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Personality and Individual Differences

The Danish Draft Board's intelligence test, Børge Priens Prøve: Psychometric properties and research applications through 50 years

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For over 50 years the Danish draft board has used the same test, Børge Priens Prøve (BPP) for cognitive abilities, involving four paper-and-pencil subtests, to assess suitability for conscription. The potential availability of test scores has been an invaluable resource for research into factors relating to intelligence. In this article the circumstances of the original development of the test are briefly presented, followed by a description of the four subtests and the conditions of testing, scoring and result registration. Over forty studies are identified, including some unpublished, which have explored the psychometric properties of the BPP and have shown the relationships between intelligence as measured by the BPP and a wide range of biological, social and health-related factors.

Key words: Intelligence, Flynn Effect, biological factors, social factors.

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THE DEVELOPMENT OF THE BØRGE PRIENS PRØVE (BPP)

Military conscription was re-introduced into Denmark after the Second World War and since that time all Danish men have, at age 18, become liable for national service. Inspired by the example of the American Army Alpha and Beta tests (Lezak, Howieson & Loring, 2004) and other cognitive screening tests used in other countries, there was expressed in the early 1950s a wish to develop a new psychological test or test battery to assess, independently of educational level, the mental abilities of recruits. The test(s) would need to be group-administered, paper-and-pencil format, to take not longer than one hour to complete and to be suitable for quick scoring. It was to replace an earlier test which had proved unsatisfactory.

The then Psychological Laboratory of the University of Copenhagen became involved in a collaboration with the Military Psychological Service, and the task fell to the psychologist Børge Prien, later director of the Danish Pedagogical Institute. His initial interest was in constructing something akin to the abstract reasoning test constructed by Raven (2000), the so-called Raven's Progressive Matrices test (RPM), but his remit was also to include three other areas of cognitive functioning, not dissimilar to the major of Thurstone's primary abilities (Gregory, 2007), namely verbal, numerical and spatial abilities.

In the development of his test battery Prien had the considerable advantage of being able to pilot, and thereafter to modify, his four tests using large numbers of subjects, namely conscripts. In all of his tests an invariant principle was to avoid the use of multiple-choice responses since these open the possibility of guessing the correct answer. Furthermore, the time limitations made it essential that items in each test should be ordered in increasing level of difficulty, a process which required repeated administrations in the pilot phase. During this phase careful analysis was also made of ''incorrect'' answers to ensure that the items did not admit of more than one correct answer.

Prien's finished version of the BPP, which was completed in six months, was taken into use in the early 1950s, but initially only for men who were actually inducted into national service. Induction was, however, and continues to be, partly based upon a lottery draw, and thus many 18-year-old men at that time did not take the BPP test. In 1956 the testing, with some small modifications to the order of items, was moved to the earlier time of assessment of suitability, what was then called the ''session''. This was a single day during which checks of physical health, vision and hearing were also made and, for those men found suitable for military service, details of the specific possibilities for service were presented and the lottery number drawn. Some 5–15% of men have, through the years, not been required to appear in person for the ''session'' day, namely those who could submit medical documentation for conditions which would disqualify them, e.g. spinal osteochondrosis and asthma. Such men would not have taken the BPP.

The BPP has remained unchanged, including its paper-and-pencil format and the order of its subtests, since its introduction and continues to be used to the present day. In the test booklet each subtest is preceded by a brief illustration to ensure understanding of what is required. The test is taken in groups of usually about 30 under invigilation. It is estimated that the BPP has been taken by over 1.5 million Danish

men, i.e., the very large majority of men now between the ages of 18 and 70.

THE FOUR SUBTESTS

The BPP is composed of four subtests:

- *Letter Matrices*: 19 items, 15 minutes. This test resembles the RPM in that it comprises a set of 3 × 3 matrices in which the bottom right-hand cell is to be deduced. Prien avoided multiple-choice, however, by using alphabetic letters, purely as symbols; the letters never form words and their order in the alphabet is irrelevant. The testee is thus required to supply the letters of the empty cell from the pattern of letters in the other eight. The use of letters also has the advantage of making the response easy to score as being correct or otherwise.
- *Verbal Analogies*: 24 items, 5 minutes: Verbal analogies have often been included in intelligence tests from their inception with Binet's 1905 test. Prien sought, however, to place a greater emphasis on implicit logical relationships rather than constructing what, in Binet's case, was to some extent a vocabulary test. Having determined in pilot work, that testees hand-writing was on occasion barely legible, Prien obviated the need to write out the missing word in the analogy by presenting the testee with an alphabetically sorted numbered list of 100 possible answers, one page for the first 12 items and another for the last 12. The answer is thus the number of the selected word. The large number of possible answers makes the risk of a correct guess almost negligible and the incorrect answers were in part taken from responses in pilot versions when the correct word was to be written in by the testee.
- *Number Series*: 17 items, 15 minutes: The principle of this test is employed in many test batteries. A set of sequences of four numbers are presented from which the next in the sequence is to be deduced. In all cases, the answer can be calculated using only addition, subtraction, multiplication and division.
- *Geometric Figures*: 18 items, 10 minutes: In this test, which somewhat resembles tangrams, the task is to indicate from which of five simple geometric figures of equal areas a set of increasingly complex and irregular gestalts can be constructed. The simple figures are shown at the top of the two pages of the test and are identified by the letters A, B, C, D and E. For each of the 18 gestalts therefore, the testee is required to circle the letters below each of the component simple figures.

