Lucid RECALL

COMPUTERISED ASSESSMENT OF WORKING MEMORY AND PROCESSING SPEED FOR 7 TO 16 YEARS

Specialist Consultant

Dr Helen St. Clair-Thompson

Administrator's Manual

Second Edition, February 2015

Lucid

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Main distributors:

Lucid Research Ltd.

3 Spencer Street, BEVERLEY

East Yorkshire, HU17 9EG, UK

www.lucid-research.com

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1 Introduction

1.1 What is Lucid Recall?

Lucid Recall is a suite of computerised tests designed for the assessment of working memory skills in the age range 7 years 0 months to 16 years 11 months. The Lucid Recall suite comprises standardised tests of the following memory processes:

- **Phonological loop (Word Recall test)**
- **Visuo-spatial sketchpad (Pattern Recall test)**
- **Central executive function (Counting Recall test)**

In addition, Lucid Recall provides the following additional standardised measures derived from those core tests:

- **Composite working memory skills**
- **Working memory processing speed**

Test administration is carried out entirely by the computer. Two editions of the program are available: **Lucid Recall Standalone Edition** (for individual computers and single administration at any given time) and **Lucid Recall Network Edition** (which is installed on a school computer network and can be used anywhere on that network to assess groups of students up to the maximum permitted at any given time by the licence). Information about the installation of Lucid Recall is provided separately with the program. Information about running the program such as registration of students and accessing reports is provided in the context-sensitive help, which is available by pressing the F1 key on the keyboard throughout the software (except for when using the Test Module). Help can also be delivered by mouse-clicking on the Help icon on the Option Menu which is always visible on the left margin of the Administration Module.

Each test begins with spoken instructions and practice items. The total suite takes 20–30 minutes. Full details of the tests in Lucid Recall, including guidelines on test administration, are given in Chapter 2. Results, based on nationally standardised norms, are available immediately. Results are given in standard score and centile score formats and age equivalents within the age range 7:0 – 16:11. Guidance on understanding results and interpreting reports are given in Chapter 3, with advice on how children with poor working memory can be helped given in Chapter 4. Finally, Chapter 4 discusses a number of illustrative case studies, providing pointers for effective intervention and classroom support.

1.1.1 What is working memory?

Working memory is a temporary storage system under attentional control that underpins our capacity for complex thought (Baddeley, 2007). Imagine, for example, multiplying two numbers together. The numbers need to be held in a short-term store whilst using learned multiplication rules to perform the calculation. Similarly, during reading comprehension text has to be maintained whilst it is processed to uncover its meaning. Working memory is therefore involved in many everyday tasks in the school classroom, and is sometimes considered as a gateway for learning.

Although there are several theoretical models of working memory, the most widely accepted model is that proposed by Baddeley (Baddeley, 2000; Baddeley & Hitch, 1974). Baddeley portrayed working memory as consisting of four components. At the heart of working memory is a ***central executive system***, a domain-general limited capacity system often likened to a mechanism of attentional control (e.g. Kane & Engle, 2003; Unsworth & Engle, 2007). The central executive is supported by two domain-specific storage components; the ***phonological loop*** that is responsible for the maintenance of auditory information, and the ***visuo-spatial sketchpad*** that is specialised for dealing with visual and spatial information. Baddeley (2000) also identified the episodic buffer as a further subcomponent of working memory, responsible for integrating information from the subcomponents of working memory and long-term memory.

There is now substantial evidence for Baddeley's multiple-component model. This has come from dual-task studies in cognitive psychology, the study of brain-damaged patients, and investigations of the brain areas that are active during working memory tasks (e.g. Baddeley, 2002; 2007). Research using a multivariate statistical technique known as structural equation modelling has also revealed that a working memory model comprised of a central executive, phonological loop and visuo-spatial sketchpad provides a good fit to data collected from students throughout the childhood years (e.g. Alloway, Gathercole, Willis & Adams, 2004; Gathercole, Pickering, Ambridge & Wearing, 2004). This model of working memory has also formed the basis for much research examining the links between working memory and students' learning. To date, however, work has focused mainly on the central executive, phonological loop, and visuo-spatial sketchpad, and hence the nature and significance of the episodic buffer remain less well understood, and tasks which could be used to assess this component relatively undeveloped at the present time.

1.1.2 Why is working memory important?

Working memory plays an important role in supporting the acquisition and development of educational skills. Performance on working memory measures is highly predictive of a number of scholastic skills, including ***literacy*** (e.g. De Jong, 1998; Swanson, 1994; Swanson & Berninger, 1995), ***mathematics*** (e.g. Bull & Scerif, 2001; De Stefano & LeFevre, 2004; Mayringer & Wimmer, 2000; Siegel & Ryan, 1989), and ***comprehension*** (e.g. Cain, Oakhill & Bryant, 2004; Nation, Adams, Bowyer- Crain & Snowling, 1999; Seigneuric, Ehrlich, Oakhill & Yuill, 2000). Between the ages of 7 and 14 years, students who perform poorly on measures of working memory also typically perform below expected standards in national curriculum assessments of English, mathematics, and science carried out in England (Gathercole, Brown, & Pickering, 2003; Gathercole & Pickering, 2000; Gathercole, Pickering, Knight, & Stegmann, 2004; Jarvis & Gathercole, 2003; St Clair-Thompson & Gathercole, 2006).

Measures of working memory that assess the central executive are typically better predictors of scholastic skills than those that assess the phonological loop and visuo-spatial sketchpad alone (e.g. Daneman & Carpenter, 1980; Daneman & Merickle, 1996; Engle, Tuholski, Laughlin, & Conway, 1999). However, there is a specific link between the phonological loop and the acquisition of vocabulary in both the native and a foreign language (e.g. Gathercole, Hitch, Service & Martin, 1997; Service & Craik, 1993; Service & Kohonen, 1995). The phonological loop and visuo-spatial sketchpad may also play a role in counting and mental arithmetic (e.g. Hitch, 1978; Logie & Baddeley, 1987; Pesenti, Tzourio, Doroux & Samson et al., 1998; Trbovich & LeFevre, 2003).

1.1.3 The diagnostic value of working memory assessment

Memory difficulties are known to be associated with a wide range of learning and neurodevelopmental disorders. Students with ***general reading difficulties*** typically show poor performance on measures of the central executive (Gathercole, Alloway, Willis & Adams, 2006; Swanson, 1993). Students with ***dyslexia*** and ***specific language impairments*** display poor performance on measures of the central executive and phonological loop (Archibald & Gathercole, 2006; Jeffries & Everatt, 2004). Students with ***mathematical difficulties*** perform below expected levels on measures of the central executive and visuo-spatial sketchpad (Gathercole & Pickering, 2000; Geary, Hoard & Hamson, 1999). Hence performance on the tests in Lucid Recall can be used diagnostically to help understand the nature of a student's educational difficulties, and sometimes to give advance warning of likely difficulties as they get older, enabling early intervention measures to be taken in order to alleviate the educationally disadvantaging effects of memory limitations. Advice on this can be found in Chapter 4, with case studies illustrating these principles in action being provided in Chapter 5.

1.1.4 The need for Lucid Recall

There are several existing assessments of working memory. Some well-known psychological test batteries, such as the *Wechsler Intelligence Scale for Children (WISC)* and the *British Abilities Scales (BAS)*, include working memory measures – most typically forwards and backwards digit recall. There are also several comprehensive assessments of working memory, such as the *Working Memory Test Battery for Children* (Pickering & Gathercole, 2001) and *Alloway Working Memory Assessment, 2nd Edition (AWMA-2)* (Alloway, 2012). However, each of these is designed for individual administration and therefore requires extensive teacher or assessor time. Furthermore, use of the WISC and the BAS is restricted to appropriately qualified psychologists. These factors severely restrict the utility of existing assessment products. The construction of Lucid Recall was motivated by the absence of a brief assessment of working memory which can be readily used in schools, is easy to administer, and is fully automated so that it does not require teacher or assessor input. Computer-based tests meet these requirements and also offer additional advantages, as outlined in the next section. Most notably, the **Lucid Recall Network Edition** allows for entire classes of students to complete the assessments at any one time. It is therefore particularly suited to large-scale screening or for research purposes.

1.1.5 Use of Lucid Recall in examination access assessments

Lucid Recall may also be used as part of assessment for examination access arrangements under JCQ regulations.[1] Section 5.2.2 of these regulations state that 25% extra time in examinations may be granted to students who show substantial impairment in literacy or **processing speed**, i.e*. "…at least one below average standardised score of 84 or less which relates to an assessment of:*

- *speed of reading; or*
- *speed of reading comprehension; or*
- *speed of writing; or*
- ***cognitive processing measures which have a substantial and long term adverse effect on speed of working."*** [our emphasis]

Section 7.5.11 of the regulations goes on to state that *'Cognitive processing assessments would include, for example, investigations of working memory, phonological or visual processing, sequencing problems, organisational problems, visual/motor co-ordination difficulties or other measures as determined appropriate for the individual by a specialist assessor.'*

Hence results all five of the measures provided by Lucid Recall can, if required, be used in completing JCQ Form 8 when applying for examination access arrangements, provided the student is not older than the test ceiling which is 16 years 11 months. Speed of reading comprehension can be assessed using another Lucid product: Lucid Exact, which is a suite of literacy tests for the age range 11:11 to 24:11.

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[1] *Access Arrangements and Reasonable Adjustments: General and Vocational qualifications. With effect from 1 September 2013 to 31 August 2014*. Joint Council for Qualifications, 2103.

Assessors planning to use Lucid Recall or Lucid Exact for this purpose should be fully familiar with current JCQ regulations, which stipulate the qualifications of assessors and conditions for assessment. In particular, the regulations state that the assessment must be carried out by a suitably qualified person, who could be a psychologist or a specialist teacher, and the Head of Centre must satisfy themselves that this person is competent to carry out such assessments (JCQ Regulations 2013-14, Section 7.3). This person then takes responsibility for selecting appropriate tests, interpreting the results, and making the recommendations for access arrangements. Careful administration is advised when using group assessment in order that individual student responses are observed and monitored. The declaration on page 5 of JCQ Form 8 stipulates that the specialist assessor carried out all the assessments in Section C. JCQ regulations give guidance on what qualifications and experience may be expected of named specialist teachers (JCQ Regulations 2013-14, Section 7.5.4). These requirements apply whatever tests are used, whether Lucid Recall, Lucid Exact or any others.

1.1.6 Advantages of computerised tests

One of the great advantages of a well-designed computer-based test is that it does not require any special expertise or training on the part of the teacher or administrator. Computers also provide more precise measurement, especially when complex cognitive skills are being assessed. Tests are administered in an entirely consistent manner for all persons taking the test, which enhances reliability of measurement. Timings and presentation speeds can be controlled precisely. The subjective judgment of the teacher or administrator does not affect the test outcome as it may in conventional tests. Lucid Recall is largely self-administered and results are available immediately; both of these factors help to reduce administrative load and avoid time delays. Provided headphones are used and certain basic precautions are taken, Lucid Recall can be administered in a room where other activities are taking place. For further information about test administration, see Section 2.2.

There is good evidence that most students prefer computer-based tests to conventional tests (whether paper-based group tests or administered 1:1 by a teacher or psychologist). This is particularly the case for less able students or those with below average literacy skills, who are more likely to feel intimidated by assessments and be embarrassed by their performance. Computer-based tests have generally been found to be less threatening and less stressful, which helps to ensure more reliable results (Singleton, 2001). There is also evidence that there is less gender bias in computer-based tests than in conventional tests, so there are good reasons to regard computer-based tests as fairer, as well as being more consistent and objective, than conventional tests (Horne, 2007).

When using conventional tests retesting can be problematic because such tests typically have fixed item order and content. When encountering the test for a second or subsequent time, students may remember items and answers, which may enable them to improve their performance over previous attempt(s). There may also be increased confidence from being confronted by familiar tasks rather than novel tasks (although students who prefer the excitement and challenge afforded by new and unfamiliar tasks may actually find this demotivating). These are usually referred to as *practice effects*, and in order to reduce practice effects it is generally recommended that there should be a suitable time interval between testing and retesting so that recollection is sufficiently diminished. Some test manuals advocate at least 12 months between assessment, while others suggest a less stringent 3–6 months. A particular advantage of computerised tests (including Lucid Recall) is that test items can be generated randomly or drawn from a large item bank so that, on retest, although the student will be confronted by the same task, the items will be different from last time, thus reducing practice effects. This means that no minimum time interval needs to be placed on retesting, nor on the number of occasions that retests are given. This can be very useful when needing to evaluate the impact of an intervention over time.

1.2 Development of Lucid Recall

1.2.1 Test development

The choice of measures to include in Lucid Recall was guided by the multiple component model of working memory described above (Baddeley, 2000; Baddeley & Hitch, 1974). One core test (***Word Recall)*** was included to assess the phonological loop. A large body of research has identified immediate serial recall as a paradigm that is suitable to assess phonological loop functioning. Another core test (***Pattern Recall***) was included to assess the visuo-spatial sketchpad. This provides a measure of visual rather than spatial short-term memory (see also Della Sala, Gray, Baddeley, & Wilson; 1997; Della Sala, Gray, Baddeley, Allamano & Wilson, 1999). The final core test (***Counting Recall***) was included to assess the central executive component of working memory. This is a variant of a complex span task in which participants have to simultaneously store and process information (e.g. Case, Kurland & Goldberg, 1982). It is assumed that such tasks involve both the storage and central executive components of working memory.

A description of each test is provided in Section 2.1. Each of the three core tests is *adaptive*, with progress through each test and point of discontinuation being determined by cumulative performance. More able students will progress through the test quicker and reach higher levels. Less able students will progress more slowly and generally avoid the unnecessary frustration of levels that are much too difficult for them. This reduces assessment time and helps to maintain the test-taker's motivation regardless of ability.

1.2.2 Types of results

Normative results in standard score and centile score form are incorporated into the Lucid Recall program for each of the three core measures. The norms are provided in 6-month age bands from 7:0 to 16:11, together with confidence intervals and age equivalents. These different types of results are explained in Chapter 3.

An overall measure of general working memory functioning, called ***Working Memory Composite****,* was obtained by combining the scores of the three subtests with appropriate weighting to allow for differential item length.

