WHICH ABILITIES DOES THE PASAT TEST?

IAN J. DEARY,* SARAH J. LANGAN,1 DAVID A. HEPBURN2 and BRIAN M. FRIER2

1Department of Psychology, University of Edinburgh, 7 George Square, Edinburgh EH8 9JZ, Scotland
2Department of Diabetes, Royal Infirmary of Edinburgh, Lauriston Place, Edinburgh EH3 9YW, Scotland

(Received 2 February 1991)

Summary—The relationships between PASAT test scores and intelligence, memory and information processing abilities were examined in ninety-four healthy young adult patients with Type 1 (insulin-dependent) diabetes. PASAT scores correlated significantly with all WAIS-R subtests. Factor analysis revealed that PASAT performance loaded on the 1st principal component (the ‘general intelligence’ factor) at about the same level as some WAIS-R performance subtests. Varimax rotation showed that PASAT scores had very low loadings on verbal and performance factors, but had high loadings on the third rotated factor, which was tentatively identified as the ‘freedom from distraction’ factor found in recent factor analyses of the WAIS-R. Scores from the 4 second PASAT presentation correlated better than 2 second PASAT scores with indices derived from the Rey auditory verbal learning test, whereas the faster PASAT test correlated at higher levels with tests of Inspection Time and Reaction Time. The PASAT test was developed to measure attention and concentration but, while this appears to have been realised to some extent, general intellectual ability is also tapped by the test. Different speeds of presentation might index other abilities to different degrees, but this finding might be explained by order effects which cannot be excluded by the present study.

INTRODUCTION

The PASAT test was developed by Gronwall (1977) as a measure of information processing capacity. The test requires the subject to listen to a series of digits (which are less than or equal to 9) played on a tape recorder. The subject must add the numbers according to the following rule: add the 1st number to the second and tell the tester the answer, add the second number to the third and give the answer, and so on. Normally, 61 digits are played (giving 60 answers). The task may be made progressively more difficult by reducing the fixed time interval between the digits. One common form of the test allows the subject to practice and then presents a series of digits at four second intervals followed by a series at two second intervals.

Gronwall and Wrightson (1981) studied two groups of young adult patients after mild closed head injury and found that problems of consolidation and retrieval of memory were not predicted by PASAT scores. However, a separate deficit which was revealed by complex tasks which require processing under the constraints of time, was predicted by PASAT performance. In the same study the authors indicated that the information processing ability indexed by PASAT was significantly related neither to general intelligence nor to arithmetic ability. This claim was tested in a study of 28 teenagers on a Youth Training Scheme by Egan (1988) who found that PASAT scores on the 4 second test correlated with a variety of standard IQ-type tests (Alice Heim 2, Raven’s Matrices, Mill Hill Vocabulary, Cattell Culture Fair) between 0.41 and 0.73. While this study raises the interesting possibility that such a brief test, which is conceptually simple, but not necessarily simple to perform, might load highly on “general fluid intelligence” (Egan, 1988), it should be noted that the small number of non-clinical subjects was given only the 4 second test, and that a marked ceiling effect occurred. Faster forms of the test are more commonly employed in clinical practice and might yield different results. Furthermore, simple correlations with general IQ-type tests do not indicate the mechanisms underlying successful performance of the PASAT test.

Therefore, in the present study we applied the PASAT test to a group of otherwise healthy young subjects who had type 1 (insulin-dependent) diabetes. We attempted to relate their performance on PASAT to their scores on Wechsler Adult Intelligence Scale subtests, to indices of short and
long term memory and to other information processing ability measures. We hoped to elucidate which of these abilities were responsible for PASAT performance.

SUBJECTS AND METHODS

Patients

Ninety-four patients with type 1 diabetes mellitus (54M, 40F) were recruited from the outpatients' clinic at the Department of Diabetes. This group of patients was participating in a study which examined cognitive function in diabetes and which will be reported elsewhere. They were selected to provide a convenient clinical cohort of subjects who had a broad range of cognitive ability. The age range of patients was 25 to 52 years (mean 40, SD 6.4). All patients had Type 1 (ketosis-prone) diabetes, the onset of which had occurred after 19 years of age, with a duration of at least 5 years (mean 13, SD 6.2). This age range ensured that all patients had achieved cognitive maturity before developing diabetes.

