divide attention between separate streams of information. Single-channel theorists (e.g. Broadbent, 1957) argued that division was not possible and that two tasks could be performed concurrently only by rapidly switching attention between the two. Multichannel theorists (e.g. Allport *et al.*, 1972) argued that division was possible and that two, or even more, tasks could be attended to simultaneously. The current popularity of capacity models of attention, such as that proposed by Kahneman (1973), has led to theoretical accounts of competing-task performance which employ notions such as the distribution of available resources over competing tasks. The net effect of much of this research has been to highlight the importance of task characteristics. Whichever attentional model one favours, it is clear that some tasks are easier to combine than others: perhaps one task requires little attention (i.e. it has become automatic); perhaps the arrival of the stimuli allows for rapid switching between the tasks; perhaps the tasks do not share processing structures. This focus of interest on task characteristics has led to some rather detailed specifications of the conditions under which tasks may be successfully combined. Fisher (1975), for example, took the view that the tasks had to be structured in such a way that rapid switching was possible. Greenwald (1972), on the other hand, believed that the `ideomotor compatibility' of the competing responses was the critical factor. Welford (1968) thought that it was a question of `stimulus–response compatibility'. Peterson (1969) took the broader view that it was mostly a function of the processing requirements of the tasks concerned and proposed that tasks could be classified into one of three levels according to the amount of attention required for their execution. The levels range from the simple emission of automatic responses to the rather complex transformation of input required by some tasks.

There is no doubt that this line of research has made a significant contribution to our understanding of competing-tasks performance. What is lacking, however, is a similarly detailed investigation of the individual characteristics important for this performance. The fact that one individual may find a particular combination easy and another find that same combination very difficult is no less interesting than the finding that some tasks are easier to combine than others. From a practical viewpoint alone, given the increasing complexity of many job situations, it is important that we try to understand the nature of the abilities involved in competing-task performance. One question concerns the prediction of this performance; considerable effort is being directed towards the construction of personnel selection tests which will provide some indication of those individuals most suited to jobs involving high information load. The main question of interest is whether or not the competing-task situation requires the same set of abilities as is required for performance of the single tasks. The alternative view is that there is a separate `time-sharing' ability which comes into play in a competing-task situation. The need for a detailed investigation of this `time-sharing' ability becomes obvious when one considers that there are suggestions in the literature that an ability to `divide one's attention' could play a major role in determining individual differences in performance on cognitive tasks. Horn (1980), for example, indicates that the decline in fluid intelligence with age can be accounted for by the lack of ability (or inclination) to divide attention. Hunt (1980) suggests that the ability to divide attention might underlie the presence of positive manifold and the general factor of intelligence. Setting aside the perhaps unresolvable question—is it possible to divide attention—it is apparent that these authors agree that an important ability is involved in situations wherein two or more tasks compete for limited attentional resources. This paper investigates this assumption.

An indication that competing tasks tap important intellectual processes comes from a study by Thurstone (1944). Thurstone included a test of two-handed coordination in a battery of perceptual tests. He found that this test loaded heavily on a factor which he identified with an ability to manipulate two configurations simultaneously or in succession. The other tests which loaded on this factor were reasoning tests. Thurstone was very taken by the fact that a two-handed coordination task (i.e. a motor task) could appear to be measuring the same sort of thing as a complex verbal reasoning test. He regarded this factor as being of great psychological interest, probably representing an important aspect of intelligence. Again, there is the implication that additional processes are involved in competing-task performance and that these processes are more closely linked with commonly accepted notions of intelligence.

Some recent studies have questioned the assumption that a separate time-sharing ability is involved where there is competition between tasks. Sverko (1977) compared performance on single tasks with performance on those same tasks administered under competing-task conditions. He found that the common variance of a component of a competing task is shared with the same task when it is given singly. On the basis of this finding, Sverko concluded that there is no time-sharing ability and that performance under the competing-task condition can best be predicted from the single tasks. However, in a more recent paper, using slightly different tasks and with some improvements in procedure, Sverko reverses his original decision and reports that a factor which was associated mainly with competing tasks was measuring a separate time-sharing ability (Sverko *et al.,* 1981). There is the suggestion that this factor has the status of a primary ability in a Thurstonian sense.

Sverko's results were obtained with combinations of relatively simple reaction-time, motor coordination and mental arithmetic tests. In our own laboratory, research which has some bearing on these questions has emerged from within the psychometric tradition. Stankov (1981) included in a battery of thirteen psychometric tests a competing task whose components were markers for two different primary factors. He noted that whereas the correlation between the two tests was about 0.26 when presented singly, this correlation rose to 0,55 when the tasks were presented together. Stankov suggested that this increase in the shared variance of the two tasks may indicate a greater involvement of the general factor in the competing-task situation. It is worth noting that out of the six dual tasks used by Sverko (1977), four showed a similar pattern.

Thurstone's study made a direct comparison between a measure of competing-task performance and other measures of intelligence. Others have been more concerned with practical problems associated with the prediction of competing-task performance. The study to be reported here is a follow-up of Stankov's (1981) work. It is based upon nine psychometric tests, most of which have been used previously, and six competing tasks formed by presenting pairs of these tests dichotically. The main interest will centre on observing what happens to the factorial structure if a battery of tests contains both single and competing tasks. Three possibilities are suggested by the literature: (a) competing tasks may load on the same factors as their single counterparts; (b) there may be a time-sharing factor involving the components of the competing tasks; and (c) there may be an increase in the general factor loadings as a consequence of competition. Of course, these are not exclusive possibilities: any combination of them, or all three, can materialize.

METHOD

Subjects

Subjects *(N* = 91) were largely Psychology 1 students who undertook to act as Ss in fulfillment of course requirements. The remainder were Adult Education students from the University of Sydney. The average age of Ss was 22.3 yr. Subjects with hearing difficulties were excluded.

Test battery—sing!e tests

Ten single tests were selected for inclusion in the battery. The tests were selected in such a way that they might serve to define four well-replicated primary factors in Gf/Gc theory (Horn, 1973; Horn and Stankov, 1981; Stankov, 1978; 1979; Stankov and Horn, 1980). It was hoped that the emergence of a clear factorial structure in the single tests would serve as a basis for comparison with previous studies which have used these tests and also as a basis for comparison with results involving competing tasks. The 10 single tests were:

1. *Chord Decomposition*—a three-tone chord was followed by three individually played tones. The *S* had to decide whether the separate tones were the same as those played in the chord(S), or whether one had moved up (U) or down (D) (after Wing. 1962).

