Lucid

ABILITY

COMPUTERISED ASSESSMENT SYSTEM FOR 4 TO 16 YEARS

Administrator's Manual

Third Edition

Lucid

Lucid Ability Administrator's Manual

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Created by Lucid Research Limited

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 Ability?

Lucid Ability is a new computer program that provides swift and effective assessment of verbal and non-verbal reasoning skills in the age range 4–16 years. The assessment activities are enjoyable and stimulating for children. The tests automatically adapt to each child’s individual ability level making assessment very time-efficient. Each module takes around 10 minutes, making a total assessment time of about 20 minutes or less. Results, based on national standardised norms, are available immediately, facilitating swift decision-making.

Lucid Ability was previously available in three versions, corresponding to the age groups 4–8, 7–12, and 11–16 years. The current version, which encompasses the full age range 4–16, has been created by amalgamating these three versions in order to provide more scope and flexibility for users. The task and item contents vary according to the age of the child.

At all age levels the tests do not require reading skills – the computer will read aloud any words that appear on-screen if the child wants this. Unlike most other ability tests, the results are independent of reading attainment, and can be used equally well with readers and non-readers.

1.2. The components of Lucid Ability

Lucid Ability comprises two tests: Verbal Reasoning and Non-Verbal Reasoning, with separate results given for each of these. These tests have been devised and standardised to provide teachers with useful and reliable measure of core intellectual skills that are critical to learning. When scores from the Verbal Reasoning and Non-Verbal Reasoning are combined, this gives a good estimate of General Conceptual Ability, which is another way of referring to general intelligence.

For the age group 4–6 years, verbal reasoning is assessed by means of a picture vocabulary task, and non-verbal reasoning is assessed by means of a mental rotation task. These tasks have been selected as being the most appropriate and reliable for this age group (where more complex tasks, e.g. those employed in Lucid Ability for older children, are generally less suitable and not as reliable).

For the age group 7–16 years verbal reasoning is assessed by means of a conceptual similarities task, and non-verbal reasoning is assessed by means of a matrix problem-solving task.

All tests are preceded by spoken instructions, demonstration, and interactive practice items with audio feedback.

1.2.1. Verbal Reasoning 4–6: Picture Vocabulary

The Picture Vocabulary test comprises 60 items in which five pictures appear on the screen in random positions (see Figure 1). One is the target picture and the other four are distractors. The child is given audio instructions: "Which picture goes best with the word …?" and has to click on the chosen picture. No feedback on correctness of response is given. The tests phase is preceded by two interactive practice items with audio feedback on responses. The program is adaptive (see Section 1.4) so children will not necessarily receive the same items, and the test automatically terminates when the child's ability level has been exceeded.

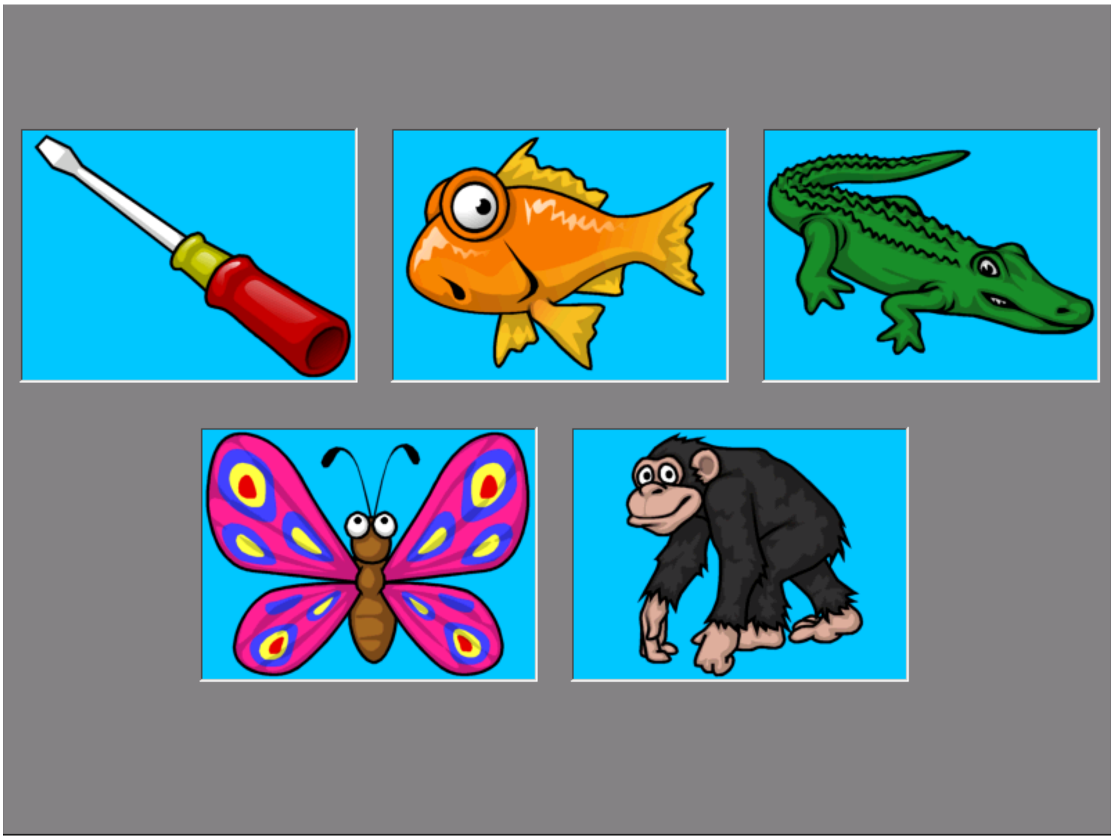

Figure 1. Example Screen for Picture Vocabulary:
"Which picture goes best with the word 'playing'?"

1.2.2. Nonverbal Reasoning 4–6: Dressing Up

Dressing Up is a mental rotation task comprising 40 items. In each item the child is presented with five characters in different orientations. Each character is depicted wearing or carrying an item or items, e.g. glove, hat, bag, umbrella (see Figure 2). The scenario is that Zoid (the character in the middle of the screen) and four of his friends are playing a dressing up game. The child's task is to decide which of the other four characters is copying Zoid exactly, by clicking on the chosen character. No feedback on correctness of response is given. The test phase is preceded by two interactive practice items with audio feedback on responses. The test automatically terminates when the child's ability level has been exceeded.

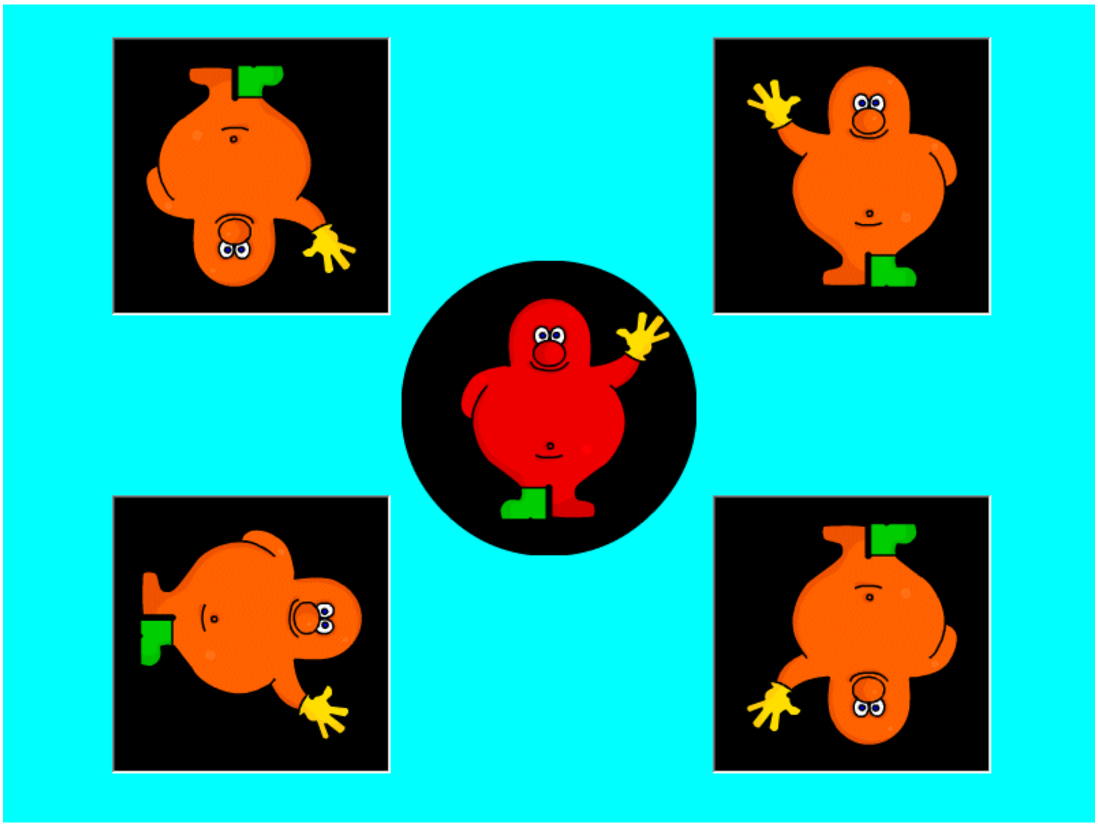

Figure 2. Example Screen for Dressing Up.

1.2.3. Verbal Reasoning 7–16: Link Word

Link Word is a test of conceptual relationships that comprises a pool of 100 items, but because the test is adaptive (see Section 1.4) children do not receive all the items. In each item two pictures are presented on the screen, separated by six words (see Figure 3). The child's task is to identify the word that provides the best conceptual link between the two pictures: this is the target word; the other five are distractors. For example, in Figure 3 the pictures are of a bottle of milk and a piece of cheese. Out of the six words on the list, the best word that links these pictures conceptually is 'dairy'. Of the five distractors, two have strong links only with one picture (in this example 'sandwich' and 'cheddar' have strong links with cheese but less so with milk) and two have strong links only with other picture (in this example 'drink' and 'chocolate' have strong links with milk but less so with cheese). The fifth distractor (in this case 'elbow') is randomly selected. (Arguably, 'cheddar' has links with both cheese and milk, but the child's task is to find the 'best' link, which is 'dairy'). If the child wishes, the computer will speak the words when they are clicked on, so reading competence is not necessary. The tests phase is preceded by two interactive practice items with audio feedback on responses. Progress through the test depends on the child's performance. The test automatically terminates when the child's ability level has been exceeded.