Strict exclusion criteria for the selection of patients were applied. Patients with a history of cerebrovascular disease, previous head injury, serious systemic disease, epilepsy, chronic alcoholism or major psychiatric illness were excluded from the study. Patients were also excluded if they were taking medications which might alter cognitive function, such as psychotrophic drugs, beta-adrenergic blockers or steroids. Patients with a visual acuity poorer than 6/9 were excluded (this would have interfered with the ability to perform some of the tests of cognitive function). All patients were examined physically for the presence of diabetic complications and the co-existence of other medical problems such as undiagnosed hypertension and macrovascular disease. None of the patients had clinical evidence of macrovascular disease, although some had microangiopathy. Blood glucose was measured in all patients before commencing the cognitive test battery to ensure that they were normoglycaemic.

Assessment of cognitive ability

The Paced Auditory Serial Addition Task (PASAT). This test was used to assess concentration and attention. Patients listened to a list of numbers which were then added together according to a given rule, as described earlier. During a practice session care was taken to familiarise the patients with the task. Initially, the test was explained to the subject by writing the numbers on a sheet of paper and explaining the addition rule. When this was understood patients attempted several items spoken by the tester at a slow pace. Patients did not commence the actual test until ten successive items on a practice tape, with four seconds between digits, had been completed correctly. After the initial practice, two trials of 61 digits were performed with 4 and 2 seconds between successive digits, respectively.

The Wechsler Adult Intelligence Scale-Revised (WAIS-R) (Wechsler, 1981). This test was used to assess intellectual level. Verbal, Performance and Full scale IQs were obtained. Because of time constraints, and to avoid fatigue in the subjects, the two subtests with poorest loadings on the Verbal and Performance factors which were extracted from a large factor analysis of the WAIS-R (Digit Span and Picture Arrangement, respectively; Canavan, Dunn & McMillan, 1986) were omitted. Performance sub-tests used were: Picture Completion, Block Design, Object Assembly and Digit Symbol. The following Verbal sub-tests were used: Information, Vocabulary, Arithmetic, Comprehension and Similarities. Tests were administered according to the instructions in the WAIS-R manual.

The Rey Auditory Verbal Learning Test (AVLT) (Lezak, 1983). This test was used to assess both short and long-term memory. Patients were given 5 trials to learn a list of 15 words which they were asked to recall: (a) immediately after each of the five trials, producing scores called AVLT 1–5; (b) after interference, where memory score for the interference list is called AVLT B, and memory score for the original list after interference recall is called AVLT 6; and (c) after a 30 minute delay where the score is called AVLT 30.

Inspection Time (IT) (Nettelbeck, 1987). This test was used to assess processing efficiency of iconic memory. This measure has been found to have moderate correlations with higher cognitive functions (in general, subjects with higher scores on IQ-type tests require shorter stimulus presentation times to make accurate discriminations). Because this test places an emphasis on
efficient processing of incoming information it appears to be a particularly relevant elementary
cognitive task to study in relation to PASAT. The task is a two-choice discrimination test and
subjects must attempt to identify the spatial position (left or right) of the longer of two
briefly-presented vertical lines of markedly different lengths. The stimuli were backward-masked,
the presentation duration was varied according to the PEST adaptive staircase algorithm, and the
amount of time needed to make a reliable discrimination (85% correct) is termed the patient’s
‘inspection time’. Stimulus lines and the backward mask were constructed from LED arrays. The
test was run on a BBC computer. Responses were made at leisure after backward mask offset.

Reaction Time (RT). A 4-choice reaction time test was used, and separate decision and movement
times were obtained. The test was run on a reaction time device similar to that described by Jensen
(Jensen & Vernon, 1986). This gives separate measures of decision time (the time taken by a subject
to release the ‘home’ button after the target light is lit) and movement time (the time taken by
subjects after releasing the ‘home’ button until they press the target button). Decision times and
their standard deviations tend to be related to higher cognitive functions (Jensen, 1982, Jensen &
Vernon, 1986). The purpose of this task was to discover whether decision processes or response
processes were related to PASAT performance.

RESULTS

The mean WAIS-R Full Scale IQ for the group was 100.0 (SD 13.2, range 70 to 136). The mean
WAIS-R Verbal IQ was 100.6 (SD 13.9), and the Performance IQ mean was 99.4 (SD 12.6). The
mean 4 second PASAT score (out of 60) was 52.6 (SD 8.3), and the 2 second mean score was 33.5
(SD 10.8). The scores from both the 4 and 2 second PASAT tests correlated significantly with all
nine WAIS-R subtests used in the study (Table 1). Although most correlations fell between 0.3 and
0.4, the highest correlations, generally between 0.35 and 0.40, were with the vocabulary, arithmetic,
digit symbol and information subtests. Verbal and Performance IQ scores correlated at very similar
levels with PASAT scores. Correlations between PASAT scores and Full Scale IQ scores were 0.48
(P < 0.001) and 0.51 (P < 0.001) for the 4 and 2 second tests, respectively.