2. *Tonal Memory*—pairs of tonal sequences comprising 3, 4 or 5 notes. One of the notes always changed in the second sequence, the task was to indicate the position of the note that had changed (after Seashore *et al.,* 1960).

3. *Tonal Reordering*—identical to Letter Reordering (Variable 7) except in that tones are used instead of letters. (Tests 3 and 7 from Stankov and Horn (1980)).

4. *Tonal Series*—a series of 6, 7 or 8 tones was played. The *S* was required to work out the rule for the series and then select, from among three notes played at the end of the sequence, the one which continued the series. The answer would be 1, 2 or 3 (Stankov and Horn, 1980).

5. *Tonal Counting*—three tones are repeated a number of times in a sequence. The same three tones are used in all of the items and are identified as `low', `medium' and `high'. Sequences were either 6, 7 or 8 tones in length but the Ss did not know the length beforehand. The task was to keep track of the number of times each of these three notes appeared in the sequence (after Massaro (1975).

6. *Letter Memory*—identical to Tonal Memory (variable 2) except in that letters were used in place of tones.

7. *Letter Reordering*—three letters (R, S, T) were presented, the *S* was asked to note the order in which the letters were presented. The same three letters were then repeated but usually in a different order, the task was to write the order of the letters on the second playing.

e.g.	S	T	R	(1st playing	………	T	R	S	(2nd playing)
	1	2	3			2	3	1	
					Ans = 231				

8. *Letter Series*—a series of 6, 7 or 8 letters was read out. The S was required to work out the rule for the series and then to write the next letter in the series. Again, this was a new test in the sense that it is usually presented in a visual form. There was some doubt that this standard induction test could be presented in an auditory form, especially with such short sequences.

9. *Letter Span*—sequences of 6, 8 or 10 letters which the S was required to reproduce.

10. *Digit Span*— as above, except that digits were used.

The tests are grouped and numbered in this fashion so that setting out will be consistent with that used in the Results section. This division of the battery into tonal and letter tests was unintentional. In fact, tonal and letter tests were often intended to serve as markers for the same factor. Letter Memory, for example, was constructed in the hope that it would serve as an additional marker for the auditory primary, Discrimination Among Sound Patterns (DASP), which has in the past been defined by Chord Decomposition and Tonal Memory (e.g. Stankov and Horn, 1980). Letter Reordering, Tonal Reordering and Tonal Counting have all been used as markers for the auditory primary, Temporal Tracking (Tc) (e.g. Stankov and Horn, 1980) and it was expected that they would define the same factor in this study. Tonal Series has been used as a marker for another auditory primary, Auditory Cognition of Relations (ACoR) (e.g. Stankov, 1980) and it was hoped that it would combine with Letter Series to define an inductive reasoning factor. The two memory-span tests were included as a check on the importance of a memory-span factor in competing-task performance.

As a general comment on the selection of these 10 single tests it must be pointed out that the aim was to define four factors and to select the components of the competing tasks in such a way that within factor and across factor combinations would be formed.

Tonal Memory/Letter Memory, for example, would be a within factor combination (DASP/DASP), whereas Tonal Memory/Letter Reordering would be an across factor combination (DASP/Tc). Comparisons between these combinations would be of some theoretical interest.

However, it must be clear to the reader familiar with factor analytic procedures that most of these factors are likely to be underdetermined in the present battery. In some cases there is the risk that there are too few markers (ACoR, Ms) and in other cases `markers' are being used for the first time, their failure would also result in the factor being underdetermined. Sacrifices of this nature were necessitated by the already large size of the battery: as it stood, the complete battery took 5 hr to administer. The achievement of a clear factorial structure among the single tasks was of primary importance, the achievement of the particular structure outlined above was considered desirable but of secondary importance. The former is sufficient to enable comparisons between single- and competing-task performance, the latter would enable comparisons between this performance and some standard Gf/Gc factors.

Test battery—competing tasks

Seven of these single tests were selected for inclusion in a set of six competing tasks. The aim was to take three of the hypothesized primary factors (DASP, Tc and ACoR) and to form the competing tasks in such a way that all possible pairings of these factors were represented. There are six possible pairings: DASP/DASP, DASP/Tc, DASP/ACoR, Tc/Tc, Tc/ACoR, ACoR/ACoR. The Ms factor was not included. Since the tests comprising these competing tasks were to be presented dichotically, it was felt that every effort should be made to make the stimuli as discriminable as possible. Accordingly, pairings were always made between letter and tonal tests. The battery of single tests was initially selected with this aim in mind. Thus, in each of the competing tasks to be described here, a tonal test came to one ear and a letter test to the other. This design, although it had the effect of making the stimuli discriminable, posed other problems. The main problem was that ear differences had often been observed with tonal and letter stimuli. A left ear advantage has often been associated with tonal stimuli (cf. Gates and Bradshaw, 1977) and a right ear advantage for letter stimuli (e.g. Kimura, 1973). Stankov (1980) found ear differences with some of the tests used in this battery. In order to control for ear difference effects, each of the six competing tasks appeared twice in the battery. One week after the first presentation of a competing task, Ss were required to attempt the same task with inputs reversed. The competing dual tasks used were:

1. *Letter Memory/Tonal Memory*—both tasks were simplified somewhat in that the sequences consisted of only 2, 3 or 4 stimuli. The S had to detect the position of the tone that had changed in one ear and the letter that had changed in the other. An item with three stimuli could be represented as follows:

(answers given in parentheses)

Left ear(letter task)	R	X	T		R	S	T	
						(2)		
Right ear(tonal task)	do	fa	re		do	fa	la	
								(3).

2. *Letter Reordering/Tonal Reordering*—in previous applications of the reordering tasks it was known which were the easier items, these items were used in the construction of this task. A typical item was like this:

Left ear(letter task)	R	S	T		S	T	R
					(2)	(3)	(1)
Right ear(tonal task)	do	mi	so		mi	do	so
					(2)	(1)	(3).