DATA RECORDING AND ARCHIVING

The BPP test is scored immediately after completion, since the result is required for the subsequent procedures in the "session" day. The number of correct answers in each of the four subtests is noted on the front page of the test booklet and the total score, from 0 through 78 is calculated. The subtest scores are not themselves used subsequently. Until the mid-1980s the total score was recorded, together with other relevant information, including educational level, on a "register card". These cards are now stored at the regional centers of the Danish National Archive (Landsarkivet). Since the mid-1980s, however, the raw total score has been re-expressed, first as a stanine score (1–9) and then recorded in a computer database only on a scale from 1 (lowest) through 5 in which 5 combines the stanine scores of 5 through 9 and indicates that at least 35 answers were correct. About 80% of men are recorded with the score of 5. The test booklets themselves are collected centrally for random checking purposes and then destroyed at the end of each half-year. It has in some years been possible to access the test booklets for research purposes before their destruction.

PSYCHOMETRIC STUDIES

Georg Rasch (1980) used BPP data to test his pioneering Latent Trait modeling which involves two parameters, one indicating the difficulty level of an item and the other indicating the ability level of a testee. In essence he found that the model fit the Letter Matrices and Numbers Series well but not the Verbal Analogies or Geometric Figures tests. This can be accounted for by the fact that the former two are "power" tests with sharply increasing difficulty levels and with almost one minute available per item. By contrast the Verbal Analogies and Geometric Figures tests, while also having the element of increasing difficulty levels, both place a greater premium on speed. The data used by Rasch stemmed from the early 1950s. Since that time Leunbach in 1987, quoted in Prien (Prien, 2000), and more recently, Kousgaard (2003) have both performed the same analyses on data from subsequent yearly cohorts and confirmed that the same characteristics still hold true. Unpublished data from 6,757 men revealed that the percentages of non-responses (as opposed to incorrect ones) were about 18% for the Letter Matrices and Number Series tests, but about 30% for the Verbal Analogies and Geometric Figures tests.

It is in the nature of the BPP that test-retest reliability data are not available, the test is only ever being re-administered in exceptional circumstances. However, Hartmann and Teasdale (2005) have shown that the internal reliability of the four subtests, measured with Cronbach's alpha, is high (ranges 0.7 through 0.8). While unquestionably tapping varying forms of cognitive functioning, the four subtests have persistently shown a strong single-factorial structure. The intercorrelations between the subtests repeatedly lie within the range 0.4 through 0.6 (Teasdale & Owen, 2008), and the first principal component has, in two independent samples, been found to be 65% (Hartmann & Teasdale, 2004) suggesting a strong 'g' component.

Two studies (Hartmann & Teasdale, 2004, 2005) have failed to replicate Spearman's Law of Diminishing Returns, according to which the "g" component of a set of cognitive tests is stronger at the lower end of the ability scales than at the high end, where more differentiated abilities begin to distinguish themselves. This negative finding was interpreted as resulting from the limited number of the four subtests and their "fluid" reasoning nature.

A study by Mortensen, Reinisch, and Teasdale (1989) examined the correlation between the BPP and the full-scale WAIS, both tests having been administered to a group of 232 men tested at average ages of 18 and 23 respectively. This correlation was found to be 0.82, providing strong evidence for the construct validity of the BPP in measuring intelligence as the Wechsler test measures it. There is further evidence of validity for the BPP. The Danish military makes use of Raven's Advanced Progressive Matrices (RAPM) in connection with their Air Force officer training programs. Unpublished data from 698 men have shown a correlation of 0.57 between the BPP and the RAPM, a value which is probably attenuated by the almost uniformly high educational level of these men. Their mean BPP score was more than one standard deviation above the average for all men tested within the last 10 years. Interestingly, the RAPM correlates almost equally with all four subtests (range $r = 0.33$ to $r = 0.44$), and the correlation is in fact lowest with the Letter Matrices tests, which it otherwise most resembles.

An internal study conducted by the Royal Danish Defence College (2005) showed that, contrary to expectations, the Verbal Analogies tests did not reveal any specific construct bias against Danish men from immigrant, non-Danish-speaking, backgrounds. Such men performed below the overall average, but to about the same degree on all four subtests.