PASAT test scores and WAIS-R subtest scores were subjected to a principal components analysis
followed by Varimax rotation (Table 2). Three factors had eigenvalues equal to or greater than
one. PASAT scores loaded on the general factor (1st principal component) at about the same level
as some of the performance subtests, suggesting that the PASAT test taps general intellectual
capacity to some extent. After Varimax rotation clear Verbal and Performance factors emerged as
the first two rotated factors. PASAT scores had low loadings on both of these, suggesting that
PASAT is not a straightforward index of verbal or performance IQ. High PASAT loadings were
obtained on Factor 3, which also had moderate loadings for Digit Symbol, Vocabulary and
Arithmetic. Although the present battery did not contain the digit span subtest, the third factor
appears to resemble the so-called ‘freedom from distraction’ factor found in factor analyses of

Table 1. Pearson (r) correlations between 4 and 2 second PASAT
scores and Wechsler Adult Intelligence Scale (WAIS) indices
(n = 94)

<table>
<thead>
<tr>
<th></th>
<th>PASAT 4 sec</th>
<th>PASAT 2 sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAIS Performance IQ</td>
<td>0.40t</td>
<td>0.50f</td>
</tr>
<tr>
<td>WAIS Verbal IQ</td>
<td>0.46f</td>
<td>0.43f</td>
</tr>
<tr>
<td>WAIS Full Scale IQ</td>
<td>0.48f</td>
<td>0.51f</td>
</tr>
<tr>
<td>Verbal subtests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information</td>
<td>0.33f</td>
<td>0.39f</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>0.47f</td>
<td>0.48f</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>0.40f</td>
<td>0.38f</td>
</tr>
<tr>
<td>Comprehension</td>
<td>0.34f</td>
<td>0.33f</td>
</tr>
<tr>
<td>Similarities</td>
<td>0.36f</td>
<td>0.26f</td>
</tr>
<tr>
<td>Performance subtests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Picture completion</td>
<td>0.23*</td>
<td>0.32*</td>
</tr>
<tr>
<td>Block design</td>
<td>0.29+</td>
<td>0.35+</td>
</tr>
<tr>
<td>Object assembly</td>
<td>0.31f</td>
<td>0.31f</td>
</tr>
<tr>
<td>Digit symbol</td>
<td>0.34f</td>
<td>0.39f</td>
</tr>
</tbody>
</table>

*P < 0.05, †P < 0.01, ‡P < 0.001.
Table 2. Factor analysis of PASAT scores and Wechsler Adult Intelligence Scale subtest scores (n = 94)

<table>
<thead>
<tr>
<th></th>
<th>1st Principal component</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information</td>
<td>83</td>
<td>86</td>
<td>25</td>
<td>18</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>84</td>
<td>82</td>
<td>16</td>
<td>38</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>72</td>
<td>55</td>
<td>31</td>
<td>37</td>
</tr>
<tr>
<td>Comprehension</td>
<td>76</td>
<td>85</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>Similarities</td>
<td>74</td>
<td>79</td>
<td>27</td>
<td>08</td>
</tr>
<tr>
<td>Picture completion</td>
<td>61</td>
<td>26</td>
<td>69</td>
<td>09</td>
</tr>
<tr>
<td>Block design</td>
<td>65</td>
<td>21</td>
<td>81</td>
<td>13</td>
</tr>
<tr>
<td>Object assembly</td>
<td>65</td>
<td>21</td>
<td>80</td>
<td>14</td>
</tr>
<tr>
<td>Digit symbol</td>
<td>61</td>
<td>12</td>
<td>60</td>
<td>44</td>
</tr>
<tr>
<td>PASAT 4 second</td>
<td>58</td>
<td>24</td>
<td>11</td>
<td>80</td>
</tr>
<tr>
<td>PASAT 2 second</td>
<td>60</td>
<td>19</td>
<td>22</td>
<td>79</td>
</tr>
</tbody>
</table>

Loadings greater than 0.35 are shown in bold type (decimal points omitted).

