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A Study of G-Factor Intelligence in Correlation with Gray Matter Volume, White Matter Volume, and Neuron Density in the Cerebral Cortex

Caitlin Healy
Regis University

A STUDY OF *G*-FACTOR INTELLIGENCE IN CORRELATION WITH GRAY MATTER VOLUME, WHITE MATTER VOLUME, AND NEURON DENSITY IN THE CEREBRAL CORTEX

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Caitlin Healy

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Thesis written by

Caitlin Healy

Approved by

Dr. Mark Basham
Thesis Advisor

Dr. Jose Lafosse
Thesis Reader

Accepted by

Dr. Thomas G. Bowie, Jr.
Director, University Honors Program

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A Study of *G*-Factor Intelligence in Correlation with Gray Matter Volume, White Matter Volume, and Neuron Density in the Cerebral Cortex

Humans vary greatly in a lot of things; intelligence is no exception. Differences in intelligence can mean major variations in quality of life. Not only can intelligence, often summarized by IQ scores, predict academic success, job income, and marriage stability, but it can also be used to determine life length (Kosslyn & Rosenberg, 2006). Research shows that every point increase in IQ can result in an increase of up to $616 in income each year (Zarorsky, 2007). Intelligence can predict a lot in a person's life, so it is important to understand intelligence and how it relates to structures in the brain.

One common element generally agreed upon in studies of intelligence is the *g*-factor or the general factor. The general factor was first described by Charles Spearman after studying different intelligence tests with factor analysis (Colom et al., 2006). Jenson (1998; as cited in Colom et al., 2006) found that the *g*-factor of intelligence encompasses all forms of intelligence in some way. Many intelligence tests are positively correlated, and *g*-factor is a combination of similar aspects shared among intelligence tests (Jenson, 1998; as cited in Colom et al., 2006). The *g*-factor can be defined as a dominant factor that encompasses an individual's competence in all cognitive abilities seen through test score correlations (Colom et al., 2006). Therefore, *g*-factor is not one measurement taken from a single test, but rather it is determined through performance on multiple tests; an individual's performance on the similar aspects of many different tests would measure that individual's *g*-factor intelligence. *g*-factor is thought to be the general contribution in determining a person's IQ, therefore, many

intelligence tests are positively correlated and therefore contain *g*-factor (Andreason & Flaum, 1993). However, at least one study showed that *g*-factor is not that simple and can relate to a number of different factors including: psychological, biological, social, and genetic factors (Jenson, 1998; as cited in Colom et al., 2006). Many theories exist about intelligence and how to test intelligence; therefore, intelligence testing can be very controversial. Nevertheless, most intelligence tests still test for g-factor intelligence.

The human brain is a complex system made up of many structures; it is divided into gray and white matter. The cerebral cortex, or gray matter, is the superficial surface of the brain containing sulci and gyri that allow the brain to accommodate more neurons, or specialized brain cells (Clayman, 1991). While the human brain contains around 100 billion neurons, there is wide variability in exact neuron numbers in each individual (Blakeman & Frith, 2005; Anderson, 2000). Most information processing occurs in the gray matter of the brain (Kosslyn & Rosenberg, 2006). The white matter is deep in relation to the cerebral cortex and mostly composed of myelinated axons; it is associated with information transfer (Kosslyn & Rosenberg, 2006). Both gray matter and white matter volume are mostly determined genetically (Hulshoff Pol et al., 2006). Neurons are almost exclusively formed during early brain development, and therefore not acquired with age (Blakeman & Frith, 2005).

Although intelligence is important, the exact anatomical and physiological factors associated with intelligence are still not conclusively known. Larger brain size does relate to higher IQ scores, but whether brain size affects intelligence or intelligence affects brain size is unknown (Colom et al., 2006; Kosslyn & Rosenberg, 2006). Many

studies yield positive correlations between brain size and IQ. A population study of intelligence, measured by IQ scores, and brain volume found positive correlations; the study also showed that correlations between IQ and brain size are higher in women and in adulthood (McDaniel, 2005). A study on college students with high and low IQ's found that higher IQ scores were correlated with larger brain sizes (Willerman et al., 1991).

