Historical Perspective

Human intelligence differences: a recent history

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Differences among humans in their mental abilities are prominent, important, and controversial. In part, the controversy arises from over-uses and abuses of mental tests, from insalubrious events in the history of mental test research, and from lack of knowledge about what is and is not currently known concerning human intelligence. In this article, some of the well-attested facts about human intelligence differences are summarized. A striking limitation of this body of research is that, whereas much is known about the taxonomy and predictive validity of human intelligence differences, there has been relatively little progress in understanding their nature, with the exception of behaviour genetic studies. An article which will follow this one explores attempts to understand human intelligence differences in cognitive terms. A previous article addressed recent research on the biological origins of human intelligence differences[1], and updates on this topic are available elsewhere[2,3].

Knowns and unknowns about human intelligence differences

The most recent furore about human intelligence differences came in the wake of the surprise US best-seller, *The Bell Curve*[4]. The book is a peculiar, incendiary sandwich, with a series of regression analyses of the National Longitudinal Study of Youth in the USA enclosed between essays relating the authors' worries about an intelligence-based social apartheid and social policy considerations. The arguments that followed its publication resulted in two remarkable documents.

The first was a full-page advertisement in the *Wall Street Journal* (December 13th, 1994) entitled 'Mainstream Science on Intelligence'. Its 25 paragraphs described 'conclusions regarded as mainstream among researchers on intelligence', and was signed by 52 researchers in the field. It is an odd place for such a document, and readers might view the signatories as one-sided, largely committed to the psychometrics-based intelligence research they were endorsing. That is why the second, the report of the American Psychological Association's (APA) Task Force, is so important[5]. As a result of *The Bell Curve*'s controversies, the APA put together a task force of 11 people to write a report on 'Intelligence: Knowns and Unknowns'. The individuals concerned came from different research traditions within and outside intelligence and were known to hold very different views on the topic. Yet, they managed to produce a wide-ranging review article that all contributors signed. It remains a touchstone for disinterested and authoritative information about intelligence differences. The following sections provide a summary of some of the 'knowns' about human intelligence differences that emerged during the 20th century.

When 'intelligence' is referred to, what is meant is 'psychometric intelligence', the human differences measured by mental tests. Psychometric mental ability tests do not cover all the capabilities of humans[6]. Nevertheless, in Carroll's massive survey[7] and re-analyses of hundreds of data sets in intelligence research there are sections on abilities in the domains of language, reasoning, memory and learning, visual perception, auditory perception, idea production, cognitive speed, knowledge and achievement, psychomotor abilities, and miscellaneous other areas. Thus, there are speeded and non-speeded abilities, education-related and -unrelated abilities, paper-and-pencil and other types of test, and tests covering a large range of human mental functions. It is not the full gamut of human performance, as emphasized by Sternberg[6] and Gardner[8], but it is an undeniably broad and important range of human mental activities.

The taxonomy of psychometric intelligence differences

Spearman's discovery, in 1904, of a general factor common to many different mental abilities, has invariably been replicated in datasets in which a large number of humans undertook a variety of mental tests[9,10]. To the onlooker during most of the 20th century, however, the taxonomy of intelligence differences must have appeared chaotic, with some past and present researchers: insisting that the general factor is important (Spearman, Jensen) or that it does not emerge (Guilford, Thurstone, Gardner, Cattell and Horn); that there is a hierarchy of mental abilities from the general factor through broad ability factors to very specific, narrow abilities (Burt, Vernon) or that there is merely a range of uncorrelated narrow abilities (Guilford)[10,11]. The resolution of these debates was available from the 1940s, but not widely recognized. By 1939, Eysenck showed that even Thurstone's own data contained a general factor that refuted his own early ideas that there were only separate abilities[12]. And in 1940, Burt described a hierarchy of mental abilities that is not distinguishable from the 'new' consensus that emerged in the 1980s and 1990s[13].

A hierarchical model of human intelligence differences came to dominate in the mid-to-late 1990s because of two lines of converging research. First, the development of structural equation modelling techniques meant that hypotheses about the structure of psychometric abilities could be tested competitively. Analyses of large, single datasets found that a hierarchical model provided best fit to the data[14,15] (see Box 1). Second, Carroll published his survey of over 400 datasets – many of them being the classic datasets in the 20th century's research on human intelligence differences – in which mental test batteries were given to human subject samples from childhood to old age[7]. He subjected them to a uniform set of psychometric procedures. He concluded from these re-analyses that the best model of ability differences was a three-stratum hierarchy.

