Brain Type as a Programming Aptitude Predictor

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Abstract

This study investigates the effect of brain type (SQ minus EQ or E-S Theory) on first year students' results of learning computer programming. It is anecdotally believed that a relatively high proportion of Computing students have high Systematizing (S) but lower Empathizing (E) personality factors and that this may be a contributing factor in student choice of subject, learning styles, and aptitude for learning to program. Two years of data are reported here, with EQ and SQ-R questionnaires being completed before any first year undergraduate teaching. The brain type of each student is calculated and compared to their final programming unit performance. There is some evidence that choice of degree subject may be related to brain type, but no evidence is found of a correlation between a male brain type (Type S or Extreme Type S) and programming aptitude.

1. Introduction

The main impetus for this work was to follow up a study conducted by Wray (2007). Wray's hypothesis was that using two personality questionnaires from the Autism Research Group at Cambridge (http://www.autismresearchcentre.com/) the Systemizing Quotient (SQ) and the Empathy Quotient (EQ), the scores either together or individually would result in a correlation with a measure of programming ability. Wray observed that SQ minus EQ is highly correlated with the programming test scores of 19 students (all male) on the BSc (Hons) Telecommunications Systems Engineering at the Royal School of Signals. The two questionnaires were administered at the end of the course, after the programming test, thus Wray postulated that the SQ-EQ could be a predictor for programming aptitude, if delivered before a programming course began.

Thus our study is being conducted to see if SQ minus EQ is a predictor of programming aptitude with a larger sample, taken from a broader participant base and including both males and females. We administered the EQ and SQ-R questionnaires to the Bournemouth University first year Computing undergraduate students in their first week at university over three years 2013, 2014 and 2015, with the intention of correlating these results against their first year Programming unit results.

Our secondary, but no less important reason, for undertaking this research is the desire to explore and advance our teaching and learning strategies for programming. That both learning to program and the teaching of programming at undergraduate level are difficult and that the failure rate is high is evidenced by practical experience (both ours and many others) and by the volume of literature that surrounds the issues (Jenkins 2002, Robins, Rountree et al. 2003, Bennedsen and Caspersen 2007, Bornat, Dehnadi et al. 2008, Watson and Li 2014, Watson and Li 2014). In developing predictors of students' performance on undergraduate programming courses, both as a means of understanding student achievements and identifying weaknesses would mean we could potentially change teaching strategies in a way that would support a wider range of students to achieve success in programming.

2. Background

2.1. Empathizing and Systemizing

Following findings that autism occurred more often in families of physicists, engineers and mathematicians and that autistic conditions are associated with scientific skills, the theory of empathizing and systemizing modes of thought has been proposed (Baron-Cohen, Wheelwright et al. 1997, Baron-Cohen 1998, Baron-Cohen, Wheelwright et al. 2001). Empathizing is defined as the drive to identify other's feelings and emotions and to respond with an appropriate emotion. Whilst systemizing is defined as the drive to understand rules governing the behaviour of a system and the drive to construct systems that are lawful(Baron-Cohen 2002, Goldenfeld, Baron-Cohen et al. 2005).

Forced-choice, self-administered questionnaires tests were developed to measure the two modes of thought the Empathizing Quotient (EQ) and the Systemizing Quotient (SQ) (Autism Research Centre, Baron-Cohen, Richler et al. 2003). The EQ is a 40-item questionnaire designed to assess cognitive and affective empathy giving the respondent a score from 0 to 80 (Baron-Cohen and Wheelwright 2004). The SQ-R, a modified version of the original SQ, has 75 items (Wheelwright et al., 2006) designed to measure the respondent's drive to systemize, resulting in scores between 0 and 150. On both the EQ and SQ-R, participants are asked to respond 'definitely agree', 'slightly agree', 'slightly disagree' or 'definitely disagree' to each item, and approximately half the items are reverse scored to avoid response bias (Baron-Cohen, Richler et al. 2003).

It is the difference between an individual's empathizing and systematizing scores that has been proposed to lead to a useful distinction in the understanding of different 'brain types' (Goldenfeld, Baron-Cohen et al. 2005). The E-S theory proposes that the difference between empathizing (E) and systemizing (S) categorises the individual 'brain type' as Type S (S > E), Type E (E > S) or Type B (E = S), where B stands for balanced. Two extreme types have also been identified Extreme Type S (S >> E) or Extreme Type E (E >> S) (Baron-Cohen, Knickmeyer et al. 2005). 'Brain type' is used throughout this paper as a shorthand way of referring to the difference (as identified by Baron-Cohen et al which is essentially continuous rather than categorical) between participants' EQ and SQ scores.