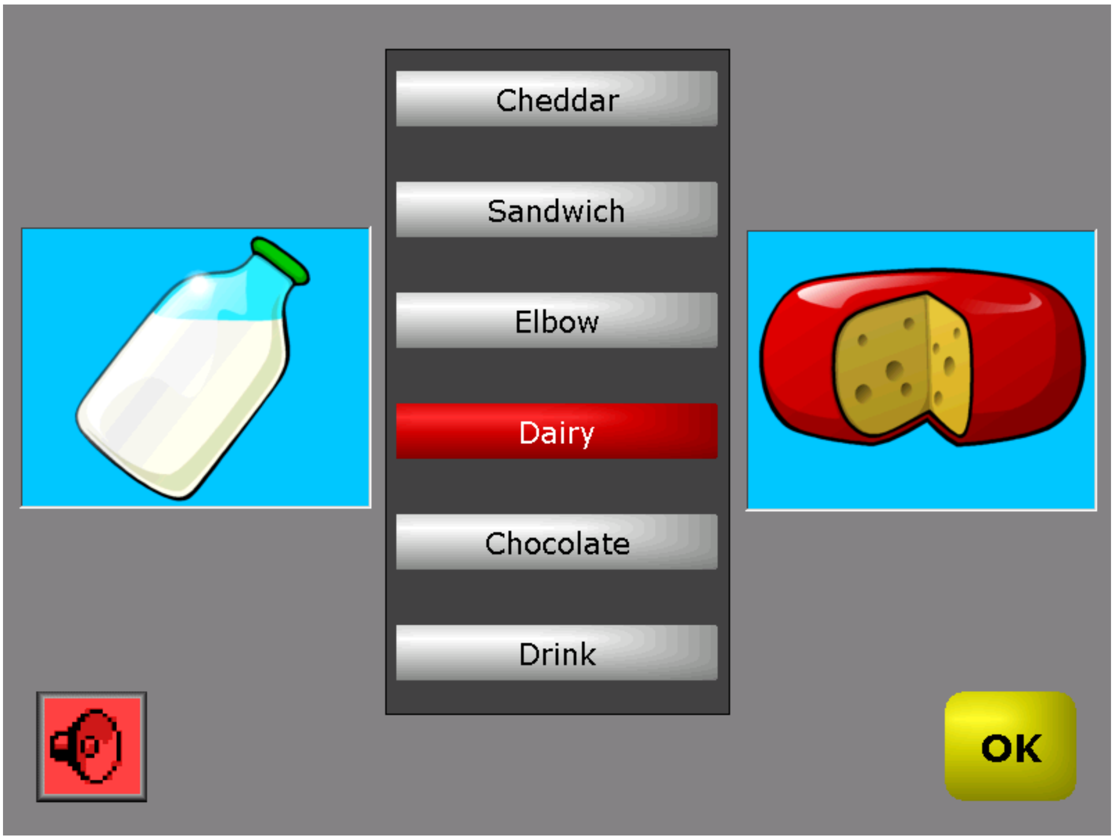

Figure 3. Example Screen for Link Word.

1.2.4. Nonverbal Reasoning 7–16: Matrix Problems

Nonverbal reasoning is an adaptive test involving matrix puzzles that can be solved by a careful application of logical reasoning, using both visual and verbal strategies. Students are shown a 3 × 3 matrix with the bottom right hand square empty. Students choose which of six squares at the bottom of the screen complete the pattern (see Figure 4). After an interactive practice phase with audio feedback, the student commences the test phase and progress through the test depends on performance. For ages 7–11 items are drawn from a pool of 57, and for ages 12–16 from a pool of 75; however because the program is adaptive (see Section 1.4) children do not receive all the items and will not necessarily receive the same items. The test automatically terminates when the student's ability level has been exceeded.

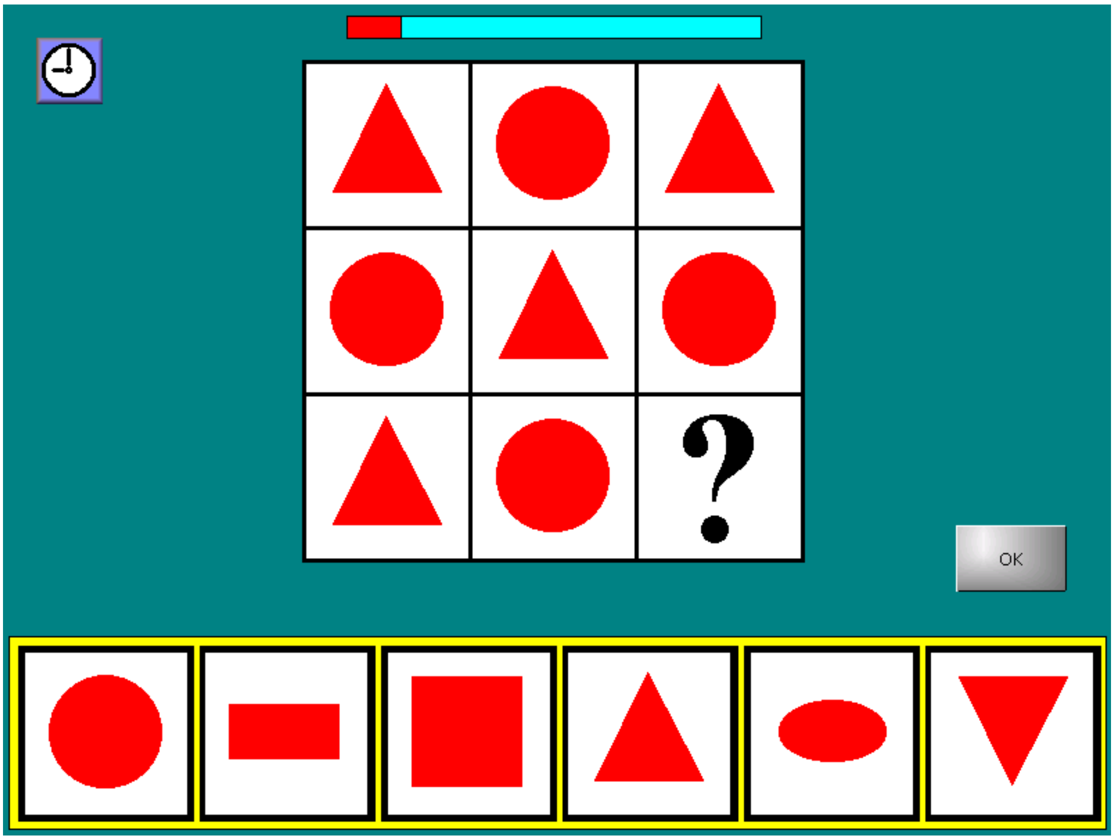

Figure 4. Example Screen for Matrix Problems.

1.3. Advantages of computer-based tests

The advantages of computerised assessment in educational settings has been explored by Singleton (see Singleton, 1997, 2001). Computers provide more precise measurement, especially when complex cognitive skills are being assessed. Tests are administered in an entirely standardised manner for all persons taking the test, which enhances reliability of measurement. Timings and presentation speeds can be controlled precisely. The subjective judgement of the Administrator does not affect the test outcome as it can in conventional tests. Lucid Ability is largely self-administered and results are available immediately; both of these factors help to reduce administrative load and avoid time delays.

The tests in Lucid Ability are adaptive, so that the performance of the individual taking the test is constantly monitored and the program varies the items given according to patterns of success or failure on previous items. Computerised adaptive psychological tests have been shown to be much more efficient than conventional tests because the person taking the test receives a smaller proportion of items that are too easy or too difficult, and a greater proportion of items that closely match the individual's ability level. Adaptive tests require fewer items overall in order to achieve an equivalent level of accuracy and reliability of measurement, and so the cognitive load on the person taking the test is reduced. Test fatigue is lessened, and positive test motivation maintained (for further discussion of adaptive assessment in education, see Singleton, 1997). (For further information on adaptive assessment see Section 1.4).

It is a fairly well-established finding that most students prefer computer-based tests to conventional tests (see Singleton, 1997, 2001). In a study carried out by Horne (2002) using LASS Secondary, the students were asked whether they preferred computer-based tests or conventional tests. Of the 75 pupils tested, 54 (72%) preferred the computer-based tests while only 17 (23%) preferred the conventional tests. There were no significant gender differences in this preference pattern. These findings have implications for assessment, especially where disaffected pupils are concerned. If students enjoy doing computer-based tests, they are likely to be more motivated and stay on-task. This helps to produce results that teachers can be confident about.

Lucid Research Ltd has a unique track record in researching and developing computerised assessment systems for use in education. The first of these, CoPS Cognitive Profiling System, was an internationally pioneering scientific development, created by Singleton, Thomas and Leedale 1995). In producing CoPS, Lucid drew upon the results of a five-year longitudinal research study on the early identification of dyslexia carried out at the University of Hull (see Singleton, Thomas and Horne, 2000). CoPS is now used in over 6,000 primary schools in the UK and elsewhere in the world. Several foreign language versions have been developed. In 1999, Lucid published LASS (Lucid Assessment System for Schools) Secondary (Horne, Singleton and Thomas, 1999), and in 2001 followed this up with LASS Junior (Thomas, Singleton and Horne, 2001). Since June 2009 these programs have been called LASS 11–15 and LASS 8–11, respectively. These programs, which are now in use in over 5,000 primary and secondary schools in the UK, provide assessment of literacy skills, cognitive abilities and reasoning. All Lucid's computerised assessment systems have been developed in accordance with stringent psychometric and scientific principles, and with the co-operation of several hundred schools and teachers, who assisted in trials for development, validation and reliability.

1.4. Adaptive assessment

The tests in Lucid Ability are adaptive. The term ‘adaptive testing’ refers to any technique that modifies the nature of the test in response to the performance of the test-taker. Paper-based tests are static instruments, fixed in their item content, item order, and duration. By contrast, computer-based assessment can be dynamic. Since the computer can score performance at the same time as item presentation, it can modify the test accordingly, tailoring it to the capabilities of the individual taking the test much more effectively than has ever been possible before (see Singleton, 2001).