The classic validation for intelligence tests, since the time of Binet has been educational level and attainment. Levels of education in Denmark have increased considerably since the 1950s, and the scales used by the draft board have necessarily changed over the decades. Since the early 1990s a six-point scale has coded from minimal grade school with no subsequent occupational training up to attainment of a baccalaureate-like certification required for entrance into universities and other higher education. Across the years the correlation of this scale with the BPP has remained stable at about 0.55. Of the four subtests, Geometric Figures correlates consistently lower with educational level than the other three.

An issue often raised in connection with the validity of the BPP is the questionable motivation of the men taking the test. It is clear that only a minority are enthusiastic about the prospect of being called upon to perform several months of national service (though not necessarily in the armed forces), and it might be expected that a negative attitude would demotivate maximal effort in taking the test. The evidence does not, however, support this expectation. In an unpublished study the author found that for 2,236 men who had attained a score of at least 35 on the BPP there was a modest *negative* relationship between the test score and a subsequently expressed attitude to being called up. The 43% whose attitude was negative scored about 0.15 standard deviations above the 23% who expressed a positive attitude. The remaining 34% who expressed neither a positive nor a negative attitude had a mean score between the other two groups. This apparently paradoxical relationship seems to be explained by the higher average educational level of the "negative" group who on the one hand can be presumed not to wish for an interruption in their plans to pursue higher education and yet on the other hand performed better on the test by virtue of being intellectually more able. Stratifying for educational level eradicated any difference in mean BPP score between the three motivation groups.

BPP AND BIOLOGICAL FACTORS

Several studies have used the BPP to examine the relationship between intelligence and biological characteristics.

In an early study Teasdale and Owen (1984) obtained BPP scores for sets of full and half brothers who had been adopted separately, together with a set of pairs of men who were genetically unrelated but who had been reared together by virtue of adoption. The results indicated a strong genetic component to intelligence with no familial environmental effect although parallel analyses revealed that educational level was influenced by both genetic and familial environmental factors. A subsequent BPP study of biological fathers and adopted-away sons showed weaker but similar effects (Teasdale & Owen, 1987a).

In the earliest internationally reported study involving the BPP, Witkin, Mednick, Schulsinger *et al*. (1976) used the test score to select intelligence-matched control groups for men identified as having the XYY or XXY chromosomal anomalies and for whom BPP scores were also available. The study was centrally concerned with criminality, but the BPP control-matching was essential since both chromosomal anomalies were known to be associated with below average intelligence, a fact which the study itself confirmed.

In addition to the BPP scores and educational level, data recorded at the "session" routinely include height and weight and tests for visual and auditory acuity. Using heights and weights to calculate Body Mass Index (BMI), Sorensen and Sonne-Holm showed in related large-scale studies that obesity was associated with lower BPP score (Sonne-Holm & Sorensen, 1986; Sonne-Holm, Sorensen, Jensen & Schnohr, 1989; Sorensen & Sonne-Holm, 1985). In a later study Teasdale, Sorensen, and Stunkard (1992), also using a large session-derived cohort, found that the relationship between BMI and BPP was not linear, but also included a quadratic component with a steep downward curve accompanying very high BMIs and also something of a decline associated with very low BMIs. More recent re-analysis has underlined the importance of educational level in the BMI-BPP relationship (Halkjaer, Holst & Sorensen, 2003; Halkjaer & Sorensen, 2004).

A weak and non-linear association between stature and BPP has also been reported (Teasdale, Owen & Sorensen, 1991) in which there is a marked fall in BPP – and educational level – among men of very small stature. The same group also noted that the correlation between stature and BPP had been falling through decades of the last century (Teasdale, Sorensen & Owen, 1989).

The positive association of intelligence and myopia is well established but the availability of very large cohort data enabled yet another study to examine the degree to which the association is linear. It was found that although myopic men scored better

on the BPP – and had higher average educational levels – the relative gain was present at the lowest levels of myopia, and increasing levels of myopia were not associated with any further gains (Teasdale, Fuchs & Goldschmidt, 1988a; Teasdale & Goldschmidt, 1988; Teasdale, Goldschmidt & Owen, 1988b).

Auditory acuity, as measured by audiogram at the "session" day, also proved to be related to the BPP, although in a more linear fashion. Teasdale and Sorensen (2007) found that moderate hearing loss and mild hearing loss were associated with mildly and moderately reduced BPP performance respectively.

A study related to handedness and writing style showed that, although there were no BPP differences between left- and right-handers, among the left-handers a claw-like manner of holding a pen, which permits the writer to read what is being written, was associated with higher BPP (Teasdale & Owen, 2001).

