Autism, Personality, and Human Diversity: Defining Neurodiversity in an Iterative Process Using Aspie Quiz

Leif Ekblad

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Autism, Personality, and Human Diversity: Defining Neurodiversity in an Iterative Process Using Aspie Quiz

Leif Ekblad[1]

Abstract

The aim of this study was to define neurodiversity in a scientific manner so it can be researched in further studies without involving disorders defined by psychiatry or popular beliefs about neurodiversity in the autistic community. Neurodiversity was defined as the primary factor output by factor analysis of a data set of human behaviors which contains evenly distributed traits of all sorts that cover all of human diversity. Neurotypical function was defined as the second factor. The study used many different traits and a large sample to find the full extent of neurodiversity, and to provide evenly distributed traits. The result was a test with 145 scoring items and 5 control items that could give participants a neurodiverse and a neurotypical score, and an indication that the participant was neurodiverse, neurotypical, or mixed. It was found that the neurodiversity score was independent of gender and age, and that the prevalence appears to have remained unchanged. There were possible differences in racial prevalence that need further research. The results correlated to many disorders defined by psychiatry, and also with several factors in personality tests. People who had been diagnosed with these disorders had considerably higher neurodiversity scores. The idea that neurodiversity was at the extreme end of a normal distribution was not supported, rather it was found that neurodiversity had its own normal distribution overlapping typical traits.

Keywords

autism, neurodiversity, personality, experimental psychology, psychology, social sciences, psychiatry, behavioral sciences, factor analysis

Introduction

The neurodiversity concept primarily relates to ASD (Autism Spectrum Disorder), ADHD (Attention Deficit Hyperactivity Disorder), Dyslexia, Dyscalculia, and Dyspraxia (Armstrong, 2010; Jaarsma & Welin, 2012; Pollak, 2009). It is proposed that neurodiversity is similar to other personality differences, such as the personality types measured with a Big Five instrument (Costa & McCrae, 1992), that is, similar to persons with transsexuality wanting to be identified by that term instead of gender identity disorder.

In the peer-reviewed medical, behavioral, and psychological literature, the concept of neurodiversity is seldom used. Instead, this literature primarily deals with disorders defined in *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text rev.; *DSM-IV-TR*; American Psychiatric Association, 2000).

ASDs are diagnosed based on difficulties in communication and social domains. Notably these involve a priori assumptions about species-typical behavior. However, our living environment has changed considerable in the last hundred years. Evolution is ongoing but still, recent research has shown that urban upbringing causes mood and anxiety disorders, as well as Schizophrenia (Lederbogen et al., 2011). Mood and anxiety disorders are frequent comorbidities to ASDs. There is also a hypothesis that autism might be an "Intense World Syndrome" (Markram, Rinaldi, & Markram, 2007). It is claimed that ASD diagnoses has increased recently (Centers for Disease Control, 2008), and these findings might account for part or all of this recent increase in diagnosis.

Regarding causes for autism, theories of imbalanced genomic imprinting (Badcock & Crespi, 2006), neurological damage (Eigsti & Shapiro, 2003), and genetic defects (Mendelsohn & Schaefer, 2008) have been proposed. Few of the theories are mutually compatible, and most of them focus only on narrow aspects of the autism spectrum. Some researchers have interpreted this diagnostic elusiveness as

[1]Independent Researcher

Corresponding Author:
Leif Ekblad, Nöbbelöv 1005, 241 93 Eslöv, Sweden.
Email: leif@rdos.net

evidence that there is no single explanation for autism (Happé, Ronald, & Plomin, 2006).

So far genetic and epigenetic studies have only managed to explain 10% to 20% of all autism cases, many of which seem to involve clusters of copy number variations (CNVs). No single mutation could account for more than 1% of autism, making it etiologically very heterogeneous (Geschwind, 2009). Epigenetic factors may play a role in the development of the autistic phenotype. A large twin study concluded that susceptibility to ASD is moderately heritable and involves a substantial shared twin environmental component (Hallmayer et al., 2011). The substantial environmental component to ASD susceptibility is likely the result of the referral bias inherent in any dysfunction-based model used to diagnose ASD. Furthermore, ASD, ADHD, and other neuropsychiatric disorders seem to share a common genetic origin (Lionel et al., 2011).

Support for the neurodiversity concept comes from a recent genome-wide analysis study (Voineagu et al., 2011). The study found that discrete, coexpressed gene modules are associated with autism but not single genes. More than 200 genes were expressed differently in autistic compared with nonautistic brains. Furthermore, these genes regulate the developmental patterning of the frontal cortex and temporal cortex.

Even less studied, due to complexity, is the relationship between autism and other personality traits. Mathematical ability has been linked to autism (Baron-Cohen, Wheelwright, Burtenshaw, & Hobson, 2007) and autistic traits have been suspected to be an independent personality dimension (Wakabayashi, Baron-Cohen, & Wheelwright, 2006).

While the initial reason for the research was related to a specific hypothesis about the cause of neurodiversity, the aim of this presentation is to remain open regarding the causes of ASD and neurodiversity, while still wanting to remove cultural and environmental issues as much as possible. It was anticipated that a large part of several high-prevalence disorders defined in the *DSM*, and typically thought to be part of neurodiversity, could be explained in terms of human diversity rather than as dysfunctions. Unlike other research that specifically focuses on the disability aspect of ASD, this study did not evaluate traits according to their possible contribution to disability.

Neurodiversity today is defined in an arbitrary way as *DSM* diagnoses are. This research defined neurodiversity as the primary factor output by factor analysis of a data set of human behaviors which contains evenly distributed traits of all sorts that cover all of human diversity. Neurotypical wiring was defined as the second factor. This provided a scientific definition that could be used in replication. The main problem in providing a test that can score neurodiversity and neurotypical wiring using these definitions was to find the full span of the neurodiversity spectrum, and to ensure that the traits used were as independent as possible while still being relevant. This required a very large population being given a large set of questions.

Method

The primary hypothesis in this study was that factor analysis of a broad ASD-related test would generate two consistent factors that could be used to score neurodiversity and neurotypical wiring. The tool used in the research (Aspie Quiz) was developed in an iterative process in six different phases.

Investigation Phase

This was the first phase in the iterative process of creating a neurodiversity test. The objective was to create a reliable test for the autism spectrum, and then to find as many traits as possible that correlated to the reliable test.

Information about year of birth, gender, and diagnostic status (no diagnosis, self-diagnosed, or professionally diagnosed) for AS/HFA/PDD (Asperger's syndrome, high functioning autism, and pervasive development disorder) and ADD/ADHD (attention deficit disorder, with or without hyperactivity) was collected in all versions. In some versions, diagnostic status for autism, dyslexia, dyscalculia, dyspraxia, bipolar, schizophrenia, Tourette, oppositional defiant disorder (ODD), and nonverbal learning disorder (NLD) have been collected.