It has been suggested that the brain type can be related to gender, Type E typifies the female brain and Type S the male brain, and E>>S typifies the extreme female brain and the S>>E the extreme male brain. Not all women have a female brain, and not all men a male brain, just that more females have a Type E brain(Baron-Cohen 2002).

Findings have also concluded that EQ and SQ scores can be related to university students' degree choice, that higher SQ scores are found for both males and females studying physical science degrees than those on humanities degrees (Wheelwright, Baron-Cohen et al. 2006, Billington, Baron-Cohen et al. 2007, Focquaert, Steven et al. 2007).

			SQ-R	EQ	n
Physical Science	Female	AVG	**59.9**	**44.7**	159
		STDEV	*19.4*	*11.3*	
	Male	AVG	**65.4**	**35.9**	294
		STDEV	*17.5*	*11*	
Biological Science	Female	AVG	**52**	**48.5**	290
		STDEV	*19.2*	*11.4*	
	Male	AVG	**62**	**41.6**	125
		STDEV	*17.8*	*11.5*	
Social Science	Female	AVG	**51.2**	**48.7**	181
		STDEV	*19.7*	*10.8*	
	Male	AVG	**61.9**	**41.4**	115
		STDEV	*18.8*	*11*	
Humanities	Female	AVG	**48.4**	**48.7**	408
		STDEV	*18*	*11.2*	
	Male	AVG	**53.7**	**40.5**	189
		STDEV	*20.6*	*11.7*	

Table 1 : (Wheelwright, Baron-Cohen et al. 2006)

			SQ-R	EQ
Physical Sciences	Female	AVG	**61.23**	**43.48**
		STDEV	*20.6*	*12.53*
	Male	AVG	**65.46**	**35.59**
		STDEV	*18.17*	*10.39*
Humanities	Female	AVG	**51.54**	**46.82**
		STDEV	*19.18*	*12.07*
	Male	AVG	**58.65**	**40.56**
		STDEV	*21.17*	*10.33*

Table 2 : (Billington, Baron-Cohen et al. 2007)

2.2. The Wray Experiment

Wray administered five tests to 19 male students on the BSc(Hons) Telecommunications Systems Engineering at the Royal School of Signals. The programming test was administered at the end of the students' course in 2006 and the remaining four tests: self-rank (from programming is easy to programming is hard), EQ, SQ and Dehnadi-Bornat tests were administered five months after the completion of the course (and the programming test) (Wray 2007).

Wray found a moderate correlation (r = 0.44, p = 0.056) between test scores and SQ (Figure 1), and a moderate negative correlation (r = -0.45, p = 0.052) between test scores and EQ (Figure2)

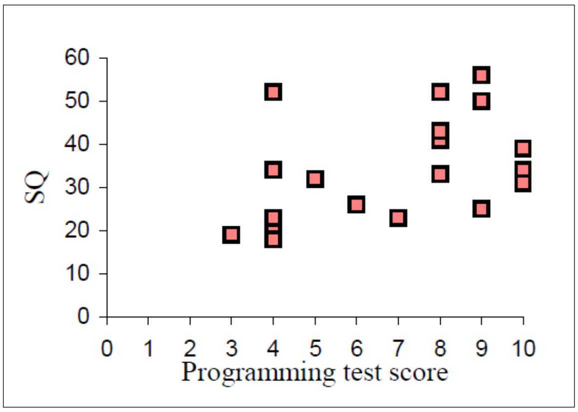


Figure 1- SQ and Test Score

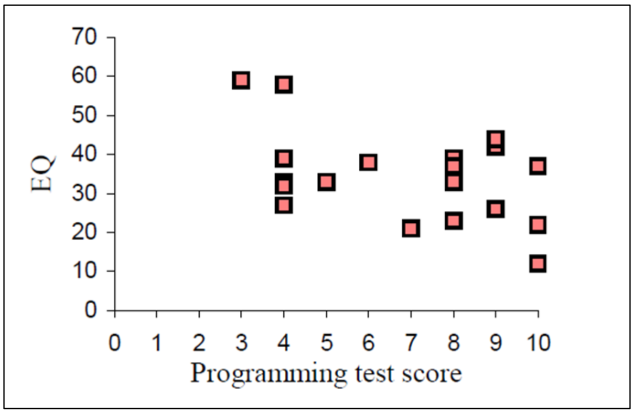


Figure 2 – EQ and Test Score

SQ minus EQ resulted in a high correlation (r = 0.67, p = 0.002) as can be seen in Figure 3.

