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Motivation to Learn Science and Cognitive Style

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This article investigates the relation between cognitive style and motivation to learn science. The concept of cognitive style proposes the interplay of two core psychological dimensions, empathizing and systemizing. The cognitive style is defined as the interplay between the two abilities. We used the so-called EQ score (empathy quotient) and the SQ score (systemizing quotient) to measure the empathizing and the systemizing dimension respectively. The motivation to learn science was measured by the so–called Science Motivation Questionnaire (SMQ), which reflects the operationalization of five basic motivational constructs. We investigated a sample of 44 high school students, 17 to 19 year-old, stratified by their sex and by their science/non-science orientation. Our data showed a highly significant and fairly strong correlation between the motivation to learn science and the systemizing quotient. However, different from what we expected, we found no correlation between the motivation to learn science and the empathy quotient. We also found no difference in the motivation to learn science neither for sex nor for science-orientation. The implications of these findings are discussed, especially in the light of school science and research of science education.

Keywords: Motivation, Cognitive Style, Learning Science

INTRODUCTION

The concept of cognitive style was originally regarded within the field of autism research (Baron-Cohen, 2002). Based on the observation that people with Aspergers syndrome (a highly skilled form of autism) had high "folk physical" abilities but were impaired in their "folk psychological" abilities, Baron-Cohen and colleagues developed a cognition concept proposing the interplay of two core psychological dimensions: empathizing (E) and systemizing (S) (Baron-Cohen, Knickmeyer, & Belmonte, 2005). The cognitive style is defined as the interplay between the two abilities. There exists a score EQ (empathy quotient) and a score SQ (systemizing quotient) to measure the empathizing and the systemizing dimension respectively. The braintype B is basically calculated as a mathematically normalized difference of EQ and SQ. The whole concept and its measuring procedures will be presented in detail in the methodological part of this article.

Based on this concept, Billington and colleagues investigated students in physical sciences and humanities (Billington, Baron-Cohen, & Wheelwright, 2007). They found that the cognitive style, characterized by systemizing and empathizing activities respectively, was much better as a predictor for the entry either into physical sciences or humanities than sex, though sex was indeed also such a predictor.

Billington and colleagues interpreted their findings in terms of a causal hierarchy. They proposed that the cognitive style is the basic variable predicting the entry into physical science or humanities, while sex is only involved through the statistical relation between sex and cognitive style.

As far as we know, these results have not yet been recognized in science education research. However, we believe that they could help to shed a new light on the motivation to learn science, because the choice of the type of studies can be seen as a raw indicator for

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State of the literature

- Cognitive style is a cognition concept that proposes the interplay of two core psychological dimensions which are the two abilities empathizing and systemizing.
- Cognitive style is better as a predictor for students' entry either into physical sciences or humanities than sex. It seems to be a basic variable while sex is only involved through the statistical relation between sex and cognitive style.
- The so-called Science Motivation Questionnaire (SMQ) reflects five basic motivational constructs in a compact scale of 30 questions and it is used to measure the motivation to learn science.

Contribution of this paper to the literature

- This study investigates the relationship between the two instruments that measure cognitive style (EQ and SQ) and the motivation to learn science (SMQ). Thus, cognitive style is compared not only to a digital indicator of attitude (entry either into physical sciences or humanities) but also to a continuous variable of motivation.
- The study reveals an impact systematizing ability has on the motivation to learn science, but not so for the empathizing ability. Previous studies had not differentiated between these two aspects.
- Results are discussed in light of science education and the study proposes further research into the issue.

motivation. Our hypothesis was that we would find also a correlation between motivation to learn science and the braintype.

To measure the motivation to learn science, we used the so-called Science Motivation Questionnaire (SMQ), introduced by Glynn and colleagues (2006, 2007), which reflects five basic motivational constructs in a compact scale of 30 questions. Another advantage of this questionnaire is that it does not distinguish between different science subjects but focuses on a general motivation to learn science.