Data collection started in June 2004. In Version 6 (2006), the dual-factor nature of Aspie Quiz was first eminent. Automatic score calculation and relevance estimation was developed after this, and gave a list of 485 items and their relevance estimates and factor loadings. Versions that did not originally use factor analysis for score calculation were recalculated to be able to use the items (and factor loadings) in later analysis.

Consolidation Phase

This was the second phase. The objective was to find the best items from the investigation phase and to create a stable core with these items. The versions were labeled R1 to R7.

Data collection started in February 2007. There was a need to iterate the item selection process in seven steps before a stable core emerged. This phase generated relevance estimates and factor loadings for 50 items in the Autism-Spectrum Quotient (AQ) test and for another 211 items.

Validation Phase

This was the third phase. The objective was to test (and refine) the stable core of items from the consolidation phase by adding various professional psychiatric instruments. The versions were labeled S1 to S12.

Data collection started in June 2007. This phase tested and produced relevance estimates and factor loadings for 405 new items.

Diagnostic Phase

This was the fourth phase. The objective was to try to provide diagnostic advice to participants. The versions were labeled N1 to N4.

Data collection started in January 2008. There was a high dependence between the selected target diagnoses. This made differential diagnosis impossible, that is, some participants got every possible diagnosis as an advice, while others got none. For differential diagnosis, one would need to include negative aspects of the target diagnoses.

Final Phase 1

This was the fifth phase. The objective was to produce a final version. Final Version 1 existed in 16 different releases (F1-F15 and FI). In some of these releases, the most promising instruments from the item selection phase were run once more. This was to get correlations that were guaranteed to be against the same item selection. A few new instruments were also tested.

The combined Final Version 1 data set was constructed by combining all English language answers to 16 different releases of Final Version 1.

Final Version 1 was launched in mid-April 2008 and run until September 2009. It had 145 items for scoring and got 88,382 answers. It had 22 neurotypical items.

Final Phase 2

In the sixth phase, a second final version (Final Version 2) was created to have six identical dimensions on the Aspie and neurotypical sides in the spider diagram that presented scores to participants (see below).

Different releases of Final Version 2 existed to test new items. The core always had the same 145 scoring items and 5 control items. Different releases saved results in different database tables.

The Final Version 2 data set was created by combining Final Version 2 releases.

In this phase information about year and month of birth, gender, country, ancestry, and diagnostic status (no diagnosis, self-diagnosed, or professionally diagnosed) for AS/HFA/PDD and ADD/ADHD, OCD (Obsessive-Compulsive Disorder), and Social Phobia were collected.

Final Version 2 was launched in late October 2009 and was run until August 2011. It had 145 items for scoring and got 174,878 answers. There were 21 neurotypical items. Used items and their properties are presented as supplementary information (see supplementary table, available in the online version of this article at http://sgo.sagepub.com/supplemental).

During the peer-review process, data collection continued. Another 176,438 answers were accumulated in the H3 release between January 2012 and January 2013. The H3 version used the Final Version 2 items.

Recruiting Participants

Links to a Swedish and English Aspie Quiz version were initially posted to a few selected autism community sites (Aspie forum Yahoo group, http://www.aspiesforfreedom.com, and http://www.wrongplanet.net). A year later, many people had recommended Aspie Quiz and had posted links to many different sites. The continued recruitment process depended on Aspie Quiz becoming a popular self-test on autism community forums. Many people added links to their blogs or live journals. Some people posted links to very popular general-discussion forums.

User Account Registration

User accounts were introduced in the validation phase (version S2). A user id was stored with all answers from version S2.

Participation

The referral report for the Final Version 1 contains 229 different links that 10 or more participants had used to do Aspie Quiz. Aspie Quiz attracted on average 300 participants a day from many different locations. The test can easily be found with search engines and Google returns 62,200 hits for "Aspie Quiz." Participation was neither controlled, nor random.

Data Analysis

Factor analysis was done with MVSP (Multivariate Statistic Package, Kovach Computing Services). Kaiser's rule was used to extract factors. The standardize data option was checked so rarer traits gained increased significance. The center data option was not checked. Unanswered items were set to 0. There were no attempts to remove duplicate answers in the database, but up to the validation phase each IP address could only enter a single answer.

DataFit was used to try to match the score difference distribution to different mathematical functions. DataFit includes a bell curve distribution function, but this function provided poor fits to the score distribution. Some distributions looked like two overlapping bell curves, and therefore a dual bell curve formula was introduced in DataFit ($a \times \exp((-(x-b)^2)/(2\times c^2)) + d \times \exp((-(x-e)^2)/(2\times f^2)) + g$).

Item Selection

An initial list of 100 items was put together in 2004 by Inger Lorelei based on our personal experience, on characterization by Martha Kate Downey (Downey), Roger Meyers (Meyer), and Tony Attwood (Attwood), and on items borrowed (but reworded) from the AQ questionnaire (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001).

In the investigation phase, the aim was to test as much as possible that could be related to neurodiversity, as this was required by the definition of neurodiversity. New items mostly came from online discussions and polls on autism community forums like http://www.wrongplanet.net and http://www.aspiesforfreedom.com.

Items from the investigation phase were used as a starting point for selecting the most unique and relevant items possible in the consolidation phase. The method used for selecting the most relevant and unique items was based on two different reports. The first report was based on all items that had previously been tested, but that was not part of the current item selection. It listed a number of these items with the lowest correlations with all other items along with their relevance estimates. The second report used items in the current item selection. It listed which of the current items had the highest dependence, presenting items in pairs, with their relevance estimates.

As the neurodiversity definition required evenly distributed traits, the goal was to create a heterogeneous set of items. The elimination criterion was to throw out items that were most similar to others, but among those that were similar, the most relevant were selected and the ones that discriminated least well between Aspies and neurotypicals were eliminated. Some of the added items were removed again because there already existed similar items in the instrument that hadn't been tested together before. The selection method added items with the lowest correlations to other items, so that Aspie Quiz would cover the widest possible range of traits with the fewest possible items.

Two additional reports were also used in the item selection process. One of these listed percentage of "?" answers for items in the current item selection. Too high percentages of "?" answers indicated an item was hard to answer for participants, and items with above 10% of "?" answers were generally not considered acceptable. The other report listed well-known environmental problems. The goal was to eliminate environmental problems, and therefore a group of items with known environmental background was used in the instrument as a reference to be able to spot and eliminate items with high correlations to them.