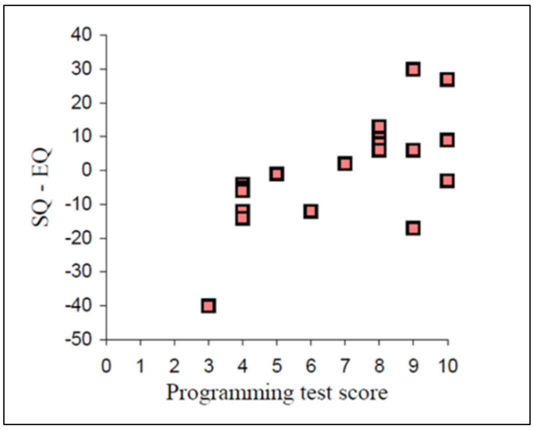


Figure 3- SQ-EQ and Test Score

From these results Wray hypothesised that the use of SQ-EQ could be a predictor for programming ability, thus if the SQ and EQ questionnaires had been completed before the students began studying programming they would have indicated resulting programming test results.

3. The Bournemouth University Study

The Bournemouth University study aimed to explore the relationship between student brain type and a student's final Programming unit grade. Following the Wray prediction we would expect to find a correlation between the male brain types (S and S>>E) and aptitude for learning to program.

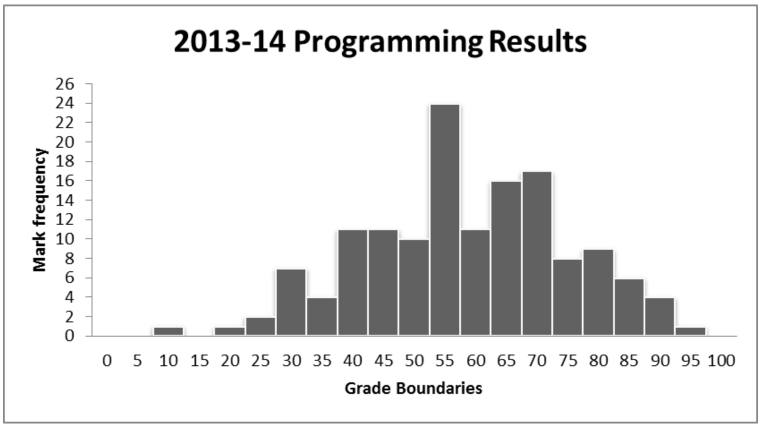
3.1. The Programming Unit

The first year Programming unit (module) is an introduction to programming, assuming no previous experience. The unit covers a basic introduction to programming covering: variables, loops selection, arrays, file reading and writing, object oriented concepts and interface development. The current language used to explore these topics is Java. This unit is taught as part of a common first year syllabus to students who can be on one of six different degrees: Business Information Technology (BIT), Computing, Computer Networks (CN), Forensic Computing and Security (FCS), Information Technology Management (ITM) and Software Engineering (SE).

The unit is taught using a typical structure of a 1 hour lecture and a 1 hour seminar per week over two semesters (26 weeks). Students also have an optional extra of a weekly 5 hour block of support which is staffed by PhD students, any first student may attend for as much or as little time as they feel they need to support the current work they are doing.