Conventional tests can be very crude instruments in which, much of the time, the individual’s abilities are not being assessed with great precision because the items are either too difficult or too easy. In an adaptive test the individual can be moved swiftly to that zone of the test that will most efficiently discriminate his or her capabilities, thus making assessment shorter, more reliable, more efficient, and often more acceptable to the person being tested. The savings in testing time are distinctive and can far outweigh any disadvantages of transferring from conventional methods to computer-based methods. For example, Olsen (1990) compared paper-based and computer-administered school achievement and assessment tests with computerised adaptive tests. The computer-based non-adaptive version took 50–75% of the time taken to administer the conventional version, while the testing time for the adaptive version was only 25% of the time taken for the paper-based version.

The statistical model used in Lucid Ability is based on item response theory (IRT), whereby each test item is selected from a large bank of items, each of which is of known difficulty for students of that age group. In each test in Lucid Ability the program first gives the student a series of ‘probe’ items to determine the range of optimal item sensitivity for that student. These are followed by a series of test items starting in the range of optimal item sensitivity and increasing in difficulty until the student’s current attainment or ability level has been exceeded beyond reasonable statistical error, whereupon the test ceases. The program incorporates a facility to regress to easier items should it turn out that, by chance, the result of the probe items has overestimated the student’s approximate ability or current attainment level.

2. Standardisation, validation and reliability

2.1. Standardisation

All the tests in Lucid Ability have been standardised using large representative samples of children from several schools. Care was taken to obtain a balance of schools to cover the full range of socio-economic groups. The number of children that took part in each component of the standardisation is shown in Table 1.

Table 1. Standardisation samples for Lucid Ability

	Age range 4 – 8	Age range 7 – 12	Age range 11 – 16
Verbal Reasoning	814	760	642
Nonverbal Reasoning	413	1107	487

2.2. Validity

In the context of psychometric tests the term validity refers to the extent to which the test measures what it purports to measure. This can be established in various ways, of which two are most appropriate here. The first is 'content validity', which refers to the extent to which the content of the test items are appropriate to the abilities being measured. In the case of Lucid Ability, content validity is clearly apparent. The second is 'concurrent validity', where the test is compared to equivalent established tests. The correlation coefficient[1] is the statistic commonly used to show the extent to which the new test measures the same characteristics as the establish test(s).

However, there are several good reasons why a computer-based test may not correlate so highly with an equivalent conventional test as two similar conventional tests correlate together (for a discussion of these issues, see Singleton, 2001. First, in computer-based tests the modes of response (typically using a mouse) are different to those used in conventional tests (typically either oral or written responses). Second, in conventional tests there is normally some reliance on reading skills, whereas in Lucid Ability there is no requirement for any reading ability. Thus for some children scores on Lucid Ability may be higher than they might achieve on similar conventional tests. Arguably, in such cases, results from Lucid Ability should be regarded as being 'truer' because of reading has been removed as a possible confounding factor. Third, there is evidence that many children, especially those who feel threatened by conventional tests (perhaps because they anticipate performing badly on such tests), are more highly motivated when attempting computer-based

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[1] The correlation coefficient, which gives a measure of the amount of relatedness between two or more variables, ranges from –1 though zero to +1. A correlation of 0 indicates no relationship at between the two variables, while a correlation of 1 indicates absolute correlation – i.e. a score on one variable will exactly predict the score on the other variable and vice versa. Absolute correlations never occur in nature, but correlations approaching 1 are found. A positive correlation indicates that as scores on one variable increase, so too do scores on the other. A negative correlation indicates that as scores on one variable increase, scores on the other decrease. Note that a significant correlation does not indicate any *causal* relationship between the two variable: the reasons for the correlation may lie in some third factor (or factors) to which both variables are related.

tests. While all these factors may contribute to a lowering of correlation values between Lucid Ability and conventional tests of equivalent skills, they do not undermine the psychometric integrity of Lucid Ability. Concurrent validation of Lucid Ability was carried out in several schools in different parts of the UK, covering a range of socio-economic groups. The number of children involved, the tests that were used for validation, and the validity coefficients are shown in Table 2. All correlations were statistically significant at the $p < 0.001$ level or better. The validity coefficients, which were in the range 0.42 – 0.72, are comparable with those obtained in similar studies of major ability tests. For example, the British Ability Scales (Second edition) [BAS-II] (Elliott, 1996) show correlations with the Wechsler Intelligence Scale for Children (Third edition, UK version) [WISC-III^{UK}] (Wechsler, 1991) ranging from 0.34 – 0.74 for equivalent measures (Elliott, 1996). The results of the validity studies for Lucid Ability, therefore, indicate satisfactory validity of the various components of the suite.

Table 2. Validation results for Lucid Ability.

	Age range 4 – 7	**Age range 8 – 16**
Verbal Reasoning	91 children British Picture Vocabulary Scale $r = 0.72$	124 children NFER-Nelson Verbal Reasoning Test $r = 0.65$
Nonverbal Reasoning	90 children British Ability Scales (2nd ed.) Matrices and Quantitative Reasoning $r = 0.42$	124 children Matrix Analogies Test $r = 0.55$

2.3. Reliability

The term 'reliability', when applied to a psychometric test, usually refers to the extent to which it can be expected to yield similar results when administered to the same individual on different occasions. This is sometimes referred to as 'test-retest reliability'. The test-retest reliability (over a four-week period) for a sample of 98 students aged 11 years 6 months and 15 years 11 months for Lucid Ability Nonverbal Reasoning has been found to be 0.56 (Horne, 2002). This figure is comparable to reliability coefficients reported for other prominent ability tests, such as the British Ability Scales (Second edition) [BAS-II] (Elliott, 1996) and the Wechsler Intelligence Scale for Children (Third edition, UK version) [WISC-III^{UK}] (Wechsler, 1991).

Another form of reliability, generally known as 'internal consistency', indicates the extent to which the items within each test are measuring the same ability or set of abilities This is usually indicated by the alpha statistic, which ranges from 0 – 1.0. Alpha statistics for Lucid Ability have been calculated at 0.96 for verbal reasoning and 0.91 for nonverbal reasoning (Kuder-Richardson formula), which is highly satisfactory.

3. What is intelligence?

Lucid Ability provides assessment of cognitive skills that relate closely to intelligence and therefore an overview of this topic is appropriate in order to help users interpret results. This section briefly reviews research in the field of intelligence. For more comprehensive reviews readers are recommended to consult Deary (2001) and Mackintosh (1998).

Intelligence is one of the most misunderstood, misrepresented and controversial topics in psychology. There are deep-seated reasons for this, often associated with people's anxieties about human abilities being 'reduced to a number' (the intelligence quotient, or IQ) and concerns about the social and educational implications of classifying children as academically 'able' or 'unable', especially when this occurs relatively early in life. However, these worries are largely about how information regarding intelligence might be *used*, rather than about the scientific validity of the concept itself. Some of the more popular scientific, but non-psychological, books on intelligence (e.g. Gould, 1984), which have often been designed to address a socio-political agenda, have displayed serious misunderstandings of the research evidence. These have further undermined public perceptions about the value (or dangers) of the concept of intelligence. As Fox (2005) has observed in his recent manual for trainee teachers, 20 years ago intelligence was accepted as a core issue in education, but now the concept is conspicuously ignored, having "…achieved a sort of intellectual pariah status". (Yet, at the same time, teachers frequently refer to their students as 'bright' or 'dull'). However, if one can put social and political sensitivities to one side, it can be appreciated that the concept of intelligence does have considerable relevance to education.

3.1. The nature of intelligence

What is intelligence? Lots of definitions can be found in the textbooks; however, two will suffice here. In a review of knowledge in the field, Neisser et al (1996) described intelligence as the ability "…to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought." In 1997, 52 international experts on intelligence all subscribed to the following definition: "Intelligence is a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience" (Gottfredson, 1997). It can be seen that there are many features in common between these two definitions, which, in very general terms, portray the sort of things that intelligence enables us to accomplish. Arguably, they still don't tell us what intelligence is.

Lay people (and some scientists, too) often get confused or upset about whether intelligence *actually exists* – whether it has a physical reality. This misses the whole point. Intelligence is a *psychological construct* – in other words, a name given to a hypothesised characteristic that underpins many human cognitive activities that are valued in society at a given time and place. What is meant by 'intelligence' may vary from culture to culture (Sternberg, 1997). We can hypothesise that construct because there is overwhelming evidence that <u>all</u> human cognitive abilities show a *high positive correlation* – in other words, they all tend to measure something in common (Body, 1992; Carroll, 1997; Jensen, 1998). The 'something' that they measure is generally referred to as 'g', or general intelligence, and it corresponds to what most lay people are thinking of when they use the term 'intelligence'. Put this way, it is clear that intelligence is no more (or less) than the common ground between a wide variety of different cognitive skills. There are definite neurobiological components to intelligence but we don't yet fully understand how they work (see Plomin & Spinath, 2005). But what is absolutely clear is that intelligence is influenced by both genetic and environmental factors. The inherited component in intelligence is substantial – approximately half the variability in IQ scores can be attributed to genetic factors (see Plomin & Petrill, 1997). However, it should be noted that heritability is a statistic that applies to a defined population, not to individual members of that population. This is important when interpreting individual IQ scores, for the inherited component for any given individual could be much smaller – or much larger – than this. The high heritability of IQ certainly does <u>not</u> mean that environment or education has insignificant impact on intelligence. For some children, the environmental or educational impact will be massive, for others less so. However, education (in its widest sense) is likely to increase intelligence not only by equipping children with new knowledge and new strategies for thinking, problem solving and remembering, but also by promoting behaviours and attitudes (such as working hard and concentrating when under pressure) that are likely to enhance test-taking performance (Ceci, 1991; Ceci & Williams, 1997; Huttenlocker, Levine & Vevea, 1998)

How can we assess intelligence? To some extent, all measures which involve cognitive abilities – memory, general knowledge, speed of information processing, etc., as well as any tests of educational attainment – are also measures of g. However, tests that are specifically designed to do the job (i.e. intelligence tests) give us much better measures. But at the end of the day all tests can only give *estimates* of g – they do not measure g *directly*. Individual tests of intelligence used by educational psychologists, such as the Wechsler Intelligence Test for Children (WISC) or the British Ability Scales (BAS), deal with the problem by including a several different subtests so that the estimate of intelligence is based on a wide variety of tasks. But such tests take an hour or more to administer and have to be done individually. For group tests – i.e. tests that can be administered to more than one child at a time – a subset of such tasks is necessary, especially where these are going to be used in the classroom where lengthy individual assessment is not an option. In the past there has been much controversy regarding whether intelligence tests are culturally biased (e.g. Gould, 1984). Extensive research has concluded that properly constructed and correctly administered IQ tests are <u>not</u> biased against different social, economic, ethnic or racial groups within an advanced culture in which education is universal (see Brody, 1992; Carroll, 1997). Of course, if individuals do not speak the language used in a verbal ability test, or if they do not come from an advanced culture or have not received any schooling, such tests would not be a fair or appropriate measure of their abilities.