More currently, research is being conducted on not only brain size and intelligence, but more specifically on whether total brain size or the size of certain areas of the brain correlate with intelligence. These studies focus on both gray matter and white matter (Andreason et al., 1993; Colom et al., 2006; Narr et al., 2007). One study found that both are associated with intelligence (Hulshoff Pol et al., 2006). MRI studies done on adults have shown a correlation between IQ scores and gray matter (Narr et al., 2007; Andreason et al., 1993). Studies done by Andreason et al. (1993) also found that white matter was not correlated with intelligence, and although Narr et al. (2007) found that white matter did relate to intelligence, the results were not statistically significant; in fact the results on gray matter volume in correlation with intelligence also lacked statistical significance.

Some studies have further divided gray matter regions, predicting that increased intelligence might lie in specific regions of gray matter as opposed to total gray matter volume. For example, the frontal lobe has been associated with *g*-factor intelligence (Colom et al., 2006). Some of the previous studies conducted testing on the frontal lobes as the main source of correlation between intelligence and size (Narr et al., 2007; Andreason et al., 1993). One study found that the prefrontal and temporal areas

contained more gray matter which correlated with a higher IQ (Narr et al., 2007). Although originally *g*-factor was thought to be associated solely with the frontal lobes, new research has demonstrated otherwise. Colom et al. (2006) found that *g*-factor intelligence correlated with all areas of gray matter including: frontal, temporal, parietal, occipital, sub-lobar, and limbic portions of the brain.

Some studies have noted a difference in gray matter volume in different structures during development. However, other studies looking at developing brain structures in correlation with intelligence found no relationship between gray matter and intelligence in early childhood; positive correlations were found between gray matter volume and intelligence in late childhood/early adulthood (Shaw et al., 2006; as cited in Narr et al., 2007). Although the results of the studies have been inconclusive, researchers agree that further research should be done (Andreason et al., 1993). Further studies could increase knowledge on the neuroanatomical substrates of intelligence.

Detailed anatomical research on correlating *g*-factor intelligence with brain structures is difficult in human subjects because of resources, costs, and ethical issues (Anderson, 2000). Although this presents a problem, *g*-factor intelligence can also be found in non-human species (Anderson, 2000). An extensive study using 424 rats in the search for g-factor intelligence was performed by Thompson, Crinella, and Yu (1990). The results showed that although no g-factor was observed in 75 unlesioned Sprague-Dawley, male rats, differences between the 75 unleisoned and 349 lesioned rats' performance in varied tasks displayed the same human characteristic g-factor. There were 49 brain regions that were bilaterally lesioned in the study which included areas

from different regions of the cortex, to the superior and inferior colliculus, and the cerebellum.

Anderson (1994, 1995, 2000) also found through comparative analysis on human g-factor intelligence and on studies completed on different cognitive abilities in Long-Evans rats, that g-factor intelligence found in humans can also be found in rats. First, he reasoned that the definition of intelligence in animal models must be established. Intelligence in humans is thought to encompass an individual's ability to use reasoning skills in order to solve a problem (Anderson, 2000). Intelligence can be found in animals when the animal is able to incorporate already learned skills to solve a similar but novel problem (Anderson, 2000). If, then, the animal is tested using different motivations, apparatuses, and sensory abilities, a generalized factor can be tested for in rats (Anderson, 2000). Through different testing apparatuses, Anderson (1994, 1995) was able to show that a *g*-factor is found in unlesioned rats because the rats consistently showed individual performance differences.

Anderson (1994, 1995) found that the detour test and two other tests, the reasoning test and novelty test, are the best to use because of their significant association with *g*-factor intelligence. The response flexibility test, or detour test, measures a rat's ability to take a previously learned path and adjust his or her route when an obstruction is present (Anderson, 1995). During the task, the rat is first introduced to the apparatus, and after having time to explore and learn where the food is located, the rat is then presented with an obstruction. The rat's ability to figure out the problem and reach the food quickly without many errors demonstrates the rat's ability in succeeding at the task. The

reasoning task assesses a rat's ability to learn a path to a food source and then, when presented with a new path/starting area or new feeding site, his or her ability to find the food (Anderson, 1994). Like the response flexibility test, this task also gives the rat time to explore the apparatus, and then the rat is assessed on how long it takes to reach the food and the amount of errors it makes in getting to the end goal. The final test, the novelty test, measures the rat's ability to discover/explore a novel item. The rat is again given time to explore the apparatus and then it is presented with the item two different times. Both times with the item, the rat is tested on how long it spends with the object; the first exposure the rat should spend more time with the item because it is new, but during the second exposure, the rat should not spend as much time with the item. Also, another way the rat is assessed in this task is through it's ability to explore the apparatus. These tests all have a significant correlation with intelligence, and the combination of the scores on the individual tasks measure *g*-factor intelligence (Anderson, 1995; Crinella and Yu, 1995).