In the validation phase, various professional psychiatric instruments were added to try to find new relevant items and to assess correlations between instrument scores and Aspie Quiz scores. A new report was created to find new relevant items and to discard similar items. This report listed the items in the current version. For each listed item, it listed all items in the current version that had a correlation with the item that exceeded 90% of the listed item's relevance estimate. This relied on an empirical finding of a linear relationship between an item's relevance estimate and average correlation with other items (Figure 1). Without this method, the requirement in the neurodiversity definition of evenly distributed traits would not be met. The cutoff at 90% was an empirical finding that provided good results. Items from the professional psychiatric instruments were included in this report. After new items from the professional instruments had been tested in the instrument, items that looked promising (high relevance estimate and low correlation to other items) were added as experimental items in the next version.

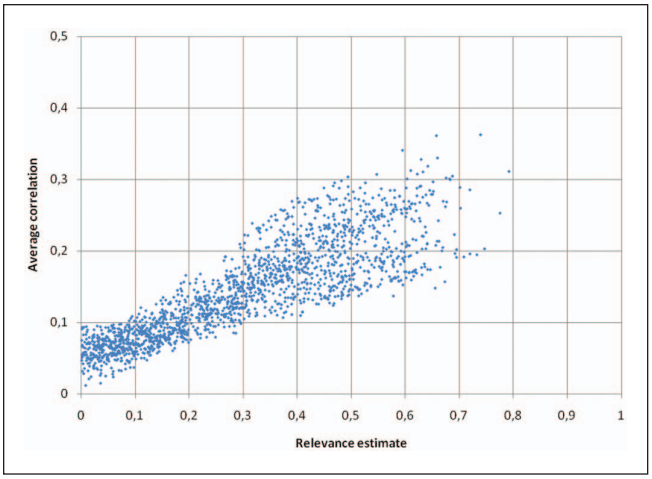

Figure 1. Average correlation with other questions versus relevance estimate for all questions.

Control Items, Ordering, and Uncertain Response

Control items were introduced in the validation phase. They were selected among existing item pairs that had large negative correlations (typically in the range of −.55 to −.65).

Five pairs of control items were added early in the validation phase. These items were designed such that one of the items in the pair would normally be answered positively by Aspies while the other would normally be answered positively by neurotypicals. When somebody answered both items with "yes" or "no," this was considered as a control item inconsistency. Participants were allowed to answer no more than one item inconsistently. This arrangement made it impossible to receive high or low scores just by checking "yes" or "no" on all items.

Starting in the validation phase, items were presented in random order to ensure that people didn't know the objective of items by looking at nearby items. This also mixed up control items with ordinary items.

The "?" (I don't know) choice was checked by default to detect unanswered items. Posting answers with too many "?" choices was disallowed by requiring a total Aspie and neurotypical weight sum of at least 200 (see also below).

Scoring

Aspie Quiz had three answer alternatives: "no" (score 0), "sometimes" (score 1), and "yes" (score 2). It also had a "?" (don't know) alternative. When the "?" alternative was checked, the item would not be part of scoring. This was

achieved by producing a total weighted score of answered items (sum of weight factors multiplied by scores), dividing this by the maximum possible score (sum of weight factors multiplied by 2) and finally multiplying it by 200. This procedure was used for the Aspie score and the neurotypical score separately.

Factor loadings were used for score calculation from the middle of the investigation phase. This resulted in two different scores based on factor loadings: Aspie score and neurotypical score. Aspie score was based on the primary (neurodiversity) factor and neurotypical (nonautistic) score on the secondary factor of Principal Components Analysis (PCA). The average of an item's factor loading in all versions the item had been part of was used. These factor loadings were multiplied by 100 and rounded to integers and gave the Aspie and neurotypical weight factors for items in the instrument. To increase span of scores, if Aspie weight factor and neurotypical weight factor were positive, the lower weight factor was replaced by zero and the higher weight factor was replaced by the difference between weight factors.

Participants got the judgment "very likely Aspie" (neurodiverse) if their Aspie score was at least 35 points higher than their neurotypical score, and "very likely neurotypical" (neurotypical) if their neurotypical score was at least 35 points higher than their Aspie score. The interval in-between was judged as "both Aspie and neurotypical traits" (mixed). The cutoff was set to 35 late in the investigation phase so that 80% of diagnosed AS/HFA/PDD would get their diagnoses confirmed.

Calculating Relevance Estimate for Items

In the investigation phase, Aspie Quiz asked for self-reported diagnostic information about AS/HFA/PDD. As it was pointed out to all subjects that the data were analyzed anonymously and people were taking part voluntarily, this self-report was seen as sufficient for classifying subjects into Aspie control group. The neurotypical control group was constructed based on the referral information that web browsers send back to a website. Referral sites unrelated to autism were included in the neurotypical control group. The Aspie control group and neurotypical control group allowed calculating the relevance estimates for each item.

In the middle of the investigation phase, scoring was changed to use factor loadings. From then on, participants were grouped based on the total instrument scores. Participants that got "very likely Aspie" were assigned to the Aspie (neurodiverse) group while participants that got "very likely neurotypical" were assigned to the neurotypical group. The relevance estimate for an item was calculated as the correlation between answers from these groups. The neurotypical control group based on referrer sites, and self-reported diagnostic information was no longer needed for relevance estimation, and was only used as a sanity check.

Comparing With Other Instruments

The AQ (Baron-Cohen et al., 2001) was used to validate item selection in the consolidation phase. It was run as voluntary in experimental version 4 (R4).

In the validation phase, the following professional instruments were used to validate Aspie Quiz and to do a preliminary check for the relation to neurodiversity:

1. SPQ-A, Schizotypal Personality Questionnaire, that was developed in 1991 by Adrian Raine, Department of Psychology, University of Southern California, Los Angeles. The test measures schizotypal traits in adults. Its validity and factor structure have been checked (Axelrod, Grilo, Sanislow, & McGlashan, 2001). It was run as voluntary in stable version 3 (S3).
2. LSAS, Liebowitz Social Anxiety Scale, that was developed by M. R. Liebowitz. The test measures social phobia. Its psychometric properties have been checked (Heimberg et al., 1999). It was run as voluntary in stable version 4 (S4).
3. MDQ, Mood Disorder Questionnaire (Hirschfeld et al., 2000). The test measures Bipolar traits and was run as voluntary in stable version 8 (S8).
4. The General Adult ADD Symptom Checklist that was developed in 1995 by Dr. Daniel Amen, University of California, Irvine School of Medicine (unpublished). The test measures ADD symptoms in adults. It was run as voluntary in stable version 9 (S9).
5. Vinegrad Revised Adult Dyslexia Checklist (Vinegrad, 1994). The test measures dyslexia in adults. It was run as voluntary in stable version 10 (S10).
6. Tourette Syndrome Diagnostic Confidence Index (Robertson et al., 1999) was modified for self-assessment. The test is used to identify Tourette syndrome in a life-perspective and gives a score proportional to severity. It was run as voluntary in stable version 11 (S11).
7. The Giftedness in Adults test that was developed by Linda Kreger Silverman, the Gifted Development Center (unpublished), was run as voluntary in stable version 12 (S12).
8. The Eating Attitude Test (EAT-26; Garner, Olmsted, Bohr, & Garfinkel, 1982). The test measures eating disorders and was run as voluntary in neurodiversity version 3 (N3).