During the last 100 years of psychological investigation into intelligence, progress in statistical techniques enabled researchers to look more closely at the components of intelligence. Different approaches resulted in alternative theories positing various numbers of different abilities or 'factors'. An early distinction was drawn between *fluid intelligence* (the ability to solve novel and abstract problems not dependent on cultural influences) and *crystallised intelligence* (the ability to solve problems dependent on knowledge learned through schooling and cultural experience). Over time, researchers have come to recognise that of the various factors, the two most important – at least for educational purposes – are *verbal ability* and *nonverbal ability*. While the former is fairly self-explanatory, the latter is not. What is meant by 'nonverbal ability'? Generally, the term refers to the ability to solve problems without explicit use of language. (In some systems, nonverbal ability would also include mathematical skills, but as maths also involves verbal abilities and is strongly dependent on teaching, mathematical ability is now usually assessed independently of non-verbal ability.) Hence nonverbal ability is closer to the earlier concept of fluid intelligence and verbal ability is closer to the concept of crystallised intelligence.

Most tests of general ability – whether individually administered or group administered – now comprise measures of verbal and nonverbal ability. There is obviously a wide range of tasks that could be used to assess these two core factors. Writing an essay or giving a speech both draw upon verbal ability. Working out a route using a map or assembling an item of flat-pack furniture both require non-verbal ability. But research has shown that tasks involving understanding of verbal concepts (verbal reasoning), and tasks involving solving problems involving pattern, shape or spatial orientation (non-verbal reasoning), are highly suitable for giving us stable and reliable measures of verbal, and non-verbal ability, respectively. They are also most appropriate for use in group tests. This is why Lucid Ability comprises tests of verbal reasoning and non-verbal reasoning.

3.2. What does intelligence predict?

Measures of intelligence have been repeatedly found to give good predictions of future educational achievement for group samples (but not necessarily for every child within the group) (for review see Brody, 1997). The average correlation between children's IQ scores and future attainment in school is about 0.5 (Neisser et al, 1996). One of the most recent and extensive studies reported is a 25-year longitudinal study of 1,265 children in New Zealand (Fergusson, Horwood & Ridder, 2005). In this study intelligence measured at age 8–9 was found to be significantly related to later educational and occupational outcomes. For example, of those children with below average IQ (less than 85) only 41% subsequently gained qualifications at school, 34% gained post-school qualifications, and 2% achieved a university degree by age 25. The corresponding figures for those of above average IQ (115+) were 98%, 75% and 59%, respectively. Members of the above average IQ group were earning almost 60% more than those in the below average IQ group. Of course, there are many other factors that could have influenced these results, including social and family factors (socioeconomic disadvantage, family stability, parental adjustment, child abuse, etc.) and individual factors (childhood conduct problems, attentional problems, temperamental and personality differences, etc.). All these factors are also associated with intelligence. What is important about this study, however, is that the impact of intelligence on later educational and occupational outcomes was still highly significant when all these other factors were statistically controlled for – i.e. their influence was removed from the analysis.

The evidence on the considerable strength of influence of intelligence should not, however, be taken as indicating that IQ is fixed and unvarying or that outcomes for individual children are somehow predetermined. On the whole, IQ scores *are* relatively stable over the life span. Using the Moray House Intelligence Test, Deary et al (2000) tested 101 people aged 77 years who had previously been tested when they were aged 11, as part of the 1932 Scottish Mental Survey. The correlation between the scores on the two occasions, some 66 years apart, was 0.73, which is remarkably high. Primrose, Fuller and Littledyke (2000) obtained scores for a sample of 146 children, who had been tested on the NFER-Nelson Verbal Reasoning Tests each year from age 8 to 13. The correlations between the test scores on the different occasions were all high, and even when there was greater than 24 months interval between tests the correlation was 0.77. Nevertheless, these authors are at pains to point out that a fair proportion of children bucked the trend. Almost half the children varied by more than seven standard score points up or down from one test occasion to the next, and one in five children varied by more than 12 standard score points. In another recent study scores of a longitudinal sample of over 10,000 pupils on the Cognitive Abilities Test (CAT) taken at ages 10+ and 13+ were compared (Strand, 2005). The three-year test-retest correlations were 0.87 for verbal reasoning and 0.76 for non-verbal reasoning. Again, however, there was significant change (10 or more standard score points) for a substantial minority of the pupils over the three years: on verbal reasoning about one in six students, and on nonverbal reasoning about one in five students showed this pattern.

It is unfortunate that widespread use of intelligence tests for school selection in the past has tarnished the reputation of such tests in some quarters. However, regardless of one's views on school selection, the scientific evidence shows clearly that reasoning tests still have considerable educational value in the identification of leaning needs and underachievement, for grouping students, and for giving helpful indicators of future academic performance. Provided, that is, one appreciates their limitations, the first of which – the fact that a fair proportion of children show considerable variation from one assessment to another – has already been pointed out. Another important limitation is that although reasoning measures are a good indicator of general intelligence, they certainly do not tell the whole story. The range of behaviours that we would regard as 'intelligent' on a day-to-day basis includes many things that are not encompassed by reasoning tests, e.g. creativity, imagination, and successful interpersonal skills. For this reason, Gardner (1993) has advocated that instead of thinking of 'intelligence' (which he regards as too conceptually restrictive) we instead think in terms of 'multiple intelligences'. Sternberg (1985) proposed that when considering intelligent behaviour we need to take account of three different dimensions: (1) the *context* of the behaviour – some behaviours may be more, or less, intelligent in different contexts; (2) the previous *experience* of the person – i.e. whether the behaviour is a response to a novel situation or a learned habit; and (3) the *information-processing skills* used to deal with the task – i.e. how we formulate strategies to solve problems. Finally, recent research has focussed on the relationships between intelligence and personality (e.g. Chamorro-Premuzic & Furnham, 2005). This work suggests that prediction of future achievement depends not only on intelligence and other cognitive factors, but also on personality variables. For example, a study by Ackerman and Heggestadt (1997) found that a personality trait known as 'Openness to Experience' is positively correlated with cognitive ability tests. The conclusion is that students who are open to new experiences are more likely to learn than students with more closed minds – something to which all teachers would no doubt subscribe!

While none of the foregoing undermines the value of reasoning tests in education it does mean that teachers should exercise caution when interpreting the results of such tests. IQ scores cannot be taken as fixed, finite measures of future academic potential, but they do give a good measure of the level of cognitive functioning at a particular point in time, and one that is independent of specific curriculum content. Hence they can be used as a yardstick against which achievement in many areas of education can be evaluated, and are useful in identifying special educational needs.

3.3. Gender differences in intelligence

Studies of gender differences in education typically find that girls out-perform boys in school attainment (see Fergusson & Horwood, 1997) and that boys are more likely to be referred for educational difficulties (see Vardill, 1996). Nevertheless, it is generally held that psychological and educational tests should, as far as possible, be free of gender bias, so that when decisions about children's progress are being made (especially where special support may be required) this can be based on information derived from sources that favour neither girls nor boys. On the other hand, it has sometimes been suggested that computer-based tests may favour boys because of their supposed greater interest in computers (see Crook, 1996). If this is the case, it could distort results obtained using a computer-based assessment such as Lucid Ability. However, there is good evidence that computer-based tests developed by

Lucid Research Ltd are not, in general, subject to gender differences (see Singleton, 2001; Singleton, Horne & Thomas, 1999). Horne (2002) carried out a study to investigate possible gender bias in the computerised assessment suite LASS Secondary[2], using 176 students aged 11 – 15 years. There were no statistically significant differences between males and females on any of the tests in LASS Secondary.

Extensive studies of possible gender differences in Lucid Ability have been carried out, using samples of boys and girls matched for age, school and class. The results are shown in Table 3, from which is it clear that there were no significant gender differences in any of the component tests in Lucid Ability .[3] [4]

Although average scores on general ability tests for males and females do not differ significantly, there is widespread evidence in the research literature that males have a wider spread of abilities than females (Deary et al, 2003; Hedges & Nowell, 1995; Mackintosh, 1998). This means that there are more males than females at the lower and higher extremes of the distribution curve of intelligence, and consequently that there are more females than males clustered near the middle of the distribution of intelligence (see
Figure 6).

However, for matrix reasoning there is evidence that, on average, males begin to outperform females slightly from about age 15 onwards (Colom & Lynn, 2004; Lynn & Irwing, 2004), but not before that age. Lynn (1999) has proposed that this is due to the differential brain development of males and females. Boys and girls mature at the same rate up to about 7 or 8, after which girls begin a growth spurt that slows down around 14–15, while the growth of boys continues until about age 18. Lynn's developmental theory suggests that abstract (nonverbal) intelligence follows the same trend. Thus girls would be expected to have a slight advantage between about 9 to 12 years, with boys catching up and then overtaking them from about 15. Lynn's evidence points to an average male advantage in nonverbal reasoning of about 5 IQ points during adulthood. Alternative explanations for this phenomenon may lie in cultural factors or in gender differences in personality (for discussion see Lynn & Irwing, 2004).

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[2] Since 2009 this program has been called LASS 11 – 15.

[3] Note that the scoring system for Nonverbal Reasoning for ages 7 – 12 was different for that for ages 11 – 16 which is why the means appear very different. For ages 7 – 12 the score is an adaptive raw score (range 0 – 67), whereas for ages 11 – 12 the score is a pass rate (range 0 – 1.0). For all other components the score is an adaptive raw score.

[4] In Table 3 SD = standard deviation, which is a measure of the variation of scores in a distribution.

Table 3. Results of studies of possible gender differences in Lucid Ability.

	Age range 4 – 8	**Age range 7 – 12**	**Age range 11 – 16**
Verbal Reasoning	Males: n = 30, mean 39.17 (SD 8.45); Females: n = 61, mean 38.03 (SD 9.72); t = 0.545, df = 89, **not significant**.	Males: n = 53, mean 38.38 (SD 22.92); Females: n = 57, mean 43.58 (SD 23.45); t = 1.175, df = 108, **not significant**.	
Nonverbal Reasoning	**Study 1** Males: n = 217, mean 11.53 (SD = 6.51); Females: n = 194, mean 10.94, (SD 6.31); t = 0.918, df = 409, **not significant**. **Study 2** Males: n=27, mean 7.52 (SD 3.63); Females: n = 50, mean 7.68 (SD 3.70); t = 0.184, df = 75, **not significant**.	Males: n = 631, mean 44.85 (SD 12.97); Females: n = 457, mean 43.46 (SD 11.65); t = 1.824, df = 1086, **not significant**.	Males: n = 99, mean = 0.54 (SD 0.80); Females: n = 73, mean 0.62 (SD = 0.70); t = 0.66, df = 170, **not significant**.