A follow up study done by Crinella and Yu (1995) concluded that Anderson's tests were indeed heavily g-loaded; however, the study also showed that the g-factor Anderson discovered using only unlesioned rats was probably due to the outbred strain of rat that was used. Therefore, g-factor intelligence analogous to that in humans can be found in rats, but Crinella and Yu (1995) believe that this intelligence can only be seen in outbred strains of rats because the inbred strains are too genetically similar to display any differences in intelligence.

Just as in humans, there are also mixed results on the relationship between the rat brain structures and intelligence. Some studies show that there is no significant relationship between neuron count and neuron density and intelligence in rats (Anderson, 1994). There is also no significant relationship between dendritic arborization, or white matter volume, and intelligence (Anderson, 1995). Anderson (1994, 1995) attributes these findings to possible errors in research, either from the species chosen for the studies, Long-Evans rats, or from using a small sample size, 39 rats. Studies done using an administered drug prenatally, methylazoxymethanol (MAM), found that cell division decreases in the cortex of the rat brain resulting in a rat that has severely impaired intelligence which suggests that there is a correlation between gray matter and intelligence (Anderson, 2000). Lesions in different areas differentially affect rats' performance on *g*-factor intelligence tests (Thompson et al., 1990). These tests were done with the inbred strain of rat, the Sprague-Dawley (Thompson et al., 1990). The inbred strains show a small amount of heterogeneity while there is more variation in the outbred strain of rat (Crinella & Yu, 1995). As the results have been inconclusive, the use of the inbred Sprague-Dawley rat with the administration of the tests developed by Anderson (1994, 1995) could provide insight into the different results across studies.

In order to test the relationship between *g*-factor intelligence and neuroanatomical structures, I will conduct research to see if *g*-factor intelligence can be found in the female, inbred strain of rat, the Sprague-Dawley, when using the same methods done by Anderson (1994, 1995). If there is a g-factor, I will try and discover whether this intelligence is correlated with an increased volume of gray matter in the brain, and if

there is not a g-factor, I will look at whether or not there are differences in brain structure that could mean an unknown relationship between differences in structures and intellectual functions. I will attempt to look at and answer these questions by hypothesizing that in female, Sprague-Dawley rats, an increased number of cell bodies and gray matter volume are correlated with *g*-factor intelligence. I will also look at white matter volume in order to come to more conclusive results.

Materials and Methods

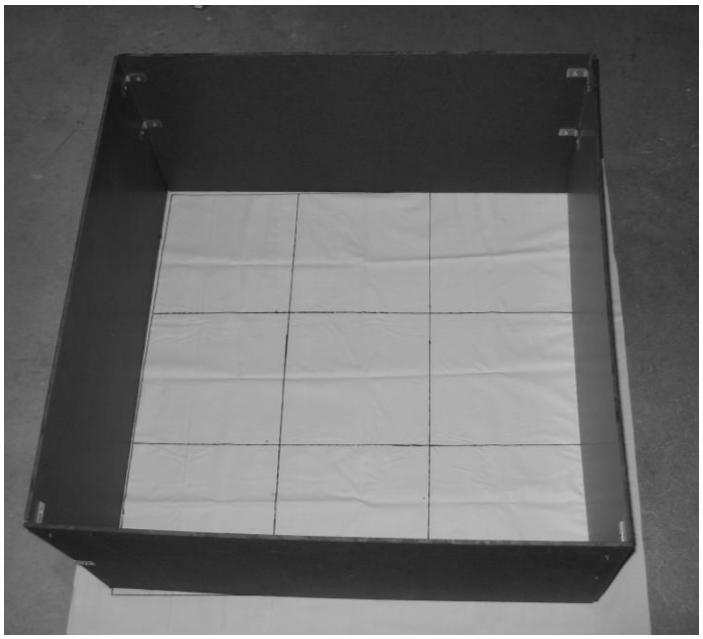
Subjects

Ten female, Sprague-Dawley albino rats were used for this study. All rats were obtained from Harlan at the approximate age of 35 days; studies began when the rats were around 45 days old. Rats were housed two per cage in the Regis University Animal Facility. The lights in the room were on a 12 hour light/dark schedule with lights on at 6:00 am. Rats were given food and water *ad libitum*.