In Final Version 1, the following professional instruments were used to check the relation to neurodiversity:

1. AQ was run as voluntary in F1.
2. The short version of International Personality Item Pool Representation of the NEO (IPIP NEO) that was developed by Dr. John A. Johnson, Professor of Psychology, Penn State University. Scoring

algorithms and factor loadings were acquired by personal communication. The test is a Big Five type personality test. It was run as voluntary in F2.
3. SPQ-A was run as mandatory in F6.
4. The General Adult ADD Symptom Checklist was run as mandatory in F7.
5. LSAS was run as mandatory in F8.
6. Tourette Syndrome Diagnostic Confidence Index was run as mandatory in F9.
7. Vinegrad Revised Adult Dyslexia Checklist was run as mandatory in F10.
8. EQ, Empathy Quotient (Baron-Cohen & Wheelwright, 2004), was run as mandatory in F12.

Grouping Traits

Initially, a particular item's relation to a group was calculated by averaging intercorrelations to items in a group for the item checked, excluding self-correlation. A report was used that listed the correlation for all presently used items to all presently used groups. The highest correlations (up to 90% of the highest correlation) were listed in a particular color, which made it easier to see misplaced items. This method was effective when most of the items were already placed in consistent groups, but often failed when novel groupings were attempted.

To remedy this, a new method using a different approach to factor analysis was developed to aid in creating novel groups. The raw material used was changed so that items with higher scores in the neurotypical group were inverted (a 0 score become a 2 score and the reverse). In the factor analysis program, data were centered to remove as much as possible of the primary factors related to neurodiversity. In this configuration, the primary factor only explained about 22% of the variance, and the secondary explained 3%, giving a much better material for finding subfactors in the material. To be relevant for the current groups, the factors were rotated to maximize loadings on presently used groups. Using these maximized factor loadings, an item's relation to a group could be calculated and presented in an updated report that used a mixture of the methods. These factor loadings were also used to calculate group scores for participants.

Grouping of traits started with some arbitrary groups based on diagnostic categories. After discovering the dual-factor nature of the data set, it became desirable to try to group traits in symmetrical Aspie and neurotypical groups. After the spider diagram was introduced in the validation phase, which has an Aspie and neurotypical side, this became even more desirable. This aim was realized with Final Version 2 when the Aspie social group was finally constructed and validated to be reasonably consistent.

Ethical Issues

The research followed principles in human research according to the Helsinki Declaration. As the study was performed independent of an institution, there was no institutional review board available. To comply with applicable ethical requirements on research on human subjects, the study was constructed in such a way that participants could not be identified. Participants got informed about the objectives of the study, and had to indicate they accepted this before they could fill out the survey.

Initially, the following text was presented to participants: "The goal of this test is to evaluate neurodiversity traits in people with formal neuropsychiatric diagnosis and self-diagnosed neurodiverse people to compare them with people in the general population. The goal is to survey traits that currently are not believed to be part of the neurodiversity/autism-spectrum. The goal is also to publish the result of the evaluation in a scientific journal. Your answers will be saved in a database. To avoid multiple answers from the same person, IP-addresses will be saved in a separate table, without a link to the quiz results. Each IP could only enter one answer into the database. To get to the quiz you must accept that your answers are saved."

After removing the requirement to save IP addresses to avoid multiple answers, and no longer doing research on new traits, the text was changed to "Statistics/results are saved in a database. The statistics might be published, used as research-data or checked in order to calibrate the test. We do not save IP addresses or other personal information."

Results

In January 2013, Aspie Quiz had tested about 1,800 different items and had been answered about 550,000 times.

Factor Stability

A central issue in the construction of Aspie Quiz was the stability of the factors used for scoring. These factors were required to be highly stable. Factor congruence coefficients were calculated for the two first factors of PCA (neurodiversity and neurotypical factor). Factor congruence coefficients between phases are presented in Table 1. It can be seen that Aspie Quiz converged as average factor congruence coefficients approached and exceed .99. In the final version, factor congruence coefficients between releases, and even with different sets of items, are much larger than for instance factor congruence coefficients between genders (Figure 2a) or age groups (Figure 2b). This shows that the item selection process was completed. Even in the very first versions, factor congruence coefficients between disparate item selections were high.

Factor Analysis Results

The 95% confidence interval for explained variance for all versions was 63.2% to 65.2% for the neurodiversity factor, 4.8% to 5.6% for the neurotypical factor, and 1.0% to 1.2%

Table 1. Factor Congruence Coefficients Between Phases.

Phase	Investigation	Consolidation	Validation	Diagnostic	Final 1	Final 2
Investigation	.978	.965	.968	.965	.958	.950
Consolidation	.965	.976	.977	.977	.971	.965
Validation	.968	.977	.987	.989	.987	.983
Diagnostic	.965	.977	.989	.993	.990	.987
Final 1	.958	.971	.987	.990	.993	.990
Final 2	.950	.965	.983	.987	.990	.996

Note. Average factor congruence coefficients between versions in different developmental phases. Self-congruence is included between the same phases.

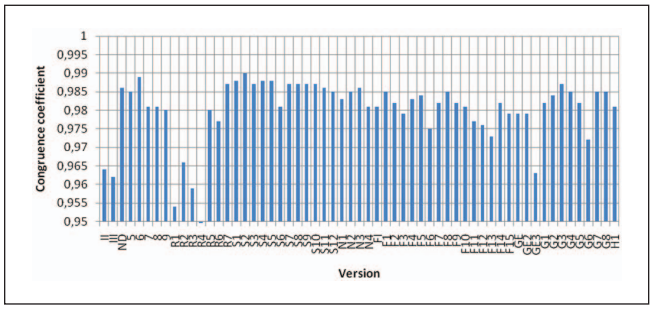

Figure 2a. Factor congruence coefficients between genders.