Because, as already mentioned, the braintype is essentially the difference between the systemizing quotient SQ and the empathizing quotient EQ, we also expected a positive correlation between the motivation to learn science SMQ and the systemizing quotient SQ, and a negative correlation between the SMQ and the empathy quotient EQ.

Motivation

To maintain the comparability of the results of this study with those of Glynn and colleagues (2006), the same theoretical framework of motivation was used. Thus motivation is defined as "…the internal state that arouses, directs, and sustains students' behaviour towards achieving certain goals." Furthermore, "in studying the motivation to learn science, researchers attempt to explain why students strive for particular goals, how intensively they strive, how long they strive, and what feelings and emotions characterize them in this process." (p. 1090). Based on research within the social-cognitive motivational framework (Bandura, 2001), the authors identify five important motivational constructs that include intrinsic and extrinsic motivation, namely goal orientation, self-determination, self-efficacy, and assessment anxiety (Glynn & Koballa, 2006). The so–called Science Motivation Questionnaire (SMQ) (see chapter 4) reflects the operationalization of these five motivational constructs. It will be described in detail in paragraph 4.2.2.

Cognitive style

The approach of cognitive styles used by Billington and colleagues is based on a recent theoretical account of cognitive style differences of Baron-Cohen et al. (2005). It proposes two core psychological dimensions, or cognitive styles: empathizing (E) and systemizing (S) (Billington et al., 2007).

Systemizing is defined as a drive and ability to analyse the rules underlying a system, in order to predict its behaviour. A system in this context is understood as an object showing a tripartite structure: It can always be analysed in terms of so-called input – operation –output patterns, where inputs are initial states of the system, outputs as subsequent states of the system, and operations as actions that transform input states into output states. Defined in this general way, systems can be found in many different domains: technical (e.g. machines and tools); natural (e.g. weather system); abstract (e.g. mathematics); social (e.g. political system); spatial (e.g. map reading); and organisable (e.g. a taxonomy). A systemizing view on objects of interest is able to understand these objects in terms of a system, which needs an ability to identify local details and their interaction and to abstract from Gestalt perceptional distracters, also known as "field independent" cognitive style (Witkin, Lewis, Hetzman, Machover, & Bretnall Meissner, 1962).

Empathizing is defined as a drive to identify another person's mental states and to respond to these with one of a range of appropriate emotions. Empathizing has thus both a cognitive and an affective component (Baron-Cohen & Wheelwright, 2004; Davis, 1980). The cognitive component involves understanding another person's thoughts and feelings and is also referred to as using a theory of mind (Wellman, 1990). The affective component of empathizing involves an emotional response that arises as a result of the comprehension of another individuals emotional state (Eisenberg, 2002).

Every human being is considered to dispose of both of these cognitive styles, empathizing and systemizing, but normally on a different level. Some individuals are rather systemisers (S>E) whilst others have a dominant empathizing cognitive style (E>S). Others show a balanced type (E=S) of cognitive styles. The relation of E and S is called the brain type of the individual. The whole concept is called the E-S model.

In order to work with the E-S model, two self-reporting questionnaires (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003; Baron-Cohen & Wheelwright, 2004) have been developed and tested by Baron-Cohen and colleagues (see chapter 4). The two questionnaires exist in different versions, but each of these calculate a systemizing quotient (SQ) and an empathizing quotient (EQ) providing a measure of the individual's capacity to use the two cognitive styles. The variable representing the brain type is essentially calculated as the normalized difference of EQ and SQ.

One of the important research results based on these questionnaires is that females on average have a stronger drive to empathize (E>S), whilst males on average have a stronger drive to systemize (Baron-Cohen, 2002). This claim only applies on average; thus there will always be individuals who are atypical for their sex. However the E-S theory also argues that, irrespective of their sex, if an individual's systemizing is at a higher level that their empathizing (S>E), then it is this profile that leads them into disciplines that require an analytical style to deal with rule-based phenomena (Billington et al., 2007).

It is in this theoretical framework that two recent studies (Billington et al., 2007; Wheelwright et al., 2006) demonstrated that physical science degree students scored significantly lower on the EQ and significantly higher on the SQ and suggested, that the academic subject one ends up studying may be better predicted by one's cognitive style than by one's sex.