3. Letter Series /Tonal Series—in the single-task condition Ss were required to write the next letter in the series or, in the case of the Tonal Series task, to indicate which of three tones, presented at the end of a series, would have continued that series. In the competing task, so that there might be a perfect correspondence between the tasks, it was necessary to adapt the Letter Series test to the format of the Tonal Series test. Accordingly, both series were presented, followed by a very brief pause, then three letter/tones were presented. The *S* had to indicate which of the letters (1st, 2nd or 3rd) continued the letter series and, at the same time, decide which of the three tones (1st, 2nd or 3rd) continued the tonal series which had come to the other ear. A typical item could be represented as follows:

Left ear(tonal)	do	re	re	mi	mi	mi	re	ti	fa
									(3)
Right ear(letters)	A	Z	B	Y	C	X	W	D	E
									(2).

4. Letter Reordering/Tonal Memory—in this case the Tonal Memory test was restricted to three stimuli so that it could fit in with the reordering test. With Tonal Memory, Ss were required to write the position of the tone that had changed in the second playing (1, 2 or 3); with the reordering task, they had to write the order of the letters on the second playing, e.g.

Left ear(tonal)	so	ti	re	do	ti	re
				(1)		
Right ear(letters)	S	R	T	S	T	R
				(1)	(3)	(2).

5. *Letter Series/Tonal Memory*—a major problem with the Letter Series test was that it had to be restricted to eight letters in the dual tasks. The reasons for the limitation are obvious when one considers the nature of some of the tests with which the Letter Series test is paired. Tonal Memory would have been too difficult with more than four stimuli in each sequence. The options were to abandon dichotic presentation for this pairing or to restrict the sequences in the series test to eight stimuli. The first option was not appealing: dichotic presentation was used in this study since it represented the strictest form of the competing-task situation. The second option was favoured and the single test itself was constructed with a limit of eight stimuli in each sequence to enable greater comparison with dual-task performance. The problem with this second option is that, with 24 items in each application of this test, it was very difficult to introduce a wide range of series. In this particular competing task, Tonal Memory consisted of sequences of 2, 3 or 4 tones with the corresponding Letter Series items comprising 4, 6 or 8 letters. The Letter Series test reverted to its original form wherein Ss were required to write the next letter in the series, e.g.

Left ear(letter task)	D	E	F	G	
					(H)
Right ear(tonal task)	mi	do	mi		
					(2).

6. *Letter Series/Tonal Counting*—in this pairing the tonal sequences contained either 4, 5 or 6 stimuli with the series items of corresponding length. For the tonal task, the *S* was required to keep track of the number of times a low note, a medium note, and a high note appeared in a given sequence. The answer was always a three-digit number. In the series task the *S* simply wrote the next letter in the series, e.g.

Left ear(tonal task)	fa	fa	ti	fa	do	ti				
							(1	3	2)	
Right ear(letter task)	K	J	I	H	G	F				
								(E).		

Overall, there were 22 tests in the battery: 10 single tests and 6 + 6 (each was administered twice) competing tasks. In order to facilitate comparisons between scores obtained from single and competing conditions, the actual tests were kept as similar as possible across these conditions. In the experimental literature, tasks typically remain unchanged across conditions. Usually the main point of such studies is to observe and measure the extent of the decrement in performance in the dual-task condition. In the present study, with the emphasis shifting to a correlational analysis, it was important to achieve a reasonable spread of scores in both conditions. This meant that tests had to be made somewhat easier for inclusion in the various competing tasks. This was usually achieved by omitting the most difficult of the single-test items and in some cases, introducing items which were easier than any of those included in the single tests. The end result of these manipulations is that roughly two-thirds of the items are retained across conditions. This effectively invalidates any comparison of means across conditions unless the analysis is based upon only those items which remain unchanged. This analysis has not yet been carried out. The results reported in later sections are based upon the complete tests.

PROCEDURE

Each single test consisted of 24 items. Ear of presentation was varied so that 12 of the items went to the left ear and 12 to the right. This procedure was followed in order to allow for closer comparison with the dual-task situation where, by necessity, each of the tasks was presented to separate ears. Thus, for each single test it was possible to derive a left ear score, a right ear score and a total score. This concern with possible ear difference effects has already been explained. MI tests, in both single and competing conditions, were presented through stereophonic headphones. Instructions and practice exercises accompanied each test. An experimenter was always present to answer queries. The tonal tests were prepared with a synthesiser. Test stimuli were presented at intervals of 300 msec with 5-sec pauses for answers. Subjects were required to note their answers on a prepared scoresheet.

With the competing tasks, Ss were instructed to attempt to solve both tasks although only one was important on each trial. Following the simultaneous presentation of the tonal and letter tests, a voice cue in the appropriate ear instructed Ss to answer either the tonal or the letter task. The postcuing technique was used to discourage Ss from concentrating on what they might consider to be the easier task. Following this postcue, Ss wrote the answer to that task on a black line on a specially designed answer sheet. If they did not know the answer they were asked not to guess but to leave the question unanswered. However, if they were able to answer this task and they were also able to answer the other task, they were instructed to write the answer to the other task on an adjoining dotted line. The importance of the cued task was stressed. Subjects were to write the answer to the other task if and only if, they had been able to solve the first. This provision for the answer to both tasks represented a departure from the procedure adopted by Stankov (1981). Its success depended upon the Ss following the instructions and not putting an answer on the dotted fine unless they were reasonably certain that they had correctly answered the cued task. Thus, instead of having only the answers to the cued tasks, as in the Stankov study, we have the additional information supplied by these second answers. Henceforth, the answers to the primary tasks will be referred to as `primary' scores and the answers to the non-cued tasks will be called `secondary' scores (bearing in mind that these two terms have a different usage in the experimental literature). Each competing task consisted of 24 items, on half of these the postcue would be *letters* and on the other half it would be *tones*.

The fact that each competing task was administered twice meant that it was later possible—assuming no ear differences—to combine scores from the two presentations and to obtain four sets of scores, each marked out of 24, from the one competing task. In the case of Competing Task 1, these scores would be: Letter Memory (primary) and (secondary) plus Tonal Memory (primary) and (secondary).

The order of presentation of the tests was systematically varied with the proviso that no competing task was attempted before the relevant single tests had been attempted. For any given *S*. the first two tests were always single tests and the third test would be the combination of the two in either its original or reversed form. The fact that testing was done in groups of less than 4 Ss meant that it was possible to ensure an equal distribution of Ss over all possible orders of presentation.