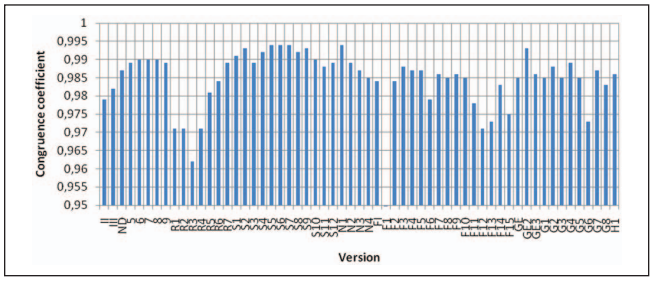

Figure 2b. Factor congruence coefficients between people born before and after 1975.

for the third factor. Analyzing males and females separately gave overlapping 95% confidence intervals. Explained variance for neurodiversity factor was correlated .71 to male neurodiversity rate (percentage of males that got "very likely Aspie"). Explained variance for neurotypical factor was correlated .62 with number of items that neurotypicals scored higher on.

In the final phase, the neurodiversity and neurotypical factor loadings had no correlation, the neurodiversity and third factor loadings had a .5 correlation, and the neurotypical and third factor loadings had no correlation.

Connections Between Measures

Explained variance seemed to relate to male neurodiversity rate and to the number of neurotypical items. Another relation was between neurodiversity rate (and especially the male rate, but also the female and overall) and explained variance for neurodiversity factor. There were also relations between number of neurotypical items and factor analysis results, primarily explained variance for neurotypical factor, but also for factor congruence coefficients. This indicates that too few neurotypical items degrade factors.

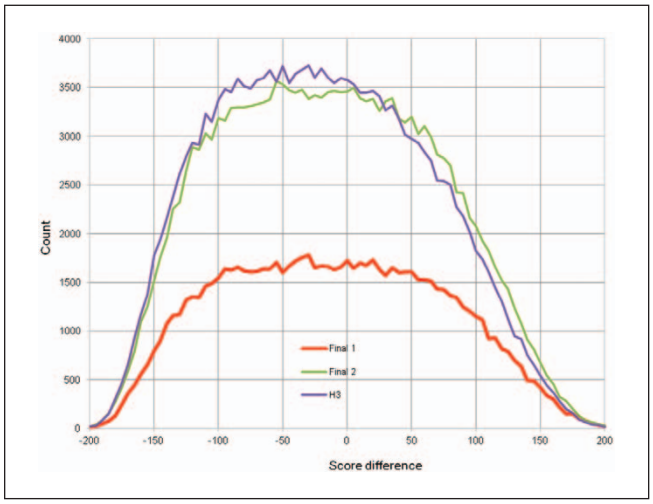

Figure 3. Score difference distributions for all answers.

Average Scores

Average scores per gender in Final Version 1 were Aspie score 94 and neurotypical score 109 for males, and Aspie score 103 and neurotypical score 103 for females.

Average scores per gender in Final Version 2 were Aspie score 93 and neurotypical score 113 for males, and Aspie score 107 and neurotypical score 102 for females. Aspie and neurotypical scores had a −.96 correlation.

Note, by checking the middle alternative on all items, a participant would get Aspie score 100 and neurotypical score 100.

Score Distribution Approximations

Figure 3 show the score difference (Aspie score – neurotypical score) distributions for all participants. These were

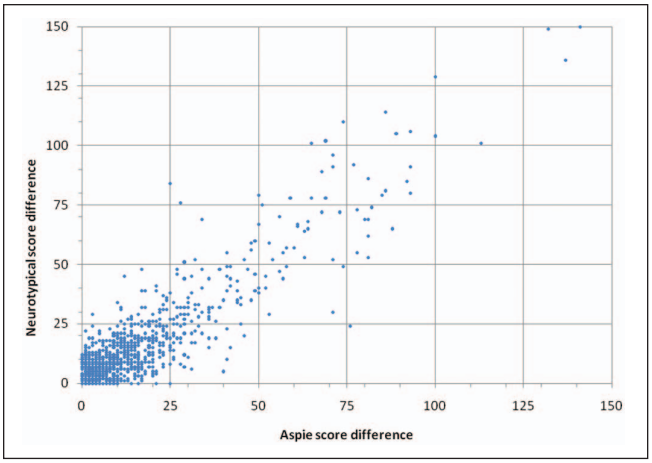

Figure 4. Score difference distribution based on registered users who did Aspie Quiz twice.

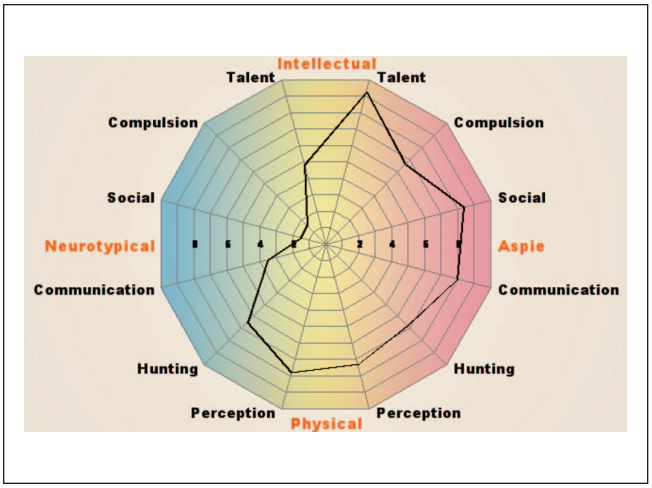

Figure 5. An example of an Aspie profile in the spider diagram.

generated by exporting frequencies of scores from Final Versions 1 and 2, and H3 in five score intervals from −200 to 200. Scores do not seem to be normally distributed. Attempting to match score distributions with a single bell curve provided poor results. Instead, it seemed like the score distributions were composed of two independent overlapping bell curves.

The best match for the total data set gave 99.7% explained variance for 10th-order polynomial, 99.4% for dual bell curve, and 91.1% for single bell curve. For the total diagnosed AS/HFA/PDD population, it gave 98.2% for 10th-order polynomial, 98.1% for dual bell curve, and 92.6% for single bell curve. The average explained variance for all answers in 32 individual versions were 90.8% for 10th-order polynomial, 90.3% for dual bell curve, and 79.6% for single bell curve. Conservative estimate and theoretical considerations (see "Discussion" section) favor the dual bell curve.

Score Stability

Figure 4 shows score difference for registered users who did Aspie Quiz twice. Most registered users have a small score difference, but there are some outliers that seemed to have manipulated their results.

When analyzing all registered users who did Aspie Quiz twice, the average Aspie score difference was 17.1 and the average neurotypical score difference was 17.6. By removing registered users who had more than 50 in root square sum of Aspie and neurotypical score difference (104 registered users out of 825), the average score difference decreases to 11.0 for Aspie score and 11.2 for neurotypical score.

When analyzing all registered users who did two different versions of Aspie Quiz (n = 219), the average Aspie score difference was 15.5 and the average neurotypical score difference was 15.8.

Retake Frequency

In the consolidation phase, there was a required item about how many times participants had done the test in the past, and 108 out of 711 participants indicated that they had done the test before (15.2%).