A measure of speed of processing was derived from the Counting Recall test by means of an algorithm that reflects the average time taken to count each item, adjusted for counting accuracy. This derived measure is referred to as ***Working Memory Processing Speed.***

For each of the three core tests comparative results are provided for ***Memory Span*** (based on the maximum difficulty level reached in each subtest) in three bands: *'low', 'average'* and *'high'*, where the 'average' range represents the modal score range for that age group, with 'low' and 'high' covering the score range below and above this respectively. Memory span is a measure of the number of items of information that the person can hold in memory at any given time.

Comparative results are also provided for ***Average Time*** on each of the three tests. This is categorized as *'fast'* (less than one standard deviation below the mean time per item of the standardisation sample), *'average'* (between one SD below and one SD above the mean time per item of the standardisation sample), and *'slow'* (more than one SD above the mean time per item of the standardisation sample).

The reason why standard scores for memory span and average time have not been provided is explained in Section 1.3.3.

1.3 Standardisation

1.3.1 What is standardisation?

Technically, 'standardisation' is the process used in psychometric test development to create *norms* so that the performance of students of different ages can be represented by means of scores that are independent of age. However, the term 'standardised' is sometimes used in a non-technical sense to refer to the *consistent administration* of a test – i.e. that test instructions and methods of administration are the same for all who take the test. Because this non-technical usage can be misleading (e.g. users may assume that a test has standardised norms when in fact it hasn't) Lucid only uses the terms 'standardisation' or 'standardised' in strict accordance with technical psychometric usage.

The most common normative scores are standard scores and centile scores. Standard scores have a mean (average) of 100 and a standard deviation[2] (abbreviated to SD) of 15. Centile scores (sometimes known as percentile scores) place individuals on a 'ladder' of attainment from 1 to 100 compared with the population of that age; e.g. a centile score of 70 means that 70% of people would have lower raw scores and 30% would have higher raw scores. (For further information about standard scores and centile scores see Section 3.2).

Eleven schools were recruited for the standardisation process. The schools were selected to include the age range of 7-16 years, and including both urban and rural schools representing a range of socio-economic backgrounds. In their most recent Ofsted report three of the schools had been rated as outstanding, and six had been rated as good or satisfactory. The remaining two schools had been in special measures within the last three years. The proportion of students eligible for free school meals was at or lower than the national average in four of the schools, and above the national average in seven of the schools. The proportion of students with special educational needs was above the national average in four of the schools, and either at or lower than the national average in the remaining seven. Students were taken on an unselected basis from entire classes of students in the participating schools. No students were excluded from taking part on any basis.

1.3.2 Standardisation sample

The standardisation sample comprised 1087 students aged 7-16 years (502 males and 585 females) [see Table 1].

1.3.3 Standardisation results

All raw data from the three tests and also the two derived measures (Working Memory Composite and *Processing Speed*) approximated to normal distributions (symmetrical bell-shaped curves), with skewness (the degree of asymmetricality of the distribution) and kurtosis (the degree of flatness and peakedness of the distribution) below the critical threshold of 1.0. Descriptive statistics for each of the core tests are given in Table 2, and for the two derived measures in Table 3. For the three core tests and Working Memory Composite the developmental progression in raw score means from the youngest to the oldest age group is approximately linear with the exception of the 16:0-16:11 age group. From Table 1 it can be seen that the number of students in the 16:0-16:11 age group was significantly smaller than the other groups, and this is the most likely explanation for the divergent results pattern found in this group. For Processing Speed, the curve is approximately linear in the range 7:0-12:11, but plateaus thereafter, as might expected with a speed measure.

[2] The standard deviation is the most common statistic for expressing variability in a set of scores and is calculated as the average amount by which the scores in the set deviate from the mean.

Table 1. Number of students in the standardisation sample by age.

Age	Males	Females	Total
7:0 - 7:11	66	56	122
8.0 - 8.11	60	75	135
9:0 - 9:11	56	67	123
10:0 - 10:11	59	59	118
11:0 - 11:11	56	57	113
12:0 - 12:11	80	105	185
13:0 - 13:11	92	119	211
14:0 - 14:11	47	45	92
15:0 - 15:11	43	46	89
16:0 - 16:11	9	12	21
All (7:0 - 16:11)	**502**	**585**	**1087**

Table 2. Raw score means and standard deviations for the tests in Lucid Recall by age.

	Word Recall		Pattern Recall		Counting Recall	
Age	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
7:0 - 7:11	8.20	4.66	19.11	9.02	6.70	5.13
8.0 - 8.11	10.03	4.46	21.67	9.93	8.47	5.66
9:0 - 9:11	10.79	4.68	26.20	9.13	9.62	5.14
10:0 - 10:11	12.53	4.90	29.94	9.14	10.54	5.71
11:0 - 11:11	14.61	5.05	31.64	8.49	12.63	6.93
12:0 - 12:11	16.59	4.61	35.48	7.46	14.97	7.53
13:0 - 13:11	17.13	5.31	36.41	6.05	16.18	7.34
14:0 - 14:11	18.16	4.97	38.09	6.47	18.85	7.12
15:0 - 15:11	19.57	6.96	41.53	9.20	21.72	6.85
16:0 - 16:11	17.71	6.94	41.29	8.60	20.19	7.85

The overall breakdown of data was considered appropriate for standardisation in 6-month age bands; however, norms in the age range 16:0-16:11 should be regarded as provisional for the time being because the number of students in this age range fell below psychometric conventions. The norms for this age were adjusted using extrapolated scores from the development curve for ages 7:0-15:11. Further standardisation data are being collected with a view to revising the norms for age 16:0-16:11 as soon as possible.

The distributions of raw scores for memory span and for average time did not permit calculation of standardised scores, because kurtosis (in the former) and skewedness (in the latter) exceeded acceptable limits. Given the nature of these particular measures (i.e. memory span and average time) these statistical findings are entirely to be expected and the overall psychometric integrity of Lucid Recall is not affected. Consequently, comparative results for these measures are provided instead, as already explained in Section 1.2.2.

Table 3. Means and standard deviations for the two derived measures in Lucid Recall.

	Working Memory Composite		**Working Memory Processing Speed**	
Age	**Mean**	**SD**	**Mean**	**SD**
7:0 - 7:11	24.22	10.49	0.75	0.15
8.0 - 8.11	28.23	11.56	0.69	0.16
9:0 - 9:11	32.40	10.13	0.62	0.15
10:0 - 10:11	36.28	10.52	0.56	0.15
11:0 - 11:11	41.71	12.42	0.51	0.17
12:0 - 12:11	47.26	11.74	0.47	0.15
13:0 - 13:11	49.12	12.59	0.48	0.15
14:0 - 14:11	54.33	11.31	0.47	0.12
15:0 - 15:11	60.15	13.66	0.47	0.13
16:0 - 16:11	56.62	14.40	0.50	0.17

1.3.4 Gender differences

Gender differences were examined for each working memory task. There was a significant effect of gender on scores on pattern recall in favour of females [$F(1,865)=7.87$, $p=0.005$], but this had a small effect size (partial eta squared=0.009). On the word recall test a gender difference favouring females almost reached significance [$F(1,832)=3.83$, $p=0.051$] and again the effect size was small (partial eta squared=0.005). There were no significant effects of gender on scores on counting recall. Overall, it was concluded that gender differences on these tests are small.

1.4 Validity of Lucid Recall

1.4.1 What is validity?

Validation of a psychological or educational test is not the same thing as the psychometric standardisation of a test, nor should it be confused with the *reliability* of a test: 'reliability' generally refers to the extent to which a test can be expected to give the same results when administered on different occasions or by a different administrator, or the extent to which the components of a test give consistent results (see Section 1.5.1). 'Validity' is a measure of the extent to which the test measures what it is supposed to measure (e.g. reading or spelling ability). Validity is usually established by comparing the test with some independent criterion or with a recognised test of the same ability. Inevitably, this raises the thorny issue of what is the 'gold standard' – i.e. which is the 'best' measure of any given ability against which all other should be compared? Professional opinions differ as to the merits of various tests and consequently there are no generally agreed 'gold standards' for assessing reading, spelling and writing. Hence the conventional method of establishing test validity is to show that a new test produces results that agree reasonably closely with well-established test(s) of the same ability.

External validity of Lucid Recall was explored in three ways. Firstly, analyses were used to examine the relationships between performance on Lucid Recall and children's attainment in school. Secondly, the Lucid Recall profiles of children with special educational needs were examined. Finally, convergent validity was explored by examining the relationships between scores on Lucid Recall and scores on the *Working Memory Rating Scale* (Alloway, Gathercole & Kirkwood, 2008).

1.4.2 Children's school attainment

Several previous studies using measures of the multiple-component model of working memory have demonstrated close relationships between working memory and children's attainment in school (e.g. Gathercole et al., 2003; Gathercole & Pickering, 2000; Gathercole et al., 2004; Jarvis & Gathercole, 2003; St Clair-Thompson & Gathercole, 2006). These have typically used formal assessments of children's progress on the National Curriculum. However, policy changes have recently resulted in schools carrying out less testing. Instead, teachers are expected to record each child's progress each academic term, measured by tasks and tests that are administered informally. Teacher ratings of the National Curriculum levels of 337 children (166 males and 171 females) from the standardization sample were therefore obtained from the schools at the time of testing. Table 5 shows the correlations between the three Lucid Recall subtests and children's National Curriculum levels at aged 7, 8, 9, 10 and 11. Consistent with previous research using other working memory tasks, there were statistically significant correlations between scores on Lucid Recall and children's scholastic attainment (see Table 4).

1.4.3 Children with Special Educational Needs

Research has suggested that performance on working memory measures can be used to accurately identify children who are likely to require special educational provision. For example, Gathercole and Pickering (2001) compared the working memory profiles of children with special educational needs to the profiles of children without special educational needs. Children with special educational needs performed significantly more poorly on measures of the central executive, and one measure of the visuo-spatial sketchpad.

Two schools who participated in the standardisation were therefore asked to supply the names of children recognised by the school or local education authority as having special educational needs. There were 37 such children. Their performance on Lucid Recall, compared to 46 age-matched children from the same schools, is shown in Figure 1. Consistent with previous studies children with special educational needs performed significantly poorer than children without special educational needs on the pattern recall task, $F\ (1, 92) = 12.23$, $p = 0.001$, and the counting recall task, $F\ (1,83) = 11.27$ $p = 0.001$. The difference between the two groups was not statistically significant for word recall, $F\ (1,91) = 1.10$, $p = 0.30$.

Table 4. Correlations between Lucid Recall scores and National Curriculum Levels.

	Reading	Writing	Mathematics
Aged 7 (N = 50)			
Word recall	.45**	.37*	.41**
Pattern recall	.36*	.29*	.34*
Counting recall	.52*	.42**	.52**
Aged 8 (N = 69)			
Word recall	.45**	.35**	.46**
Pattern recall	.45**	.41**	.43**
Counting recall	.58**	.50**	.56**
Aged 9 (N = 71)			
Word recall	.45**	.43**	.31**
Pattern recall	.35**	.44**	.37**
Counting recall	.48**	.60**	.48**
Aged 10 (N = 81)			
Word recall	.50**	.58**	.45**
Pattern recall	.46**	.52**	.47**
Counting recall	.45**	.39**	.45**
Aged 11 (N = 66)			
Word recall	.48**	.50**	.40**
Pattern recall	.46**	.55**	.41**
Counting recall	.31*	.32*	.32**

Note: *** correlation is significant at the p<0.01 level, * correlation is significant at the p>0.05 level (2 tailed test).*

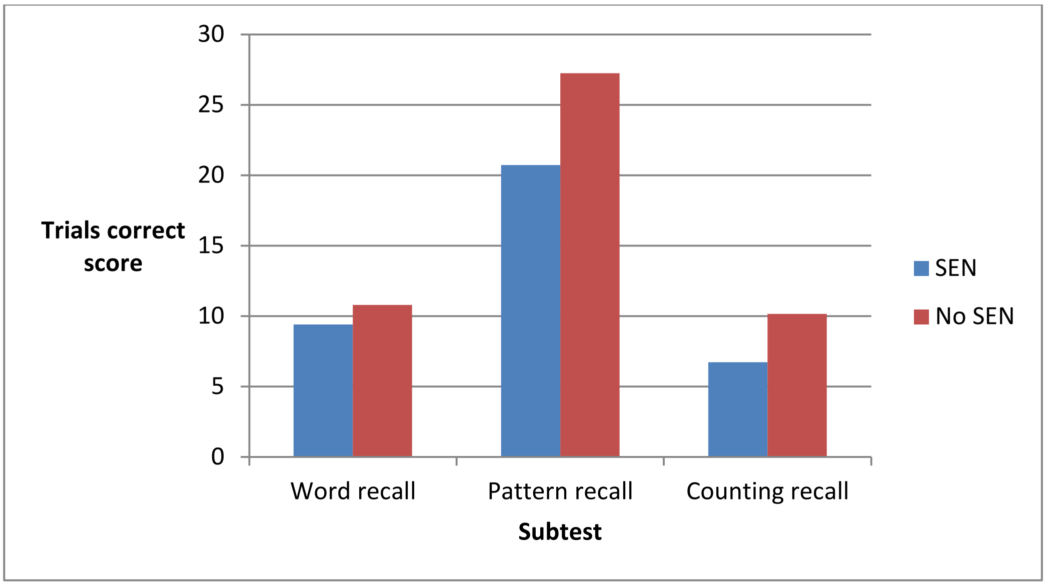


Figure 1. Profiles of children with and without special educational needs.

1.4.4 Scores on the Working Memory Rating Scale

Researchers have suggested that there are a number of behaviours typically associated with a poor working memory. These include, for example, children losing their place in complex tasks with multiple steps, or requiring regular repetition of instructions in the classroom. Such behaviours can be examined using the Working Memory Rating Scale (Alloway, Gathercole, & Kirkwood, 2008). Using this scale teachers are asked to rate how typical each behaviour is of a child using a four point scale. Cognitive assessments of children's working memory have been found to be significantly related to teacher ratings on the Working Memory Rating Scale (e.g. Alloway, Gathercole, Kirkwood, & Elliott, 2009; St Clair-Thompson, 2011). Therefore to further establish the validity of Lucid Recall the relationships between scores on each subtest and scores on the Working Memory Rating Scale were explored. Ratings were obtained for 51 children (27 males and 24 females) aged 7 years of age. The correlations are shown in Table 5.