Therefore, at present there is consensus that there is a general cognitive factor that accounts for about 50% or so of the variance in a broad assembly of mental tests given to a large sample of the population. The general factors from different batteries of mental tests show very high correlations, often well above 0.9 (Ref. 10). When that variance is taken into account, there is still variance attributable to separable 'group' factors of intelligence. The most commonly emerging group factors are verbal, spatial, memory and processing speed, though different numbers and types of group factors may be found depending on the

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Box 1. The hierarchical structure of mental ability differences

For the present article a new analysis was performed on the American standardisation sample of the Wechsler Adult Intelligence Scale-III (WAIS-III; Ref. a). The model was a hypothesis about the structure of the variances and co-variances of the 13 tests of the WAIS-III. The hypothesis was tested using the EQS structural equation modelling program (maximum likelihood method; Ref. b). The model is a strict hierarchy: each test was allowed to load on only one group factor, and all group factors were assumed to load on the general factor (*g*). No associations were allowed among tests or group factors, other than through the latent variables at the level higher in the hierarchy.

The results can be seen in Fig. 1. This analysis was based upon the variances and co-variances among the 13 subtest scores available on 2450 subjects in the test manual. The model fits well by many criteria. The 13 tests first agglomerate into four group factors, the names of which are derived from the WAIS-III manual. Note that each subtest has a high loading on only one group factor. These parameter weights are estimated by the structural equation modelling programme and are like partial beta weights in a regression model. Note too that all four of the group factors have high associations with the general factor.

Correlations among the group factors are between 0.63 and 0.83 with a mean of 0.76, refuting the idea that there might be independent 'primary mental abilities' at this group factor level. The fact that the group factors are so closely related to *g* means that most of the variance apparently arriving at the tests from the group factors actually comes from *g*. Take the example of matrix reasoning. Its parameter weight from the 'perceptual organisation' group factor is 0.77, meaning that just over 59% (100×0.77^2) of variance in this test is due to this group factor, which is shared with the three other tests, and the rest is variance specific to the test and error variance. However, the 'perceptual organisation' group factor has 88% (100×0.94^2) of its variance due to *g*, the factor shared with all three other group factors. Therefore, about 52% of the variance ($100 \times 0.59 \times 0.88$) in matrix reasoning is due to *g* and only about 7% (12×0.59) due to the group factor.

References

a Wechsler, D. (1997) Manual for the Wechsler Adult Intelligence Scale-III, Psychological Corporation

b Bentler, P.M. (1995) EQS Structural Equations Program Manual, Multivariate Software, Inc.

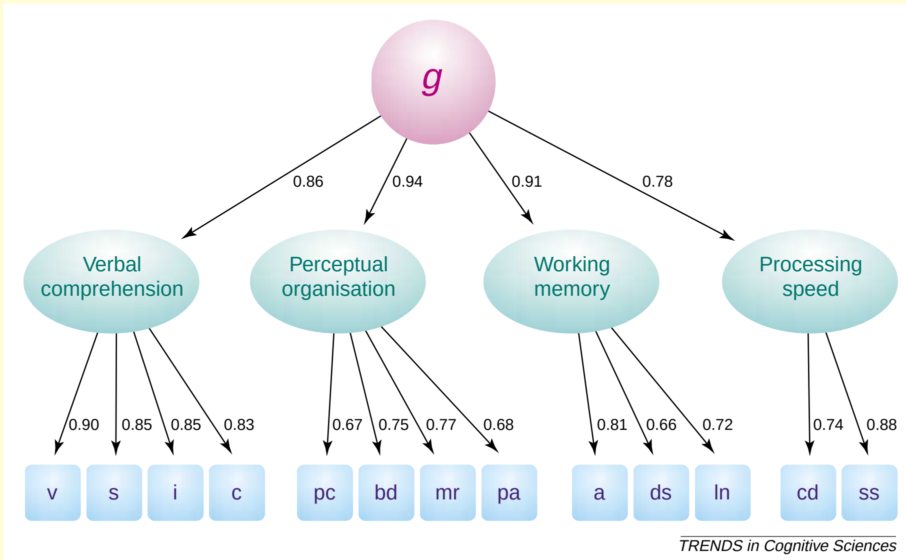

Fig. 1. The blue squares represent the 13 WAIS-III subtests (for abbreviations see below). The ellipses and the circle containing *g* (general factor in intelligence) are latent variables whose names are adopted for convenience. Fit indices are given for each variable and subtest. The average of the off-diagonal absolute standardized residuals was 0.027 (below 0.04 is good). The following fit indices have values of 0.9 or greater in well-fitting models: Bentler-Bonett normed fit index = 0.965; Bentler-Bonett non-normed fit index = 0.959; and the comparative fit index = 0.968. The present model is very economical. As is typically the case with large sample sizes the chi square value for the model is significant (= 663.4, d.f. = 61, $p < 0.001$). Abbreviations: v, vocabulary; s, similarities; i, information; c, comprehension; pc, picture completion; bd, block design; mr, matrix reasoning; pa, picture arrangement; a, arithmetic; ds, digit span; ln, letter–number sequencing; cd, digit-symbol coding; ss, symbol search.