4. Interpreting scores from Lucid Ability

4.1. Types of scores

All raw scores on Lucid Ability 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 child. 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. Reports will have been based on the student's date of birth and age at testing and in some instances graphs calculated before the error was corrected may have used the wrong norms. 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, which are displayed on the results screen:

- Standard scores
- Centile scores
- Age equivalents

The first of these is shown in graphical (bar graph) format as well as numerical format, while the remaining two are shown only in numerical format (see Figure 5 for example of a report).

4.2. Standard scores

Standard scores have a mean (average) 100 and a standard deviation of 15. [5] They are distributed in a normal (bell shaped) curve as shown in Figure 6. 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 – 114, which is the area shaded blue on the graph in Figure 6). In some scoring systems the range 85 – 114 is regarded as the 'average range', while other systems treat 90 – 109 as the '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.

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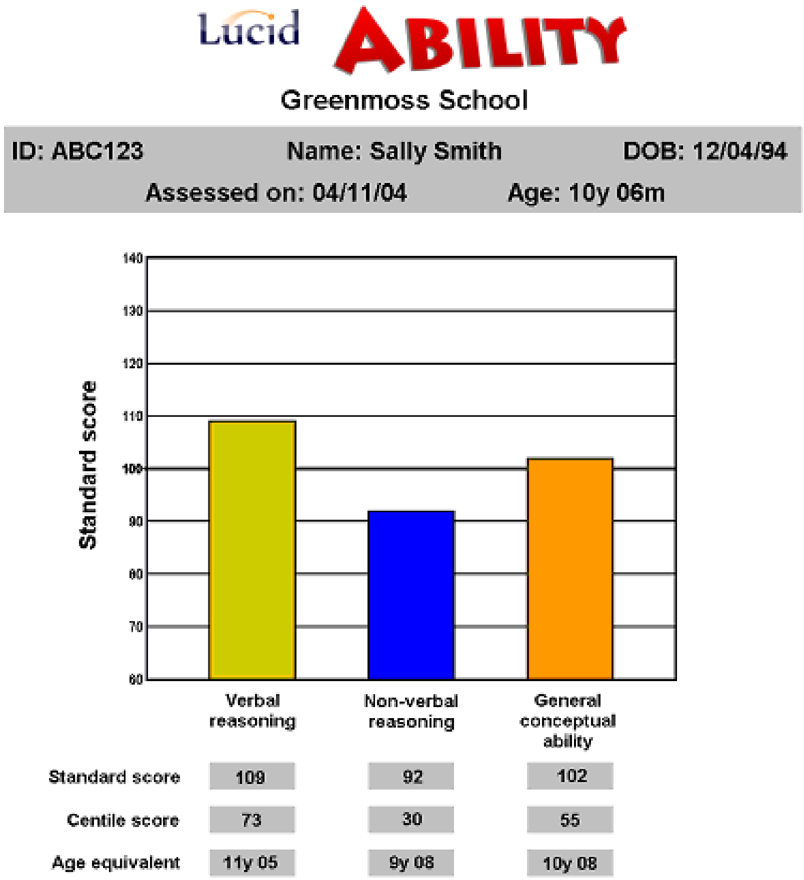
[5] The standard deviation is a measure of the variation of scores in a distribution.



Lucid ABILITY

Greenmoss School

ID: ABC123 Name: Sally Smith DOB: 12/04/94

Assessed on: 04/11/04 Age: 10y 06m

	Verbal reasoning	Non-verbal reasoning	General conceptual ability
Standard score	109	92	102
Centile score	73	30	55
Age equivalent	11y 05	9y 08	10y 08

Figure 5. Example report.

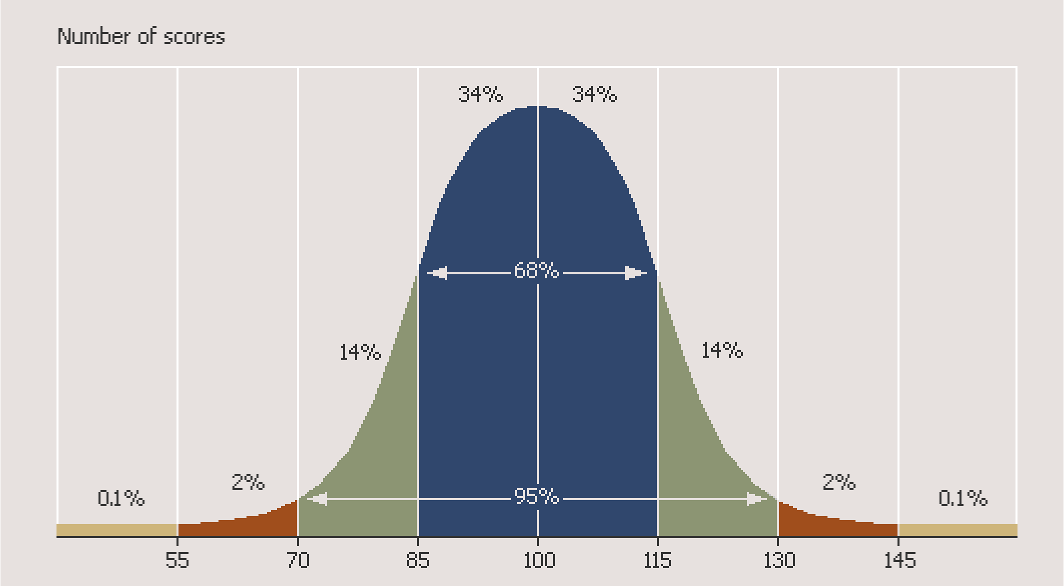


Figure 6. Distribution of Lucid Ability scores on a normal curve (see text for explanation).

4.3. Centile scores

Centile scores represent the student's performance in comparison with the population norms in centile units (sometimes referred to as 'percentile' scores), 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 6, centile scores have a strict relationship with standard scores; this is shown in Table 4.

Table 4. 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

4.4. Age equivalents

Age equivalents may be defined as the approximate chronological age (or chronological age range) of students who would be expected to achieve a given raw score on the test. The most common type of age equivalent in educational testing is the 'reading age'. For example, to say that a child has a reading age of 8 means that they read like an average 8-year-old, regardless of their chronological age. Early intelligence tests used the concept of 'mental age', a term that has now gone out of fashion. But, in truth, an age equivalent for the result of a reasoning test is just the same as a mental age. However, it should be noted that age equivalents are a much cruder and less accurate way of representing results than standard scores or centile scores, but in some circumstances they are useful.

5. Administering Lucid Ability

5.1. General advice on administration

5.1.1. Administrator preparation

Assessing students with Lucid Ability 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, they should not be used when testing a student unless absolutely necessary.

Before testing, each student must be registered for the program (name and date of birth). From the Main Menu select 'Register Pupils' (see the **Software User Guide** for guidance on this). The tests are selected from the Tests Menu screen. There is no recommended order in which to administer the tests. For each test in Lucid Ability, instructions are spoken by the computer, and practice items are given to familiarise the student with the test requirements. When the student has completed the practice items, the test phase begins.

5.1.2. Testing environment and equipment

The ideal testing environment is one that is reasonably quiet, with minimal distractions. This could be a separate room, but Lucid Ability has been designed to use in the ordinary classroom, where distractions are often unavoidable. Visual and auditory distraction (both to the student being tested and to other students in the class) should be minimised. It is recommended that the computer and the student are 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. 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).

The teacher or supervisor should check that the equipment being used for the assessment is functioning correctly. This includes checking that the sound system (speakers or headphones) is audible (not too loud or to soft, and without interference), and (c) the mouse is functioning correctly (most need regular cleaning) and is positioned in front of the student on a suitable surface so that its movements are unimpeded. Lucid Ability 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 Ability.

5.1.3. Student preparation

It is important that the student understands the nature of the tasks in Lucid Ability, 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 very young children or children with disabilities. Students should not be allowed to take the tests if they are unwell, as results are likely to be unreliable.

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.

It is not recommended that students attempt the tests when other students are standing or sitting 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 responses and their behaviour may influence the decisions of the student being tested.

In general, students will experience no difficulty in understanding the instructions spoken by the computer and in following the practice tasks. This should enable them to progress to the test phase without special attention from the teacher. However, if the student does not understand any instructions 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.

5.1.4. Supervision

It is usually not necessary for students of this age to be closely supervised while attempting the tests, unless the teacher has a particular reason to do so. The tests in Lucid Ability 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. However, where the teacher suspects that a student may not be well motivated to complete the test, or may be easily distracted, closer supervision is advisable. Disaffected students may display non-compliance by clicking on test items at random, rather than thinking about the tasks and selecting items on which to click after careful reasoning. Such students, or those with very low ability, may need closer 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 for the supervisor to ensure that during the test:

- the student is paying attention, is 'on task' and is not distracted
- 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).

5.1.5. 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. There is a risk of feedback differentially affecting students, so that some are encouraged and others discouraged. Nevertheless, some students (particularly younger children or children 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".

5.2. Assessing students who have limited English

Assessment of any student who has limited proficiency in spoken English is often problematic. But there is evidence that Lucid Ability is better than many conventional methods of assessment, because of its strongly visual format, minimal reliance on spoken instructions, and no requirement for reading ability. 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 is commonly accepted that nonverbal tests are less affected by linguistic and cultural factors and so are closer to the concept of *fluid intelligence*, whereas verbal ability is closer to the concept of *crystallised intelligence* (see Section 3). In cases where there is concern that a student's experience or knowledge of English may be limited, when drawing conclusions it is advisable to rely more on the results of the nonverbal reasoning tests in Lucid Ability than on the results of the verbal reasoning tests.