BPP AND SOCIAL FACTORS

Research has also suggested that social factors have a major influence on BPP performance. As noted above, there is a strong association between the BPP and measures of educational level. It has always seemed probable that the association of educational level and intelligence is the result of a reciprocal causality. On the one hand, more intelligent persons are more likely to remain within the educational system, and on the other hand remaining within the educational system would itself enhance intelligence test performance (Sternberg, Grigorenko & Bundy, 2001).

Teasdale and Berliner (1991) provided indirect evidence to suggest an effect on the BPP of kindergarten attendance. For local authority districts across Denmark a positive correlation was found between the level of provision of kindergarten places in districts, which at the time of the study was not (as now) uniformly high, and later average BPP scores of men who had spent their pre-school years there.

Prien himself employed the BPP in a set of studies conducted in the late 1950s of schoolchildren of various ages in which the test scores were found to be sharply different as a function of class stream and paternal socio-economic status (Prien, 1967). There were, however, only small differences between boys and girls. From the published tables it can be estimated that boys averaged overall about one to two IQ points higher than girls on the BPP, most of which difference came from their relative advantage on the Number Series test.

One of the most widely studied and discussed phenomena in intelligence research of the last century has been the so-called "Flynn Effect". In two seminal reviews, Flynn (1984, 1987) demonstrated that in the United States and in other developed countries performance on intelligence tests had improved dramatically across decades of the last century. Although sometimes attributed to nutrition and public health improvements (Lynn, 1990), the effect has most commonly been ascribed to social and educational developments (Niesser, 1998). The availability of the BPP test scores made Denmark one of the best equipped countries for studying the Flynn Effect, together with Norway where draft-board intelligence data for decades since the 1950s are also available (Sundet, Barlaug & Torjussen, 2004).

In an early study, Teasdale and Owen (1987b) showed that the effect had manifested itself in BPP scores which had shown sharp rises between the late 1950s and the 1980s. They also noted that the gains were greater at the lower ends of the test scores, with little change at the highest percentiles (Teasdale & Owen, 1989). More recently, it has been found that the BPP scores have plateaued with very little change since the late 1990s up to the present time (Teasdale & Owen, 2005, 2008).

BPP AND HEALTH

An increasing number of studies have examined the relationship between the BPP and various forms of somatic and psychological health.

Several studies have demonstrated associations between pre- and perinatal factors and BPP test scores. Reinisch, Sanders, Mortensen, and Rubin (1995) showed that prenatal exposure to phenobarbitals is associated with lower BPP scores, suggesting a harmful effect on the fetus. Similar apparent harmful effects on BPP have been found for maternal smoking during pregnancy (Mortensen, Michaelsen, Sanders & Reinisch, 2005a) and maternal alcohol consumption (Mortensen, Jensen, Sanders & Reinisch, 2006; Mortensen, Sorensen & Gronbaek, 2005b).

In two independent studies, low birth weight has been shown to be related to poorer BPP performance (Mortensen, Andresen, Kruuse, Sanders & Reinisch, 2003; Sorensen, Sabrow, Olsen, Rothman, Gillman & Fischer, 1997), whereas breast-feeding has been found to be associated with above average BPP scores (Mortensen, Michaelsen, Sanders & Reinisch, 2002).

Injury during childhood has been found to be associated with reduced performance on the BPP. Osler, Andersen, Laursen, and Lawlor (2007) suggested that intelligence and higher educational level are protective factors against injury risk. Correspondingly, Teasdale and Engberg (1997) found indications that even mild concussions during early adolescence were associated with poorer BPP performance such as to suggest that cognitive deficits were a risk factor for both sustaining concussions and poor BPP performance. However, Teasdale and Engberg (2003) also found that more severe brain injury, during childhood and adolescence, resulted in more greatly reduced BPP performance in a manner which was interpreted to suggest that the injury had had a direct causal effect on cognitive functioning.

Osler, Lawlor, and Nordentoft (2007) found that reduced BPP was associated with increased later risk of both schizophrenia spectrum disorders and bipolar disorders. Parnas *et al*. (2007), by contrast, found that the association between BPP and schizophrenia depended on the diagnostic system employed, and that the association was strongest for hallucinations and negative symptoms.

In a larger-scale study Urfer-Parnas, Mortensen, Sæbye, and Parnas (2009) again found premorbid schizophrenia to be associated with lower BPP scores, but also found this to be true for

non-schizophrenic, non-affective psychoses, affective, personality and neurotic/stress disorders.

THE FUTURE

It is unclear how long the BPP will continue to be used for draft board assessment, but there is currently no apparent political consensus favoring the abolition of conscription in Denmark. Since the BPP has proved to be immune to the obsolescence that necessitated continual revisions of, for instance, the Wechsler intelligence tests (Gregory, 2007), and since there would be little obvious advantage to reformatting it for computer administration, it seems likely that it will continue to be used in its present form for some years yet. When the BPP does cease to be used for its present purpose, but not before, it is likely that the test would be released for academic research use.

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