Testing was carried out in two sessions, each of 2½ hr. duration, with a period of 1 week between sessions. Each session was broken up as much as possible to allow the Ss some respite from these very demanding tests. The two presentations of each competing task were always separated by 1 week.

RESULTS AND DISCUSSION

Preliminary analyses

Two major statistical techniques were used in analysing the data. The first of these is subprogram Reliability from the Statistical Package for Social Scientists (SPSS). This subprogram provides a means of evaluating multiple item scales through the computation of coefficients of reliability (in this study, Cronbach's alpha was used). The program provides basic summary statistics including item means, standard deviations, item to scale correlations and summary statistics of the item means, variances, inter-item correlations and covariances. The other technique was factor analysis based on image analysis and orthoblique rotations as embodied in Little Jiffy, Mark IV (Kaiser and Rice, 1974).

As noted previously, in the single tests items were presented to each ear alternately. This procedure was followed in case ear differences turned out to be an important variable and it became necessary to compare left and right ear scores on the single tests. In fact, this situation did not eventuate and in this paper all such scores are combined. This meant that the single-test scores were to be based on a total of 24 items, 12 of which had been presented to the left ear and 12 to the right. Competing-task scores were treated in the same fashion. Each competing task had been presented twice to enable the component tests to be prepared to each ear. Thus, for Competing Task 1, Letter Memory came to the left ear on one presentation and to the right ear on the other. These scores were combined in the analyses which follow. In general, there is no evidence that ear differences affected scores in either single- or competing-task presentations. There were some exceptions: for example, right ear scores were lower than left ear scores for some tonal tests—this was in accordance with some other findings of ours but these differences were not noteworthy and did not warrant the continued separation of left and right ear scores.

Preliminary analyses also showed that two of the single tests, Memory Span Letters and Memory Span Numbers, formed a doublet. They were highly correlated (0.70) compared to the root-mean-square correlation of 0.41 for all tests and they had almost identical factor loadings in a factor analysis of all single tests. On these bases, the two tests were combined to form a single variable—Memory Span (Ms).

These changes meant that we were left with a battery of 33 variables: 9 single tests, 12 primary tasks and 12 secondary tasks. Reliability analyses were conducted on these variables. As a result of these analyses some items were deleted and the reliability of that scale reassessed. The aim was to achieve the highest possible internal consistency reliability before commencing a more extensive analysis of these tests. Table 1 includes the final estimates of reliability for each scale and the number of items upon which this estimate is based. All future analyses refer to these (in some cases revised) scales.

Table 1. Summary statistics for all variables

Variables	X	S	Reliability*	No. of items
Single				
1. Chord Decomposition (CD)	17.00	4.58	0.82	24
2. Tonal Memory (TM)	18.45	4.26	0.83	24
3. Tonal Reordering (TR)	14.04	4.64	0.81	24
4. Tonal Series (TS)	11.32	3.95	0.74	20
5. Tonal Counting (TC)	7.87	4.90	0.84	24
6. Letter Memory (LM)	20.12	3.17	0.81	24
7. Letter Reordering (LR)	18.68	4.41	0.84	24
8. Letter Series (LS)	9.48	3.29	0.69	20
9. Memory Span (MS)	22.00	4.90	0.86	48
Competing tasks – primary				
10. Tonal Memory (with LM)	16.39	3.93	0.75	24
11. Tonal Memory (with LR)	14.98	4.25	0.76	24
12. Tonal Memory (with LS)	11.67	3.77	0.67	24
13. Tonal Reordering (with LR)	8.50	4.23	0.76	24
14. Tonal Series (with LS)	7.30	2.96	0.51	20
15. Tonal Counting (with LS)	6.84	4.28	0.77	24
16. Letter Memory (with TM)	18.98	2.86	0.59	24
17. Letter Reordering (with TM)	17.87	3.81	0.73	24
18. Letter Reordering (with TR)	15.84	3.70	0.73	24
19. Letter Series (with TM)	8.01	3.49	0.70	21
20. Letter Series (with TS)	10.28	3.04	0.59	21
21. Letter Series (with TC)	6.68	2.83	0.60	20
Competing tasks – secondary				
22. Tonal Memory (with LM)	13.37	6.20	0.89	24
23. Tonal Memory (with LR)	7.93	5.63	0.89	24
24. Tonal Memory (with LS)	4.32	4.45	0.72	24
25. Tonal Reordering (with LR)	3.24	3.21	0.78	24
26. Tonal Series (with LS)	2.80	3.24	0.80	24
27. Tonal Counting (with LS)	0.70	1.34	0.82	22
28. Letter Memory (with TM)	16.34	5.60	0.89	24
29. Letter Reordering (with TM)	9.80	6.03	0.88	23
30. Letter Reordering (with TR)	4.45	4.84	0.88	24
31. Letter Series (with TM)	4.03	3.09	0.88	24
32. Letter Series (with TS)	5.65	4.50	0.84	24
33. Letter Series (with TC)	2.14	2.67	0.69	20

* Cronbach's alpha coefficient of reliability used throughout.

Table 1 presents summary statistics for all variables. It is fairly clear that scores in the competing-task condition are lower than single scores. This is in spite of the fact that single tests were simplified somewhat before inclusion in these combinations. It is also evident that secondary scores are lower than corresponding primary scores. This is not surprising since the primary scores came from the answers to the postcued tasks whereas secondary scores were obtained only where Ss were able to attempt this primary task and then also answer the non-cued task. In some competing tasks, for example Letter Memory combined with Tonal Memory (variables 10, 16, 22, 28), Ss did not experience much difficulty in responding to both tasks. In other instances, for example Letter Series combined with Tonal Counting (variables 15, 21, 27, 33), Ss experienced great difficulty.

It is also worth noting that reliabilities of the primary scores are lower than those of single and secondary scores. The most likely explanation is that Ss did not always follow instructions to attend equally to both tasks. Some Ss admitted that they focussed on just one of the tasks, others admitted that they tried to guess what the postcued task would be. Such variations would tend to lower the reliabilities of the primary scores. Subjects did not do this to such an extent with the secondary scores where it was fairly obvious when a S had attempted the secondary task when, contrary to instructions, they had not been able to attempt the primary task. Consequently, reliabilities are higher for secondary scores.

Table 2 presents the correlations obtained between all 33 variables.

