The Relationship between Projected IQ from QEEG and Neurocognitive Ability

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ABSTRACT

Intelligence Quotient (IQ) scores are used as a measure to predict intelligence through a series of tests. Studies show that various methods can be applied in order to acquire ones IQ score. Of key interest, new technology such as the use of an electroencephalograph (EEG) can be used. An EEG is a computerized recording of the electrical activities of the brain, and with one reading it is able to give an assessment of the brain as well as the IQ scores. This is important because it could mean that instead of having people undergo a battery of tests in order to acquire an IQ score, one intervention can be utilized – the EEG. Currently, there is minimal discourse regarding the relationship between an EEG's projected IQ scores and neurocognitive functionality. Potential for neurocognitive ability can be measured through scores of tests, which are used to determine IQ and these are usually administered by a registered professional. The aim of this paper is to bring to light the ability of the EEG to measure IQ as well as to highlight the benefits of using EEG measurements for IQ rather than the conventional ways of testing. This can be done by collecting QEEG measurements of projected IQ which has three categories namely, global, verbal and nonverbal intelligence and then correlate these scores with scores attained from conventional tests with similar categories. Research that has been previously done confirms this paper's preliminary hypothesis in finding significant correlations between EEG and intelligence, thus demonstrating predictive ability of EEG to measure neurocognitive performance.

Keywords: Electroencephalogram (EEG), Intelligence Quotient (IQ), neurocognitive performance, projected IQ, global intelligence, nonverbal intelligence

INTELLIGENCE

Intelligence has been a focus of research for many years and considerable efforts have been made in order to understand it. The exact definition of intelligence has been a point of interest and controversy for a long period of time (Groth-Marnat, 1990). The reason for this is that intelligence is an abstract concept and it does not have an actual basis in concrete, objective and physical reality. Numerous individuals have attempted to define intelligence and one of the earliest definitions were given by Alfred Binet and Theodore Simon (1916 as cited in Groth-Marnat, 1990) who described it as:

> *'...judgment, otherwise called good sense, practical sense, initiative, the faculty of adapting one's self to circumstances. To judge well, to comprehend well, to reason well, these are essential activities of intelligence.'*

Binet had come up with a model of intelligence that has been heavily researched to present day (White, 2000). He viewed intelligence as consisting of layers and complex functions that were placed at higher levels while simpler functions were placed at lower levels (White, 2000). A more well-known person in the line of intelligence is Wechsler and he considered intelligence to be a global concept that involved an individual's ability to act purposefully, to think in a rational manner as well as to deal effectively with his environment (Groth-Marnat, 1990). The reason why it is so important to get a clear conceptualization of intelligence is so that the tester can fully appreciate the complexity of what it is that they trying to evaluate (Groth-Marnat, 1990).

In 1904, Binet sought government funds in order to develop a tool that would be able to distinguish people that are capable of learning at normal rates from those that are in need of slower-paced educational programs. In the first decade of the 20th century, Binet and Simon (1916) put forward a scale called, 'Measuring Scale of Intelligence' that was used to ascertain children's readiness for school. Spearman on the other hand, was more concerned with what it was exactly that intelligence tests were supposed to measure (White, 2000). He also indicated that a general factor, 'g' factor, is common to all types of intellectual activity. What Spearman emphasized is that different tests of intelligence were greatly correlated and that individuals who dealt effectively in one area were generally effective in other areas as well. This meant that there is a 'g' factor operating that serves to integrate and enhance most of a person's abilities (White, 2000).

Intelligence Quotient (IQ)

Later, Terman revised the Simon-Binet theory and the notion of intelligence being measured by an intelligence quotient (IQ) was put into consideration. Since that time, IQ has been thought of as a direct reflection of one's intellectual ability. IQ is used as a standardized measure of human intellectual capacity and it takes into account a wide range of cognitive skills (White, 2000). Generally, IQ is considered to be stable across the lifespan and scores of IQ can be used to predict educational achievement, employment prospect, and general level of intelligence (Wechsler, 1990).

Measures of Intelligence

So far, the Stanford-Binet test and the Wechsler scales have dominated the assessment of intelligence. In the 1930s, Wechsler began studying a number of standardized tests and selected 11 subtests to form his test battery (Posthuma, Neale, Boomsma, & de Geus, 2001). Wechsler states that professionals who use this test and any other measures of intelligence should avoid equating test performance with general intelligence (Wechsler, 1990). Scores that are acquired from the performance and verbal subtests yield the performance IQ and the verbal IQ respectively. The scores on both the groups combined yield the full IQ. Table 1 below indicates the two types of scales and their subtests.