Intelligence Testing Materials

The novelty testing was done in a plywood open field apparatus (dimensions 23.5 inches x 23.5 inches x 12.0 inches). The open field box was placed on a vinyl mat with a nine square grid, with each grid assigned a number 1-9 (from left to right, top to bottom), measuring approximately 7.8 inches x 7.8 inches each. See Figure I. The novelty item was an orange Sanford highlighter (4.75 inches x 0.6 inches).

Figure I: Novelty Test Apparatus



The response flexibility testing was done in a plywood maze (overall dimensions: 48.85 inches x 23.45 inches x 23.9 inches) with contact paper covering the bottom. It had a starting chamber, middle chamber (in which the rats explore to find food), and goal chamber (where the food is located). The starting chamber was 13.0 inches x 8.45 inches and the goal chamber was 10.95 inches x 6.85 inches. In the middle section (27.5 inches x 22.5 inches) in front of the goal chamber, a 15.1 inch x 22.3 inch piece of plywood could be inserted to create a ramp to obstruct, but not cover, the entrance to the goal chamber. The goal chamber was painted black and the rest of the maze was painted white. See Figure II.

Figure II: Response Flexibility Test Apparatus

The reasoning task was done in an eight armed maze with the following dimensions: 29.85 inches x 4.25 inches x 6.75 inches x 22.75 inches. See Figure III.

Figure III: Reasoning Test Apparatus

Procedure

All three of the intelligence tests were based on the tests used by Anderson (1995, 1994); these tests were developed by Bernett (1975) and Berlyne (1960), N.R.F Maier (1929), and Thompson, Harmon, and Yu (1984; as cited in Anderson, 1994). Each test resulted in two measurements and the combined scores were correlated in order to find *g*-factor intelligence.

Novelty testing occurred twice a week for ten minutes each session; the first testing started about age 45 days. During the first session, the rats were placed in grid three and given ten minutes to explore the open field before a novelty item was introduced. For each rat, the number of times any part of their body crossed a grid line as

well as the amount of time spent in each of the nine boxes, assuming they were in the box for more than four seconds, was recorded. During the second session, the novelty testing began with a ten minute exposure to an orange marker. The marker was placed in box five, the center of the testing field. The rats were tested in the same manner with number of crossings and amount of time in the grids recorded, with attention to the amount of time spent with the novelty item in grid five. The rats then had a second exposure to the marker four days later using the same experimental setup. Again, special attention was given to the amount of time each rat spent with the novelty item in the number five grid. After each exposure, the apparatus was wiped down with ethanol.

About two weeks after novelty testing was completed, the rats were tested for response flexibility. Prior to testing, the rats were food deprived to between 80% and 90% of their weight. On the first day of testing, the ramp was not present. The goal chamber was filled with 5 Froot Loops and each rat was placed in the apparatus for five minutes. Two days later the test was repeated but the rats were only in the apparatus for three minutes. The next two trials were test trials; one Froot Loop was placed in the goal chamber and the rats were timed from the starting chamber to the goal chamber. The fifth trial was conducted with the middle board slanted at about a four inch height; the highest end faced toward the starting chamber. This obstructed the rats' view of the goal chamber, but did not actually prevent them from reaching the goal chamber. Again, rats were timed from the starting chamber to the goal chamber. Furthermore, we recorded the number of times any part of their bodies crossed a line drawn directly underneath the elevated middle board.

The reasoning test was completed after the response flexibility testing in the eight arm maze about a month later. The rats were again food deprived prior to testing. Different colored pieces of paper were placed on three of the walls of the testing room to give the rats spatial clues. The colors used were four red pieces (South wall), two yellow pieces (East wall), and three green pieces (West wall); a wooden door was on the North wall. The arms were numbered 1-8; arm number one pointed north.