Table 5. Correlations between scores on Lucid Recall and ratings on the Working Memory Rating Scale.

	Working Memory Rating Scale score
Word recall	-0.52**
Pattern recall	-0.53**
Counting recall	-0.46**

Note: ** *correlation is significant at the .01 level.*

Performance on each memory subtest was significantly negatively related to teacher ratings on the Working Memory Rating Scale. Negative correlations are expected because on the Lucid Recall subtests a higher score indicates a better working memory, whereas on the Working Memory Rating Scale a higher score indicates more problematic behaviours.

In summary, Lucid Recall has good validity. Correlations revealed that the scores on Lucid Recall are significantly related to children's academic performance across the childhood years. Children with special educational needs performed significantly more poorly than age-matched controls on the pattern recall and counting recall subtests. Finally, scores on Lucid Recall were significantly related to teacher ratings of children's behaviour on the Working Memory Rating Scale (Alloway et al., 2008). It can therefore be concluded that Lucid Recall is a valid assessment of children's working memory.

1.5 Reliability of Lucid Recall

1.5.1 What is reliability?

'Reliability' generally refers to the extent to which a test can be expected to give the same results when administered on a different occasion, or by a different administrator, or to the extent which the components of a test give consistent results. Note that this is not the same as the validity of the test (see Section 1.4.1).

1.5.2 Reliability results

Test-retest reliability of Lucid Recall was assessed using a subgroup of children from the standardisation sample. A total of 119 children (62 males and 57 females) aged 7-9 years, and 45 children (22 males and 23 females) aged 13 years were given the three Lucid Recall core tests on two occasions. These were separated by an interval of 6 weeks. As test-retest reliability is expected to reduce over time this was a fairly stringent test of reliability. For each core test reliability was computed using the Pearson's product moment correlation coefficient. The resulting reliability estimates are shown in Table 6.

Each of the word recall, pattern recall, and counting recall subtests demonstrated good test-retest reliability. Although reliability was lower for Counting Recall in children aged 7-9 than children aged 13 years this finding could be attributed to some children finding it difficult to grasp this task, particularly at the first time of testing (as reflected in the large proportion of younger children that obtained low scores on this task). Previous research has also revealed similar test-retest reliability values for counting recall in children (e.g. Pickering & Gathercole, 2001).

Table 6. Reliability estimates on each subtest (test-retest after 6 weeks).

	Aged 7-9	**Aged 13**
Word recall	0.71	0.68
Pattern recall	0.69	0.77
Counting recall	0.49	0.76

1.6 Installing the Lucid Recall program

Instructions for installing the Lucid Recall program can be found in the appropriate documents on the Lucid Recall CD. Installation information can also to be found in the Technical Help section of the Lucid website www.lucid-research.com

If you experience problems installing Lucid Recall, contact your system administrator or IT department in the first instance. If they are unable to help, get your system administrator or IT department to get in touch with Lucid.

1.7 Running the Lucid Recall program

To run the program click on the Lucid Recall icon on the desktop.

If you find you need help when using Lucid Recall press F1 and this will open a help file to assist you. This help is sensitive to the program context and should offer the most likely advice for the situation. However, if you wish you can search the full help files. These can also be accessed by clicking on **Help** on the **Tools Menu** available when logged in as **Administrator**.

2 Test administration

2.1 Details of the tests in Lucid Recall

2.1.1 Word Recall

This is a test of *phonological loop* functioning in which the child hears sequences of words through the computer speakers/ headphones. They are then required to recall the words in the *same order* in which they were presented, using the computer mouse to select (i.e. click on) the target words from within a 3 x 3 matrix of nine words on the computer screen (for example, see Figure 2). All the words in this test (target words and distractors) are common single-syllable words between three and five letters in length, selected at random from a large data set, with built-in checks to avoid rhyming or alliterative pairs.

The test begins with a demonstration of what is required, followed by four **practice items**, two items in which there are two words to remember, and then two items in which there are three words to remember. During these practice items the child receives aural feedback to inform them whether they were correct or incorrect.

There are then a **maximum of six test items** at each list length (of 2–6 words), during which no feedback is given. Each list length is regarded as a **level**. If four items at any particular level are recalled correctly then the program jumps to the next level, omitting the remaining one or two items in that level (which are credited to the score). The task is discontinued when three or more trials at any level are recalled incorrectly.

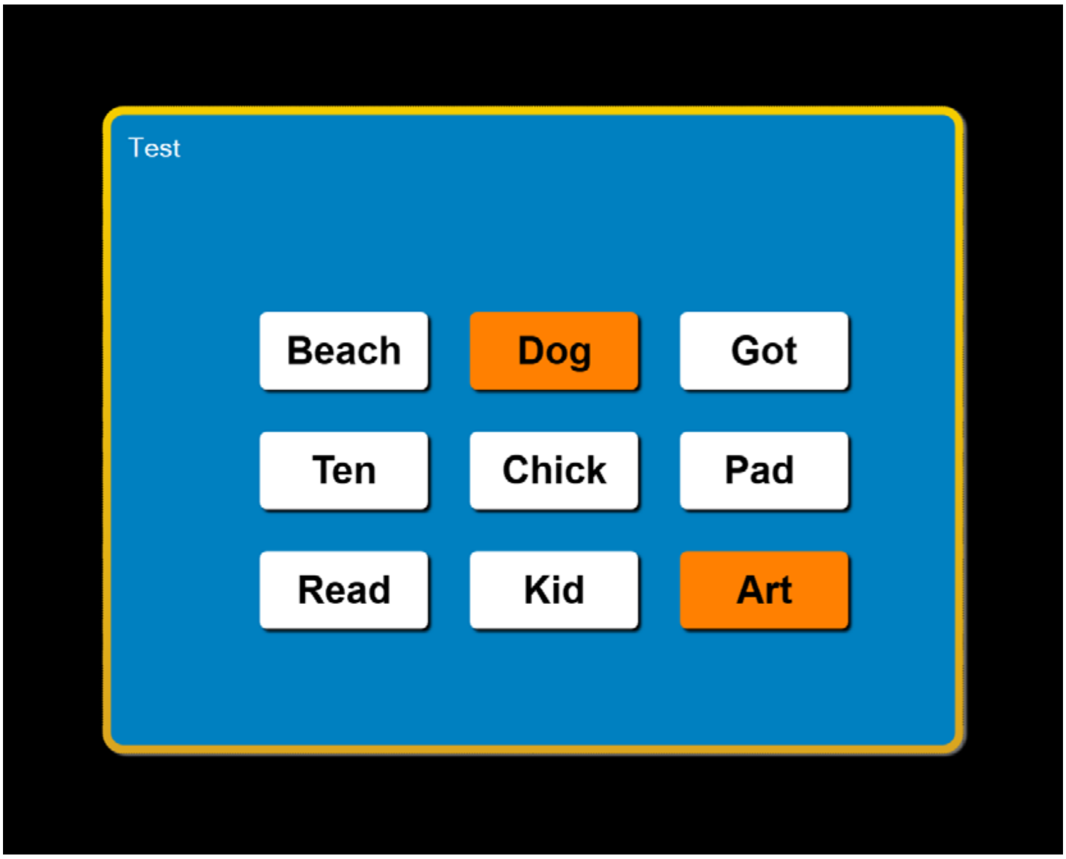


Figure 2. Example screen from the Word Recall test.

2.1.2 Pattern Recall

This is a test of the functioning of the *visuo-spatial sketchpad* in which the child sees a matrix pattern of filled (black) and unfilled (white) squares on the computer screen. When the pattern disappears they are presented with a blank matrix of all white squares and they are then required to recreate the pattern by using the computer mouse to click on the squares to be filled (for example, see Figure 3). All patterns used in this test are generated randomly.

The test begins with a demonstration of what is required, followed by four **practice items**, two with a matrix of four squares (2 x 2), and then two with a matrix of six squares (2 x 3). During these practice items the child receives aural feedback to inform them whether they were correct or incorrect.

There are then a **maximum of six test items** at each matrix size, starting with four squares and increasing by two squares per level up to a maximum of 24 squares (some matrices being necessarily irregular in shape), during which no feedback is given. Each matrix size is regarded as a **level**. If four items at any particular level are recalled correctly then the program jumps to the next level, omitting the remaining one or two items in that level (which are credited to the score). The task is discontinued when three or more trials at any level are recalled incorrectly.

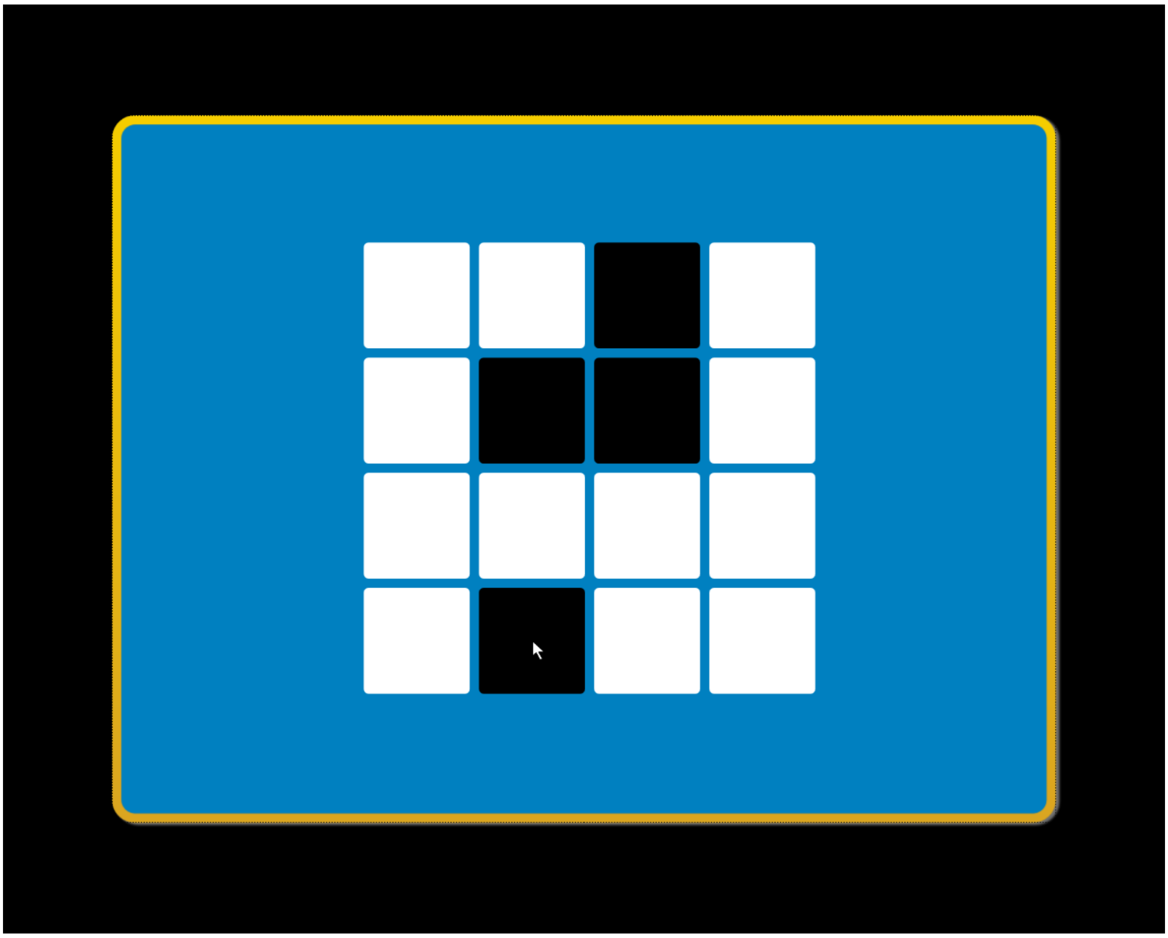


Figure 3. Example screen from the Pattern Recall test.

2.1.3 Counting Recall

This is a test of *central executive* functioning that involves carrying out a sequence of between two and six independent counting tasks whilst simultaneously remembering the results of each count in the same order. In each count the child is presented with an array of different shapes, the numbers and locations of which are randomly generated, and is required to count the number of red circles, using the computer mouse to select the correct answer at the bottom of the screen (for example, see Figure 4). At the end of each item (i.e. sequence) they are asked to recall the number of red circles in each counting array, in the same order in which they were presented.

The test begins with a demonstration of what is required, followed by **four practice items**, two with two-count arrays, and then two with three-count arrays, during which no feedback is given. There are then a **maximum of six test items at each sequence length** (from two to a maximum of six counts in the sequence), during which no feedback is given. Each sequence length is regarded as a **level**. If four items at any particular level are recalled correctly then the program jumps to the next level, omitting the remaining one or two items in that level (which are credited to the score). The task is discontinued when three or more trials at any level are recalled incorrectly.