Retake frequency could also be estimated by checking user accounts. There were 18,639 answers saved by registered users. In all, 14,916 users had only entered a single answer, 825 users had answered twice, while 361 users had answered more than twice. This means that 7.4% of the registered users had done Aspie Quiz more than once. As the reason for registering a user account was to be able to follow up on score stability, this should be an upper limit for how many answers are from the same individual.

Groups

Grouping of traits ended up with six symmetrical groups on the Aspie (neurodiverse) and neurotypical side. The groups were talent, compulsion, social, communication, hunting, and perception. Figure 5 shows a typical Aspie profile in the spider diagram used to present results to participants.

Prevalence of Neurodiversity

Because of the way participants were recruited, it was not possible to directly calculate prevalence of neurodiversity in the general population. Rate of neurodiversity in the final version was around 30% for males and around 40% for females. Some referrer links recorded in Aspie Quiz with many participants showed as low rates as 10% to 15%. A guess is that the rate in the general population might be 10% to 15%. The much higher average scores in the total population is indicative that participants' own feelings about being different was an important factor when people decided to do Aspie Quiz or not.

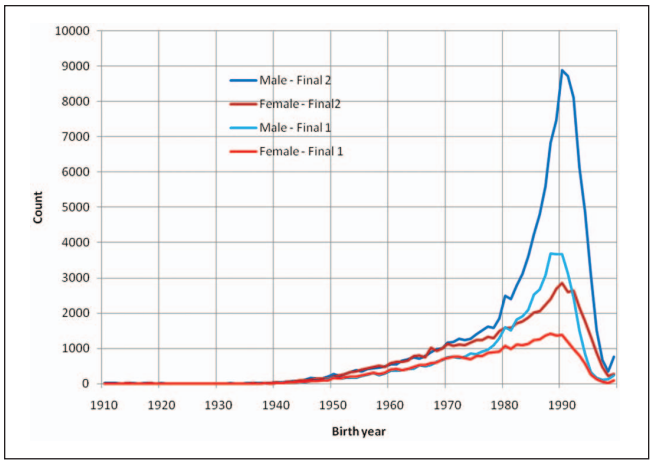

Figure 6. Demographics of participants in Final Versions 1 and 2.

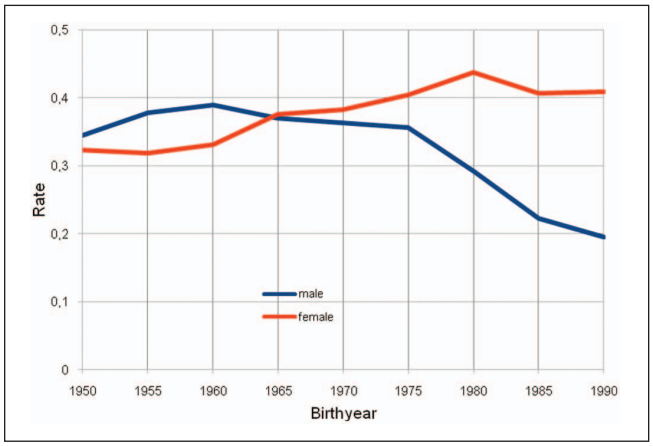

Figure 7. Rate of very likely Aspie per gender and birth year in 5-year intervals from Final Version 2.

Figure 6 shows that most participants were young males. The age distribution seemed similar to how the number of ASD diagnoses had increased during recent years (King & Bearman, 2009). The primary group that took Aspie Quiz was young people, presumably because of increased awareness and that most people diagnosed with ASD are young.

Figure 7 shows the neurodiversity rate per gender and birth year (5-year intervals). The neurodiversity rate seems to be stable and not related to year of birth.

Gender Bias in Prevalence

A data set with no gender bias in participation was required to study a possible gender bias. The data set selected included only people born up until 1970 from Final Version 2. It contained 15,127 males and 14,205 females (1.06:1 ratio). In all, 36% of the males scored as neurodiverse, while 34% of the females scored as neurodiverse. It therefore seemed like neither interest rate nor neurodiversity rate was related to gender for people born up until 1970. Additional evidence for the absence of a gender bias comes from the fact that male:female gender ratio for all participants correlated .84 with female:male gender ratio of participants that scored as neurodiverse, indicating that a bias in male participation resulted in a similar bias in fewer males scoring as neurodiverse. It seems likely that the lower scores and higher participation rate of young males is a cultural issue that is related to popular beliefs about ASD.

Racial Bias in Prevalence

The U.S. sample was used to study the racial prevalence because the proportion of different ethnic groups is well known from U.S. census information. Table 2 presents ancestry information for the U.S. sample for Final Phases 1 and 2. Native American Indians had higher than expected participation rates and higher neurodiversity rate in all three data sets. Asians had the expected participation rate, but lower neurodiversity rates in all three data sets. People of African descent had only about 1/5th of the expected participation rate, but a similar neurodiversity rate in all three data sets. These differences were significant at $p < .05$ in each of the data sets.

Racial Differences in Factors

Table 3 presents factor analysis results for various populations. Native American Indians, in the United States, and as a total group, had higher than expected explained variance for the neurodiversity factor in both data sets. Asians had lower than expected explained variance for the neurodiversity factor. Africans and Europeans were intermediate.

Neurodiversity Contribution to DSM Diagnoses and Personality

It was found that many professional tests correlated to Aspie score difference. These were initially run during the validation phase, and then rerun in the final phase. Results for the validation phase are listed in Table 4 and results for the final phase are listed in Table 5. The AQ test had the highest correlation.

Another way to analyze neurodiversity contribution to *DSM* diagnoses was to check neurodiversity rate for people who had indicated they had been diagnosed with various *DSM* diagnoses. In Final Version 2 (H3), 63% of diagnosed ASD, 62% of diagnosed Social Phobia, 56% of diagnosed OCD, and 44% of diagnosed ADD/ADHD scored as neurodiverse. In all, 28% of the participants scored as neurodiverse in this data set, which indicates that all of these diagnoses had considerably higher neurodiversity rates than the average rate.

A traditional personality test correlated well with Aspie Quiz scores. The IPIP NEO Big Five personality questionnaire had two factors that were highly correlated to Aspie

Table 2. Ancestry Information.