5.3. Assessing students outside the age range

Like all good normative tests, Lucid Ability is not generally recommended for use outside the age ranges specified for each of its three versions. Any test which meets basic psychometric criteria (which Lucid Ability does) must be standardised on a given population and this will determine the range of applicability of the test. Lucid Ability is designed for use with students aged 4 years 0 months to 16 years 11 months. Use with students outside this range can create difficulties for interpreting results. For example, if the student is older than 16:11, then the program will use the norms for 16-year-olds when analysing results and this could lead to an overestimation of the student's performance. Similarly, if the child is younger than 4:0, then the program will use the norms for 4-year-olds when analysing results, and this could lead to an underestimation of their performance. For this reason it is not advisable to administer Lucid Ability to any child under the age of 4 as results may not be reliable.

It is not good assessment practice to use any test outside its stipulated age range on a routine basis. 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') when the evidence for this is unsound. However, if on occasions it is necessary to use Lucid Ability to assess students older than age 16, age equivalents would be the preferred form of scores for the teacher or administrator to use, and results should always be interpreted with caution. An age equivalent is defined as the chronological age range of individuals that would be expected to achieve a given raw score. Age equivalents are a much cruder and less accurate way of representing results than standard scores or centile scores. 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 thus pitch work at the correct level. For further information about age equivalents, see Section 4.4).

5.4. Re-testing

Occasionally there may be situations where a teacher needs to re-administer one or both of the tests in Lucid Ability. This may be because it is discovered that when the child first took the tests he or she was unwell and so the results may not give a true indication of abilities. Or there may be some doubt as to whether on the first attempt the child was applying proper attention or effort to the tasks. Whatever the reasons, it is permissible to re-test the child but, in such circumstances, a delay before re-administering the test(s) is desirable to avoid the child recalling specific test items in detail. A delay of at least two weeks is usually recommended.

6. Interpreting and applying the results

6.1. General principles

The results from Lucid Ability are no different in type and applicability to those from any other ability test, whether computerised or conventional. Hence, with one exception, there need be no special factors to take into account when considering the results, other than those which would generally apply, such as the pupil's state of health and motivation at the time of assessment. The single exception is that unlike most conventional tests, Lucid Ability does not require the child carry out any reading (e.g. of instructions or test items). This means that children who have reading difficulties can be assessed using Lucid Ability without worrying about how much the results reflect their reading skills rather than their intelligence or. However, it also means that a child with reading difficulties may well score higher on Lucid Ability than s/he does comparable conventional tests that require reading. Arguable, the results from Lucid Ability will be a better reflection of the child's 'true' abilities than comparable conventional tests.

The use of the results from Lucid Ability will depend largely on why the child was assessed in the first place. In some cases, assessment will be part of routine assessment carried out in the school, perhaps to assist allocation of pupils to different teaching groups or streams. In such cases is it worth reflecting on how the two components – verbal and nonverbal ability – relate to the curriculum areas under consideration. Children with good verbal reasoning scores may be expected to do well curriculum areas that necessitate fluent verbal thinking, such as English, history and modern languages. Children with good nonverbal reasoning scores may be expected to do well curriculum areas that depend more on visual thinking and practical problem-solving, such as maths, technology and the visual arts. Many areas of the curriculum (e.g. science, geography, drama and ICT) utilise both verbal and nonverbal skills.

In other cases children will have been assessed for specific diagnostic purposes, e.g. to help determine whether they have special educational needs. Here again, however, it is worth considering any differences between the child's verbal and nonverbal ability. The majority of children show no more than a discrepancy of 10 standard score points between verbal and nonverbal ability. Where the difference between verbal and nonverbal reasoning is more than 15 standard score points then this will represent a significant discrepancy and will be important to understanding who they think and learn. In such cases the general conceptual ability (GCA) score is much less useful as an indicator of the child's learning potential. Even when the difference between verbal and nonverbal reasoning is between 10 and 15 standard score points then this should be regarded as an important feature of the child's psychological make-up.

It should also be borne in mind that Lucid Ability provides only one measure of verbal ability and one measure of non-verbal ability for any given age group. This is in contrast to some tests used by psychologists, such as the British Ability Scales (BAS) and the Wechsler Intelligence Scale for Children (WISC), which employ several different measures of each. Whilst the use of fewer tests has the benefit of making the assessment much shorter, it also has the drawback of 'putting all the eggs in one basket' (or, more strictly, two in this case). A consequence of this is that occasionally a child will score below or above expectations because they happen to be particularly good or bad at that particular task. Although the tests in Lucid Ability have been devised to avoid this as much as possible, administrators should be aware that it can happen. In particular, a few individuals may have difficulty with matrix reasoning tasks in general, even though they have no problems tackling other types of non-verbal intelligence tasks.

As well as being employed in its own right to assess children's verbal and non-verbal reasoning ability, Lucid Ability can be used diagnostically in conjunction with other tests in order to identify or clarify learning problems. The computer-based test suites Lucid CoPS, LASS 8-11 and LASS 11-15 are ideal for this purpose and the following sections illustrate how this can be achieved.

6.2. Using Lucid Ability with Lucid CoPS

Lucid CoPS is a suite of eight tests of cognitive skills for children aged 4 to 8 years. It assesses various aspects of memory and phonological skills and is useful identifying dyslexia and other learning problems before, or during the early stages of, reading acquisition. The program is used in over 6,000 schools in the UK and several foreign language versions have been developed in other countries. For more information go to www.lucid-research.com

Because it is designed primarily as an early identification tool, CoPS does not include any tests of reading or spelling. Nor does it include measures of intelligence, which in most cases are unnecessary for CoPS to be effective. However, in certain cases, use of Lucid Ability in conjunction with CoPS would be very helpful. For example, if a child scores very low on all the measures in CoPS it can be difficult to distinguish between a severe specific learning difficulty (such as dyslexia) and a more general learning difficulty. Lucid Ability can be used in conjunction with CoPS in order to extend the scope of the assessment and also provide clarification of the likely causes of problems in learning in certain cases.

6.2.1. Case study – Mark (5 years 4 months)

Mark's CoPS profile (see Figure 7) shows that he is performing at a low level (around or below the 10th centile) for all the CoPS tests (note that for simplicity in this context, time scores have been omitted in this figure). This could be indicative of a severe specific learning difficulty or part of a wider profile characteristic of a child with more general learning difficulties. By administering Lucid Ability, these two possibilities can be distinguished. If Mark's scores for Lucid Ability are in the average range or above (i.e. greater than 25th centile) then the CoPS test results represent significantly weak cognitive skills in the areas of memory and phonological processing, which strongly suggests that he has specific learning difficulty (i.e. dyslexia). However, if Mark's Lucid Ability scores turn out to be below average or low (i.e. below the 25th centile) then his profile suggests general low ability. If one of the two Lucid Ability tests is above the 25th centile and the other below, the decision is more complex. Verbal intelligence is generally a better predictor of educational attainment, so if this is above 25th centile then it is likely that his educational potential is at least average and hence his CoPS results indicate a specific learning difficulty that will impede his educational progress. On the other hand, children with dyslexia typically have non-verbal intelligence higher than non-verbal intelligence, and because dyslexia can depress verbal intelligence it is often argued that non-verbal intelligence is a better indicator of potential in such cases. One way to resolve dilemmas that this may cause is to use the General Conceptual Ability (GCA) measure in Lucid Ability, which takes into account the results of both the verbal and non-verbal reasoning tests. Provided the GCA score is above the 25th centile, it is usually safe to assume that the child should be achieving within the average range (or better) in most areas of the curriculum. It is only when there are very large (i.e. greater than 25 centile points) differences between verbal and non-verbal intelligence that cases become so exceptional that general guidelines such as these cannot be applied.

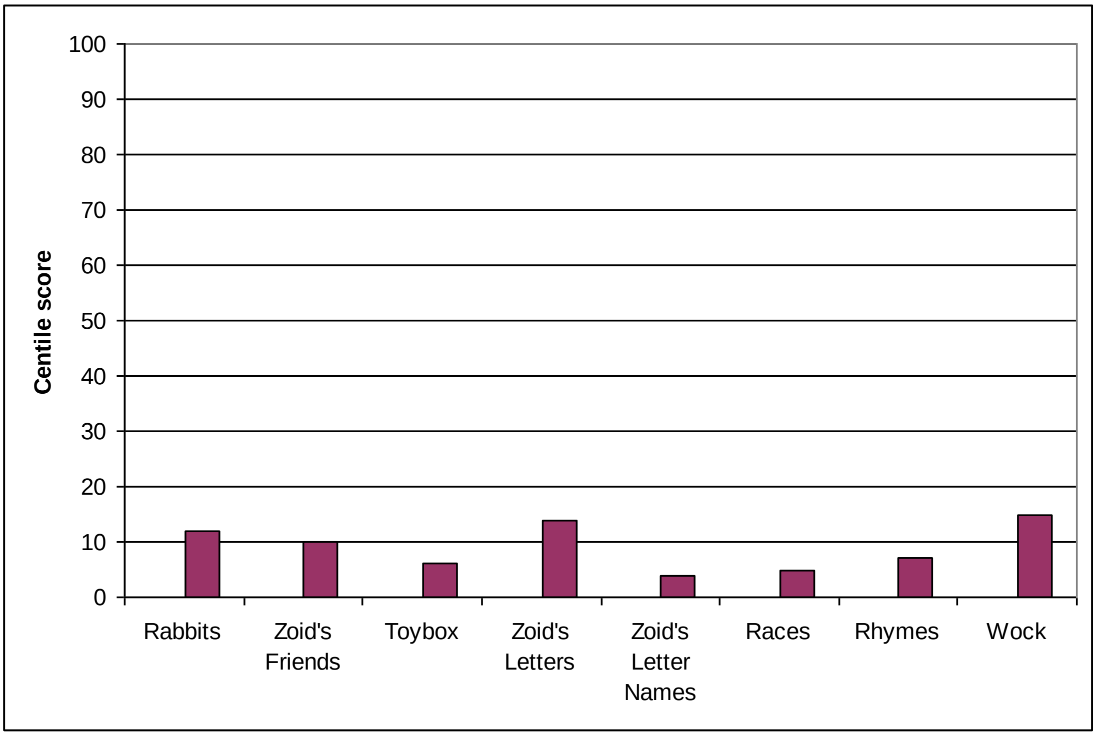


Figure 7. CoPS profile for Mark (5 years 4 months)

6.3. Using Lucid Ability with LASS 8–11 and LASS 11–15

LASS 8 – 11 and LASS 11 – 15 are multifunctional suites of computerised tests that are useful for identifying and understanding learning problems (such as dyslexia), measuring attainment in literacy and charting progress. They comprise tests of reading (word reading, sentence reading and non-word reading), spelling, memory (visual and auditory-verbal), phonological processing (syllable segmentation and phoneme deletion), and non-verbal reasoning. For more information go to www.lucid-research.com

LASS 8 – 11 and LASS 11 – 15 both include a test of non-verbal reasoning but they do not include a test of verbal reasoning. Hence the verbal reasoning test in Lucid Ability can be used in conjunction with LASS in order to extend the scope of the assessment and give a better understanding of the nature of pupils' problems in learning. The following case studies, which are based on examples given in the LASS Teacher's Manuals, demonstrate how results from the Lucid Ability verbal reasoning test can be integrated with LASS results.