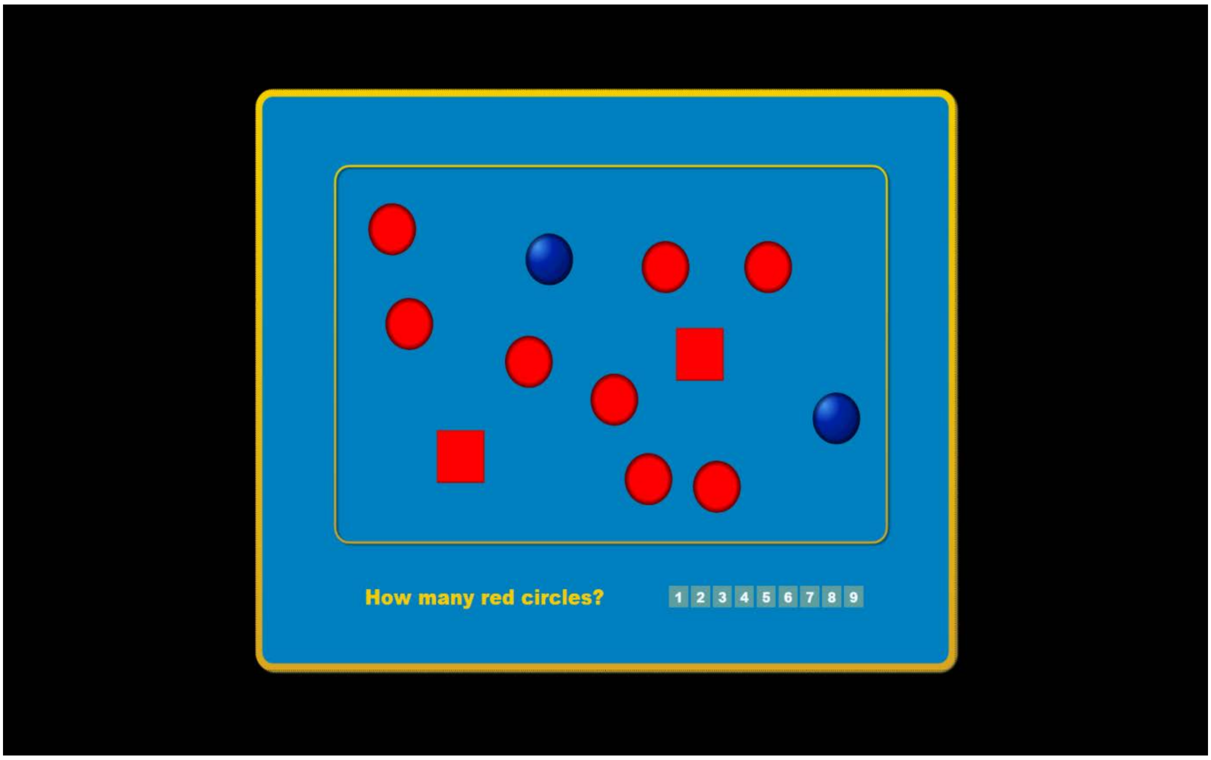


Figure 4. Example screen from Counting Recall test.

2.2 Administration guidelines

2.2.1 Trial run-through including how to exit during a test

Assessing students with Lucid Recall is straightforward but before the teacher or administrator attempts to test any student it is advisable first to run through the complete suite of tests to familiarise themselves thoroughly. To do this, register yourself as the ‘student’. If you wish to exit any test and return to the tests menu before the end, then press **F4**. This quick exit from a test is also useful when demonstrating the program to other teachers or for use in training sessions. However, the **F4** key should not be used when testing a student unless absolutely necessary, as data from that test will not be saved.

2.2.2 Testing environment and equipment

The ideal testing environment is one that is reasonably quiet, with minimal distractions. Ideally, this should be a separate room, but Lucid Recall has been designed to be robust for use in the ordinary classroom, provided visual and auditory distraction (both to the student being tested and to other students in the class) have been minimised. To minimise auditory distraction, headphones are recommended. Inexpensive lightweight headphones of the type used for portable audio equipment will be adequate (but not the type that are inserted into the ear). Teacher or supervisor judgement is paramount in ensuring the appropriate testing environment.

If assessment is going to be carried out in an ordinary classroom in which there are other pupils, the computer and the student should be positioned in such a way that the student is not looking directly at the rest of the class, nor should the rest of the class easily be able to see the monitor screen. The best position for this is usually in the corner of the room. Students should not attempt the tests when other students are in a position in which they can become involved in the task or act as a distraction. It will be hard for other students to inhibit their reactions and their behaviour may influence the decisions of the student being tested.

The teacher or supervisor should check that the equipment being used for the assessment is functioning correctly. This includes checking (1) that the sound system (speakers or headphones) is audible (not too loud or too soft, and without interference), and (2) that the mouse is functioning correctly.

1. **Sound System.** Lucid Recall includes a ***sound volume check*** that allows the teacher or other administrator to test the sound level on any computer (you need to be running Lucid Recall on that computer with the headphones or speakers plugged in). In the ***Administrator Console***, click on the icon for ‘Sound Volume Check’ to hear a voiced sample sound, which will be the same voice used throughout Lucid Recall. If the sound is not at the desired volume, please exit from Lucid Recall and alter the computer’s sound volume. There may be a speaker icon with a slider control on the Taskbar at the bottom right of the computer’s monitor screen.
2. **Mouse.** Please ensure that the mouse is functioning correctly (non-optical types, particularly, require regular cleaning) and is positioned in front of the student on a suitable surface so that its movements are unimpeded. Lucid Recall should ideally be used with a mouse (wired or wireless) rather than a touch pad as the latter may affect response times.

Lucid Recall should not be used for testing when any other applications are running on the computer, as these can interfere with the timings and recording of results. Please close down all other applications before starting Lucid Recall.

2.2.3 Student preparation

Before testing, each student must be registered for the program (name and date of birth). Use the program’s help files by pressing F1 (see the Section 1.7 for guidance). The tests are selected from the Tests Menu screen (see the help files by pressing F1 from within the program). The tests can be done in any order but it is usually best to start with word recognition which students generally find quick and easy. Instructions are spoken by the computer, and each test commences with a practice or demonstration of the task. When the student has completed the practice items, the test phase begins.

The student should be sitting comfortably at a suitable level in front of the computer screen (not too high or low, in order for them to see the screen and use the mouse satisfactorily). It is not recommended that students attempt the tests standing up, as they are more likely to move about and alter the angle at which the screen is viewed – this can lead to failure to see everything that is happening on the monitor, and can also disrupt mouse control. The supervisor should check for reflections on the monitor from windows and lights that could impair the student's perception. To do this the supervisor should check by viewing the screen from the same position that the student will adopt.

If necessary, students should be shown how to indicate responses to the computer using the mouse, and when to respond (essentially when the tests will allow them to respond). This is particularly important when testing students with physical disabilities. As with any format assessment, students should not be allowed to take the tests if they are unwell, as results are likely to be unreliable.

Most students will experience no difficulties in understanding what is required of them when taking the tests in Lucid Recall, enabling them to follow the practice tasks easily and progress to the test phase without special attention from the teacher or supervisor. However, it is important that the administrator ensures that students understand the nature of the tasks in Lucid Recall: that they are tests and not games, and they must work swiftly but thoughtfully and try their best at all times.

In the rare event that a student does not understand the instructions spoken by the computer the supervisor may re–express them in a more suitable manner. Explaining and re-expressing the task requirements to the student may continue into the demonstration and practice stages of each test. This is particularly useful for any student who is experiencing problems in understanding the true nature of the task. It is often easier for the student to comprehend the task requirements by experience of the practice stages, than by more abstract oral explanation. Once the test items commence there should be no further aid given to the student.

The three tests in Lucid Recall can be completed in any order.

2.2.4 Supervision

It is usually not necessary for students to be closely supervised while attempting the tests, unless the teacher or administrator has a particular reason to do so. Lucid Recall is specifically designed for group testing and to require minimal input from the teacher or administrator. Note that if the results are being used to apply for exam access arrangements, JCQ regulations require the specialist who signs the JCQ forms to supervise the assessment.

Children with special educational needs may require additional support during assessment. If children struggle with word reading they may find it particularly difficult to complete the word recall test, which relies upon children being able to remember words, but also read the target words and distractor items. Support can therefore be offered so that children can recall the words out loud and a teacher or support worker can click on these words on the screen to provide a response. Using this method the scores will still reflect a child's working memory, but will not be influenced by reading ability.

The tests in Lucid Recall have been designed to be interesting and stimulating for students in this age group and the vast majority of students are highly motivated to do their best. Once the teacher is satisfied that the student understands the requirements of a test, has completed the practice items and has moved on to the test items, the teacher may leave the student to complete that test.

Where the teacher suspects that a student may not be well motivated to complete the test, or may be easily distracted, or may be performing deliberately below their capabilities, closer supervision will be necessary. Disaffected students may display non-compliance by clicking on answers at random, rather than thinking about the tasks and selecting answers after proper consideration. Such students, or those with very low ability, may need close supervision in order to provide encouragement and ensure they remain on task.

In order for the assessment to be 'fair' (i.e. to give a reasonably accurate representation of the student's abilities) it is essential to ensure that during the test:

- the student is paying attention, is 'on task', is not distracted and trying their best
- the student does not become unduly fatigued
- there is no teaching or helping with the task during the test items (whether from the supervisor or other students)
- that feedback from the supervisor is minimised and encouragement consistent (see further comments below).

2.2.5 Giving encouragement, prompts and feedback

As much as possible, the supervisor should avoid giving specific feedback to students during a test, because this may influence their behaviour in an undesirable fashion. This is good practice in any testing situation. There is a risk of feedback differentially affecting students, so that some are encouraged and others discouraged. Nevertheless, some students (particularly younger students or students with special educational needs) will try to elicit feedback from the supervisor about their performance. This may take the form of both verbal and non-verbal behaviours. For example, the student may ask directly if they were correct. Many students will look for the supervisor's facial and bodily reactions to their responses. Some students may even try to evaluate the supervisor's reaction by observing the supervisor's reflection in the monitor screen. For these reasons it is usually preferable that if the supervisor is going to be near the student to observe the assessment they should sit to the side and slightly behind the student to minimise any feedback to the student which may bias the results.

Rather than specific feedback, general encouragement should be given to the student. This encouragement should be referenced to task completion rather than task accuracy and ideally should be delivered equitably to all students. However, it is inevitable that some students will require more encouragement than others, and where this is the case the teacher should be mindful of the possibility of influencing results unduly. Differential encouragement between students is likely to have an influence on the results obtained, and therefore should be avoided where possible. Some key phrases and general incentive prompts which may be used to aid the administration of the tests include: "well done"; "you were good at that, now try the next one"; "you will like this game"; "now concentrate on this"; "try hard"; "listen very carefully"; "have a go at these ones"; "have a try"; "just do your best".

2.2.6 Timing of the assessment

It usually takes about 20–30 minutes for most children to complete the three tests in Lucid Recall. However, children who take a long time to respond to each trial, or more able children who progress to the most difficult levels, may take slightly longer. However, it is recommended that no time limit should be imposed upon children, who should be instructed to complete the tasks in their own time.

Each test is administered using a span procedure. This means that at the beginning of each test there are only a few items to remember, but the number of items then increases over successive trials. Testing is automatically terminated when a child continues to respond incorrectly, indicating that the number of items to be remembered has exceeded their memory span. This minimises the amount of time it takes to complete the assessments.

The time required to complete each test is also minimised by using a progression rule. A trial is one sequence of items or one pattern that is presented for recall. Each test is organised in blocks of six trials which have the same level of difficulty (i.e. the same number of items to remember). If a child correctly recalls four trials in any one block they automatically progress to the next block and full credit is given for the omitted trials. When three or more errors are made within a single block testing is automatically discontinued.

2.3 Assessing students outside the 7–16 age range

2.3.1 Assessing students under 7:0

It is standard practice that normative tests are not generally recommended for use outside the age range for which they have been designed and standardised. Any test, such as Lucid Recall, which meets basic psychometric criteria must be standardised on a given population and this will determine the range of applicability of the test (see Section 1.3 for explanation of the standardisation process). Tests appropriate to the students' chronological age should be used wherever possible, to avoid the dangers of inappropriate decisions being made – e.g. that a student is 'at risk' (or not 'at risk') or requires intervention (or no intervention) when the evidence for this may be unsound.

If the student being assessed is younger than age 7:0, then Lucid Recall will use the norms for the age range 7:0 – 7:5 when analysing results, and this will almost certainly lead to an underestimation of their performance as chronological age generally has a major impact on performance in childhood. However, it is also important to be aware that the tests in Lucid Recall were not designed for children under the age of 7; such children may find the tests too difficult, scoring at, or close to, what is called the *floor* of the test (i.e. the minimum raw score obtainable on a test; in Lucid Recall this is zero). On the word recall test, more than 10% of children under 7:0 would be expected to score at floor level. On the pattern recall test, more than 4% of children under 7:0 would be expected to score at floor level. On the counting recall test, more than 21% of children under 7:0 would be expected to score at floor level.

From these figures it can be seen that Lucid Recall loses much of its discriminatory power at lower skill levels when used with children under 7:0, this is most apparent on the counting recall test (on which the test does not discriminate below SS 88), somewhat less marked on the word recall test (on which the test does not discriminate below SS 81, and least of all on the pattern recall test (on which the test does not discriminate below SS 73).

On the other hand, if a child under 7 is believed to be *ahead of* his or her peers in cognitive development, Lucid Recall may be useful in revealing how advanced their development is. In such circumstances **age equivalents** would be the preferred form of scores for the teacher or administrator to use, rather than standard scores or centile scores, and results should always be interpreted with care. For further information about age equivalents, see Section 3.2.4).

Consequently, use of Lucid Recall with students under the age of 7 is not recommended except under special circumstances as outlined above.

2.3.2 Assessing students older than 16:11

Lucid Recall was designed for use with students aged up to 16 years 11 months and use with students older than this can create problems when interpreting results. However, provided assessors are aware of the issues involved and results are interpreted with care, Lucid Recall can be used with students older than 16:11.[3]

Just as the use of Lucid Recall with children younger than age 7 can confront the assessor with test floor issues, Lucid Recall with students older than age 16:11 may occasionally create *test ceiling* issues. Strictly speaking, the ceiling of a test is the *maximum raw score* obtainable, and that is the meaning used here. Sometimes, however, the term is applied to the *upper age limit* for which the test has been normed, because over this age limit the standard score norms will not be valid.

On the word recall test, more than 3% of students over age 16:11 would be expected to score at ceiling level (raw score 30). On the pattern recall test, more than 1% of students over age 16:11 would be expected to score at ceiling level (raw score 66). On the counting recall test, more than 5% of students over age 16:11 would be expected to score at ceiling level (raw score 30).

While the proportions of students over age 16:11 scoring at ceiling level on Lucid Recall are generally smaller than the proportions of students under age 7:0 scoring at floor level, it is still apparent that some discriminatory power is lost when Recall used with more skilful students over age 16:11. Above this age the word recall test does not discriminate above SS 128, the pattern recall test does not discriminate above SS 139, and the counting recall test does not discriminate above SS 124. However, this is probably less of a problem than younger students scoring at the floor of the test because the principal use of Lucid Recall is likely to be in identifying students who have working memory difficulties. If the focus of interest is in those students whose working memory is well below that of their peers, the lack of discriminatory power with older students who have superior memory skills is not a serious concern.