Ancestral group	Participants	U.S. census rate 2010 (%)	Participation rate (%)	Very likely Aspie rate (%)
Native American	823	0.9	1.7-1.9	41.9-48.7
	1,858		2.0-2.2	38.5-43.0
	1,796		1.6-1.8	35.3-39.8
Afro-American	937	12.6	1.9-2.2	32.6-38.7
	2,407		2.6-2.8	34.4-38.3
	2,861		2.6-2.8	31.7-35.1
Hispanic	1,821		3.8-4.2	28.0-32.3
	4,717		5.1-5.4	26.1-28.7
	5,506		5.0-5.3	27.0-29.4
European	37,233	72.4	81.2-81.9	31.6-32.5
	71,106		78.6-79.1	31.2-31.9
	90,462		84.3-84.7	26.4-27.0
Asian	2,122	4.8	4.5-4.8	22.2-25.8
	4,779		5.2-5.4	22.5-24.9
	5,661		5.2-5.4	20.2-22.3

Note. Demographic data from the U.S. sample. The first row is for Final Version 1, the second row is for Final Version 2, and the third row is for H3. Rates are presented with 95% confidence intervals.

Table 3. Factor Analysis Results Per Population.

Ancestral group	Participants	Explained variance for neurodiversity factor (%)	Explained variance for neurotypical factor (%)
U.S. Native American	1,858	67.5	4.5
Native American	2,413	66.8	4.5
Russian	4,450	66.4	3.4
U.S. Afro-American	2,407	65.2	4.4
U.S. European	71,106	64.3	5.2
African	4,231	64.3	4.5
U.S. Hispanic	4,717	62.7	5.1
Asian	11,255	62.1	4.8
U.S. Asian	4,779	61.5	5.3

Table 4. Correlation Between Various Instruments and Aspie Quiz Score Difference.

Condition/factor	Total sample	Answers	Correlation
Autism spectrum (AQ)	1,757	648	.83
Schizotypal Personality Questionnaire (SPQ-A)	2,366	616	.66
Attention Deficit Disorder (ADD)	2,184	439	.62
Social phobia (Liebowitz Social Anxiety Scale [LSAS])	3,069	875	.61
Dyslexia	1,805	521	.43
Tourette	2,509	100	.45
Bipolar (Mood Disorder Questionnaire [MDQ])	2,348	619	.26
EAT-26 (Eating Attitude Test)	4,980	1,331	.26
Giftedness	3,646	1,594	.25

Note. Correlations between various instruments and Aspie Quiz score difference run in the validation phase. Results are sorted in correlation order. All conditions/factors have significant correlations ($p < .0001$).

score, the extraversion factor and the neuroticism factor. The conscientiousness, agreeableness, and openness factors had small (but significant; Table 5) negative correlations to Aspie score. It was also found that the factor structure of Aspie Quiz was more stable than the factor structure of IPIP NEO. There was a .9 factor congruence coefficient between the factor analysis of only the Aspie Quiz part compared with analyzing the Aspie Quiz part and the IPIP NEO part. This

Table 5. Correlation Between Various Instruments and Aspie Quiz Score Difference.

Condition/factor	Total sample	Answers	Correlation
Autism spectrum (AQ)	2,525	715	.83
Empathy (EQ)	414	414	−.72
Schizotypal Personality Questionnaire (SPQ-A)	1,778	1,778	.67
SPQ—Constricted affect	1,778	1,778	.64
Attention Deficit Disorder (ADD)	2,399	2,399	.62
Social phobia (Liebowitz Social Anxiety Scale [LSAS])	1,757	1,757	.62
SPQ—Odd speech	1,778	1,778	.61
SPQ—Social anxiety	1,778	1,778	.58
Big Five—Neuroticism	2,609	747	.58
SPQ—Odd behavior	1,778	1,778	.57
Dyslexia	4,225	4,225	.53
SPQ—No close friends	1,778	1,778	.53
Big Five—Extraversion	2,609	747	−.52
SPQ—Unusual perception	1,778	1,778	.48
SPQ—Suspiciousness	1,778	1,778	.44
SPQ—Ideas of reference	1,778	1,778	.40
Tourette	1,663	1,663	.34
SPQ—Odd beliefs	1,778	1,778	.26
Big Five—Agreeableness	2,609	747	−.24
Big Five—Conscientousness	2,609	747	−.21
Big Five—Openness	2,609	747	−.19

Note. Correlations between various instruments and Aspie Quiz score difference run the Final Phase 1. Results are sorted in correlation order. All conditions/factors have significant correlations ($p < .0001$).

means that a significant part of the traits researched in personality research are related to neurodiversity.

Comparing Aspie Quiz With AQ

The Autism-Spectrum Quotient or AQ test measures autistic traits in adults. To compare the AQ test with Aspie Quiz it was necessary to administer both tests to the same population. This was first done in the consolidation phase ($n = 684$). Analysis gave a correlation between AQ score and Aspie score of .81, a correlation between AQ score and neurotypical score of −.84, and a correlation between AQ score and score difference of .83. In all, 81% of diagnosed AS/HFA scored above the cutoff in the AQ test compared with 75% in Aspie Quiz (6% difference). A total of 66% of all males scored above the cutoff in the AQ test compared with 58% in Aspie Quiz (8% difference). A total of 50% of all females scored above the cutoff in the AQ test compared with 43% in Aspie Quiz (7% difference).

The AQ test consistently gave higher scores in all groups (but primarily in the whole group and the male group).

A second attempt to compare the AQ test with Aspie Quiz was done in the Final Version 1. Out of 2,525 people, 715 did the Aspie Quiz and the AQ test. This resulted in the same correlations between scores as in the consolidation phase.

Using DataFit's linear regression analysis between AQ test score and various Aspie Quiz scores from the Final Version 1 gave the following equations for converting the AQ test score to Aspie Quiz scores:

$$\text{Aspie score} = 17.7 + 3.2 \times \text{AQ}$$

$$\text{Neurotypical score} = 193.5 - 3.4 \times \text{AQ}$$

$$\text{Score difference} = -175.8 + 6.6 \times \text{AQ}$$

In an evaluation of the AQ test (Woodbury-Smith, Robinson, & Baron-Cohen, 2005), control group 2 scored on average 16.4. Recalculating this score to Aspie Quiz scores using the above formulas gave Aspie score 70 and neurotypical score 138. In Aspie Quiz' neurotypical control group, 95% average confidence interval for 32 versions is [75, 79] for Aspie score and [122, 128] for the neurotypical score. This means that Group 2 in the AQ test evaluation is slightly more neurotypical than Aspie Quiz' neurotypical control group.

Baron−Cohen suggested an AQ score of 32 or above should be considered an indication of autism (Baron-Cohen et al., 2001). A recalculation of this AQ score to Aspie Quiz score difference give 35, which is the current cutoff for being neurodiverse in Aspie Quiz.

In a later paper (Woodbury-Smith et al., 2005), it was suggested that a cutoff at 26 was optimal. This corresponds to an Aspie Quiz score difference of −4. The cutoff to neurotypical

in Aspie Quiz was set to −35 for symmetry reasons. The range between −34 and 34 was judged as mixed in Aspie Quiz.