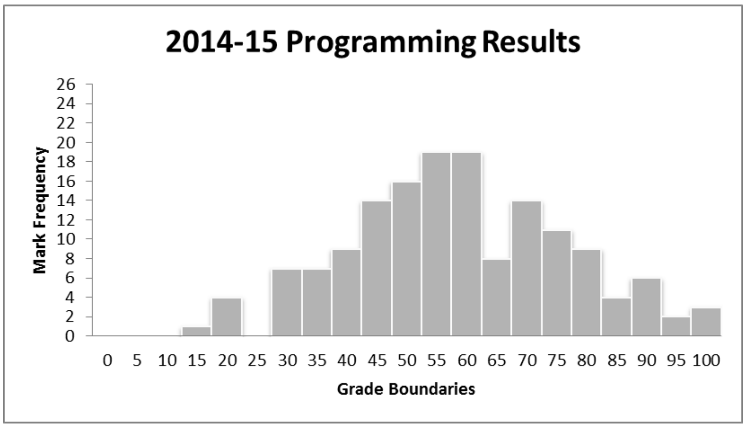
3.2. The Programming Assessment

The students undertook a range of assessments throughout the year, during the first semester they did a number of small programming tasks, designed to both build student confidence and to promote coding on a regular basis, all tasks together were 15% of their final programming grade. Students undertook two online, multiple choice tests, one in the first semester and one in the second, each test was 10% of the students overall grade. In the second semester students had a larger single assignment that was a design, build, test and document assignment that was worth the final 15% (giving the coursework a value of 50%). The final written exam was the other 50% of the students' grade. Results for the two complete years 2013-14 and 14-15 are below; the 2015-16 academic year is not yet finished at time of writing.



2013-14	
CW1	64.1
Test1	70.2
SEM1	66.5
Test2	58.1
CW2	55.5
SEM2	55.2
CW AVG	60.9
EXAM	51.1
UNIT	56.0

Figure 4: 2013-14 Programming Unit Results



2014-15	
CW1	61.3
TEST1	67.9
SEM1	63.9
TEST2	58.9
CW2	50.9
SEM2	52.0
CW AVG	57.8
EXAM	54.4
UNIT	56.1

Figure 5: 2014-15 Programming Unit Results

3.3. Method

Students were issued with the EQ and SQ-R questionnaires during their first session in Induction Week (prior to any formal teaching by the university) during three consecutive academic years 2013-14, 2014-15 and 2015-16. The students were given a brief introduction to the research and asked to voluntarily participate; a number chose not to and some students returned forms that they either didn’t sign (*for identification and consent*) or didn’t fully complete. Students who did not complete the final exam were also removed from the study as they were deemed not to have completed the unit.

For the 2013-14 cohort of 222 students we had 143 students who completed all assessments and the survey, 20 female and 123 male respondents. For the 2014-15 from a cohort of 236 students we had 153 surveys, 25 female and 128 male.

3.4. Questionnaire Results

A first analysis was carried out to see if the SQ-R and EQ averages and standard deviation were consistent with those found by other researchers when exploring EQ and SQ-R scores by gender and degree subjects.

BU 2013-14		**SQ-R**	**EQ**	**n**
Female	AVG	**59.50**	**44.30**	20
	STDEV	15.4	9.6	
Male	AVG	**63.91**	**40.51**	123
	STDEV	19.5	10.7	
BU 2014-15				
Female	AVG	**59.36**	**40.00**	25
	STDEV	15.9	8.5	
Male	AVG	**64.82**	**38.72**	128
	STDEV	18.1	9.3	

Table 3: EQ and SQ-R Scores by gender

At first glance the scores, especially those for the female students (*both SQ-R 59.9 and 61.23 and EQ 44.7 and 43.48*), are in line with those for the Physical Sciences found by both the Wheelwright and the Billington studies. The male SQ-R scores are similar (*compared to 65.4 and 65.46*), but both years’ male EQ scores are higher (*compared to 35.9 and 35.59*), this may be because of the broader nature of the six degrees supported by the first year Programming unit, such that those on the business degrees (BIT and ITM) may more closely resemble those on Social Sciences.

Following the method defined by Wheelwright et al we used the following formulae to identify the five defined brain types. Firstly to derive S and E: S = (SQ-R - <SQ-R>) / 150 and E = (EQ - <EQ>) / 80. So subtracting the population mean (denoted by <…>) from the scores, then dividing this by the maximum possible score for each questionnaire (150 for SQ-R and 80 for EQ). D is then calculate as D = (S – E) / 2, which is the difference between the normalized SQ and EQ scores, thus the measure of the difference between an individual’s empathizing and systemizing scores, so it allows us to determine an individual’s brain type. A positive D score indicates a Type S or Extreme S, a negative score indicates a Type E or Extreme E and a score close to zero indicates a brain Type B (Wheelwright, Baron-Cohen et al. 2006)

When plotting brain type against the final programming grade for 2013-14 (Figure 6) there is no evidence of any correlation (r = -0.065, p = 0.440).