If the student is older than 16:11 then the program will use the norms for age 16:6–16:11 when analysing scores. For this reason, when assessing students over age 16:11, **age equivalents** are the preferred form of scores for the teacher or administrator to use. For further information about age equivalents, see Section 3.2.4).

2.4 Retesting

It is often desirable to retest a student after the initial assessment, either to monitor progress or because the first assessment was unreliable for some reason (e.g. because the student was unwell, unmotivated or misunderstood the requirements). As explained in Section 1.1.6, due to practice effects, retesting using conventional tests can be problematic and minimum intervals between testing sessions (e.g. 6 or 12 months) are stipulated to try to counter these effects, or parallel forms of the test are used.

Since item content in Lucid Recall is generated at random, practice effects are minimised and consequently there are no stipulated intervals between testing and retesting with Lucid Recall, nor any restrictions on the number of times students may be retested. This is particularly useful when needing to evaluate the impact of intervention over time. Indeed,

[3] Be aware that some regulations (e.g. JCQ regulations for exam access arrangements) insist that students being assessed are within the normed age range for the test.

Lucid Recall has been set up to facilitate retesting. When a student completes all three tests in the Lucid Recall suite *a new test record is automatically created* so that the program is ready for the student to be retested whenever that may be. When a student has completed the test suite a second time, their results can be viewed in **Historical Report** format, which displays the results of the last four occasions on which the student was tested.

2.5 Assessing students who have limited English

Assessment of any student who has limited proficiency in spoken or written English is often problematic. But there is evidence that Lucid Recall is much better than many conventional methods of assessment, because of its strongly visual format and minimal reliance on spoken instructions. In order to tackle the Word Recall test the student will need to have had sufficient familiarity with simple English words in their written form and to tackle the test of Digit Recall the student will need to know the digits 1–9 in written form. The practice items enable most students, even those with very little English, to understand the tasks, and where there is uncertainty a teacher or assistant who speaks the student’s mother tongue can help with explaining instructions. It can be seen that these are pretty basic requirements that are unlikely to be a problem for most students for whom English is an additional language (EAL).

For a discussion of working memory in relation to learning a second language, see Juffs and Harrington (2011).

3 Understanding results

3.1 Types of report

Lucid Recall is able to create two types of reports for each student, both of which are in pdf format and which be viewed on-screen or printed out.

The **Single Assessment Report** occupies a single A4 page and presents all the results for a given student on a single given assessment (for example, see Figure 5). A box is provided at the bottom of the page in which the Assessor can add comments (the box will accept about 150 words depending on font size). All results are shown in tabular format, with standard scores also being shown in graphical format as a bar chart. To aid speedy identification of areas of difficulty, the bars on the chart are coloured blue if the standard score is 85 or above (i.e. within the normal range or better), and pink if below 85 (i.e. below the normal range, indicating that the result is a matter of concern).

The **Historical Assessment Report** comprises three A4 pages and presents all the results for a given student obtained on a maximum of the last four assessments. This aids comparison of results over time and facilitates evaluation of progress and the impact of interventions. All results are shown in tabular format with standard scores also being shown in graphical format as a bar chart on the first page. An example of the first and second pages of an historical report is shown in Figure 6 and Figure 7. Bars on the graphical chart are colour-coded to facilitate discrimination of results, these colours being replicated in the table below which gives assessment dates and comparative results. Scores below standard score 85 are hatched. Tables of normative results for each assessment session are provided on page 2, and the comments made by assessors on each occasion are given on page 3.

3.2 Types of scores

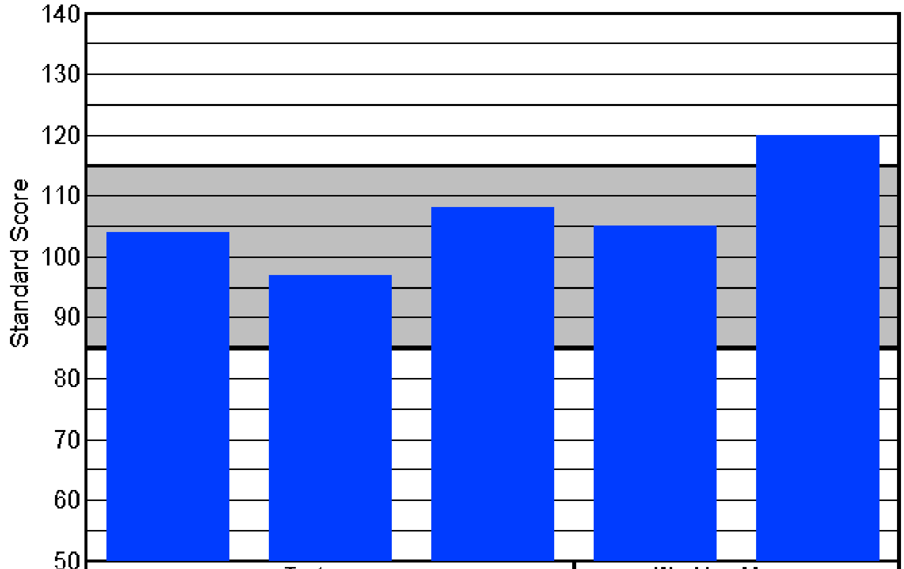
All raw scores on Lucid Recall are saved automatically to a single data file on completion of each test. The data saved also includes the date and time the test was completed, as well as the registered details of the student. If a test has been abandoned before completion, then no results will be saved for that test. Reports are calculated in real time (at the moment of access or viewing) so that if ever any information has changed it will be incorporated in the current displays. This is important, for example, where errors have been made in entering the student's date of birth, in which case the wrong norms may have been used by the program. Therefore if any mistakes of this nature were made then it is important to recalculate the results by generating new reports after any corrections have been made.

The program then refers to the standardised norms in order to convert raw scores to the following three types of score.

- Standard scores (and Confidence band)
- Centile scores
- Age equivalents

The first of these is shown in graphical (bar chart) format as well as numerical format, while the remaining two are shown only in numerical format. These different types of score formats are explained in the following sections.

Lucid RECALL Results Profile	Lucid Research Limited		
	Student's Name	**DOB**	**Identifier**
	Jessica Lambert	12/06/2005	2739
	Page 1 of 1 Printed on 12/06/2013 at 16:28		



	Tests			Working Memory	
	Word Recall	**Pattern Recall**	**Counting Recall**		
WM Function	**Phonological Loop**	**Visuo-Spatial Sketch Pad**	**Executive Function**	**Composite**	**Processing Speed**
Standard Score	104	97	108	105	120
Confidence Band	90-118	85-109	96-120	93-117	109-131
Centile Score	61	43	71	64	91
Age Equivalent	9:0-9:5	7:6-7:8	10:6-10:11	9:3-9:5	12:6-13:5
Raw Score	11	19	11	31	0.47
Test Date	12/06/2013	12/06/2013	12/06/2013	12/06/2013	12/06/2013
Test Age	8:0	8:0	8:0	8:0	8:0

Memory Span (Items)			Average Time (Seconds)		
Word	Pattern	Counting	Word	Pattern	Counting
4 (high)	5 (avg)	3 (avg)	3.73 (fast)	2.89 (fast)	5.98 (fast)

Assessor's Comment

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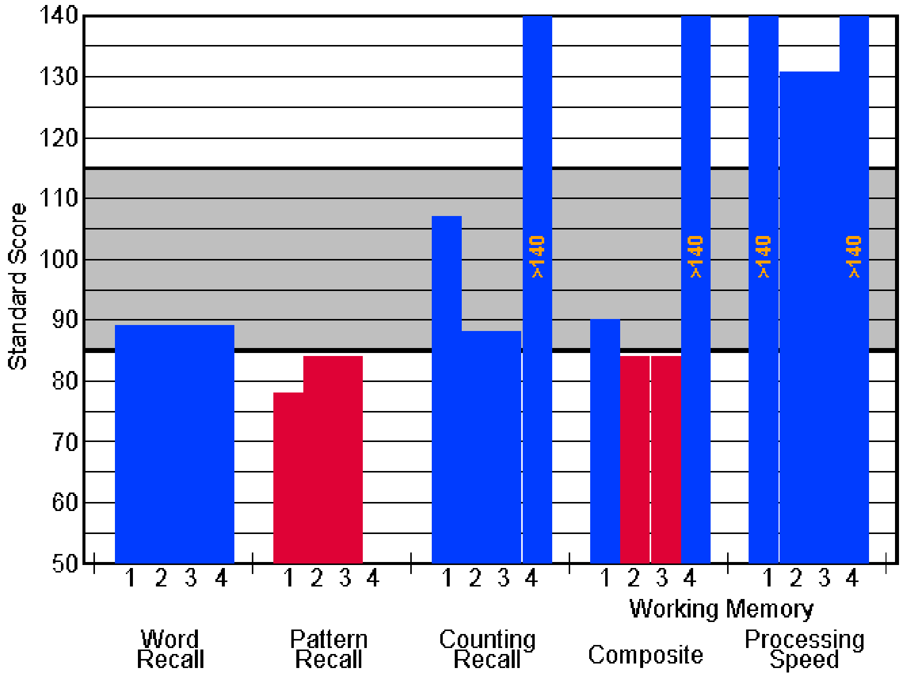
Figure 5. Example Single Assessment Report.

Lucid RECALL Results Profile	Lucid Research Limited		
	Student's Name	**DOB**	**Identifier**
	Claire Thompson	07/01/2006	5
	Page 1 of 3 Printed on 12/06/2013 at 11:46		

NOTE: As this is a historical report of the student's progress, and only contains the last four tests that they have completed, the may have done more tests that are not present on this report.



	Date Test Completed	Comparative Results					
		Memory Span (Items)			Average Time (seconds)		
		Word Recall	Pattern Recall	Counting Recall	Word Recall	Pattern Recall	Counting Recall
1	09/06/2013	2 (avg)	2 (low)	3 (high)	2.46 (fast)	36.47 (slow)	2.43 (fast)
2	10/06/2013	2 (avg)	3 (low)	0 (low)	2.46 (fast)	36.47 (slow)	2.31 (fast)
3	11/06/2013	2 (avg)	3 (low)	0 (low)	2.46 (fast)	36.47 (slow)	2.31 (fast)
4	12/06/2013	2 (avg)	4 (avg)	6 (high)	2.46 (fast)	36.47 (slow)	2.16 (fast)

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Figure 6. Example (Page 1) Historical Assessment Report.

Lucid RECALL Results Profile

Lucid Research Limited		
Student's Name	**DOB**	**Identifier**
Claire Thompson	07/01/2006	5
Page 2 of 3 Printed on 12/06/2013 at 11:46		

Date Test Completed	Word Recall	Pattern Recall	Counting Recall	Working Memory	
				Composite	Processing Speed
Standard Score					
09/06/2013	89	78	107	90	>140
10/06/2013	89	84	88	84	131
11/06/2013	89	84	88	84	131
12/06/2013	89	N/A	>140	>140	>140
Confidence Band					
09/06/2013	75-103	66-90	95-119	78-102	129-151
10/06/2013	75-103	72-96	76-100	72-96	120-142
11/06/2013	75-103	72-96	76-100	72-96	120-142
12/06/2013	75-103	N/A	128-152	128-152	129-151
Centile Score					
09/06/2013	24	7	69	26	99
10/06/2013	24	14	22	14	98
11/06/2013	24	14	22	14	98
12/06/2013	24	N/A	99	99	99
Age Equivalent					
09/06/2013	5:0-5:5	<5:0	8:6-8:11	<5:0	>16:11
10/06/2013	5:0-5:5	<5:0	<5:0	<5:0	14:6-15:5
11/06/2013	5:0-5:5	<5:0	<5:0	<5:0	14:6-15:5
12/06/2013	5:0-5:5	N/A	>16:5	>16:11	>16:11
Raw Score					
09/06/2013	3	3	8	12	0.32
10/06/2013	3	7	0	06	0.43
11/06/2013	3	7	0	06	0.43
12/06/2013	3	78	30	68	-0.37
Test Age					
09/06/2013	7:5	7:5	7:5	7:5	7:5
10/06/2013	7:5	7:5	7:5	7:5	7:5
11/06/2013	7:5	7:5	7:5	7:5	7:5
12/06/2013	7:5	7:5	7:5	7:5	7:5

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Figure 7. Example (Page 2) Historical Assessment Report.

3.2.1 Standard scores

Standard scores are provided in 6-month age bands from 7:0 to 16:11. Standard scores have a mean (average) 100 and a standard deviation of 15. [4] They are distributed in a normal (bell shaped) curve as shown in Figure 8. Approximately two-thirds of the population will have scores that fall between plus or minus one standard deviation of the mean (i.e. score range 85 – 115, which is the area shaded blue on the graph in Figure 8). In some scoring systems the range 85 – 115 is regarded as the 'normal' or 'average' range, while other systems treat 90 – 110 as the 'normal' or 'average' range; in the latter case, 50% of the population will fall into the average band. The more extreme the score the fewer individuals are found in that category, so that only about 2% of the population have very low scores (less than 70) and about 2% have very high scores (130+). This distribution of scores is a characteristic of all human attributes (height, weight, strength, sociability, etc.), i.e. most people tend to cluster around a central point and as one approaches the extremes (known as the 'tails' of the distribution) fewer people are found.