If, in interpreting results of LASS, a comparison is being made between actual results of individual attainment tests (e.g. reading, spelling) or diagnostic tests (e.g. memory, phonological skills) and expected results based on non-verbal intelligence, then the addition of a verbal intelligence estimate can help to resolve anomalies. Where the result of the Lucid Ability verbal reasoning test is at a similar level to that of the non-verbal reasoning test in LASS, this will generally strengthen conclusions made regarding the meaning of significant discrepancies between scores for attainment or diagnostic tests and non-verbal reasoning scores. Where the result of the Lucid Ability verbal reasoning test is at a much lower level than that of the non-verbal reasoning test in LASS, this will generally weaken conclusions made regarding the meaning of significant discrepancies between scores for attainment or diagnostic tests and non-verbal reasoning scores. An exception, however, is in cases of classic dyslexic, in which the condition itself can depress verbal intelligence scores. Thus the typical dyslexic shows much better non-verbal, compared with verbal, reasoning. Where the result of the Lucid Ability verbal reasoning test is at a much higher level than that of the non-verbal reasoning test in LASS, this will allow a comparison to be made between the verbal reasoning score and scores for attainment or diagnostic tests in LASS. In attempting to establish whether or not such discrepancies are statistically significant, administrators should refer to the guidance given in the LASS Teacher's Manuals under 'Calculating discrepancy'.

6.3.1. Case study – Sian (10 years 4 months)

Sian recently transferred schools. There were no indications from her records of literacy or learning difficulties, and she was generally described in previous school reports as performing at an 'average' level. Her LASS results are shown in Figure 8. On the basis of these results, Sian seems to be a girl of good average intellectual ability (***Reasoning***: centile 71), but she clearly has weaknesses in literacy skills (***Sentence Reading***: centile 22; ***Single Word Reading***: centile 12; ***Spelling***: centile 29). In fact, all the discrepancies between the literacy measures and ***Reasoning*** are statistically significant, so the term 'specific learning difficulty' would be justified. However, Sian's visual memory is strong (***The Haunted Cave***: centile 85) and her auditory-verbal memory (***Mobile***: centile 44) and phonological abilities (***Word Chopping***: centile 33) are both within the average range so there do not appear to be any cognitive indications of dyslexia.

Silly Words[6] uses nonwords (i.e. letter strings that conform to the rules of English but which aren't real words); examination of Sian's result on this test (centile 13) shows that she has poor phonic skills, so it is most likely that she has failed to acquire adequate phonic decoding skills and so has become over-dependent on visual strategies in reading, relying on her good visual memory. In fact, further investigation revealed that Sian had suffered from persistent glue ear from early childhood, leading to phonological discrimination difficulties. This will have impeded her acquisition of effective phonic skills and so she would have become increasingly reliant on visual and contextual strategies in reading. When confronted by unfamiliar words she has few decoding strategies that she can use, and so tends to guess. She managed to cope on this basis during most of her primary school years and hence her teachers did not previously think she had any special educational needs. However, the visual approach is now failing her and will continue to do so in the face of the more demanding secondary school curriculum. Sian therefore needs attention to her phonic decoding skills as a matter of urgency, otherwise she is liable to show further decline relative to her peers and have great difficulty in coping in secondary school.

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[6] This test is sometimes called 'Funny Words'.

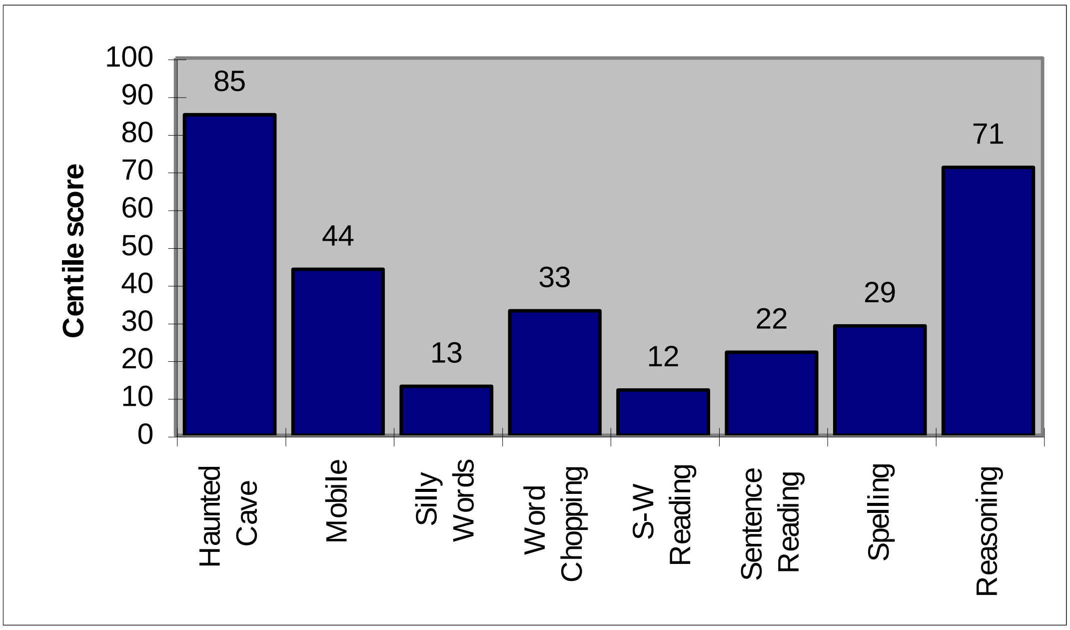

Figure 8. LASS 8–11 profile for Sian aged 10 years 4 months.

If Sian's verbal reasoning score on Lucid Ability turns out to be similar to her LASS non-verbal reasoning score (centile 71) then this will simply strengthen the conclusions drawn above. However, if her verbal reasoning score is much higher than her non-verbal reasoning score, this would increase the amount of statistical discrepancy between intelligence and her auditory-verbal memory as well as her phonological skills and also emphasise the extent of her underperformance in literacy. This would lead to the conclusion that it is likely that she does have dyslexia and hence her problems may be much more difficult to remedy. On the other hand, if Sian's verbal reasoning score is much lower than her non-verbal reasoning score, this would probably rule out dyslexia. It would also indicate that to some extent her weakness in reading comprehension (***Sentence Reading*****,** centile 22) is likely to be due to underlying limitations in verbal intelligence, hence improvements brought about in phonic skills, which should result in gains in word recognition ability, may have weaker impact on reading comprehension.

6.3.2. Case study – Rory (9 years 5 months)

Rory is a boy of who was referred for assessment with LASS 8–11 because of persistent spelling difficulties. His results (shown in Figure 9) indicate that he is probably very bright (***Reasoning***: centile 95), with average reading skills in context (***Sentence Reading***: centile 55) but poor ***Single Word Reading*** (centile 11) and ***Spelling*** (centile 14). This discrepancy clearly justifies the label 'specific learning difficulties'. His phonological skills are satisfactory (***Word Chopping***: centile 40) and he can cope fairly well with ***Silly Words*** (centile 33), suggesting that he has absorbed some phonics knowledge. Nevertheless, the clear evidence of memory weaknesses (***The Haunted Cave***: centile 17; ***Mobile***: centile 7) strongly suggests quite serious dyslexia. His high intelligence has probably enabled him to compensate for his difficulties to a certain extent (e.g. in prose reading) and subsequent enquiries with Rory's parents also revealed that he had received some specialist tuition, focusing on phonic skills from a private tutor, when he was 6–7 years old. Nevertheless, the will definitely require further support otherwise he is likely to under perform in many areas of the curriculum.

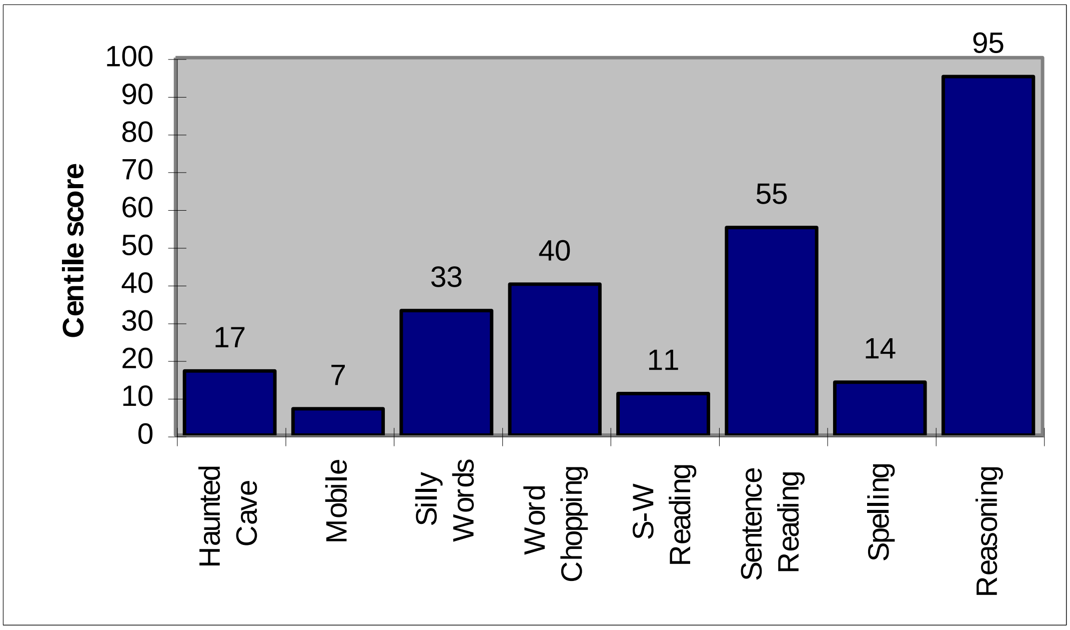

Figure 9. LASS 8–11 profile for Rory, aged 9 years 5 months.