METHOD

We investigated a stratified sample of 44 students of upper secondary level. In our country, students of upper secondary level cannot yet be classified as science or non science students. Every student has to take part in all subjects of science and non science disciplines. However these students decide on their so-called specializing issues, where they enjoy a higher education, like mathematics and physics, biology and chemistry, languages, or music and arts. In this study we therefore distinguished only between more science-oriented students and non-science-oriented students. We chose 22 female and 22 male students. Both of these groups consisted of an equal number of science-oriented and non-science-oriented students. We stratified our sample into male and female students because of the known relation between sex and braintype. Women tend to have an empatizing braintype, and men tend to have a systemizing braintype (Baron-Cohen, 2003). The stratification into science-oriented and non-science-oriented students reflected the results of Billington et al. (2007), that science students statistically had a sytemizing braintype, whereas students of the humanities had an empathizing braintype.

Procedures and Measures

Procedure

The students were visited at their school. They were informed about the study and they consented to participate. Every student filled in one combined questionnaire and received his/her personal results by e-mail if s/he requested it.

The Questionnaire

Part A, cognitive style. In part A of our questionnaire, we used the German version of the SQ and the EQ questionnaire by Baron-Cohen (Baron-Cohen, 2004). A pre-test showed that some of the questions had to be slightly modified to be useable for our students ("car" for example was replaced by "motorbike"). Both the SQ and the EQ questionnaire are 60-item, forced choice format, containing 40 cognitive style items and 20 control items. The SQ asks questions such as "I like music shops because they are clearly organized" and "When I learn a language I become intrigued by grammatical rules". Similarly, the EQ asks items such as "I am good at predicting what someone will do" to measure cognitive empathy or "I usually stay emotionally detached while watching a film" to measure the affective component of empathy.

On both the EQ and the SQ, participants are asked to respond "definitely agree", "slightly agree", "slightly disagree" or "definitely disagree", and approximately half the items are reverse scored to avoid response bias. Scores on both the SQ and the EQ range from 0 to 80.

An EQ from 0-32 is considered as low, 33-52 as average range (most women score about 47 and most men score about 42), 53-63 is above average, 64-80 is very high.

A SQ of 0-19 is considered as low, 20-39 as average (most women score about 24 and most men score about 30), 40-50 as above average, 51-80 as very high.

A "Brain Quotient" BQ was calculated for each participant following a method reported in Wheelwright et al. (2006). To this end, EQ and SQ were standardized to $E=(EQ-\langle EQ\rangle)/80$ and $S=(SQ-\langle SQ\rangle)/80$, where $\langle EQ\rangle=44.3$ and $\langle SQ\rangle=26.6$ are the population means

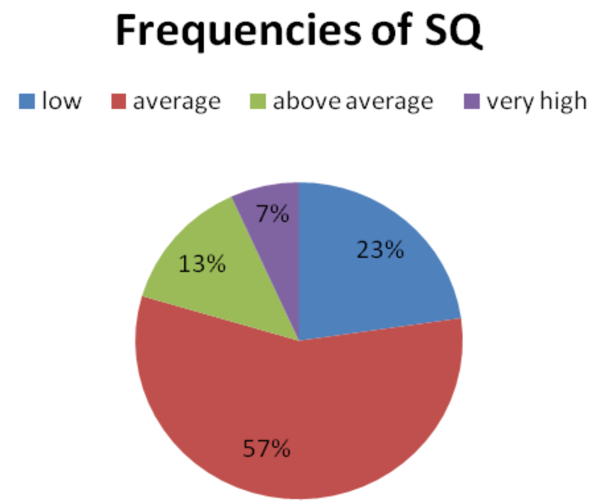

Figure 1. Relative frequencies of the Systemizing Quotient SQ

found in literature (Baron-Cohen et al., 2003; Wheelwright et al., 2006). The division by 80 reflects the maximal score of EQ and SQ respectively. The "Brain Quotient" B then represents a coordinate transformation of the standardized S and E defined by:

B=(S-E)/2 and

C=(S+E)/2

B essentially calculates the difference between E and S. If it is negative then (E>S), and vice versa.