Table 1: Wechsler Intelligence Test: Types of Scales and Subtests

Verbal Scales	**Performance Scales**
Information	Object Assembly
Comprehension	Geometric Design
Arithmetic	Block Design
Vocabulary	Mazes
Similarities	Picture Completion
Sentences*	Animal Pegs*

*Animal pegs and sentences are optional subtests

Typically, when assessing IQ in both adults and children, the Wechsler Adult Intelligence Scale (WAIS) and the Wechsler Intelligence scale for Children (WISC) are used, respectively. The Wechsler Abbreviated Scale of Intelligence (WASI) is quick and, according to Posthuma et.al. (2001), is a reliable measurement of intelligence that is used in a variety of clinical and educational settings. According to the manual, when attempting to estimate IQ and a full evaluation is not possible this test is the most appropriate (Wechsler, 1990).

Advantages of IQ testing

IQ tests are excellent predictors of learning ability; therefore they can be used to predict how well a child will perform at school. IQ tests are also useful in that they can help to identify individuals that may need extra help at school or students that must be placed in advanced classes (Groth-Marnat, 1990). Another advantage is that intelligence tests provide valuable information about an individual's cognitive strengths and weaknesses. They are important for researching – as well as understanding – things like the effect of environmental variables on cognitive functioning (Groth-Marnat, 1990). Through the interaction between the examiner and the individual, an initial impression can be made of the individual's self-esteem, anxiety, social skills and motivation while intellectual functioning is obtained at the same time. With these in mind, it can be understood that intelligence is an important tool to acquire as it assists in all these instances (Taljaard & Owen, 1996).

Disadvantages of IQ testing

Intelligence tests have been said to have some limitations and many of these tests are still under review today (Ireland, 2010). There are several factors that could lead to a less than accurate score of IQ which could result in detrimental outcomes for the test taker. That score is said to determine their job application for example, and because of a 'bad day' they may not get the job in the end (Ireland, 2010). A bad score can be attributed to the way that a person is feeling on that day, or even to the surroundings in which they find themselves when writing the test.

IQ tests also take a long time to administer as it is done using a battery of tests. This may leave the patient tired so that later tasks scores are less than valid (Groth-Marnat, 1990). Intelligence tests can be used to classify children into certain categories which will then limit their freedom to choose particular fields of study (Groth-Marnat, 1990). IQ tests are also likely to place creative individuals at a disadvantage because they have an inherent bias towards emphasizing convergent, analytical and scientific modes of thought (Groth-Marnat, 1990). There are a few other disadvantages that are discussed briefly below.

Socio-economic Status (SES): The question of the extent to which socio-economic status affects test bias has become increasingly important to psychologists over the years. People of a low socio-economic status cannot afford to send all their children to school and even the ones that are in school may not have the same opportunities or be exposed to as many things as children with a higher socioeconomic standing. Therefore, the tasks presented to them in IQ testing may be strange to them or regarded as unimportant, resulting in poor performance.

Culture

Being a part of a particular culture stimulates a particular form of cognitive development and this means that intellectual abilities are bound by culture (Taljaard & Owen, 1996). Many different researchers point out that although the components of cognitive systems are found in most cultures, there have complicated connection systems and certain deviations occur as a result of specific characteristics of a particular (e.g. literacy) of a particular culture (Taljaard & Owen, 1996). The language used in a particular test must be such that everyone understands what is expected of them in a given situation (Taljaard & Owen, 1996). If this is not the case, then it contributes to 'cultural bias.' The language differences between the person taking the test and the person administrating it can also pose a problem (Ireland, 2010). The translation of tests can give rise to numerous problems in respect to concepts, cultural interpretation and connotations (Taljaard & Owen, 1996). Difficulty in performing culture appropriate intelligence tests is a problem across the world; however, some researchers have attempted to formulate assessments that are appropriate for their cultures.

South African Context

In South Africa there are other, more culturally specific, tests that are used to measure intelligence when the Wechsler tests cannot be used (van Eeden, 1992). The Senior South African Individual Scale – Revised (SSAIS-R) is one such test. It is a battery of 11 tests that each measures a facet of general intellectual ability (van Eeden, 1992). Nine of the tests are combined to form three scales, namely the Verbal, Non-verbal, and the Full Scale where IQ scores are calculated respectively. The SSAIS-R consists of two verbal tests (Similarities and Number Problems) and two non-verbal tests (Block Designs and Missing Parts). This test, like the Wechsler tests, can be used to assess an individual's general level of intellectual ability and then be compared with those of others in their particular age group. In essence, these scores provide diagnostic and prognostic information (van Eeden, Robinson, & Posthuma, 1994). As the name suggests, this test is used for adults. Younger children's intelligence is assessed with tests such as the Junior South African Individual Scales (JSAIS) (van Eeden, 1992). These tests were constructed in response to a need for an intelligence scale that would provide a profile of the preschool child's abilities and they were published in 1981 (van Eeden, 1992).