Using the above cutoffs, it was possible to calculate mismatches between professional AS/HFA/PDD diagnosis and Aspie Quiz results. In Final Version 1, 13% of diagnosed AS/HFA/PDD tested as neurotypical, 21% as mixed, and 66% as neurodiverse (n = 5,141). In Final Version 2, 15% of diagnosed AS/HFA/PDD tested as neurotypical, 24% as mixed, and 61% as neurodiverse (n = 4,965).

When comparing results between the AQ test and Aspie Quiz, the following was observed:

- 59% of diagnosed AS/HFA/PDD scored above the cutoff in the AQ test compared with 70% in Aspie Quiz (11% difference)
- 42% of all males scored above the cutoff in the AQ test compared with 46% in Aspie Quiz (4% difference)
- 45% of all females scored above the cutoff in the AQ test compared with 50% in Aspie Quiz (5% difference)
- 16% in the neurotypical control group scored above the cutoff in the AQ test compared with 19% in Aspie Quiz (3% difference)

Aspie Quiz consistently gave higher scores in all groups (but primarily in the diagnosed and female group and to a lesser extent in the whole group and the control group). These findings seem to show that Aspie Quiz has different properties than the AQ test, which is expected when they were constructed with different goals in mind. Some of the properties of professional diagnosis, like more males receiving ASD diagnoses, seem to be reflected in the AQ test, but not in Aspie Quiz.

Problems With Online Questionnaires

There are potential problems with data quality when using online questionnaires. As Aspie Quiz has become a popular self-test in the autistic community, many people there today know how to get low or high scores on Aspie Quiz. This could cause biased results, but fortunately, only a minority of the answers seem to come from the autistic community In Final Version 1, 2,540 participants (2.9%) came from the popular wrongplanet.net site, which was the major contributor from the autistic community. In Final Version 2, 4,146 participants were from wrongplanet.net (2.4%). It therefore seems likely that only a minority of the participants in the Final Version 1 came from the autistic community, and that even fewer did in the Final Version 2. As Aspie Quiz contains many novel questions with unknown linkage to Autism Spectrum Conditions (ASC) outside of the autistic community, this increases chances of truthful answers. Other problems include participants not being honest, leaving items unchecked, or tending to answer positively (or negatively) on everything to get the scores they want. These problems were addressed with control items and requiring certain number of items to be answered. Results indicated that these methods worked.

Further Details and Data

Detailed results from the software-generated evaluation used to construct Aspie Quiz can be found at http://www.rdos.net/eng/aspeval. The source code can be found in a SVN repository at http://rdos.net/vc/viewvc.cgi/trunk/aspie-quiz/

Discussion

The aim of Aspie Quiz was to find a way to score neurodiversity traits in a novel way, independent of diagnostic categories. The actual diversity of the items used was not planned in advance, rather was discovered in the construction process. The main idea was to find traits. To exclude environmental problems, a group of common environmental problems were used to spot issues closely related to environment.

Aspie Quiz defines the terms *Aspie* (neurodiverse) and *neurotypical* itself, based on factor analysis. This is not circular as traits were not selected based on diagnostic criteria, or based on prevalent stereotypes, but in an automatic item selection process. The result that the Aspie Quiz neurodiversity definition maps well to ASD diagnosis and the AQ test is because ASDs are based on the same traits as those that got selected in Aspie Quiz, and not because of how Aspie Quiz was constructed.

Aspie Quiz' neurodiversity definition might differ from the traditional definition, which is not based on scientific research, but on people's opinions. In addition to defining neurodiversity, Aspie Quiz also defines neurotypical function. About half of the traits define neurodiversity, while the other half defines neurotypical function. Often, neurotypical traits are described in terms of problems or absence of function. The intention is that the traits in Aspie Quiz should represent evolved traits, and problems can never evolve. Instead, some traits could have evolved in the neurotypical population and then be absent in the neurodiverse population, causing problems in a culture based on neurotypical preferences. For example, having problems with verbal instructions is placed in the neurotypical talent group, implying that being good (or average) with verbal instructions is an evolved neurotypical trait, and having problems with verbal instructions is the absence of this trait. For social and communication traits, the picture is slightly different. Here there really is no absence of traits, but rather the social and communication issues related to neurodiversity are pure differences. The absence of typical social and communication traits are the central issues in ASD diagnosis, but the presence of other social and communication traits is not considered, which means that many of these traits are virtually unknown of. It took a lot of effort to produce the symmetric neurodiverse and neurotypical social and

communication groups because these traits are differences rather than presence/absence of function.

Aspie Quiz does not support the idea that neurodiversity is similar to Asperger's syndrome or the entire autism spectrum. To begin with, it was the intention to produce a test that could predict an Asperger's syndrome diagnosis, but when the dual-factor nature of the material was discovered, this aim was dropped. The term *Aspie* was retained as that term was thought to represent the positive aspects of Asperger's syndrome rather than the negative aspects described in *DSM*. In the final form, Aspie Quiz' Aspie category maps pretty well with the ordinary neurodiversity definition that includes ASD, ADD/ADHD, Dyslexia, Dyscalculia, Dyspraxia, and Tourette syndrome, as is evidenced by the correlations scores on professional tests for these conditions have with Aspie Quiz scores.

The idea that neurodiversity/autistic traits lie on the extreme end of a normal distribution is not supported by Aspie Quiz, rather the neurodiversity traits seem to have its own normal distribution overlapping the normal distribution of typical traits. This property was also reflected in the fact that factor analysis produced two factors rather than a single factor. The scores based on these two factors were almost inverse, implying that the traits involved in typical function and neurodiverse function are mutually exclusive. The two factors combined explained 70% of the variance, and thus of human diversity, leaving only 30% for other types of variation in the traits used in Aspie Quiz.

Conclusion

The study found support for the usefulness of Aspie Quiz as a tool to assess neurodiversity in an unbiased manner. Aspie Quiz neither has a gender bias nor an age bias in key psychometric properties, like traditional ASD-related test and screening procedures have, which makes it suitable to assess neurodiversity.

The data from Aspie Quiz contradict the view that neurodiversity is a cultural or social construct, as all the traits are correlated to each other, pointing to an inherited rather than social component. The absence of other major factors of human variation in the factor analysis of Aspie Quiz speaks against the idea that neurodiversity is one of the many possible dimensions of human diversity, rather pointing to neurodiversity being the major component of human diversity. The connection to traditional personality traits agrees with this interpretation.

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Author Biography

Leif Ekblad has an MSc at LTH, Lund, Sweden and works as a software engineer. His primary research interest is the function and evolution of neurodiversity. He identifies as neurodiverse and is the parent of two children with ASD diagnoses.