Part B, motivation to learn science. In Part B of the questionnaire, we asked students to respond to the 30 items on the Science Motivation Questionnaire SMQ. Previous findings (Glynn & Koballa, 2006) indicated that the SMQ is reliable in terms of its internal consistency, as measured by Cronbach's alpha (.93), and valid in terms of positive correlations with college students' science grades, decision to major in science, interest in science careers, and number of science courses taken. The total score on the SMQ serves as a comprehensive measure of the students' motivation (Glynn, Taasoobshirazi, & Brickman, 2007).

The items were translated into German and also tested in a pre-test.

The SMQ items were developed based on the motivation concepts described earlier in this article. The SMQ items ask students to report on intrinsically motivated science learning (items 1, 16, 22, 27, and 30), extrinsically motivated science learning (items 3, 7, 10, 15, and 17), relevance of learning science to personal goals (items 2, 11, 19, 23, and 25), responsibility (self determination) for learning science (items 5, 8, 9, 20, and 26), confidence (self-efficacy) in learning science (items 12, 21, 24, 28, and 29), and anxiety about science assessment (items 4, 6, 13, 14, and 18). Typical items for this questionnaire are "I enjoy learning science" (item 1) or "Earning a good science grade is important to me" (item 7) or "I am confident I will do well on the science labs and projects" (item 21). Students respond to each of the 30 randomly ordered items on a 5-point Likerttype scale ranging from 1 (never) to 5 (always). The anxiety about science assessment items are reverse scored when added to the total, so a higher score on this component means less anxiety. The SMQ maximum total score is 150 and the minimum is 30. A score in the range of 30–59 is relatively low, 60–89 is moderate, 90–119 is high, and 120–150 is very high (Glynn & Koballa, 2006).

RESULTS

We computed statistics results by means of the Statistical Program for the Social Sciences, version 15.0 (SPSS).

Because we translated the questionnaires and (slightly) adapted them to adolescents, the testing of the reliability (internal consistency) of the used questionnaires was essential. Cronbach alpha coefficients were α=0.872 for SMQ (30 Items), α=0.897

Table 1. Skewness an Kurtosis of SMQ, EQ, and SQ

		SMQ	EQ	SQ
N	Valid	44	44	44
	Missing	0	0	0
Skewness		-.162	.084	1.489
Std. Error of Skewness		.354	.357	.357
Kurtosis		.237	.134	2.131
Std. Error of Kurtosis		.695	.702	.702

Table 2. Bivariant Pearson Correlations between SMQ, EQ, and SQ

		SMQ	EQ	SQ
SMQ	Pearson Correlation	1	-.104	.544(**)
	Sig. (2-tailed)		.501	.000
	N	44	44	44
EQ	Pearson Correlation	-.104	1	-.249
	Sig. (2-tailed)	.501		.104
	N	44	44	44
SQ	Pearson Correlation	.544(**)	-.249	1
	Sig. (2-tailed)	.000	.104	
	N	44	44	44

** Correlation is significant at the 0.01 level (2-tailed).

Table 3. Bivariant Correlations of SMQ, EQ, and SQ (Spearman's rho) Correlations

			SMQ	EQ	SQ
Spearman's rho	SMQ	Correlation Coefficient	1.000	-.049	.396(**)
		Sig. (2-tailed)	.	.754	.008
		N	44	44	44
	EQ	Correlation Coefficient	-.049	1.000	-.121
		Sig. (2-tailed)	.754	.	.433
		N	44	44	44
	SQ	Correlation Coefficient	.396(**)	-.121	1.000
		Sig. (2-tailed)	.008	.433	.
		N	44	44	44

** Correlation is significant at the 0.01 level (2-tailed).

Table 4. Correlation between braintype B and EQ controlling for SQ Correlations

Control Variables			SMQ	B
SQ	SMQ	Correlation	1.000	-.038
		Significance (2-tailed)	.	.808
		df	0	41
	B	Correlation	-.038	1.000
		Significance (2-tailed)	.808	.
		df	41	0

for SQ (40 items), and α=0.911 for EQ (40 items) indicating that 87%, 90%, and 91% respectively of the variance of the total scores on these questionnaires could be attributed to systematic variance. This means that the questionnaires have preserved their high internal consistency in the new context.