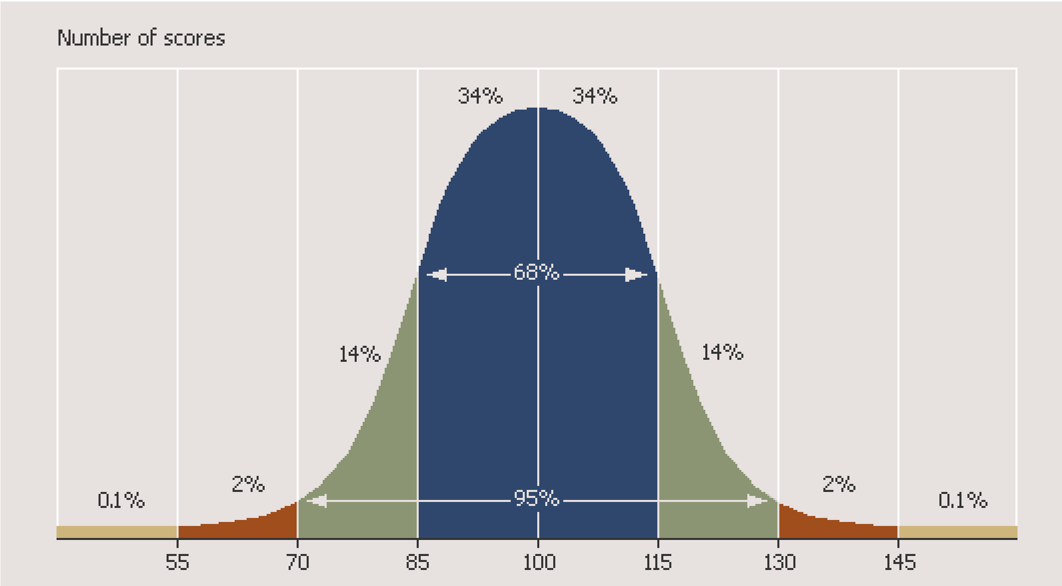


Figure 8. Distribution of Lucid Recall scores on a normal curve (the figures along the bottom of the diagram correspond to standard scores)

3.2.2 Confidence intervals

When reporting a standard score, it is good practice also to report the *confidence band (or interval)* associated with that score. The reason for this is that all psychological and educational tests scores give only *estimates* of ability, based on a sample of behaviour at a given point in time. If you were to assess a student on several occasions you would not expect them to obtain exactly the same score each time – there would be a spread of scores and somewhere within that spread we would expect the (hypothetical) *true score* to lie. The amount of spread or variation of actual scores obtained by an individual is dependent on the *reliability* of the test. The confidence interval is the zone around the standard score in which we are reasonably confident the *true score* lies. Different confidence intervals may be set: for Lucid Recall we have set a confidence level of 90%, which means that there is a 90% probability that the true standard score lies within the stated confidence interval. Put another way, if the student was retested 100 times, on 90 out of 100 occasions the score would lie within the stated confidence interval.

[4] The standard deviation is a statistical measure of the average variability of scores in a distribution.

Confidence intervals are calculated on the basis of the *Standard Error of Measurement* (SEM) of a test which, in turn, is determined by the reliability of the test and the standard deviation of test scores (see Section 1.5).

3.2.3 Centile scores

Centile scores are provided in 6-month age bands from 7:0 to 16:11. Centile scores (sometimes referred to as ‘percentile’ scores) represent the student’s performance in comparison with the population norms in centile units which range (roughly) from 1 to 99. A centile score of 63, for example, means that the students’ score lay at the point where 63% of the population scored less, and 37% scored more. A centile score of 50 indicates that the student’s score lay exactly on the median (middle point) of the distribution, with half the age group scoring higher and half lower. As will be obvious from Figure 8, centile scores have a strict relationship with standard scores as shown in Table 7.

Table 7. Relationship between standard scores and centile scores.

Standard score	70	80	85	90	100	110	115	120	130
Centile score	2	9	16	25	50	75	84	91	98

3.2.4 Age equivalents

Age equivalents are provided for the age range 5:0 to 16:5 or 16:11, depending on the test (over this age, age equivalents become meaningless). Age equivalents may be defined as the average chronological age of students who would be expected to achieve a given raw score on the test. Age equivalents are another way of expressing how a given student is performing in relation to his or her peers. The most common type of age equivalent in educational testing is the ‘reading age’. For example, to say that a student has a reading age of 14 means that they read like an average 14-year-old, regardless of their chronological age.

Note that because of the way that age equivalents are calculated they are not as precise as standard scores or centile scores; age equivalents should be regarded as approximations and hence are often given in bands. Age equivalents should be used with caution and only in cases where standard scores or centile scores would be inappropriate or unhelpful. It is embarrassing and demotivating for a teenager or adult to be told (for example) that they are performing at the age of a 7-year-old! However, some teachers working in special education prefer to use age equivalents rather than centile scores, because age equivalents enable them to conceptualise the ability level of the student they are teaching, and so pitch the work at the correct level. Also, when circumstances dictate the use of Lucid Recall for assessing a student younger than 7:0 or older than 16:11, age equivalents can prove useful (see Section 2.3 for further information on this).

3.2.5 Raw scores

Raw score are the actual scores obtained by the student on each test. For all except Working Memory Processing Speed the raw scores represent the number of correct items on the test (for Working Memory Composite scores have been weighted to reflect the different numbers of items in each test). For Working Memory Processing Speed the raw score represents the average time in seconds per item counted. For most purposes, raw scores are not particularly useful or interesting, but they may be relevant for some researchers. Note that two students can obtain the same raw score on a test but have different standard or centile scores if their chronological ages are different.

3.3 Memory span

The tests in Lucid Recall are constructed in levels, each level representing an increase in the number of items of information that have to be held in working memory. The maximum number of items of information that an individual can hold in working memory is called their 'memory span', and for each of the three core tests in Lucid Recall this figure is shown on the report. The memory span range is fairly small: for the age range used in Lucid Recall (7:0 – 16:11) the span ranges are 2–6 for word recall and counting recall, and 4–10 for pattern recall. For this reason, the data are not suitable for standardisation in the conventional sense, because the basic psychometric principles of normality of distribution, including kurtosis being below acceptable limits, are not met (for further explanation of the reasons for this, see Section 1.3.3). So instead of presenting memory span in terms of standard scores and centiles, a simple comparison with the age group is provided in three bands: *'low', 'average'* and *'high'*, where the 'average' range represents the modal score range for that age group, with 'low' and 'high' covering the score range below and above this respectively.

Memory span is dependent on the nature of the information being processed. For example, for an 8-year-old, a memory span of five is above average for words but only average for patterns. This is partly because words require more memory storage space than simple patterns, and partly because the child learns to process visual information before being faced with the complexities of relating spoken words to their printed forms. Memory span also tends to increase with age. For example, a memory span of seven for patterns is above average at age 8 but below average at age 12.

3.4 Average time

The average time per item on each of the three core tests is shown in seconds. As with memory span, the data are also not suitable for standardisation in the conventional sense, because the basic psychometric principles of normality of distribution are not met. In this case, the most obvious violation of those principles is that skewedness exceeded acceptable limits. This is very typical of time-related data, which tends to be distributed with a high positive skew (i.e. scores bunching to the lower or left tail of the distribution, with a long, thin, extended right tail). So instead of presenting memory span in terms of standard scores and centiles, a simple comparison with the age group is provided in three bands: *'fast'* (less than one standard deviation below the mean time per item of the standardisation sample), *'average'* (between one SD below and one SD above the mean time per item of the standardisation sample), and *'slow'* (more than one SD above the mean time per item of the standardisation sample).

3.5 Interpreting scores

If a child has a poor or below average working memory it is likely that they will struggle in the school classroom and be at risk of poor educational attainment. In such cases it may be appropriate to consider a full and detailed assessment of a child's working memory and related skills. In such cases it is also necessary to explore interventions to reduce the chance of children failing on learning activities as a result of a poor working memory. If a child has an average working memory they may also benefit from some of the interventions. It may be possible for them to improve their working memory to an above average or good level. If a child already has an above average or good working memory, they will be well equipped to perform well in the school classroom and achieve good levels of scholastic attainment. Details about teaching strategies and interventions that can be used for children with a poor working memory are discussed in detail in the next chapter.

4 Helping children with a poor working memory

4.1 Poor working memory in the classroom

Children with a poor working memory make frequent errors in learning activities. These include forgetting lengthy instructions, place-keeping errors (e.g. missing out letters or words in a sentence), and failure to cope with simultaneous storage and processing demands (e.g. Alloway & Gathercole, 2006). In general, children are not able to meet the memory demands of many structured learning activities (Gathercole & Alloway, 2008). Consequently, working memory can become overloaded and information that is needed for successful task completion is lost from working memory. If children frequently fail in learning activities their progress in acquiring complex knowledge and skills in areas such as literacy and mathematics will be slow and difficult. Thus, the majority of children with a poor working memory are slow to learn throughout childhood, and are at risk of poor academic attainment (e.g. Gathercole & Alloway, 2008; Gathercole & Pickering, 2000; Gathercole et al., 2004; Jarvis & Gathercole, 2003).

It is, however, important to note that children with a poor working memory are not often described by their teachers as having memory problems (e.g. Gathercole et al., 2006). Rather, they are often described as having attentional problems, or being likely to engage in "mind-wandering" (e.g. Kane, Brown, McVay & Silvia et al., 2007). This phenomenon has been referred to as 'zoning out', and is common is situations in which working memory is overloaded and therefore it is not possible to keep the information needed in mind. Children therefore fail to remember crucial information, and so they shift attention away from the task in hand. This often leads to concerns about inattentiveness. However, children with a poor working memory do not show attentional deficits if rated using the Conners' Teacher Rating Scale (e.g. Alloway & Gathercole, 2006). The behavioural profile of children with poor working memory is also unlike disorders like ADHD.

Poor working memory is therefore difficult to recognise in the school classroom. However, Lucid Recall provides a reliable, valid, and efficient method for identifying children with a poor working memory. It can be administered in group settings, and no teacher or researcher input is required. Therefore teachers and researchers now have access to an easy and efficient tool to screen large numbers of children for working memory problems. This should make it easier for working memory difficulties to be identified.

After identifying that a child has a poor working memory, steps can then be taken to minimise the chance of a child failing on learning activities as a result of a poor working memory. There are two main approaches to intervention. These are discussed in detail in the following sections.

4.2 Teaching strategies

The first approach to ameliorating the difficulties experienced by children with a poor working memory is to reduce the working memory demands of classroom activities. A number of guidelines have been proposed to support children with poor working memory (e.g. Gathercole & Alloway, 2008). After recognising working memory failures teachers should try to evaluate the working memory load of classroom activities. This involves being mindful that heavy loads are caused by lengthy sentences, unfamiliar content, and demanding mental processing activities. Where possible, teachers should then reduce working memory demands. For example, children with a poor working memory have particular difficulties with sentence writing (e.g. Alloway & Gathercole, 2006). Processing difficulty can be lessened by reducing the linguistic complexity of the sentences. This can be achieved in a variety of ways, such as simplifying the vocabulary and using common rather than unusual words. The syntax of the sentence can also be simplified, by using simple structures such as active subject-verb-object constructions rather than complex clausal structures.

It is particularly important to ensure that a child can remember what he or she is doing. On many occasions, children with a poor working memory simply forget what they have to do next. Therefore teachers should provide simple instructions, breaking them down into separate independent steps, should repeat important information, or ask a child to repeat it. Teachers should also provide external memory aids such as number lines and useful spellings (e.g. Gathercole & Alloway, 2004; 2008). Children with a poor working memory often choose not to use such devices (e.g. Alloway & Gathercole, 2006), instead using lower-level strategies with lower processing requirements, resulting in reduced general efficiency. For example, instead of using aids such as Unifix blocks and number lines designed to reduce processing demands, children with a poor working memory are likely to rely upon error-prone strategies like simple counting. In order to encourage children's use of memory aids it may be necessary for teachers to give children regular practice with using aids in simple activities with few working memory demands.

Teachers should also encourage children to develop their own strategies for dealing with a poor working memory. These might include asking for help, rehearsing important information, note taking, and organisational strategies. Arming a child with such help-strategies will promote their development as an independent learner.

4.3 Working memory training

The second approach to alleviating the difficulties that arise from a poor working memory is to improve working memory directly. Interventions have included approaches as diverse as mindfulness or meditation training (e.g. Zeidan, Johnson, Diamond, David & Goolkasian, 2010), neurofeedback (e.g. Cannon, Lubar, Gerke & Thornton et al., 2006), physical exercise (e.g. Lachman, Neupert, Bertrand & Jette, 2006), and long-term training on musical instruments (e.g. Jones, 2007). However, one approach rapidly gaining prominence within the psychological literature is cognitive training. Many commercial products have become available, are promoted as being backed by scientific research, and make promises such as improved grades in school, better control of attention and increased IQ.

The majority of training studies have been conducted using *Cogmed* working memory training software. This involves several verbal and visuo-spatial memory span tasks that have been embedded within video games. It is an adaptive program, in that trial-by-trial performance determines how much information a participant is required to remember. Participants are expected to engage in intensive training, completing sessions on a daily basis. Several studies have found improvements in working memory as a result of training using this program. For example, Kingberg, Fernell, Olesen and Johnson et al. (2005) found significant effects in children with attention-deficit hyperactivity- disorder (see also Holmes, Gathercole & Dunning, 2009; Klingberg, Forssberg & Westerberg, 2002). Thorell, Lindquist, Bergman and Bohlin et al. (2009) also found improvements in normally developing preschool children. There is, however, mixed evidence regarding the effects of transfer. That is the extent to which training also improves performance on other cognitive tasks. Klingberg et al. (2002) and Klingberg et al. (2005) reported improvements on the Raven's progressive matrices. However, Holmes et al. (2009; see also Holmes, Gathercole, Place & Dunning et al., 2010) failed to find any improvements on measures of reasoning. Dahlin (2011) reported improvements on one measure of comprehension, but not on another two, and Holmes et al. (2009) did not find improvements on measures of reading or mathematics.

An alternative approach to working memory training involves teaching children how to use memory strategies. For example, St Clair-Thompson, Stevens, Hunt, and Bolder (2010) asked children to use *Memory Booster* (Leedale, Singleton & Thomas, 2004), an enjoyable adventure game for children that teaches and encourages the use of rehearsal, visual imagery, creating stories, and grouping. Rehearsal is the simple repetition of verbal information. Visual imagery involves creating pictures in the mind to represent information that has to be remembered. Creating stories refers to generating a narrative that links together information in the form of a story. Finally, grouping involves using higher-order conceptual categories such as 'living things' to group items. St Clair-Thompson et al. (2010) found significant improvements in children's working memory after using *Memory Booster* for a period of 6-8 weeks. Children also showed significant improvements on tasks of mental arithmetic and the ability to follow instructions in the school classroom. However, evidence suggests that memory strategies are often context specific and thus that transfer may be somewhat limited (see also Shipstead, Redick, & Engle, 2012).