The rats started by exploring the maze in groups of two for ten minutes; they were started in the middle of the apparatus. For the next trial, the researcher placed one rat in a blocked arm (goal arm) with a Froot Loop and the rat had two minutes to eat. The researcher then placed the rat in a different arm (starting arm); food was placed in the goal arm, and the goal arm was unblocked. The rats completed a trial once a day in which each rat had one opportunity to move from a starting arm to the goal arm and receive a Froot Loop reward. On the first day the rats started in arm 6, and the food was placed in arm 1; day two, the rats started in arm 5, and the food was in arm 3; the third day, the rats started in arm 2, and the food was in arm 7; day four, the rats started in arm 3, and the food was located in arm 4; and the last day, the rats started in arm 8, and the food was located in arm 6. During all test trials, the rats were timed based on the amount of time it took them to find the food; each entry (meaning whole body) into an arm or space not containing food was recorded as an inaccuracy. The researcher cleaned the maze with ethanol between each rat and between the two trials each rat completed. The rats completed five consecutive days of testing and trail scores were averaged.

Perfusion. After behavioral testing was completed, the rats were overdosed with sodium pentobarbital (130 mg/kg) and perfused first with phosphate buffered saline and then with 3.7% formaldehyde. The brains were removed and stored overnight in 3.7% formaldehyde before being transferred into 10% sucrose in 3.7% formaldehyde solution for 24 hours, followed by 20% sucrose in 3.7% formaldehyde solution for 24 hours, and finally into 30% sucrose in 3.7% formaldehyde solution for about 72 hours.

Histology. The brains were frozen. The brain was blocked so it had a flat surface to mount to the chuck, placed, flat side down, on top of a frozen layer of OCT, and then the entire brain was covered with OCT. Once the entire specimen was frozen, it was sectioned in coronal sections anterior to posterior from the emergence of the corpus callosum until the third ventricle was visible and 35µm sections were cut on a cryostat at -20°C. Every third or fourth section was mounted on a warm, gelatin coated slide.

The mounted sections were stained with Thionin as follows. Warmed, dehydrated slides were rehydrated in a series of ethonals (100%, 70%, 50%) ending in water, then stained in Thionin for one minute, rinsed in water, de-stained in a solution of 70% ethanol with 2 drops of acetic acid for approximately 30 seconds each. The slides were then re-hydrated in a series of ethanols (50%, 70%, 100%) and cleared in xylene and then covered with a coverslip with permount (preservaslide).

Microscopy. Slices chosen for measurement contained both a contiguous corpus callosum and a contiguous anterior commissure. Using a compound microscope, the thickness of the cortex (gray matter) was measured at 4X using a clear ruler to measure immediately posterior to the peak in the corpus callosum on each hemisphere of the brain

(see figure IV); two measurements were taken for each animal and results were averaged. At the same peak, measurements of the thickness of the corpus callosum were also obtained. At 100X magnification, neuron density was measured (on the left hemisphere posterior to the peak in the corpus callosum); all neurons completely in the frame were counted while only neurons with a visible nucleus were counted if partially in the frame. Some images were captured digitally; they were saved and used for further analysis with a Nikon digital camera. Analysis of data was completed using Pearson correlations through the SPSS data program.

Results

We did not find differences in g-factor intelligence between Sprague-Dawley rats. There were no significant correlations among the scores on the three different intelligence tests (Table I). There were, however, correlations within the tests; there was a large positive correlation between scores on the response flexibility time to reach goal and response flexibility number of errors (r=0.920), and between the reasoning time to goal and the reasoning number of errors (r=0.753); see Table I. These results were expected; the rats that found the goal quicker in each of the two tests should also show a smaller number of errors.

The results in Table II show the mean scores and the standard deviations for each of the tests.

Table I: Pearson Correlations for Intelligence Tests and Brain Structures

	I	II	III	IV	V	VI	VII	VIII	IX
I. Novelty: difference between trials II and III	1.000	-0.469	0.283	0.321	0.170	-0.160	-0.018	0.006	0.033
II. Novelty: number of lines crossed	-0.469	1.000	-0.211	-0.151	-0.366	-0.134	-0.007	-0.119	-0.289
III. Response Flex: time to reach goal	0.283	-0.211	1.000	0.920**	0.500	-0.042	0.196	0.420	-0.426
IV. Response Flex: number of errors	0.321	-0.151	0.920**	1.000	0.371	-0.106	0.292	0.241	-0.386
V. Reasoning: time to reach goal	0.170	-0.366	0.500	0.371	1.000	0.753*	0.219	0.603	-0.255
VI. Reasoning: number of errors	-0.106	-0.134	-0.042	-0.106	0.753*	1.000	0.486	0.610	-0.017
VII. Gray Matter Thickness	-0.018	-0.007	0.196	0.292	0.219	0.486	1.000	0.615	0.241
VIII. White Matter Thickness	0.006	-0.119	0.420	0.241	0.603	0.610	0.615	1.000	0.028
IX. Neuron Density	0.033	-0.289	-0.426	-0.386	-0.255	-0.017	0.241	0.028	1.000