Table 2. Correlations between all variables*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1																																	
2	65																																
3	66	65																															
4	44	48	55																														
5	51	47	48	50																													
6	11	27	21	15	32																												
7	31	54	52	33	41	13																											
8	13	19	28	20	35	30	36																										
9	38	47	43	29	51	39	34	36																									
10	59	72	65	59	56	37	54	29	56																								
11	46	51	59	43	52	47	40	33	46	65																							
12	46	39	43	38	43	22	29	23	38	54	56																						
13	57	68	77	58	54	21	52	31	50	63	63	57																					
14	38	44	37	46	44	22	17	11	34	48	38	48	49																				
15	43	46	53	52	61	28	40	42	51	58	58	47	66	50																			
16	23	33	17	37	49	44	29	27	47	48	46	43	35	39	48																		
17	34	47	46	28	37	41	44	38	51	50	50	45	47	31	45	52																	
18	30	50	37	34	32	42	36	26	54	50	36	27	42	29	34	56	71																
19	12	22	31	20	36	40	24	49	34	35	42	36	31	16	31	34	37	32															
20	24	33	31	30	35	41	21	42	33	37	41	49	34	33	30	37	49	43	50														
21	23	37	27	26	46	40	32	51	44	42	46	29	28	21	42	41	53	45	36	51													
22	51	60	59	54	58	34	49	24	56	70	66	55	63	45	62	56	36	35	28	25	35												
23	42	53	54	45	58	27	52	25	55	60	62	52	60	45	52	46	44	33	31	33	30	78											
24	37	39	42	45	48	17	35	12	33	48	39	57	50	36	43	41	27	21	19	33	17	63	70										
25	46	47	56	50	56	10	40	24	50	50	40	45	67	42	53	39	40	35	16	18	20	60	66	66									
26	37	30	27	38	48	07	22	10	25	34	31	37	35	35	33	43	19	20	02	21	25	55	59	75	62								
27	21	24	41	37	39	13	22	13	39	35	32	29	49	37	46	36	38	36	14	19	20	41	48	61	64	53							
28	31	44	40	51	49	39	49	40	52	55	52	37	46	28	55	58	38	35	33	31	43	80	71	56	52	51	39						
29	25	40	43	43	54	27	53	37	47	45	52	39	45	32	47	49	50	37	34	28	35	66	79	58	64	55	44	75					
30	25	26	32	37	47	10	39	22	38	31	29	32	39	26	36	42	30	26	09	17	16	51	63	61	81	64	53	56	75				
31	21	23	37	45	52	26	38	44	37	35	45	35	45	24	43	44	32	28	43	44	33	55	60	59	55	54	54	65	67	56			
32	22	19	22	29	38	17	27	21	18	15	23	11	21	09	17	21	13	16	16	30	27	34	46	53	41	63	33	50	56	49	56		
33	15	15	23	27	35	12	19	22	22	17	20	12	29	24	32	29	20	20	09	15	26	32	40	55	54	59	75	39	46	52	60	54	

*Decimal points omitted.
Correlation coefficients greater than 0.20 are significantly different from zero at the 0.05 level.

Results

The results of a factor analysis of all 33 variables are presented in Table 3. It is apparent that three first-order factors and one second-order factor can best account for the covariation present in our data. It is also apparent that factors which guided our selection of tests in this study did not appear. This is a consequence of the fact that an insufficient number of markers for Temporal Tracking, Auditory Cognition of Relationships, Tonal Memory and Memory Span were included in our battery. We shall devote more attention to the second-order factor in a later section of this paper.*

First-order factors

The first-order solution of Table 3 displays a rather interesting feature of the present data. Namely, it is apparent that Factors I and II have properties which are clearly different from those of Factor III. These differences exist with respect to content – the first two factors involve tonal and verbal material, respectively, while the third factor cuts across the content category – and with respect to the mode of presentation: the third factor involves mainly variables from the secondary components of the competing tasks whereas the first two factors have salient loadings from single and primary components.†

It is tempting to use a content category to label the first factor as something akin to Tonal Memory. This term is a commonly used label for a primary factor which has appeared many times in work on musical abilities and variables 1, 2, 10, 11 and 12 from our battery have consistently defined it in previous work. It is apparent, however, that Factor I also involves more complex operations with tones as exemplified by Tonal Reordering (variables 3 and 13), Tonal Series (variables 4 and 14) and Tonal Counting (variables 5 and 15). This means that processes represented by this factor are broader than tonal memory and that they probably implicate fluid intelligence to some extent. Another possibility is suggested by our previous work with auditory tests (e.g. Horn and Stankov, 1981; Stankov, 1978). Auditory variables in this work define a broad auditory function, Ga, which transcends tonal quality and involves perception of rhythm and perception of distorted or distracted speech. For this reason we prefer to refer to Factor I as broad auditory function (Ga) —although calling it a 'tonal' factor would probably do as well.

The second first-order factor is certainly broader in its scope than the first factor. Although it is somewhat restricted in content, being mostly defined by letter tests, there are also loadings from some tonal tests (variables 5 and 11). Furthermore, there is no preponderance of markers for a particular primary factor: several primary factors are about equally represented. The problem this time is that two broad factors seem to be equally responsible for the emergence of this factor. Fluid intelligence (Gf) is indicated by markers for a Temporal Tracking primary factor (variables 5, 7, 17 and 18) and inductive reasoning (variables 8, 19, 20 and 21). On the other hand, a short-term acquisition and retrieval function (SAR) (see Horn, 1976) is indicated by Memory Span (variable 9) and Tonal and Letter Memory tests (variables 6, 11, 16). Since older literature and some recent findings (see Stankov *et al.*, 1980) indicate that it is sometimes hard to separate Gf and SAR factorially, fluid intelligence might be a preferred label for Factor II. Conversely, since memory may be seen as a limiting factor propagating individual differences

* It is important to note that root-one criterion applied to the correlational matrix (with ones in the main diagonal) of Table 2 indicates seven factors at the first order. Latent roots corresponding to these principal components are 14.17, 9.30, 3.08, 2.26, 1.33, 1.01. Maximum likelihood criterion, on the other hand, suggests that a smaller number of factors would provide a satisfactory fit. We decided to retain three factors at the first order after a series of exploratory analyses using different criteria of factor extraction, different procedures of analysis and different selections of variables. Factors beyond the first three are either blown-up singlets or doublets and as such do not qualify for the status of a primary factor. The first three first-order factors account for 80% of the total variance.