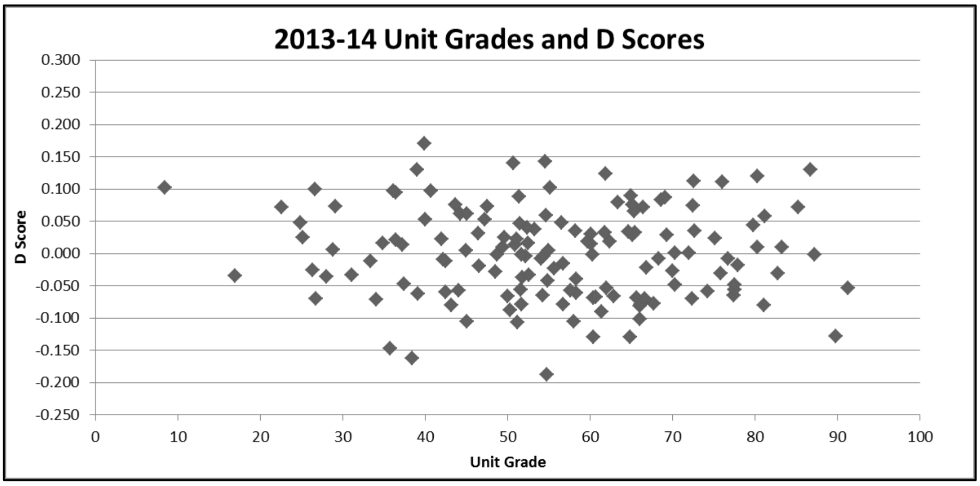


Figure 6: 2013 Brain Type plotted against final grade

Likewise when plotting the subsequent academic year, 2014-15, there is no evidence of any correlation (r = -0.095, p = 0.243).

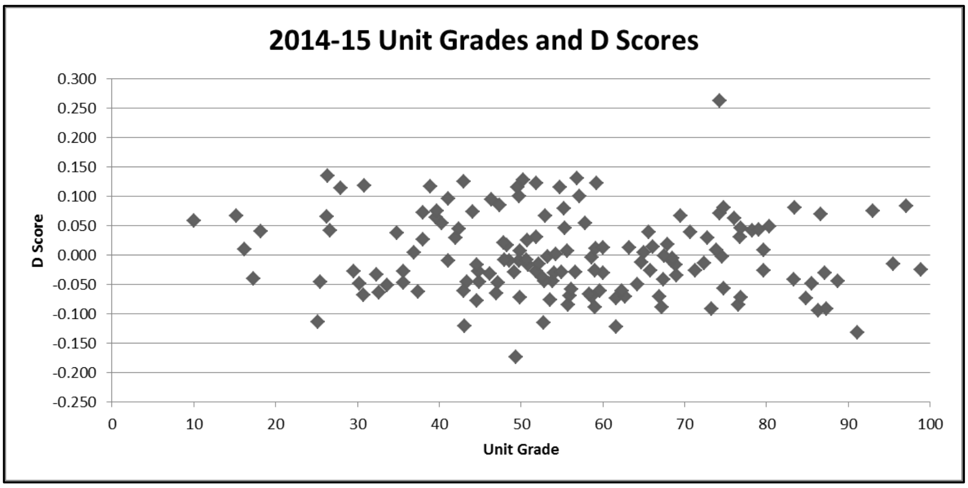


Figure 7: 2014 Brain Type plotted against final grade

Thus the overall correlation of calculated brain type and the final scores of both years showed no relationship between the two.

Given that brain type has been suggested to relate to gender, the male and female populations were explored further. In plotting the female populations brain type against grade there did appear some indication of a negative trend (figures 8 and 9), this however was not significant given the population size of 20 in 2013 (r = -0.247, p = 0.294) and 25 in 2014 (r = -0.147, p = 0.483).