It is also important to note that despite some encouraging findings from experimental studies, the extent to which training can help children with working memory and associated learning difficulties to progress educationally is still unclear. In particular, we do not know the long-term effects and extent of transfer of training. Many studies into working memory training have also been criticised for not placing enough emphasis on exploring relevant confounds, for not employing appropriate control groups, and for neglecting the importance of understanding the mechanisms underlying training based improvements (e.g. for a review see Shipstead, et al., 2012). However, the first step towards providing appropriate interventions is of course to identify working memory problems, something which is now substantially easier due to Lucid Recall.

5 Case Studies

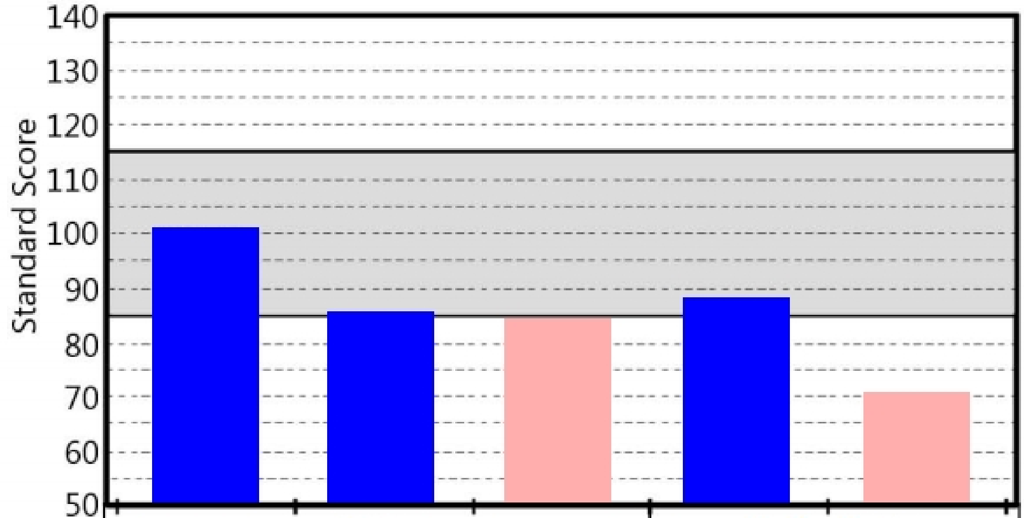
The following four case studies illustrate how the results of Lucid Recall may be interpreted. It should be recognised that in each case conclusions can only be tentative because the information from a 20-minute screening program is inevitable limited. Nevertheless, it can be seen that in most cases the information provided by Lucid Recall can help a teacher or parent understand a child's difficulties. This will allow them to move forward and to consider strategies that could be used to minimise the chance of the child failing on learning activities as a result of inadequate working memory resources.

5.1 Rachel (7 years 10 months)

Rachel's performance on Lucid Recall is shown in Figure 9. Overall her results indicate she has below average working memory. An inspection of Rachel's scores indicates satisfactory performance on the word recall test, so she has no problems with remembering and recalling sequences of verbal information. However, Rachel's performance on the pattern recall task was below average, and her performance on the counting recall task was poor. This profile of scores is typical of some children with special educational needs, who perform more poorly than age matched controls on measures of the visuo-spatial sketchpad and central executive components of working memory. Of particular concern is Rachel's score on the counting recall task, which indicates she has severe difficulties with coping with simultaneous processing and storage demands. Her working memory processing speed is also well below average. These results indicate that Rachel is likely to make slow progress with acquiring knowledge and skills in areas such as literacy and mathematics, and without appropriate intervention is at risk of poor educational attainment.

Overall Rachel's results lead to several recommendations. Firstly, it is important that Rachel's teachers recognise that she has a poor working memory, and that her difficulties are not a result of other problems such as inattentiveness. Teachers can then try to evaluate the working memory load of classroom activities, and where possible reduce working memory demands (see Section 4.2). Intervention work should focus on simultaneous processing and storage demands. For example, Rachel will benefit from some training related to using visual aids, so that they can be effectively used to reduce the amount of information that needs to be remembered during on-going processing tasks. It would also be useful for a teacher or teaching assistant to work closely with Rachel to encourage her to develop strategies for dealing with her poor working memory, including note taking. It is also important to reiterate to Rachel that it is OK to ask for help when it is needed. Finally, Rachel's teachers may also want to suggest some kind of working memory training (see Section 4.3). This would be likely to lead to some improvements in working memory. Although at the moment the long-term consequences of working memory training are unknown, training should at least improve Rachel's confidence and beliefs in her ability to deal with complex processing and storage tasks.

Lucid RECALL Results Profile	Lucid Research Limited		
	Student's Name	**Date of Birth**	**Identifier**
	Rachel Smith	18/04/2005	559
	Date Report Printed: 11/04/2013 at 13:39		



	Tests			**Working Memory**	
	Word Recall	**Pattern Recall**	**Counting Recall**	**Composite**	**Processing Speed**
WM Function	**Phonological Loop**	**Visuo-Spatial Sketch Pad**	**Executive Function**		
Standard Score	101	85	84	88	<70
Confidence Band	87-115	73-97	72-96	76-100	59-81
Centile Score	54	16	14	22	1
Age Equivalent	8:0-8:5	5:0-5:2	<5:0	<5:0	<5:0
RawScore	9	9	0	13	1.09
Test Date	18/02/2013	18/02/2013	18/02/2013	18/02/2013	18/02/2013
Test Age	7:9	7:9	7:9	7:9	7:9

Memory Span (Items)			Average Time (Seconds)		
Word	Pattern	Counting	Word	Pattern	Counting
3 (avg)	3 (low)	2 (avg)	5.53 (fast)	1.02 (fast)	0.8 (fast)

(Assessor's comment (You can enter your own comments and observations in this area.)

Rachel's working memory seems to be below average. An inspection of Rachel's results indicates good performance on the word recall test, so she has no problems with remembering and recalling sequences of verbal information. However, Rachel's performance on the pattern recall task was below average, and her performance on the counting recall task was poor. Rachel's difficulties are due to her poor working memory. Classroom activities will have to take this into account.

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Figure 9. Lucid Recall results for Rachel (age 7:10).

5.2 Emma (11 years 11 months)

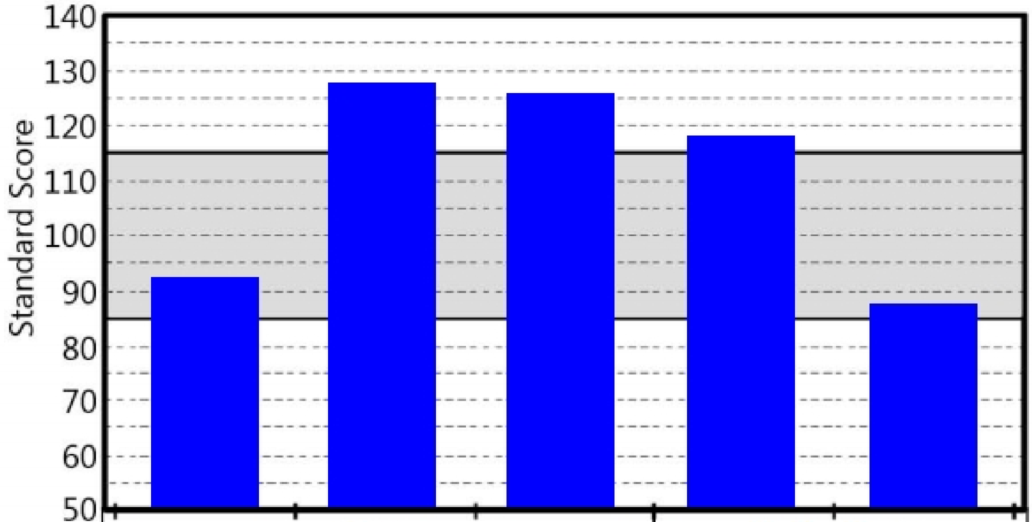
Emma’s performance on Lucid Recall is shown in Figure 10. Emma’s results indicate that she has good working memory. An inspection of her scores reveals that she achieved above average scores for the pattern recall and counting recall task. Her performance was not as high on the word recall task, but still within the average range. These results suggest that Emma is unlikely to have problems with simultaneous processing and storage of information or with remembering information in the visuo-spatial domain. It is therefore unlikely that Rachel will be recognised as having special educational needs, and in general she should perform well in the school classroom.

It is important, however, to acknowledge Emma’s somewhat poorer score on the word recall task. Firstly, it would be useful for teachers to check that a low score was not a result of Emma struggling to read the words during the recall phase of this task. As detailed in Section 2.2.4, word recall relies upon children being able to remember words, but also read the target words and distractor items. Emma could therefore be asked to complete the task again, with a teacher or support worker asking Emma to repeat the words she can remember, and then clicking on these words on the screen to provide a response for her. Using this method the scores will reflect Emma’s working memory, in particular her phonological loop, but will not be influenced by reading ability. If Emma’s score no longer indicates poor performance on this task, then teachers should be aware that Emma may have problems with single-word reading, and needs some practice to improve this skill. If Emma’s score is still indicative of poor word recall, this will lead to several recommendations.

Poor performance on the word recall task, but not on the other tasks in Lucid Recall, usually indicates a specific problem with the immediate serial recall of verbal information. Firstly, it is important for teachers to recognise this difficulty with remembering verbal information. A student affected in this way may struggle with remembering instructions for a task or remembering sentences to write down. Teachers should therefore break down instructions into separate steps, and regularly repeat important information. They should also use memory aids, for example, note task instructions on the class whiteboard. Training which includes appropriate strategies for remembering verbal information (e.g. rehearsing information to be remembered, or forming visual images of items) would be beneficial. One suitable training tool would be *Memory Booster*, mentioned above (see Section 4.3). Students whose recall of verbal information is weak should also be encouraged to use these strategies with other stimuli, for example to practice using rehearsal when remembering a telephone number or a shopping list.

It should also be noticed that Emma’s working memory processing speed was close to the lower boundary of the average range, suggesting that she works at a slower rate than most other students. This could impact on her studies as she gets older, especially in examinations and timed assessments. It would be useful for Emma to understand this herself and to be given advice regarding working more quickly.

Lucid RECALL Results Profile	Lucid Research Limited		
	Student's Name	**Date of Birth**	**Identifier**
	Emma Watson	19/03/2001	560
	Date Report Printed: 11/04/2013 at 13:56		



	Tests			**Working Memory**	
	Word Recall	**Pattern Recall**	**Counting Recall**		
WM Function	**Phonological Loop**	**Visuo-Spatial Sketch Pad**	**Executive Function**	**Composite**	**Processing Speed**
Standard Score	92	128	126	118	87
Confidence Band	78-106	116-140	114-138	106-130	76-98
Centile Score	31	97	96	89	20
Age Equivalent	10:6-10:11	>16:05	>16:5	>16:11	9:0-9:3
RawScore	13	53	25	62	0.63
Test Date	19/02/2013	19/02/2013	19/02/2013	19/02/2013	19/02/2013
Test Age	11:10	11:10	11:10	11:10	11:10

Memory Span (Items)			Average Time (Seconds)		
Word	Pattern	Counting	Word	Pattern	Counting
4 (avg)	9 (high)	2 (low)	2.24 (fast)	2.04 (fast)	0.72 (fast)

(Assessor's comment (You can enter your own comments and observations in this area.)

Overall Emma appears to have good working memory. An inspection of her scores reveals she has achived above average scores for the pattern recall and counting recall tasks. However, Emma's performance was poorer on the word recall task. This indicates that Emma has no problems with the simultaneous processing and storage of information or with remembering information in the visuo-spatial domain. It is therefore unlikely that Emma will be recognised as having special educational needs, and she should perform well in the school classroom.

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Figure 10. Lucid Recall results Emma (age 11:11).

5.3 David (12 years 11 months)

David's performance on Lucid Recall is shown in Figure 11.

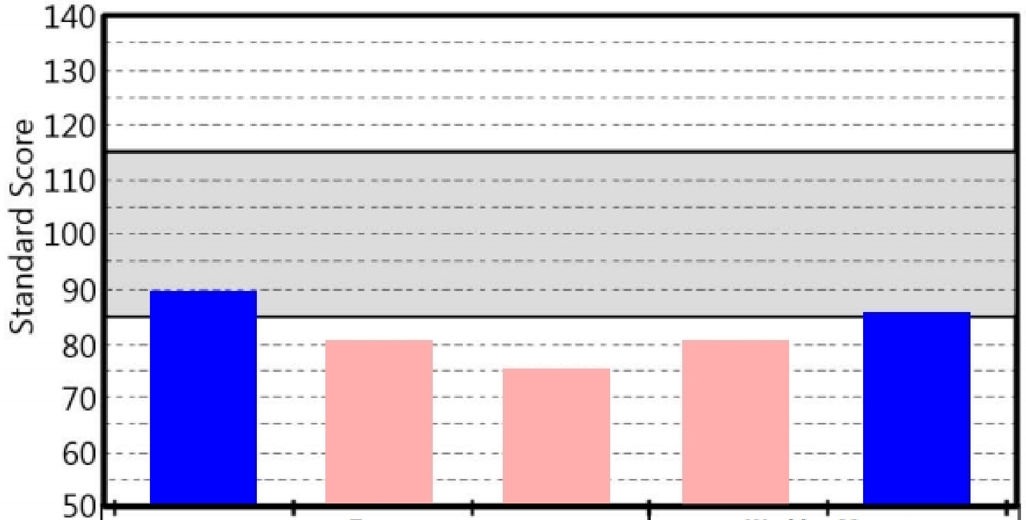
It is apparent that David has rather poor working memory. An examination of the Lucid Recall scores reveals that his performance was poor (below standard score 85) on two of the working memory subtests, and was particularly poor for the pattern recall and counting recall tasks. These scores indicate that David has a general deficit in working memory. This profile of scores is typical of some children with special educational needs, who perform more poorly than age matched controls on measures of the visuo-spatial sketchpad and central executive components of working memory. Therefore it is likely that David should be recognised as needing extra support for learning, and he is likely to make slow progress with acquiring knowledge and skills in areas such as literacy and mathematics, and is therefore at risk of poor educational attainment.