† In order to check on the possibility that the first two factors were not a consequence of the fact that parallel forms of the same variables were included in the analysis (e.g. Letter Series and Tonal Memory each appear three times), we obtained six separate solutions each involving the nine single tests plus the primary components of a particular competing task. These six analyses, therefore, were each based on 11 variables. Since the obtained results did not differ appreciably from the results of Table 3, they are not presented here.

Table 3: First and second-order factor solution and first principal component for 33 variables*

Variables	1st principal component	2nd order factor	1st order factors			
			I	II	III	SMC§
Single						
1. Chord Decomposition (CD)	57	46	60	-06	00	70
2. Tonal Memory (TM)	67	55	55	04	-14	75
3. Tonal Reordering (TR)	70	57	59	07	00	79
4. Tonal Series (TS)	63	51	33	02	14	61
5. Tonal Counting (TC)	72	58	20	18	21	68
6. Letter Memory (LM)	41	31	-06	53	-28	55
7. Letter Reordering (LR)	58	48	21	20	02	62
8. Letter Series (LS)	44	35	-11	49	-15	56
9. Memory Span (MS)	65	55	19	30	-05	61
Competing tasks-primary						
10. Tonal Memory (with LM)	76	62	48	15	-14	78
11. Tonal Memory (with LR)	72	59	30	30	-13	74
12. Tonal Memory (with LS)	62	52	34	12	00	71
13. Tonal Reordering (with LR)	77	63	57	-06	07	83
14. Tonal Series (with LS)	54	43	35	-01	06	55
15. Tonal Counting (with LS)	52	41	32	17	03	68
16. Letter Memory (with TM)	64	51	-06	45	02	70
17. Letter Reordering (with LM)	63	50	13	45	-22	77
18. Letter Reordering (with TR)	57	45	13	39	-21	70
19. Letter Series (with TM)	43	35	-03	50	-27	56
20. Letter Series (with TS)	51	40	00	48	-22	68
21. Letter Series (with TC)	72	58	-05	54	-24	63
Competing tasks-secondary						
22. Tonal Memory (with LM)	83	68	28	16	20	86
23. Tonal Memory (with LR)	82	69	15	18	34	82
24. Tonal Memory (with LS)	72	59	11	-04	57	82
25. Tonal Reordering (with LR)	77	64	26	-12	56	86
26. Tonal Series (with LS)	63	50	-03	-04	66	78
27. Tonal Counting (with LS)	51	41	08	-05	52	79
28. Letter Memory (with TM)	77	63	-07	40	24	84
29. Letter Reordering (with TM)	78	64	-13	35	39	87
30. Letter Reordering (with TR)	65	54	-09	03	67	85
31. Letter Series (with TM)	70	57	-17	32	40	69
32. Letter Series (with TS)	49	39	-25	18	50	69
33. Letter Series (with TC)	61	49	-17	02	62	75

* Decimal points omitted.
† Salient loadings from Little Jiffy's first-order solution are underlined.
‡ Details regarding hierarchical solution employed here can be found in Stankov (1980).
§ `SMC' = squared multiple correlation.

in Temporal Tracking (see Stankov and Horn, 1980) and possibly in the series task used here, this factor might be called SAR. Since with the available data we cannot decide one way or the other, it is probably best to display our indecision by calling this factor Gf/SAR.*

It is important to note that both Ga and Gf/SAR factors are defined mostly by single and primary scores. Furthermore, there is a close correspondence between the loadings of any single test and its primary task equivalent. Lack of additional information would justify the claim that competing tasks do not measure more than is measured by single tasks. However, the presence of the third factor raises some doubts about such a conclusion. This factor represents a new and important finding since it provides evidence that secondary components of the competing tasks do measure something distinct and common to all but two of them. It is possible that this is an example of the elusive 'time-sharing' factor. Its emergence with the secondary components could only be explained by

* In the older literature on fluid and crystallized intelligence, Gf and SAR were treated as identical.

proposing that secondary scores, in this study, are a better measure of divided attention in that they require that both primary and secondary components be attempted. This is, of course, a *post-hoc* explanation. It is assumed that primary scores provide a measure of divided attention but that this measure is weakened to some extent by failure of some Ss to attend equally to both tasks. This raises the possibility that the third factor may represent some instructional artifact – perhaps an inclination, not necessarily the ability, to answer the non-cued component. At present we favour the view that the secondary scores defined a third factor because they provided a better measure of divided attention.

Competing tasks and general factor loadings

In addition to the three first-order factors, covariation among the test scores may be accounted for, in part, by the second-order factor. This factor reflects the presence of positive manifold typical of cognitive tests and in this section we will look at what happens to this broad factor when the battery contains competing tasks.

Since Stankov (1981) was alerted to the possibility of an increased involvement of the general factor by the presence of higher correlations between the components of the competing tasks, it is logical to begin our investigation by examining the pattern of correlations obtained with our competing tasks. Table 4 presents the correlations

Table 4. Correlations between single, primary and secondary scores

	Single		*Primary*		*Secondary*	
	r	*p**	*r*	*p*	*r*	*p*
1. Letter Memory – Tonal Memory	0.27	0.33	0.48	0.72	0.80	0.90
2. Letter Reordering – Tonal Reordering	0.52	0.63	0.42	0.56	0.81	0.98
3. Letter Series – Tonal Series	0.20	0.30	0.33	0.60	0.63	0.77
4. Letter Reordering – Tonal Memory	0.54	0.65	0.50	0.67	0.79	0.89
5. Letter Series – Tonal Memory	0.19	0.26	0.36	0.53	0.59	0.74
6. Letter Series – Tonal Counting	0.35	0.47	0.42	0.62	0.75	1.00
mean *r* =	0.35	0.44	0.42	0.62	0.73	0.88
mean *r* †=	0.35	0.45	0.42	0.58	0.74	0.81

* *p* = correlations corrected for attenuation.
† mean *r* = average calculated after applying Fisher's transformation to raw correlations.