exact battery of tests that is employed. Beyond the general factor and group factors some test performance variance is not accounted for, and is manifest in very specific mental abilities. This so-called three-stratum model affords freedom from otiose arguments about being 'for or against the general factor.' The three stratum account has been called a theory. It is not. And it is not a model of the modal human cognitive architecture: rather, it is a taxonomy or model of test variances and co-variances. The taxonomy does not explain human intelligence differences, it describes them. It offers target pools of variance (general to specific) for explaining by investigations which inquire about the origins of variation in human mental abilities[16].

Stability and ageing of psychometric intelligence differences

Across several decades of adulthood mental ability differences show high stability coefficients. Typically, more crystallized abilities (age-resistant) show higher stability than more fluid (age-sensitive) abilities; the former can be around 0.8 and the latter at or above 0.6 (Ref. 17). Our own follow-up study, 66 years later, of 101 participants of the Scottish Mental Survey of 1932 found a stability coefficient of 0.63 (0.73 when corrected for attenuation of the ability range in the re-tested sample) for test scores on the Moray House Test from age 11 to 77 years[18].

So-called 'crystallized' abilities hold up well with healthy ageing. Examples of such abilities are vocabulary, general knowledge and some number skills. 'Fluid' abilities show decrements as people grow older[19–21]. Fluid intelligence is often described by tasks that require abstract reasoning, maybe under pressure of time, with novel materials, in situations where past knowledge and education can offer no assistance in coming to an answer. Tasks including memory, processing speed, and types of reasoning show ageing decrements. Ageing largely affects the general factor in batteries of tasks that decline with age[22]. Once that effect is taken into account, there is little residual effect of age on more specific abilities. Moreover, there are some strong data and advocacy for the theory that cognitive ageing is largely caused by slowing of speed of information processing[23].

Environmental and genetic influences on psychometric intelligence differences

Reviews of family, adoption and twin (reared together and apart) studies put beyond doubt that there is a substantial heritability to psychometric intelligence differences[24,25]. Within the research area there is relatively little concern with the exact estimate. Nevertheless, combining all studies puts heritability at about 50%, with strong suggestions that heritability might be different at different ages, with especially high levels in old age[26]. Behaviour genetic studies also inform us about environmental contributions, and it appears that, as one grows from childhood to old age, the effect of shared family environment declines almost to zero. One's own specific environmental experience has a large effect at all ages. The search has begun, using molecular genetic techniques, to identify individual genes which contribute variance to individual differences in psychometric intelligence[27–29]. The common wisdom is that, if any such effects are found, there will be many genes each with a small contribution.

Predictive validity of psychometric intelligence differences

Psychometric intelligence tests have applications in the field of education, occupation and medicine, among other sites[5]. In general, they are moderately strong predictors of educational and occupational outcomes. For example, in a review of thousands of reports over about 80 years, a general mental ability test emerged as one of the strongest predictors of job success[30]. The correlations averaged about 0.5. Clearly, there are other important things contributing to job success. Other aspects of the predictive validity of mental ability differences are discussed by Jensen[10] and Gottfredson[31] who emphasize the practical implications of general ability differences.

Understanding intelligence differences

Were it not for their predictive validity – their usefulness, that was evident since their invention[32] – it is doubtful whether the taxonomy of mental ability differences would be so intensively studied. And it is unlikely that so many researchers would be interested in the cognitive and biological origins of mental ability differences. This tripartite examination of intelligence differences – their structure, their utility and their causes – has long existed. It was explicit in Huarte's 16th century treatise on 'mens' wits': he discussed the variety of cognitive abilities, their predictive validity for professions, and discussed classical and then-contemporary evidence that differences in the brain's dryness and temperature were the origins of mental ability differences[33]. At the beginning of the 20th century, Spearman was more concerned with the taxonomy and causes of intelligence differences[9], whereas Binet focussed on the predictive validity of intelligence measures[34].

Before psychology became an experimental discipline the philosophers Thomas Hobbes[35] (17th century) and Christian Wolff[36] (18th century) recognized individual differences in intelligence and discussed their varieties (taxonomy) and origins, essentially coming up with cognitive accounts of mental ability differences. This search for the psychological elements of ability differences emerged again with Galton's[37] suggesting and Spearman's[9] testing the idea that intelligence differences were based partly or wholly upon sensory discrimination differences, an idea that has re-emerged recently[38,39]. Galton also considered reaction-time differences to be basic to higher cognitive differences.