Column labels are the same as the row labels

** Correlation is significant at the 0.01 level (two-tailed)

* Correlation is significant at the 0.05 level (two-tailed)

Table II: Average Scores for Intelligence Tests

Intelligence Test Results	Mean	Standard Deviation
Novelty: difference between trials II and III	5.48 seconds	5.12
Novelty: number of lines crossed	82.46 lines crossed	19.82
Response Flex: time to reach goal	193.50 seconds	131.34
Response Flex: number of errors	9.70 errors	4.42
Reasoning: time to reach goal	121.05 seconds	59.26
Reasoning: number of errors	5.49 errors	3.60

We did not find any significant variation in brain structures; we also did not find any significant correlations between intelligence tests and brain structures (See Table I). Although an initial assessment, through personal observation, of the raw data showed that slight differences do exist between neuron density and volumes of white and gray matter, the differences between these structures were not significant. The mean score for neuron density was 75.5 neurons with a standard deviation of 7.43. The mean gray matter thickness was 1.63 mm (σ =0.13), and the mean white matter thickness was 0.69 mm (σ=0.106).

Figure IV: Slice of brain with collected measurements (4X)

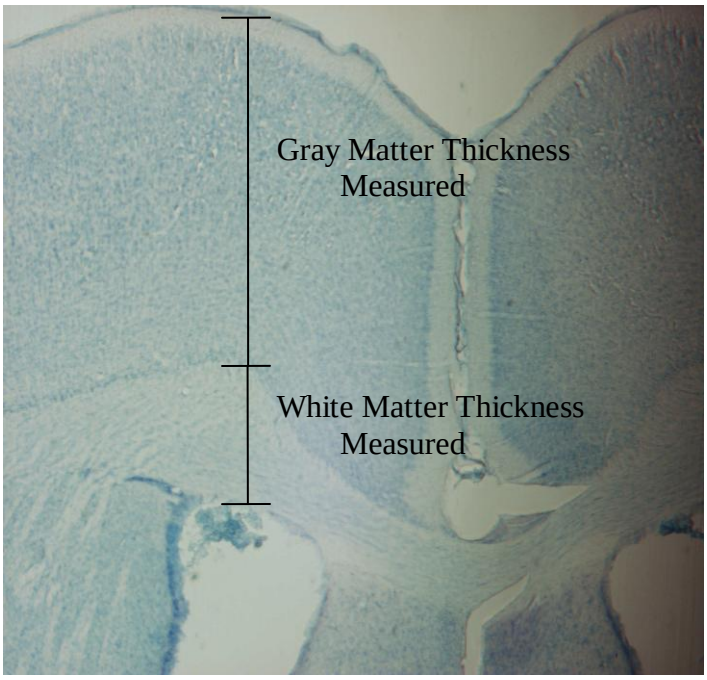
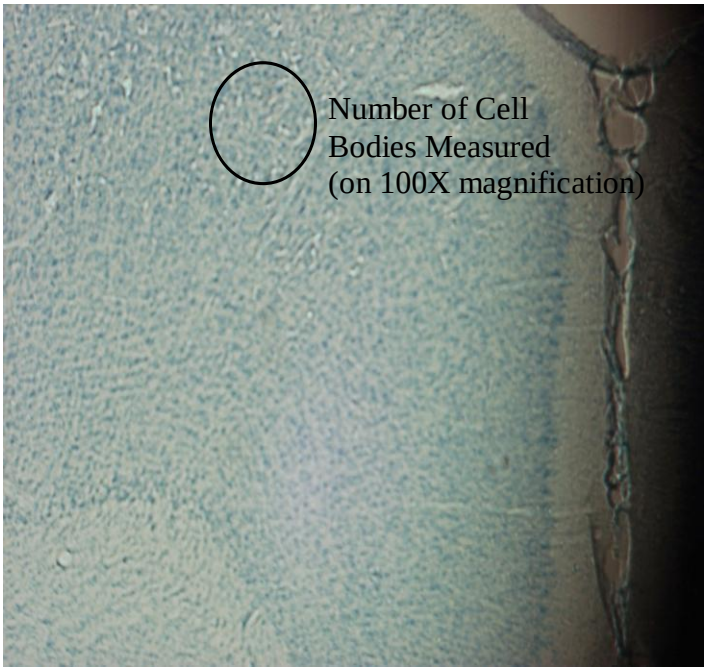