David's results lead to several recommendations. Firstly, it is important that David's teachers recognise that he has a poor working memory, and that his difficulties are not a result of other problems such as inattentiveness or lack of interest in learning. Teachers can then try to reduce the working memory demands of common classroom activities. This involves being mindful that heavy loads are caused by lengthy sentences, unfamiliar content, and demanding mental processing activities. Therefore, where possible teachers should simplify sentences, and use familiar and common words. Teachers should also ensure that David remembers what he is supposed to be doing in any given task, by repeating important information, and also asking David to repeat it. David may also benefit from some training related to using visual aids, so that they can be effectively used to reduce the amount of information that needs to be remembered during on-going processing tasks. David should also be encouraged to develop strategies for dealing with poor working memory, including note taking. It is also important to tell David that it is OK to ask for help when it is needed. At nearly 13 years of age it also important to realise that David has been coping with a poor working memory for some time. Frequent failures on learning tasks as a result of a poor working memory may have therefore been very detrimental to David's confidence and self-belief. David may therefore benefit from increased support, praise and encouragement during learning activities. Finally, teachers may also want to suggest some kind of working memory training (see Section 4.3). Although we do not currently know the long-term consequences of working memory training, nevertheless this should at least improve David's confidence and beliefs in his ability to deal with complex processing and storage tasks.

Like the previous case (Emma), David's working memory processing speed was close to the lower boundary of the average range, suggesting that he works at a slower rate than most other students. This could impact on his studies as he gets older, especially in examinations and timed assessments. It would be useful for David to understand this himself and to be given advice regarding working more quickly.

Lucid RECALL
Results Profile

Lucid Research Limited		
Student's Name	**Date of Birth**	**Identifier**
David Fisher	19/03/2000	561
Date Report Printed: 11/04/2013 at 13:58		



	Tests			Working Memory	
	Word Recall	**Pattern Recall**	**Counting Recall**		
WM Function	**Phonological Loop**	**Visuo-Spatial Sketch Pad**	**Executive Function**	**Composite**	**Processing Speed**
Standard Score	89	80	75	80	85
Confidence Band	75-103	68-92	63-87	68-92	74-96
Centile Score	24	9	5	9	16
Age Equivalent	10:6-10:11	9:0-9:2	7:6-7:11	9:0-9:2	9:0-9:3
RawScore	13	24	6	30	0.64
Test Date	19/02/2013	19/02/2013	19/02/2013	19/02/2013	19/02/2013
Test Age	12:10	12:10	12:10	12:10	12:10

Memory Span (Items)			Average Time (Seconds)		
Word	Pattern	Counting	Word	Pattern	Counting
4 (avg)	5 (low)	2 (low)	2.24 (fast)	1.52 (fast)	0.72 (fast)

(Assessor's comment (You can enter your own comments and observations in this area.)

David has poor working memory. An examination of the Lucid Recall scores reveals that his performance was poor across all three of the working subtests, and was particularly poor for the pattern recall and counting recall tasks. These scores indicate that david has a general deficit in working memory.

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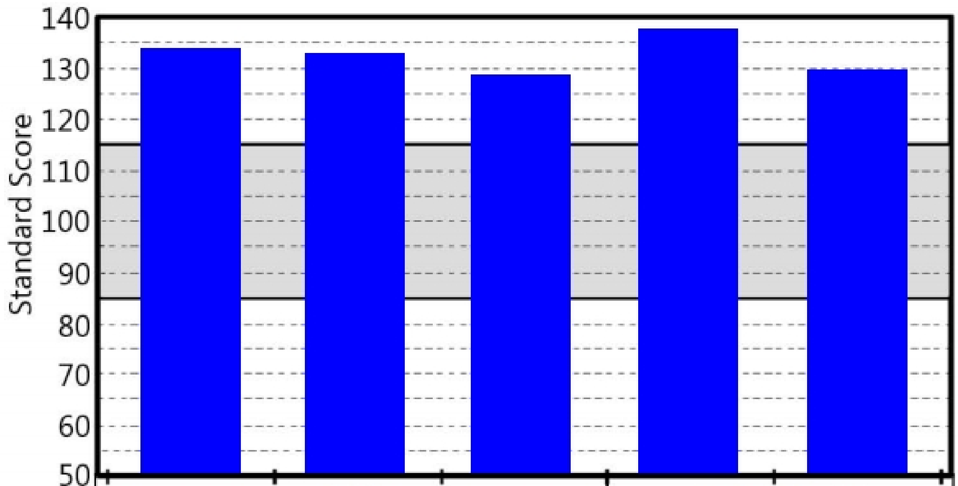
Figure 11. Lucid Recall results for David (age 12:11).

5.4 Rohan (13 years 0 months)

Rohan's Lucid Recall scores are shown in Figure 12.

Lucid RECALL Results Profile	Lucid Research Limited		
	Student's Name	**Date of Birth**	**Identifier**
	Rohan Polinski	19/02/2000	562
	Date Report Printed: 11/04/2013 at 13:58		



	Tests			Working Memory	
	Word Recall	**Pattern Recall**	**Counting Recall**		
WM Function	**Phonological Loop**	**Visuo-Spatial Sketch Pad**	**Executive Function**	**Composite**	**Processing Speed**
Standard Score	134	133	129	138	130
Confidence Band	120-148	121-145	117-141	126-150	119-141
Centile Score	98	98	97		97
Age Equivalent	>16:5	>16:05	>16:5	>16:11	>16:11
RawScore	30	58	28	84	0.12
Test Date	19/02/2013	19/02/2013	19/02/2013	19/02/2013	19/02/2013
Test Age	12:11	12:11	12:11	12:11	12:11

Memory Span (Items)			Average Time (Seconds)		
Word	Pattern	Counting	Word	Pattern	Counting
6 Error	10 (high)	5 (avg)	Error (fast)	1.85 (fast)	0.33 (fast)

(Assessor's comment (You can enter your own comments and observations in this area.)

Rohan has above average working memory. It is not difficult to see why. His performance on each of the subtests was higher than average for children of his age. This suggests that Rohan is good at remembering information in both the verbal and visuo-spatial domains, and does not have problems with simultaneous processing and storage of information. Rohan is therefore well equipped for performing well in learning activities and is likely to achieve good levels of educational attainment.

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Figure 12. Lucid Recall results for Rohan (age 13:0).

It is apparent that Rohan's working memory skills are above average. It is not difficult to see why. His performance on each of the three core tests was higher than average for children of this age. His working memory processing speed was also well above average. This suggests that Rohan is good at remembering information in both verbal and visuo-spatial domains, and does not have problems with the simultaneous processing and storage of information. Rohan is therefore well equipped for performing well in learning activities and is likely to achieve good levels of educational attainment. If any problems do arise for Rohan, his profile suggests that these will not result from his cognitive skills, but rather, other factors that are important in education, such as motivation and engagement. This is not to say that Rohan would not benefit from interventions such as working memory training or advice on improving study skills. For example, evidence suggests that children with a good working memory still benefit from using *Memory Booster*, although not to the same extent as children with a poor working memory. However, intervention is not seen as critical for children with such a good working memory.

5.5 Boris (15 years 10 months) [Examination access assessment]

Boris is in Year 10 and will be sitting GCSE examinations at the end of the year. His literacy skills are average and he shows good conceptual understanding of material, but he works at a very slow rate so that he rarely completes written exam papers within the time limit. He has been encouraged to increase his rate of working but this turned out to be counterproductive because it dramatically increased the number of errors in his work. Teachers have recognised that when it comes to assessing Boris's skills and knowledge his slow speed of processing disadvantages him substantially and have consequently agreed a school policy to allow him 25% extra time in class written tests, internal exams. The time has now come for him to be assessed for possible access arrangements in forthcoming GCSE exams.

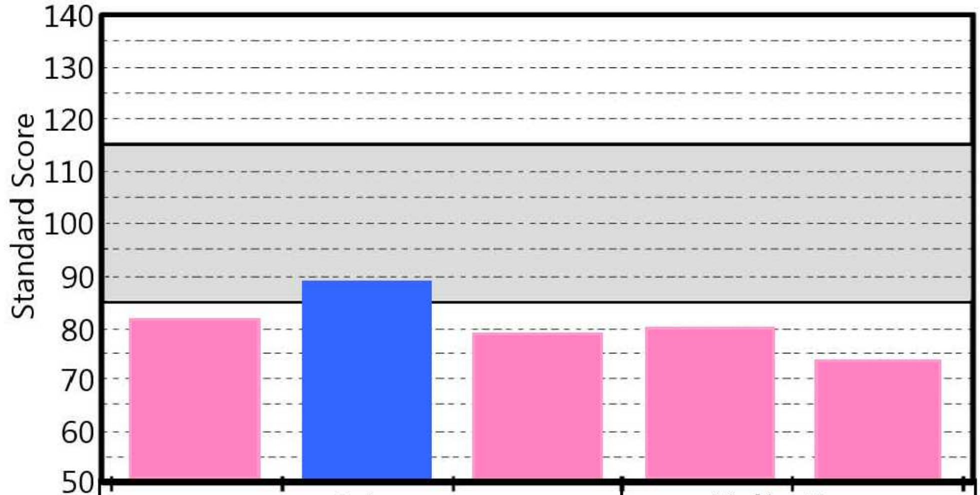
The JCQ regulations that govern procedures for granting access arrangements make provision for students who have slow speed of working, specifically that students with significantly below average performance (i.e. standard scores below 85) on *'cognitive processing measures which have a substantial and long term adverse effect on speed of working'* are valid evidence for provision of exam access arrangements [JCQ Regulations, 2103-14, Section 5.2.2]. Section 7.5.11 of these regulations goes on to state that *'Cognitive processing assessments would include, for example, investigations of working memory, phonological or visual processing, sequencing problems, organisational problems, visual/motor co-ordination difficulties or other measures as determined appropriate for the individual by a specialist assessor.'*

The SENCo, who is also the school's qualified assessor for exam access arrangements, assessed Boris using Lucid Recall, together with other tests to measure his reading, writing and spelling skills, according to JCQ requirements. His Lucid Recall results, shown in Figure 13, indicate that he has poor working memory and slow speed of processing. All his scores, except on Pattern Recall are below standard score 85 and therefore he is eligible for 25% extra time in GCSE examinations.

Boris's results were entered on to JCQ Form 8, along with the results of the literacy tests and information about his history of need and the various provisions made for him by the school, as required by JCQ. The results from Lucid Recall were entered into part 5 of Section C on Form 8 (see Figure 14), which provides space for two main test results to be reported, although further results can be reported in the box labelled 'Other relevant information'. If there are more than two suitable measures with standardised scores of 84 or less that could be reported then it is up to the assessor to judge which are the most important results or the ones that most clearly demonstrate the candidate's difficulties. In this case the most appropriate were the Working Memory Composite score of 80 and the Processing Speed score of 74.

Lucid RECALL
Results Profile

Student's Name	Date of Birth	Identifier
Boris Tompkins	20/01/98	731
Date Report Printed: 12/01/14 at 14:05		



	Tests			Working Memory	
	Word Recall	**Pattern Recall**	**Counting Recall**		
WM Function	**Phonological Loop**	**Visuo-Spatial Sketch Pad**	**Executive Function**	**Composite**	**Processing Speed**
Standard Score	81	88	79	80	74
Confidence Band	67 - 95	76 - 100	67 - 91	68 - 92	63 - 85
Centile Score	10	21	8	9	4
Age Equivalent	9:6 - 10:5	11:4 - 11:7	10:6 - 10:11	10:8 - 10:9	7:4 - 7:7
RawScore	12	32	11	38	0.74
Test Date	24/11/13	24/11/13	24/11/13	24/11/13	24/11/13
Test Age	15:10	15:10	15:10	15:10	15:10

Memory Span (Items)			Average Time (Seconds)		
Word	Pattern	Counting	Word	Pattern	Counting
3 (low)	9 (ave)	4 (low)	7.71 (slow)	4.80 (slow)	10.12 (slow)

(Assessor's comment (You can enter your own comments and observations in this area.)

Boris has poor working memory and slow speed of processing. All scores except Pattern Recal are below standard score 85 and therefore Boris should be eligible for 25% extra time in GCSE examinations.

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Figure 13. Lucid Recall results for Boris (age 15:10).

In the box ‘Which type of processing does this test assess?’ the SENCo entered ‘Working Memory’ and ‘Visual Processing Speed’ respectively.[5] The results of the three subtests were reported in the box labelled ‘Other relevant information’ (see Figure 14).

Candidate’s name: Boris Tompkins

5. Is the candidate’s cognitive processing (e.g. phonological, auditory or visual processing) in the **below average range**? – (**i.e. at least 1 standard deviation below the mean on a nationally standardised test, a standardised score of 84 or less?)**

YES ☒ **NO** ☐

Name of test(s)	Lucid Recall	Lucid Recall
Test ceiling	16 years 11 months	16 years 11 months
Date of administration	24/11/13	24/11/13
Which type of processing does this test assess?	Working Memory Composite	Visual Processing Speed
Cognitive processing speed standardised score (composite for subtests where appropriate)	80	74
Cognitive processing speed standardised score (scale score for a subtest where appropriate)*		
***Please name the subtest you are quoting where appropriate**		
If you have further below average scores for processing that you have not entered in this or other sections of this form please record them in the ‘Other Relevant Information’ section below.		

Other relevant information

For candidates requiring more than 25% extra time a very substantially below average speed of processing standardised score is required – a standardised score of 69 or less. Please see section 2.2 of the JCQ publication *Access Arrangements, Reasonable Adjustments and Special Consideration*).

Lucid Recall subtest reslts
Word Recall (Phonological Loop functioning) – 81
Pattern Recall (Visuo-spatial Sketchpad) – 88
Counting Recall (Executive Function) – 79

6

Figure 14. Lucid Recall results for Boris entered into JCQ Form 8 Section C(5).

5 Although it may be argued that any counting task necessarily involves use of verbal labels in order to arrive at an answer, the counting task in Lucid Recall chiefly involves visual processing (see Sections 1.2.2 and 2.1.3) and hence is best described in this manner on JCQ Form 8.

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