Neurological-Biological Approaches

Approaches to understanding intelligence all assume that there is an underlying neurological substrate on which intelligence is eventually dependent (Wechsler, 1990). Therefore, it is important to conceptualize in some way the neuroanatomical and neurophysiological processes underlying the behaviors that are discussed as being intelligent (Groth-Marnat, 1990). Halstead proposed a theory of biological intelligence and he indicated that a number of brain functions that relate to intelligence are relatively independent of cultural considerations. More contributors to the biological approach are Cattell and Hebb and they conceptualized the idea of fluid and crystalized intelligence as well as the idea of A and B intelligence, respectively (Groth-Marnat, 1990). Hebb referred to intelligence A as being innate, biological and directly tied to brain function which requires an intact nervous system. Cattell offers something similar which he termed fluid intelligence and is dependent on the brain's efficiency and relative intactness. These two terms are primarily non-verbal and independent of culture and can be measured by tests such as figural analyses, number/letter series and so forth (Posthuma, Neale, Boomsma, & de Geus, 2001). Intelligence B according to Hebb (1972) is based on experience and can be reflected in the extent of a person's accumulated knowledge. Castell referred to this as crystalized intelligence and suggested that it is relatively permanent and generally less susceptible to effects of brain damage. This is the dimension of intelligence that most tests measure. These neurological bases of intelligence are also studied using brain imaging techniques.

Brain Imaging Techniques: EEG

Brain imaging techniques allow doctors and researchers to view activity or problems within the human brain, without invasive neurosurgery. There are a number of accepted and safe imaging techniques in use today in research facilities and hospitals throughout the world (Demitri, 2007). These include the magnetic resonance imaging (fMRI), computed tomography (CT), electroencephalograph (EEG), positron emission tomography (PET) and magnetoencephalograph (MEG). These and many other neuro-imaging techniques have the capacity to reveal changes in the brain as it engages in brain activity (Mureriwa, 2011). Despite the arrival of modern neuroimaging techniques, the EEG still remains the main tool for investigating brain functioning in normal healthy humans (Anokhin & Vogel, 1996). Therefore, the focus of this paper will be on the EEG.

What is it?

All living brains produce electricity, which is detectable on the scalp or the surface of the head (Mureriwa, 2011). An EEG is a computerized recording of the electrical activities of the brain. EEGs are frequently used in experimentation because the process is non-invasive to the research subject. The EEG is capable of detecting changes in electrical activity in the brain on a millisecond-level (Demitri, 2007). It is one of the few techniques available that has such high temporal resolution. The object of the EEG is to measure the distribution of electrical potentials over the scalp. Quantitative EEG (QEEG) that uses digital analysis through computers was developed in the 1960s and was motivated by the low sensitivity and low inter-rater reliability of eye-ball examination for non-epilepsy cases (Thatcher, 2012). The exact definition of QEEG is very broad and pertains to all numerical analyses such as EEG coherence, phase measures and amplitude.

How it works

In order for an electrical activity to be recorded, the clinician or technician places electrodes on specified locations on the patient's head according to the 10-20 system. There are 21 scalp locations when using an EEG cap (Fp1, Fp2, A1, A2, Fz, F3, F4, F7, F8, Cz, C3, C4, T3, T4, T5, T6, O1, O2, Pz, P3, and P4). The computer screen will show the different waves as recorded from the EEG cap corresponding to each of the 21 locations. The quantitative analysis of the EEG can allow the clinician to derive certain measures that can – among other things – infer the cognitive abilities of a given patient (Mureriwa, 2011).

EEG Measurements and Intelligence

Coherence, according to Thatcher, North, & Biver (2005), is a statistical measure of phase consistency between two-time series. In other words, coherence measures the extent to which two brain locations work together (Mureriwa, 2011). This is done by comparing the shape of the brain waves at two locations. In a study conducted by Thatcher et al. (2012), coherence was more strongly correlated with IQ than were the power measures of EEG. What this indicates is that the network properties of shared information as reflected by the EEG were, in this study, the most predictive of IQ.