As psychology progressed through the twentieth century the attempts to relate psychometric intelligence differences to cognitive elements were desultory until the rise of cognitive psychology in the 1970s. There was then excitement and optimism around the possibility that the new science of the mind would deliver a catalogue of mental components that would explain human intelligence differences (discussed in detail elsewhere[16]).

> 'There seems to be widespread concurrence among theoreticians and methodologists alike that new approaches to studying intelligence should somehow combine the differential and cognitive [information-processing] approaches that have been used in the past, and that the combination should somehow enable the investigator to isolate components of intelligence that are elementary [at some level of analysis].' (Ref. 40, p. 196)

The success of these ideas is covered in a review that follows this one. It will describe the last few decades of research on the cognitive bases of intelligence differences, and will call for a stronger collaboration between experimental/cognitive psychologists and differential psychologists in understanding human intelligence differences.

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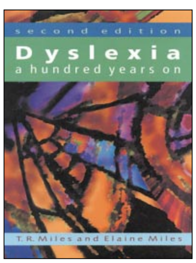
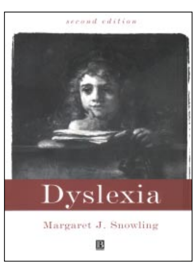
Book Review

Reading difficulty: an update



Dyslexia: A Hundred Years On (2nd edn)
by T. R. Miles and Elaine Miles
Open University Press, 1999.
£15.99 (vii + 208 pages)
ISBN 0 335 20034 6



Dyslexia (2nd edn)
by Margaret J. Snowling
Blackwell, 2000.
£50.00 (hbk) / £14.99 (pbk), (xvi + 253 pages)
ISBN 0 631 22144 1 (hbk)/ ISBN 0 631 20574 8 (pbk)

It is now just over a century since W. Pringle Morgan, a general practitioner in Sussex, England, published what is commonly regarded as the first case history of developmental dyslexia. This was the case of Percy, a bright boy who would have been 'the smartest lad in the school' except for the fact that he was unable to read, even at the age of 14 when Morgan saw him. Morgan thought of his condition as 'congenital word blindness', a term later replaced by 'dyslexia', or developmental dyslexia if there is a need to distinguish the condition from acquired dyslexia.

The ensuing century has seen the phenomenon of dyslexia emerge from the doctor's surgery, coming to be recognized as a major educational problem as well as a fascinating object of study. The fact that children often find it difficult to learn to read and spell was of course generally recognized as soon as universal schooling was introduced in the latter part of the 19th century and, regrettably, too often ascribed to lack of intellectual ability. The concept of dyslexia, on the other hand, assumes a specific disorder of reading and spelling. It is worth recalling that a different theory was also advanced early on that focused on the difficulties inherent in the nature of alphabetic writing and individual orthographies. Thus we find, in Iceland, the linguist Björn M. Ólsen (who became the first rector of the University of Iceland in 1911) publishing in 1889 the results of a detailed count of spelling errors by students in the Reykjavik grammar school, and from the pattern of errors arguing for specific changes to be made in the Icelandic orthography. He found, however – as have almost all would-be spelling reformers – that the force of tradition is overpowering in matters of orthography.

The two books reviewed here give an excellent view of the current state-of-the art in dyslexia research, as is to be expected from these authors, who are recognized authorities in the field. In both cases the books are updated editions of works published just over a decade ago. The quickening pace of research ('explosion' is Snowling's term; 'on a massive scale' according to Miles and Miles) into dyslexia necessitated the new editions; indeed because of this Snowling deemed it 'necessary to write a completely new book' (p. xiii) whereas the Miles duo have done 'some extensive rewriting' (p. vi).

There are interesting commonalities as well as differences in the approaches of the two books, although both make an honest attempt to come to grips with what often seems 'a bewildering conflict of evidence' or even 'bewilderingly contradictory' research results, to quote from *Dyslexia: A Hundred Years On*. Of the two books, this is the more eclectic. It is historically organized, giving a succinct account of the history of research into dyslexia, tracing the beginnings back to attempts to localize brain function in the 19th century, before describing the early medical studies of Morgan, Hinshelwood, Orton and others. From these beginnings, the book moves on to more recent work, dealing in different chapters with current language-based models of dyslexia, especially with regard to the role of phonology, genetics and brain research, as well as work on possible sensory deficits in dyslexia. The book also has a practical touch; for example, there are two useful chapters on methodology and, at the end, chapters dealing with remediation and

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