between the single, primary and secondary components. It can be seen that for almost all competing tasks, correlations increase as one moves from single to primary and thence to secondary scores. In Competing Tasks 2 and 4 there is no increase but this could be due to the already high correlations between single scores (in the 0.50's). Otherwise, there are no exceptions to this pattern. Furthermore, when reliabilities are taken into account and correction is made for attenuation, the trend becomes very clear: shared variance of competing tasks increases relative to single-task presentation. It should be noted, however, that the increase in correlation from single to primary tasks is smaller than the increase from primary to secondary tasks. At the 0.05 level, non-directional tests of the differences between single- and primary-task correlations indicate that only in Competing Task 1 (Letter Memory/Tonal Memory) is there a significant difference between coefficients.* When directional tests are applied the results indicate that there is a significant difference between the coefficients in Competing Task 5 (Letter Series/Tonal Memory) as well. Differences between the primary and secondary correlations and, of course, between single and secondary correlations, are all significant. This is in agreement

* The test for statistical significance applied here is, strictly speaking, inappropriate. This test, based on Fisher's z-transformation, is designed to indicate whether an obtained correlation *(r)* is likely to have come from a population with a correlation coefficient *(p)* (see Hays, 1963, p. 529). Our own inappropriate use of this statistic involves the treatment of the second correlation coefficient as if it were the population value, *p*. In this way, it as analogous to testing whether a sample mean comes from a distribution with a specified population mean. What is needed is a proper test of the differences between two, in our case `correlated', correlation coefficients.

with the finding that there is a certain similarity between the single and primary scores and implies that the effects of competition will be more pronounced with the secondary scores of this study. The question of whether this increase reflects the greater involvement of the general factor begs another question: what do we mean by the general factor? In this post Spearmanian era, the general factor is typically defined in terms of the first principal component or, relatedly but not necessarily equivalently, in terms of the highest-order factor obtained from a battery of cognitive tests. Setting aside important problems related to the sampling of variables and Ss with our particular test battery, there are several ways in which one can look at changes in general factor loadings.

One way is by reference to the first principal component and the second-order factor of Table 3. It can be easily ascertained that loadings of single tests are generally lower than corresponding competing-task measures. In fact, the average loading of single tests on the first principal component is 0.60 whereas corresponding values for primary and secondary scores are 0.62 and 0.69, respectively. The same trend is apparent with the loadings of the second-order factor (0.48 for single, 0.50 and 0.56 for primary and secondary). On these grounds it is reasonable to claim that components of the competing tasks used in our battery represent better measures of the general factor than do their single-task equivalents.

It can be observed, however, that all competing tasks include variables which were constructed to serve as parallel forms of certain single tests. It is conceivable that this parallelism may be responsible, at least in part, for the particular nature of the general factor of this battery. In other words, it may be claimed that the general factor is the way it is simply because there are repetitions of the same test in our battery. Higher loadings of the components of the competing tasks could occur as a consequence of this parallelism. This reasoning suggests a different strategy for looking at the changes in the general factor loadings. As a first step, calculate the value of the first latent root (or simply the proportion of total variance accounted for by the first factor) with nine tests only. Secondly, the same indices can be obtained from another battery involving single and competing tasks. This second battery can be formed by starting with the nine single tests and replacing a pair of single tests with either their primary or their secondary counterparts. After that, another pair of single tests can be replaced, and so on until all possible replacements have been made. The final battery would be the same size as the original battery of nine single tests but it would now consist of some single and some competing tasks. No parallelism would be present.*

With our data, the first latent root from the battery of nine single tests is 4.157 or 46.2% of the total variance. When a battery of single and primary tasks was constructed according to the above principles (involving single variables 1, 6 and 9 and primary scores 10, 16, 13, 18, 15, 21) the first latent root was 4.629, which accounted for 51.1% of the variance. When another battery was constructed with the same single scores and the following secondary scores – 22, 28, 25, 30, 27, 33 – the first latent root was 4.727, which represented 52.5% of the variance. Thus, with this measure as well, it can be seen that the inclusion of competing tasks increases the amount of variance accounted for by the first principal factor. Whether this increase is noteworthy or not is a different matter. The increase of 5–7% may appear small. On the other hand, since the effort to change the loadings is of theoretical interest and since a limited number of studies have addressed this issue, the present findings are important. From our data, it does appear that competing tasks involve the general factor to a greater extent than do the component single tests. At this stage, however, a few cautionary comments are necessary. It can be observed that our battery of tests does not contain variables based on verbal material involving comprehension, knowledge or fluent production. Nor does it contain material involving visualization, perceptual speed, etc. There are no markers for speediness or carefulness. This effectively rules out the possibility that the general factor obtained in

* The procedure described in the text is, in fact, a compromise. Ideally, it would be desirable to compare the analysis involving only competing tasks. This was impossible since two of the nine tests, Memory Span and Chord Decomposition, were not given under competing conditions.

our battery is the same as Spearman's general factor. For the same reasons, it could not be identified as crystallized intelligence, long-term storage and retrieval function, broad visualization, or a number of other broad functions. Conceptually, the most appropriate label for the factor obtained in this battery is fluid intelligence measured, as it were, with auditory tasks. We are constructing competing tasks involving other broad functions in order to see whether this same increase in general factor loadings will be repeated.

In interpreting the present data it should also be noted that our sample is rather homogenous with respect to educational level and general ability. One would expect that a heterogeneous sample would provide more pronounced effects than those reported here. Supporting evidence is present in Stankov's (1981) work. Stankov found a larger increase in correlations between single and primary scores than the increases reported here. He also found that primary scores have a higher correlation with educational level than their single counterparts.

CONCLUSIONS

A battery of nine auditory psychometric tests was presented to a group of 91 Ss. Seven of these tests were selected for inclusion in a set of six competing tasks which were then presented dichotically along with the single tests. Subjects were instructed to attend equally to both competing tasks but a verbal postcue instructed them to answer just one of the tasks. From these answers a set of primary scores was obtained. Subjects were then instructed to attempt the other task if, and only if, they had been able to attempt the primary task. Thus the battery yielded two sets of competing task scores – primary and secondary – for comparison with single scores. The main points of interest lay in possible changes in the pattern of abilities involved in competing-task performance as opposed to single-task performance. To reiterate, the possible changes were: (a) competing tasks could load on the same factors as their single counterparts; (b) a separate time-sharing factor may be involved with competing-task performance; (c) there may be an increase in general factor loadings as a consequence of competition; (d) some combination of the above may result.