If Rory's verbal reasoning score on Lucid Ability turns out to be high or average then this will strengthen the conclusions already drawn. It is unlikely that Rory's verbal reasoning score would be below average or low because his reading comprehension is average; however, if Rory's verbal reasoning score is below average or low, then interpretation will depend on the relative differences between this and the various components of the LASS profile (see discussion of the case of Mark in section 6.2.1).

6.3.3. Case study – Eva (12 years 2 months)

Eva was not on the school's SEN register but has consistently performed at the lower end of her class in most areas of the curriculum. Recently, her parents have raised the question of whether Eva has dyslexia, and so LASS 11–15 was administered. The results are shown in Figure 10. The score on ***Reasoning*** at the 16th centile suggests that Eva has below average intelligence, although it should be remembered that LASS only assesses non-verbal intelligence; to check Eva's verbal intelligence, Lucid Ability verbal reasoning test could be used. It is notable that Eva appears to be holding her own in some areas, such as reading accuracy (***Single Word Reading***: centile 42) and ***Spelling*** (centile 28), since these are higher than might have been predicted from her ***Reasoning*** score. Her phonic skills (***Nonwords***) are also in the average range (centile 38), suggesting that decoding has been well taught. Her main problem is with ***Sentence Reading*** (centile 12), which suggests problems of comprehending text, which could be due to low verbal IQ but could equally be due to other causes, such as lack of reading experience and/or visual stress. Visual stress is the experience of unpleasant visual symptoms when reading text (e.g. illusions of movement or colour in the print, headaches and eyestrain). About 15—20% of the population suffer from this problem, which can be treated using coloured overlays or tinted lenses. For further information on visual stress visit www.lucid-research.com/visualstress.htm

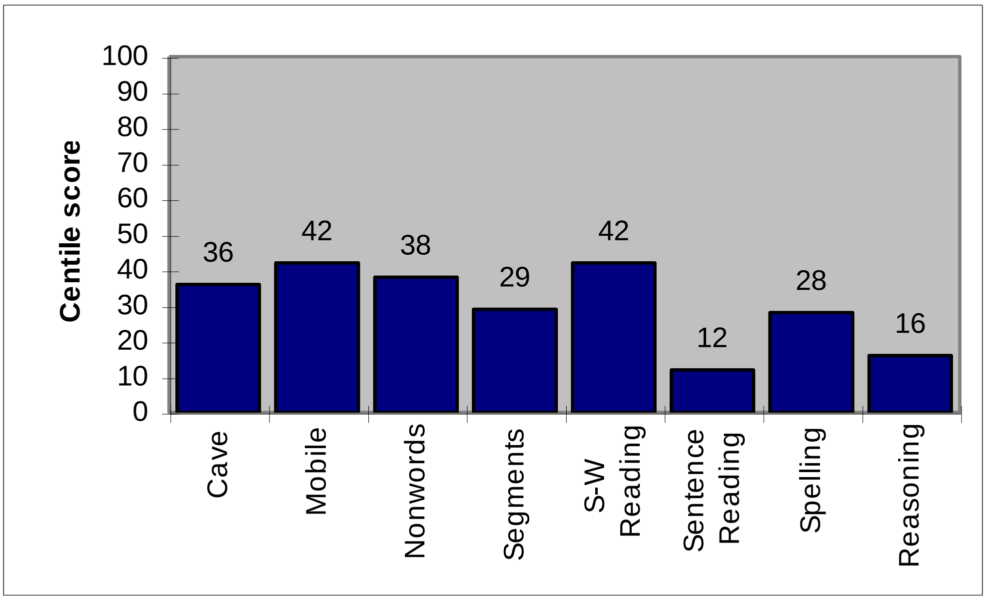

Figure 10. LASS 11–15 profile for Eva (12 years 2 months).

Eva's diagnostic test results are all in the low-average range (rather than being well below average), so it seems unlikely that she has dyslexia (***Cave***: centile 36; ***Mobile***: centile 42; ***Segments***: centile 29). However, the Lucid Ability verbal reasoning test would help to resolve the dilemma. If Eva's verbal reasoning score on Lucid Ability turns out to be low like her non-verbal reasoning score then this will confirm this conclusion. But if her verbal reasoning ability is within the average range or above average this would put a rather different complexion on things because her profile would then be consistent with dyslexia. Alternatively (or additionally) she may have dyspraxia. Children with dyspraxia (also known as Developmental Coordination Disorder) often score much lower on non-verbal reasoning tests than they do on verbal reasoning tests. As well as affecting aspects of coordination, dyspraxia also tends to impair writing skills and all activities where planning is involved. Dyspraxia is often comorbid with dyslexia – i.e. it is found in children who also have dyslexia. For further information on dyspraxia see Kirby & Drew (2002), Portwood (2000), Ripley (2001) and Ripley, Daines & Barrett (1997).

Of course, it may simply be that Eva is one of those individuals who do not perform well on matrix reasoning tasks, despite otherwise good non-verbal intellectual skills. If this is the case then the ***Reasoning*** test in LASS will have underestimated her non-verbal ability.

7. References

Ackerman, P.L. & Heggestadt, E.D. (1997) Intelligence, personality and inter4ests: Evidence for overlapping traits. *Psychological Bulletin,* 121, 219-245.

Brody, N. (1992) *Intelligence* (2nd edition) San Diego: Academic Press.

Brody, N. (1997) Intelligence, schooling and society. *American Psychologist,* 52, 1046-1050.

Carroll, J. B. (1997) Psychometrics, intelligence and public perception. *Intelligence*, 21, 25-52.

Ceci, S.J. (1991) How much does schooling influence general intelligence and its cognitive components? A reassessment of the evidence. *Developmental Psychology,* 27. 703-722.

Ceci, S.J. & Williams, W.W. (1997) Schooling, intelligence and income. *American Psychologist, 52, 1051-1058*

Chamorro-Premuzic, T. & Furnham, A. (2005) Intellectual competence. The Psychologist, 18, 352-354.

Colom, R. & Lynn, R. (2004) Testing the developmental theory of sex differences in intelligence on 12-18 yearolds. *Intelligence*, 36, 75-82.

Crook, C. (1996) *Computers and the collaborative experience of learning: A psychological perspectiv*e. London: Routledge.

Deary, J. J. (2001) *Intelligence: A very short introduction.* Oxford: Oxford University Press.

Deary, I.J. et al. (2003) Population sex differences in age at age 11: the Scottish mental survey 1932. *Intelligence,* 31, 533-542.

Fergusson, D.M. & Horwood, L.J. (1997) Gender differences in educational achievement in a New Zealand birth cohort. New Zealand Journal of Educational Studies, 32, 83-96.

Fergusson, D.M., Horwood, L.J. & Ridder, E.M. (2005) Show me the child at seven II: Childhood intelligence and later outcomes in adolescence and young adulthood. *Journal of Child Psychology & Psychiatry,* 46, 850-858.

Fox, R. (2005) *Teaching and learning: Lessons from psychology.* Oxford: Blackwell.

Gardner (1993) *Frames of mind: The theory of multiple intelligences.* (10th edition). New York: Basic Books.

Gottfredson, L. S. (1997) Mainstream science on intelligence. *Intelligence*, 24, 13-23.

Gould, S. J. (1984) *The mismeasure of man.* New York: Norton.

Hedges, L.V. & Nowell, A. (1995) Sex differences in mental test scores, variability, and numbers of high-scoring individuals. *Science*, 269, 41-45.

Horne, J. K. (2002) *Development and evaluation of computer-based techniques for assessing children in educational settings.* Unpublished PhD Thesis, University of Hull.

Horne, J. K., Singleton, C. H. and Thomas, K.V. (1999, 2009) *LASS 11–15 Assessment System.* Beverley, East Yorkshire: Lucid Research Limited.

Huttenlocker, J., Levine, S. & Vevea, J. (1998) Environmental input and cognitive growth: A study using time-period comparisons. *Child Development,* 69, 1012-1098.

Jensen, J. (1998) *The g factor.* London: Praeger.

Lynn, R. (1999) Sex differences in intelligence and brain size: a developmental theory. *Intelligence,* 27, 1-12.

Lynn, R. & Irwing, P. (2004) Sex differences on the progressive matrices: A meta-analysis. *Intelligence,* 32, 481-498.

Mackintosh, N.J. (1998) *IQ and human intelligence.*

Neisser, U. et al. (1996) Intelligence: knowns and unknowns. *American Psychologist*, 51, 77-101.

Plomin, R. & Petrill, S.A. (1997) Genetics and intelligence: What's new? *Intelligence*, 24, 53-77.

Plomin, R. & Spinath, F.M (2005) Intelligence: Genetics, genes and genomics. *Journal of Personality & Social Psychology,* 86, 112-129.

Primrose, A.F., Fuller, M. & Littledyke, M. (2000) Verbal reasoning scores and their stability over time. *Educational Research,* 42, 167-174.

Singleton, C.H. (1997) Computerised assessment of reading. In J.R. Beech and C.H. Singleton (Eds.) *The psychological assessment of reading.* London: Routledge, pp. 257-278.

Singleton, C.H. (2001) Computer-based assessment in education. *Educational and Child Psychology*, 18, 58-74.

Singleton, C. H., Horne, J.K. and Thomas, K.V. (2001) *Lucid Adult Dyslexia Screening (LADS)*. Beverley, East Yorkshire: Lucid Research Ltd.

Singleton, C. H., Thomas, K.V. and Horne, J.K. (2000) Computer-based cognitive assessment and the development of reading. *Journal of Research in Reading,* 23, 67-80.

Singleton, C. H., Thomas, K. V. and Leedale, R. C. (1996) *Lucid CoPS Cognitive Profiling System.* Beverley, East Yorkshire: Lucid Research Ltd.

Sternberg, R. J. (1985) Beyond IQ: A triarchic theory of human intelligence. Cambridge: Cambridge University Press.

Sternberg, R. J. (1997) The concept of intelligence and its role in lifelong learning and success. *American Psychologist,* 51, 677-688.

Strand, S. (2005) Consistency in reasoning test scores over time. *British Journal of Educational Psychology,* 74, 617-631.

Thomas, K. V., Singleton, C. H. and Horne, J.K. (2001, 2009) *LASS 8–11 Assessment System.* Beverley, East Yorkshire: Lucid Research Ltd.

Vardill, R. (1996) Imbalance in the numbers of boys and girls identified for referral to educational psychologists: Some issues. *Support for Learning,* 11, 123-129.