Descriptives

We investigated 44 students. By our stratification, 22 were male (50%) and 22 were female (50%). 23 were science oriented (52.3%) and 21 were non-science oriented (47.7%). The mean age was mage= 17.21 years (SD=0.62).

On average, our students showed in the SMQ score a high motivation to learn science (MSMQ=99.84, SD=13.72). The minimum was SMQmin=74, the maximum SMQmax=135 points. The mean EQ of our students is within the population average, but rather low (MEQ=40.31, SD=11.68). The minimum was EQmin=6, the maximum EQmax=60 points. The mean SQ of our students was also in the population average (MSQ=28.27, SD=12.83). The minimum was SQmin=14, the maximum SQmax=72 points.

The examination of skewness and kurtosis statistics (see Table 1) shows that our data of the SMQ and the EQ met the assumption of univariate normality.

The frequency distribution of the SQ is positively skewed and leptokurtic. 7% of the students have an SQ of more than 50 points, which is classified as very high (Figure 1). These are three students, one female and two male students, interestingly they all belong to the non-science-oriented group, though they have a high motivation to learn science between 103 and 135 points. Their mean EQ is low (M=24.67, SD 19.55).

The impact of gender and of science-orientation

In our data, no significant impact of sex or science-orientation on the motivation to learn (SMQ), the systemizing quotient (SQ), or the empathizing quotient (EQ) can be seen. The same holds, if the analysis is restricted to the science students.

The impact of the braintype, and of SQ and EQ

There is a positive Pearson correlation between SMQ and the Brain Quotient B (r=.414). This correlation is highly significant (p<.01, 2-tailed). The correlation is however not significant if Spearman's rho is applied to take into account the non-normal distribution of the SQ.

Because the Brain Quotient B is a complex variable combining the two factors SQ and EQ, we investigated a correlation table (Person, Table 2, and Spearman's rho, Table 3) containing all three variables SQ, EQ and B.

In Table 2 it can be seen that there is a highly significant strong Pearson correlation between SMQ and SQ (r=.544, p<0.01, 2-tailed). Between SMQ and EQ, the correlation is not significant. The situation remains the same if Spearman's rho is applied to take into account the non-normal distribution of the SQ (Table 3).

We asked if the correlation between SMQ and BQ could be really a correlation between SMQ and SQ. This assumption was confirmed by the calculation of the partial correlations controlling for the SQ (Table 4).

While zero-order correlation between SMQ and B was, as we already have seen, positive (r = .414) and statistically highly significant (p < 0.01), the partial correlation of the SMQ and B controlling for the SQ, is now negligible (r = -.038) and not statistically significant (p = .808).

We therefore conclude that the essential correlation is the one between the SQ and the SMQ. The scatterplot between the SMQ and the SQ (Figure 2) shows a fairly strong relation between the SMQ and the SQ:

Based on the Pearson correlation of the SMQ and the SQ the effect size is calculated as R2 = .30, meaning that 30% of the variation in SMQ is accounted for by variation in SQ (and vice versa).

DISCUSSION

Our sample consisted of a sex stratified group of 44 students in the upper secondary level, who all had to study both science and non science subjects. Our data did not show a significant difference in motivation to learn science, measured by the SMQ score, neither for sex nor for science-orientation. There was also no significant sex or science-orientation difference concerning the empathizing and the systemizing dimension of the cognitive style, measured by the EQ and the SQ scores respectively.

However there was a highly significant and fairly strong correlation between the motivation to learn science and the braintype, measured by B. The correlation between the SMQ and the SQ was even stronger. However, different from what we expected, we found no significant correlation between the SMQ and the EQ. Furthermore, the partial correlation of the SMQ and the braintype B controlling for the SQ was negligible and not statistically significant, suggesting the existence of a fairly strong essential relation between the SMQ and the SQ.