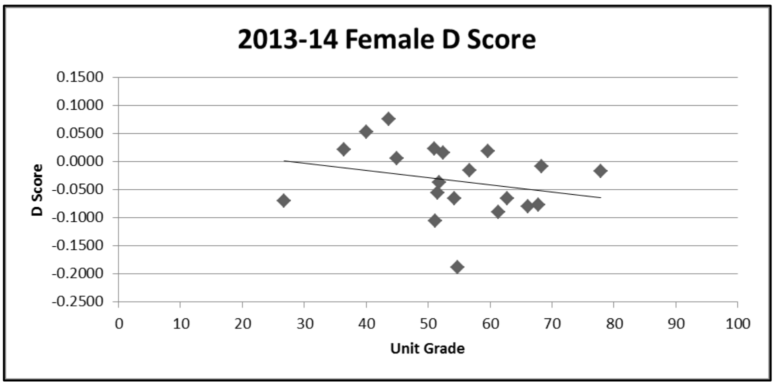


Figure 8: 2013 Females' Brain Type plotted against final grade

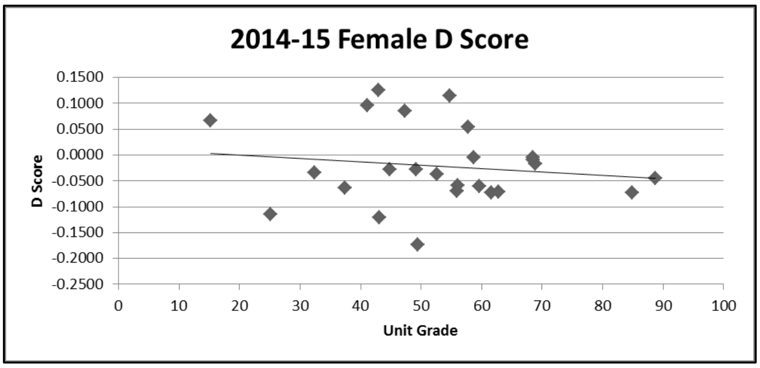


Figure 9: 2014 Females' Brain Type plotted against final grade

Both indicated a negative trend, thus suggesting a more Type E brain achieved a higher programming grade than a Type S. Although neither correlations of brain type and result being significant for either year, the EQ results were plotted against grade also to explore the relationship further. The correlations for 2013-14 ($r = 0.403$, $p = 0.0781$) and for 2014-15 ($r = 0.182$, $p = 0.384$) whilst showing no significance both indicate a positive trend so are potentially worthy of further investigation.

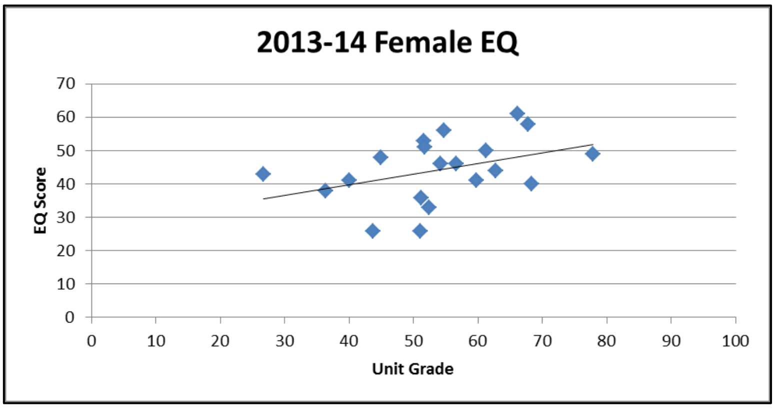


Figure 10: 2013 Females' EQ Scores plotted against final grade

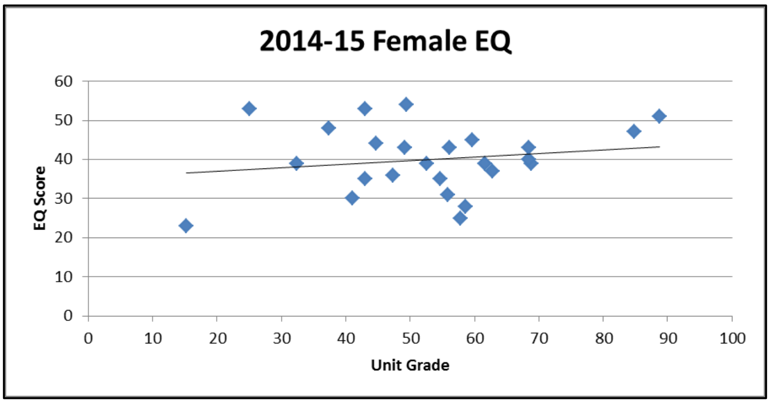


Figure 11: 2014 Females' EQ Scores plotted against final grade

4. Discussion

The results to date (there is still the 2015-16 year to explore) would suggest that brain type is not a predictor of programming aptitude as was suggested by Wray (2007). On the contrary, an opposing tendency has been observed that indicates a Type E brain or that a higher EQ score alone could be a predictor of programming ability.