Phase lag can be defined as a measure of the speed of communication between different brain sites (Mureriwa, 2011). Phase angle can then be defined as the lag delay between a two time series. Thatcher (2012) found that the shorter a person's phase delay is, then the higher their IQ.

EEG amplitudes are simply the size or height of the brain waves in microvolts while EEG power refers to the amount of energy in each frequency at each location of electrodes (Mureriwa, 2011). EEG recordings of absolute power were positively correlated with full scale verbal and performance IQ (Posthuma, Neale, Boomsma, & de Geus, 2001). What this means is that the higher the absolute amplitude or power of the EEG then the higher the expected IQ (Thatcher et al., 2005).

Anokhin and Vogel (1996) conducted a study that aimed to show alpha rhythm frequency as being positively related to mental abilities in a normal adult population and that the relationship that would be found would vary with specific abilities and brain regions. The outcome of the study gathered that the frequency of alpha rhythm is significantly related to cognitive abilities (Anokhin & Vogel, 1996). This is consistent with a study conducted by Klimesch (1999) that said that within the alpha frequency range EEG power is positively correlated to cognitive performance. Another study found that non-verbal IQ in particular was significantly correlated with alpha (Polunina & Davydov, 2006). This study concluded that EEG spectral parameters may predict performance on WAIS. Finally, another study hypothesized whether alpha power in different sub-bands (in other words lower 1, lower 2 and upper alpha) is in any way related to intelligence (Doppelmayr, Klimesch, Stadler, Pöllhuber, & Heine, 2002). The study found strong positive relationships between the intelligence and alpha power (Doppelmayr et.al, 2002). The use of the EEG to measure IQ is not yet a well-researched area, thus the scope of this literature review is limited to research that was conducted that shows the link between certain EEG phenomena and specific areas of intelligence.

METHOD

These studies were all done by using EEG recordings during the administration of the intelligence tests. For the purposes of this research, I propose that participants of all races, ages, socioeconomic status and educational levels should undergo conventional IQ testing in order to attain their IQ scores. Thereafter, each of these individuals should undergo EEG testing and their predicted IQ scores must be recorded. The EEG should yield a tabulated list of predicted scores of cognitive performance. The list gives 11 predicted scores from tests that are done when a test is done manually. The last three neuropsychological tests on the list are full IQ, verbal IQ and Performance IQ. These scores should then be compared to the manually done tests in order to see if they yield similar results. This data would then be used as a platform to determine whether or not the EEG projected reading of IQ is accurate.

Importance of EEG measuring IQ

- There is no cultural bias with the EEG as brains are more or less similar. This is a salient problem with conventional testing methods and using the EEG would eliminate this problem altogether as cultural appropriateness would not qualify.
- Another advantage is that EEG testing would be less time consuming than conventional testing. People would not have to spend half the day doing tests as an EEG would take 15 to 20 minutes at the most to be administered.

As with any studies, there are limitations to the EEG's capabilities of measuring IQ. One such limitation is that the EEG is only able to give a present projection of IQ. This means that it cannot depict previous cognitive abilities. Another is that, during the EEG, there should not be any electrical interference as this will taint the results. The person being assessed should also not be too tired during the test; otherwise slow waves may be misinterpreted as being a slow learner when the waves are only being slow as a result of being sleepy.

CONCLUSION

As there is little discourse on the abilities of EEG to measure IQ, this essay is meant to serve as grounded theory (setting a basis for future researchers to develop the hypothesis) for future practice. Future studies must be done in order to infer the reliability and validity of QEEG in measuring IQ. Previous research has shown that there are positive correlations between various numerical QEEG readings and intelligence. It can be seen that when measuring QEEG apart from all other findings, IQ can also be seen. EEG does not have to be the pinnacle of IQ tests; however, it can serve as a proxy. The apparent gap between conventional intelligence tests' measures of IQ and the QEEG projected measures of IQ suggests future opportunities for research.

BIOGRAPHICAL NOTES

Davidzo Mashiri is an Assistant to the Psychometrist at Biofeedback Laboratories in Tshwane, South Africa. She graduated from the University of Cape Town (UCT) with a Bachelor of Social Science degree in Psychology and Media and Writing in 2012. The following year, she graduated from the University of South Africa (UNISA) with an Honours degree in Psychology. She is currently working towards her Master's degree in Psychology at Unisa. Her ambition is to achieve a doctorate in the same field. She has a passion for children, education and neuropsychology. While at UCT she was a volunteer in the SHAWCO organisation where she tutored children from under-privileged backgrounds.

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