Firstly – though not in the focus of our interest - the lack of a significant sex differences is an interesting result, because it does not support the existence of the notorious gender gap in science achievement, science course taking, and choice of career in science (Britner, 2008). However it confirms the findings of Glynn et al. (2007), who could in fact not find any correlation between gender and motivation to learn science in a survey of 369 non-science majors in a large-enrolment college science course. Glynn and colleagues had interpreted this unexpected result in terms of the special conditions in science courses for non-science students: "…In science courses for non science majors there is a relatively 'level playing field' that supports the women's motivation as well as the men's" (p. 1101). Our results seem to extend these findings to a non selected sample of students. In so doing, they do not support their interpretation in terms of special learning conditions in non science classes, since our students learned under quite various conditions, some of them also in a more science-oriented educational environment. In our data we cannot find a sex difference in motivation to learn science for our students, irrespective of whether they were more science-oriented or non-science-oriented.

However, in our results there is also no significant sex difference in the EQ and SQ, though these scores show the expected pattern of female students having higher mean EQ scores an male students having higher mean SQ scores. Therefore based on our results we cannot present any conclusions as to the relation between sex, braintype, and motivation to learn.

Secondly, our results confirm our hypothesis that the braintype would correlate with the SMQ, the science motivation quotient. This means the more systemizing cognitive style a student shows, the more he is motivated to learn science in general. These results are consistent with the findings of Billington et al. (2007), which were the starting point of our own research.