The results of our study indicate that when primary scores are used as the index of competing-task performance, both single- and competing-task scores are measuring the same thing. Evidence for this lies in the high correlations between the two measures and also in their very similar factorial patterns. However, when secondary scores are used, there is some indication that a separate ability is involved in competing-task performance. The evidence for this comes from the third factor of Table 3, which is defined exclusively by the secondary scores. Secondary scores probably provide a better measure of divided attention in this study because they mostly reflect the situation wherein Ss were able to answer both tasks. We conclude that the presence of this third factor with secondary scores offers some support for Sverko *et al.'s* (1981) finding that a separate time-sharing ability is associated with dual-task performance. However, we offer this conclusion with some reservations: it is possible that this third factor represents some sort of instructional/strategical artefact.

There is also support for claims that competing-task performance draws more heavily upon the general factor. In this study, the highest-order factor is certainly not *`g'* – the range of tests is too restricted – but is more likely representative of fluid intelligence (Gf). Various analyses conducted in this study, including examination of first principal component loadings and second-order factor loadings, indicate that competing-task measures have higher loadings on these factors. These loadings increase as one moves from single, to primary, to secondary scores. This finding ties in with Stankov's (1981) work. A study currently being planned at this university should help to decide whether or not competing tasks might serve as a good index of a more broadly defined general factor. At this stage, it seems safe to conclude that competing tasks, as opposed to single tasks, will certainly draw more heavily upon whatever general factor is measured by a particular battery of tests.

REFERENCES

ALLPORT D.A., ANTONIS B. and REYNOLDS P. (1972) On the division of attention: a disproof of the single channel hypothesis. *Q. Jl exp. Psychol.* **24**, 225-235.

BINET A. (1890) La concurrence des etats psychologiqes. *Revue Philosoph. France L'etranger* **29**, 138-155.

BROADBENT D.E. (1957) A mechanical model for human attention and immediate memory. *Psychol. Rev.* **64**, 205-215.

BROADBENT D.E. and GREGORY M. (1965) Some confirmatory results on age differences in memory for simultaneous stimulation. *Br. J. Psychol.* **56**, 77-80.

BROADBENT D. E. and HERON A. (1962) Effects of a subsidiary task on performance involving immediate memory by younger and older men. Br. *J. Psychol.* **53**, 189-198.

DOWNEY J.E. and ANDERSON J. E. (1915) Automatic writing. *Am. J. Psychol.* **26**, 161-195.

FISHER S. (1975) The microstructure of dual task interaction: 1. The patterning of main-task responses within secondary task intervals. *Perception* **4**, 267-290.

GATES A. and BRADSHAW J. L. (1977) The role of the cerebral hemispheres in music. *Brain Language* **4**, 403-431.

GREENWALD A.G. (1972) On doing two things at once: time-sharing as a function of ideomotor compatibility. *J. exp. Psychol.* **94**, 52-57.

HAYS W.L. (1963) *Statistics* Holt, Rhinehart & Winston, New York.

HORN J.L. (1973) Theory of functions represented among auditory and visual test performances. In *Contribution* of *Multivariate Analysis to Psychology* (Edited by ROYCE J.R.), pp. 203-239. Academic Press, New York.

HORN J.L. (1976) Human abilities: a review of research and theories in the early 1970's. *A. Rev. Psychol.* **27**, 437-485.

HORN J.L. (1980) Concepts of intellect in relation to learning and adult development. *Intelligence* **4**, 285-319.

HORN J.L., DONALDSON G. and ENGSTROM R. (1981) Apprehension, memory and fluid intelligence decline in adulthood. *Res. Aging* **3**, 33-84.

HORN J.L. and STANKOV L. (1981) Auditory and visual factors of intelligence. *Intelligence.* In press.

HUNT E. (1980) Intelligence as an information processing concept. *Br. J. Psychol.* **71**, 449-474.

KAISER H. and RICE P. (1974) Little Jiffy, Mark IV. *Educ. psychol. Measur.* **37**, 111-117.

KAHNEMAN D. (1973) *Attention and Effort.* Prentice-Hall. Englewood Cliffs, New Jersey.

KIMlJRA D. (1973) The asymetry 0f the human brain. *Scient. Am.* **228**, 70-78.

MASSARO D.W. (1975) *Experimental Psychology and Information Processing.* Rand McNally, Chicago.

PAULHAN F. (1887) La simultaneite des actes psychiques. *Revue Scient.* **39**, 684-689.

PETERSON L.R. (1969) Concurrent verbal activity. *Psychol. Rev.* **76**, 376-386.

SEASHORE C.E., LEWIS D. and SAEVEIT J.C. (1960) *Manual of Instruction and Interpretation for the Seashore Measures of Musical Talent,* 2nd Revision The Psychological Corporation, New York.

SOLOMONS L. and STEIN G. (1896) Normal motor automatism. *Psychol. Rev.* **3**, 492-512.

STANKOV L. (1978) Fluid and crystallised intelligence and broad perceptual factors among 11-12 year olds. *J. educ. Psychol.* **70**, 324-334.

STANKOV L. (1979) Hierarchical factoring based on image analysis and orthoblique rotations. *Multivar. behav. Res.* **14**, 339-353.

STANKOV L. (1980) Ear differences and implied cerebral lateralisation on some intellective auditory factors. *Appl. psychol. Measur.* **4**, 21-38.

STANKOV L. (1981) The role of competition in human abilities. *Multivar. behav. Res. Monogr.* Submitted for publication.

STANKOV L. and HORN J.L. (1980) Human abilities revealed through auditory tests. *J. educ. Psychol.* **72**, 21-44.

STANKOV L., HORN J.L. and ROY T. (1980) On the relationship between Gf/Gc theory απd Jensen's Level I/Level II theory. *J. educ. Psychol.* **72**, 796-806.

SVERKO B. (1977) Individual differences in time-sharing ability. *Acta Inst. Psychol.Univ. zagreb.* No. 80.

SVERKO B., JERNEIC Z. and KULENOVIC A. (1981) Prilog istrazivanju sposobnosti za simultano djelovanje. *Acta Inst. Psychol. Univ. zagre.* In press.

THURSTONE L.L. (1944) A factorial study of perception. *Psychomet. Monogr.* No. 4.

WELFORD A.T. (1968) *Fundamentals of Skill.* Methuen, London.

WING H.D. (1962) A revision of the Wing Musical Aptitude Test. J. *Res. musical Educ.* **10**, 743-791.