Four second PASAT scores correlated at highly significant levels with all Rey AVLT indices except AVLT B (recalled words from the distraction list) (Table 3). Correlations between 2 second PASAT scores and Rey AVLT indices were all in the positive direction, but only two relatively small correlations (with the 4th and 5th repeats of the original word list) achieved significance. This implies that the slower PASAT presentation taps memory ability to a greater extent than the faster 2 second test.

Because of occasional computer failures, 4 patients did not have full reaction time data and 11 patients were not assigned an inspection time. A highly significant correlation of −0.35 was observed between the 2 second PASAT scores and Inspection Time estimates, indicating that subjects with faster visual encoding speeds performed better on the PASAT test (Table 4). The correlation between IT and the 4 second PASAT test was significant, but lower (−0.23). Correlations between PASAT scores and reaction time indices were all in the expected direction, but all except one small correlation (between 2 second PASAT and median decision time, \( r = -0.24, P < 0.05 \)) were non-significant. In general the faster PASAT test had higher correlations with measures of information processing speed.

Using the WAIS-R Full Scale IQ and inspection time scores to predict 2 second PASAT performance in a multiple regression analysis resulted in an \( R \) of 0.55, indicating that the inclusion of these two variables accounted for 28% (adjusted \( R^2 \)) of PASAT score variance. Prediction of the 4 second PASAT scores was made by WAIS-R Full Scale IQ and AVLT 4 resulting in an \( R \) of 0.60. The adjusted \( R^2 \) indicates that 34.7% of PASAT test variance was accounted for by these two tests.

**DISCUSSION**

The present study attempted to elucidate the cognitive correlates of performance on the PASAT task. Somewhat contrary to the claims of its inventor (see Gronwall & Wrightson, 1981), and in partial agreement with Egan (1988), the test did correlate highly significantly with a widely used index of general mental ability, the WAIS-R. However, the correlation was not simply with general fluid intelligence, as suggested by Egan. A group of type 1 diabetic patients was studied, although this assessment could be made in any population sample. All patients were normoglycaemic at the time of testing.
We had originally chosen the WAIS-R subtests on the basis of the very large sample factor analysis by Canavan et al. (1986), which indicated that there were two main factors underlying performance on the test battery, viz 'verbal-general' and 'spatial-performance'. After beginning the study we noted the report by Crawford et al. (1990), which suggested that WAIS-R performance was appropriately described by three factors: a verbal factor, with high loadings for Vocabulary, Information, Comprehension and Similarities; a perceptual organisation factor with highest loadings for block design and object assembly, and moderately high loadings for the other Performance subtests; and a freedom from distraction factor with high loadings for digit span and arithmetic, and a moderately high loading for digit symbol. Our results appear to be congruent with the three factor model. PASAT had very high loadings on our third factor, which had moderate loadings on digit symbol, arithmetic and vocabulary. Therefore, despite the fact that PASAT does index general cognitive ability to some degree, Gronwall's description of the test as an index of attention and concentration seems appropriate, given its loading on the third WAIS-R factor, and its separation from verbal and performance factors after Varimax rotation.

This is validated further by the observation of a significant correlation between the 2 second PASAT scores and inspection time, a test of perceptual processing speed which is also related to scores on IQ-type tests. Correlations between PASAT and reaction time measures were generally low and non-significant, but all were in a direction which indicated that high PASAT scores were associated with faster RTs.

In agreement with Gronwall and Wrightson (1981), we found that 2 second PASAT scores were correlated with memory ability at very low levels, which were usually non-significant. The pattern was very different for the 4 second PASAT test where most of the correlations with AVLT memory performance indices were of moderate magnitude and very highly significant. This might indicate that the slower test is vulnerable to short-term memory forgetting, and that the decay of retained numbers in working memory is a rate-limiting step in the performance of the slower form of the test. By contrast, the lack of memory correlations with the faster form of the test, and the fact that it shows a slightly higher correlation with inspection time, indicate that the early processing of information in sensory memory might be the chief rate limiting factor in the 2 second test. Therefore, different PASAT speeds appear to index underlying process stages to different degrees.

One possible confounding factor in the above interpretation is the fact that the 4 second PASAT test was always given before the 2 second version, as is customary for the test. This could be taken to indicate that, as the patient becomes more familiar with the test, it begins to tap different abilities. Such an explanation appears to be unlikely. Patients were given adequate practice and achieved very high average scores on the initial 4 second test. Given that the test is brief, fatigue does not appear to be a likely explanation either. In summary, the different paces of the two forms of the test appear to uncover individual differences in different underlying abilities.

Acknowledgement—This research was supported by Grant 949 from the Scottish Hospital Endowments Research Trust.

REFERENCES