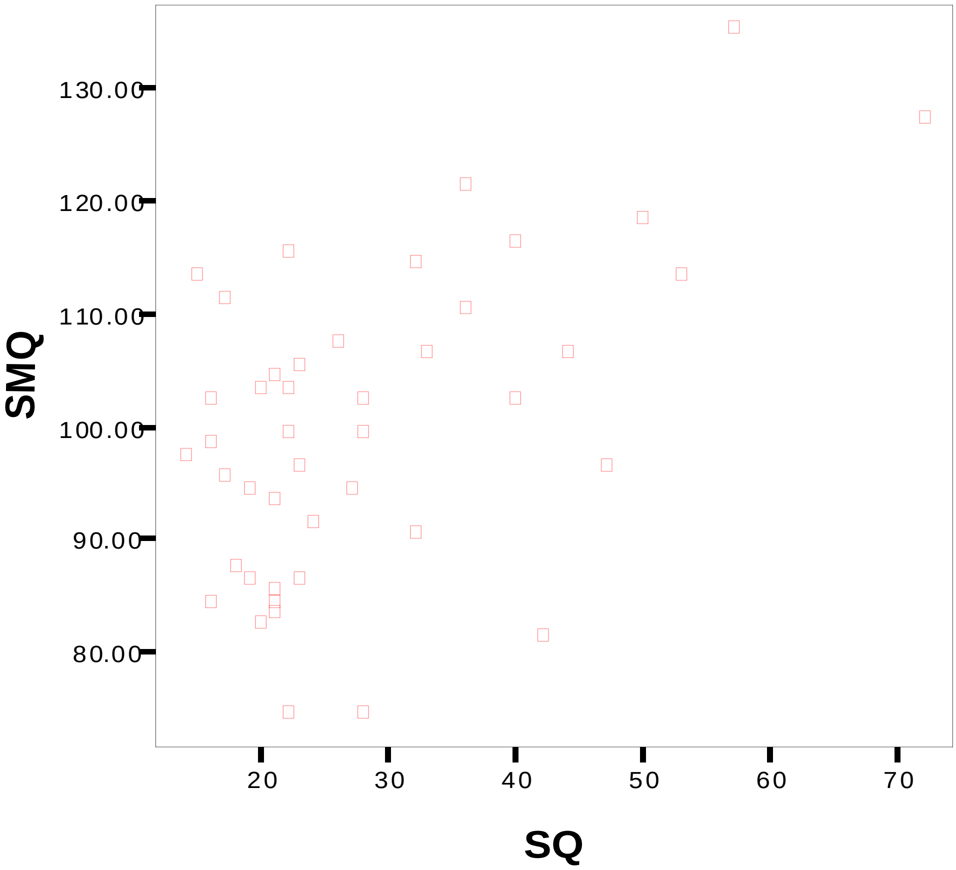

Figure 2 . Scatterplot of SMQ and SQ

New, however, is our finding, that while the correlation between the SQ and the SMQ is highly significant, it is not so for the EQ and the SMQ. More than that, while the zero-order correlation between the SMQ and the B is positive and statistically significant, the partial correlation between the two parameters, controlling for the SQ, is negligible and not statistically significant. These results suggest that it is not the braintype that controls the motivation to learn science, but rather its systemizing dimension SQ, and that there exists a fairly strong effect of the SQ on the SMQ. The second dimension of the B, the empathizing EQ, however, has only a negligible and not significant impact on the SMQ. Our second hypothesis therefore has actually not been confirmed by our data. This is remarkable, since a non-systematical cognitive style could well have a negative impact on the motivation to learn science.

It seems important to stress that the concept of cognitive style is basically a biological concept summarizing a large body of empirical research findings not only in psychology, but also in various bio-medical disciplines as neurology, anatomy, and endocrinology (Baron-Cohen et al., 2005). It is therefore not a mere tautology, as it might appear at face value, to say that a systemizing braintype predisposes for high motivation to learn science, but a far reaching statement on a stable attribute of personality, including a valid and reliable way to test it.

The SMQ score was fairly high. In explorative research we had found similar levels of motivation to learn science (authors). We had explained this by the fact that these students had been tested in a science learning centre, which could mean that they were very motivated towards science or else that their science teacher was very much engaged in teaching. However our new results are comparable. It might be that students on higher secondary level in our country (so-called Gymnasium) generally show an above average motivation to learn science.

CONCLUSIONS

More research must be done to be able to reliably link our findings to the situation in the real science class room. Nevertheless, we would like to conclude this article – with due precautions – by outlining some thoughts that emerge from the study as possible implications for school science. Our results seem to point to two important lines of reasoning.

Firstly, as mentioned above, good systemizers have a high motivation to learn science. In reference to the definition provided by Glynn and colleagues (2006), this is "the internal state that arouses, directs, and sustains students' behavior toward achieving certain goals" (p. 1090). Good systemizers are not necessarily good at (school) science, but they are more likely to strive for it, which is important for becoming a successful science student.

Secondly, and equally as important, empathizers do not necessarily have a low motivation towards (school) science. Good empathizers tend to be less good at systemizing, and therefore, on average, they tend to have a lower motivation to learn science. However, statistically, a very good empathizer can also be a very good systemizer. In this case, s/he can easily show a high motivation to learn science although s/he is a strong empathizer.

The challenge for school science seems to be – at least from this point of view – the students with low SQ scores, be they good empathizers or not. It could be an interesting research question, how these two groups differ, and how they should be approached to improve the systemizing dimension of their cognitive style, i.e. their drive and ability to analyze the rules underlying a system, in order to predict its behavior. Our findings suggest that a success in improving the systemizing dimension of these students' cognitive style could spontaneously lead to an improvement in their motivation to learn science. Research must show if, and to what degree, the initial level of systemizing can be improved and how this could be done.

Another interesting research project would be to study if there is a relation between our findings and the concept of cultural border crossing, which stems from Aikenhead and colleagues (Aikenhead, 2000). This is a cultural concept that perhaps could be contrasted with the biological concept of cognitive style. At first glance, the "potential scientists" of Aikenhead, the students who enter the culture of (school) science without problems, seem to correspond with the highly systemizing students. Aikenhead estimates that approximately 5% of high schools students are potential scientists, which is comparable to the amount of highly systemizing students in our sample. It is of interest whether the categories of cultural border crossing can be characterized by the EQ and the SQ. It seems appropriate to use a qualitative research method to find out more about these issues, or else a mixed method approach.

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