Figure V: Slice of brain (25X)



Discussion

The rats did not show any significant correlations among the intelligence tests and therefore variations between the rats in g-factor intelligence were not found. The correlations within the tests were expected, however, no correlations were found between the tests. The results were consistent with results obtained by Crinella and Yu (1995) who showed that inbred strains of rats are too genetically similar to show any evidence of differences in g-factor, and therefore, g-factor could not be measured between the individual rats. The rats in the current study were also raised in very similar environments, and therefore, their intelligence was not altered because of differences in environmental factors.

Overall, our results showed that there were no differences in *g*-factor intelligence, however, differences in *g*-factor could be present in the Sprague-Dawley, female rats. First, the abbreviated tests developed from Anderson's (1994, 1995) tests could have prevented us from seeing accurate results. Our apparatuses were slightly altered, in apparatus dimensions and time between testing, from Anderson's tests, because of time and resources, which could have changed the sensitivity of the results. If more sensitive tests were used to detect *g*-factor intelligence, better conclusions could have been drawn; however, this is unlikely because we were consistent with the treatment of each rat; also, our results are consistent with past studies including the one done by Thompson, Crinella, and Yu (1990) and the one done by Crinella and Yu (1995). Secondly, the small number of test subjects could have affected the accuracy of the results. The correlations would have been more accurate with more research and since some scores were close to being

statistically significant, if an increased number of subjects were used, different results could have been obtained. Also, as stated in the introduction, age has been shown to affect the ability to find relationships between intelligence and brain structures. In fact, the reasoning test was completed last and this task has highest correlations, though they are not statistically significant, between brain structures and task scores. However, although rats began testing at 45 days of age, about 20 days before sexual maturity, all the scores actually used in our results were obtained around the time of sexual maturity if not after. So, although this could have affected our results, this probably did not factor into our results accuracy.

The structural analysis also yielded negative results; there were no statistically significant differences in brain structures observed. The gray matter volume, white matter volume, and neuron density were similar among all the subjects. Again, this is most likely attributed to the use of the inbred strain of rat, as it was found in the study by Crinella and Yu (1995).

Although the Sprague-Dawley rats might be too genetically similar to find differences in brain structure, given more time and resources, more accurate results could have been found. First, given the time and ability to test more areas of the brain, testing could have lead to more conclusive results. Also, an increased number of test subjects could have led to more accurate results. Finally, given more resources, personal errors, such as errors in measurements, could have been avoided that might have contributed to alterations in the results.

Though significant correlations do not exist, it is important to note that correlations were present between some of the different intelligence tests and white matter thickness. White matter thickness showed correlations of 0.603, 0.610, and 0.615 with reasoning time to reach goal, reasoning number of errors, and gray matter thickness. Although these are not significant, they are high correlation values. Another important thing to note, however, is that the correlations are all positive. This indicates a reverse relationship than what would be expected between the white matter volume and the reasoning scores; this shows that as the white matter thickness increases, it is more likely for the rat to take longer to find the goal and they are more likely to make more errors. This therefore suggests that increased white matter thickness could be associated with lower intelligence.

Our results do not yield any conclusive outcomes regarding the relationship between g-factor intelligence and brain structure. Therefore, further research should be done using outbred strains of rats, larger numbers of subjects, and testing differences in all areas of the brain. New testing should also attempt to use female subjects since no extensive research has been completed with female rats and there is evidence that in human subjects, females tend to show higher correlations between IQ and brain size (McDaniel, 2005). Also, new testing should explore the use of older, or more mature, rats since studies have shown that gray matter correlations with *g*-factor intelligence might not be present during early childhood or might not be as prominent until adulthood (Shaw et al., 2006; as cited in Narr et al., 2007).

Conclusion

Coming to concrete conclusions on the relationship that the brain and intelligence share could help not only enlighten human knowledge, but it could aid in curing diseases as well as increasing human intelligence. Although this study did not find any conclusive correlations between brain structure and intellectual function, further research should be done. This knowledge could spur further studies to explore not only why some people are more intelligent than others, but also relationships between diseases associated with lower intelligence. Findings could help understand the variability in human intelligence, and could ultimately aid in increasing human intelligence through revisions in education that promote different brain capabilities.

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