A notable difference between the two studies, Wray's and ours, is the point at which the EQ and SQ-R questionnaires were administered. Wray administered them at the end of the first year course; we administered them at the beginning. The results found by Wray therefore could have been influenced by students' undertaking their computing degree. The learners may have become attuned to both language and behaviours that then bias their responses to these questionnaires. Whilst the test-retest reliability of the questionnaires has been shown to be high in children (Auyeung, Wheelwright et al. 2009), it would be interesting to see if our students' scores remain stable across the course, or whether immersion in a particular discipline could have an impact on them.

The first year Programming Unit is almost entirely taught by females, the lecturer and the three seminar tutors are all female. There are two male PhD students who staff the extra support sessions, these however are optional and are based on the student request for help. The teaching style and approach, being delivered by females could specifically favour the female students with a female brain type. The brain type of the lecturer could have been an influencing factor on the results as it is reasonable to assume that the Type E lecturer of this study could have positively influenced and encouraged Type E students.

Our Computing students EQ and SQ-R scores are similar to those found by other researchers exploring university degree choice and EQ and SQ-R scores, most notably for the females. Our first year Computing Framework underpins six different degree routes, from software engineering to business IT, how can we then categorise the whole student body as being a physical science or social science when we do potentially have both?

Whilst we did endeavour to survey the entire cohort of students for all three years, this didn't happen. Some students were not present during the first session of induction week, some students elected not to participate and others failed to complete the questionnaires fully. Brain type could have an impact on early attendance, on willingness to participate with the study or on attention span for completing questionnaires.

The programming ability of the students on entry to university is not uniform, whilst the unit taught programming from the very basics, assuming no prior knowledge; many students had already encountered programming. This prior knowledge was in some instances very positive; students had programmed for many years (for study, pleasure and/or remuneration) and were very confident and skilled in developing code, and enjoyed the process. Others, however, had already developed a dislike of programming (many students report "I hate programming") and an opinion that it was a very difficult subject, such that they were nervous and concerned about the unit. Such pre-existing skills and emotional responses to the subject could well cut across any potential brain type aptitude for programming that might be exhibited.

What is meant by programming aptitude and ability for a first year undergraduate student and how it is measured, could also have an impact upon the results. Wray used a specifically written 10 question test designed to test understanding of function and method calls in object-oriented Python to evaluate his participants programming ability (Wray 2007). Our study used the complete assessment diet of the first year students, including small coding exercises, on-line multiple choice tests and a final written exam. Using a broader spectrum of assessment of ability could potentially obfuscate the impact of brain type on final grade, as skilled programmers are not necessarily skilled at undertaking coursework or exams. Simpler, cleaner measures of programming ability may yield more interesting results.

The results found by Wray suggest a link between brain type and programming aptitude, but the potential uniformity of the 19 male, army personnel, who had elected to take further study during their army career may account for the finding. Our university students, enrolled on one of six different undergraduate courses, both male and female, could be expected to be a much more inconsistent and diverse group, for whom multiple factors would impact upon their programming ability. The conditions that the participants find themselves in not being the least of those factors, settled in a structured army life and building a career, compared to a complete change of both home life and daily educational structure. Brain type could well be expected to have an impact upon how an individual coped with such change and a university student's ability to succeed in it.

5. Future Work

The third year of the survey data needs to be collated, once the 2015-16 academic year is complete. With three years of data complete the students could be split by degree title, it would be interesting to explore if there were any differences for students on the BIT degree compared to SE degree.

In the second year of the Computing Framework, students can elect which units to study (they have no choice at first year). The comparison of brain type to the second year programming results could be completed to see if there is a relationship. Also contrastingly this second year unit is taught by a male only teaching team.

Evaluating brain type against only those components that involved the writing of code may indicate a relationship, so removing other forms of coursework that may themselves require a particular aptitude.

Re-testing students at different points in their degree would give some indication as to whether undertaking the course may have had an impact upon their questionnaire responses. It would be interesting to see if the results remained stable over time.

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