Science adjustment, parental and teacher autonomy support and the cognitive orientation of science students

Tomas Jungert and Richard Koestner

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Abstract

Research has shown that autonomy support has positive effects on academic development, but no study has examined how systemizing cognitive orientation is related to important outcomes for science students, and how it may interact with autonomy support. This prospective investigation considered how systemizing and support from teachers and parents influence motivation, self-efficacy, and science performance of science students. 288 high school students (143 females and 145 males) completed surveys at two times and records of their achievements were collected. Teachers' autonomy support and systemizing were significantly positively related to motivation, self-efficacy and achievement over time, while parental support for autonomy was not directly related to the outcomes. Finally, two significant interaction effects showed that the relation of parental autonomy support to motivation and self-efficacy was moderated by systemizing. This is the first study to demonstrate that autonomy support may be especially helpful for individuals with an intrinsic disposition in a domain.

Keywords: parental autonomy support; teacher autonomy support; systemizing cognitive orientation; motivation; self-efficacy; science students

*Science Adjustment, Parental and Teacher Autonomy Support
and the Cognitive Orientation of Science Students*

A valued goal for many adolescents is to achieve success in their studies, particularly in those related to their future career aspirations. This academic striving becomes especially salient as an adolescent nears completion of high school and anticipates the transition to University. The present study explored the role of support from parents and teachers in facilitating students' adaptation as they undertake their final year of advanced science studies. Our first aim was to confirm that autonomy support from both parents and teachers would facilitate science students' success in navigating their final year of high school. Success was operationalized in terms students performing well in their classes, reporting high levels of interest and value in their studies, and reporting high levels of confidence in their ability to master the sciences. A second aim was to examine whether students who appeared to have an innate predisposition for scientific concepts might better adapt to their final year of high school in which the science courses become especially challenging. Our final aim was to explore if high levels of support, from both teachers and parents, would particularly energize students with an innate predisposition toward science (but allow students who lack this predisposition to shift their focus away from the sciences). Specifically, we examined whether a systemizing cognitive style would moderate the motivational impact of receiving autonomy support. The study controlled for parental involvement in science and for parental education.

Recent motivation research, guided by self-determination theory, highlights the importance of support of autonomy in facilitating internalization, learning, and persistence (Deci & Ryan, 2000, 2008). Autonomy support describes an interpersonal style in which a teacher or parent takes the perspective of a student or child into account, presents rationales for the behaviors requested, and provides opportunities for choice and self-initiation (Deci & Ryan, 2000). Self-determination theory proposes that socializing agents such as parents and teachers can promote the motivation, competence and learning of students by acting in

autonomy supportive rather than controlling ways. For example, a study by Deci, Schwartz, Sheinman, and Ryan (1981) showed that teacher reports of autonomy support were significantly positively associated with their students' level of intrinsic motivation and perceived competence. A subsequent study showed that parental autonomy support was associated with children's self-regulation, school grades and achievement (Grolnick & Ryan, 1989). There are many other examples of longitudinal studies that have found positive relations between autonomy support and various outcomes (see e.g. Adie, Duda, & Nikos, 2012; Bonneville-Roussy, Vallerand, & Bouffard, 2013; Jang, Kim, & Reeve, 2012; Julien, Senécal, & Guay, 2009; Seiffge-Krenke & Pakalniskiene, 2011). Similarly, a three year prospective study showed that parental autonomy support was predictive of higher motivation and achievement (Joussemet, Koestner, Lekes, & Houliort, 2004). Interestingly, it was shown that parents continue to have an important influence on their children's academic motivation during late adolescence despite the common belief that they can do little to motivate their offspring during this period of life (Guay, Marsh, Senecal, & Dowson, 2008).

Many studies have confirmed these findings by showing that parental autonomy support is related to positive academic outcomes (Deci, Driver, Hotchkiss, Robbins, & Wilson, 1993; Gottfried, Fleming, & Gottfried, 1994; Grolnick, Gurland, DeCoursey, & Jacob, 2002). For instance, parental autonomy support for homework is associated with better grades, higher standardized tests scores, and higher rates of homework completion (Cooper, Lindsay, & Nye, 2000), positive attitudes toward science (George & Kaplan, 1998; Hein & Lewko, 1994) and decreased school drop-out (Otis, Grouzet, & Pelletier, 2005; Vallerand, Fortier, & Guay, 1997).

Studies have shown that teachers' autonomy support also positively influences students' motivation, course grades, feelings of competence, and actual performance in class (Filak & Sheldon, 2008; Grolnick & Ryan, 1989; Niemiec & Ryan, 2009; Roth, Assor, Kanat-

Maymon, & Kaplan, 2007; Ryan & Connell, 1989). By contrast, negative motivational effects have been observed when teachers have exhibited various forms of controlling behavior (Assor, Kaplan, Kanat-Maymon, & Roth, 2005; Reeve, Jang, Carrell, Jeon, & Barch, 2004). Controlling teachers are less effective in their teaching (Flink, Boggiano, & Barrett, 1990), and students taught by controlling teachers make more errors (Garbarino, 1975).

Seven studies have simultaneously assessed the relation of both teacher and parent support of autonomy in the development of academic interests (Alivernini & Lucidi, 2011; Chirkov & Ryan, 2001, two samples; Ferguson, Kasser, & Jahng, 2011, three samples; Vallerand et al., 1997). Participants' ages in the studies varied between 14 to 19 years old. The samples were from the U.S., Canada, Italy, Denmark, Russia, and South Korea. Table 1 displays the correlations of parental autonomy support and teacher autonomy support with a summary index of the school outcomes derived for each study. It can be seen that *both* parental and teacher autonomy support were significantly related to positive school outcomes, mean r 's = .25, and .32, respectively. The consistency of these findings across studies and countries is impressive.

Insert Table 1 About Here

The results described above suggest that receiving autonomy support from parents as well as teachers provides a significant advantage for students' academic development. Although autonomy support has clear main effects on students' academic outcomes, previous studies have not considered whether certain student characteristics moderate the effects of autonomy support. It seems possible that the impact of autonomy support on children's academic development may be conditional on whether children have an intrinsic interest and

affinity for the domain that is being examined. We propose that in judging the impact of teacher and parental support on science outcomes it will be important to consider students' intrinsic predisposition to be interested in science as a field. It seems likely that autonomy support, which encourages choice and voluntary initiation, would be most effective with children who had a strong affinity for involving themselves with the field of science

There is now considerable evidence that a systemizing cognitive style is associated with greater interest and aptitude for math and sciences. (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003). Systemizing refers to a persons' drive to analyze systems in the physical environment, and to make predictions about the behavior of those systems. There seem to be innate biological causes for the differences (Baron-Cohen et al., 2003; Von Horn, Bäckman, Davidsson, & Hansen, 2010). Research has shown that the majority of students who choose to study science have a highly systemizing cognitive orientation, even if we cannot be sure if this was present prior to study or if it was grown or reinforced via science study (Billington, Baron-Cohen, & Wheelwright, 2007). Would the beneficial effects of autonomy support depend on whether a young person was predisposed to be absorbed by sciences? Given that empathy and perspective-taking are central to autonomy support (Deci & Flaste, 1996) it seems possible that a truly autonomy supportive parent or teacher might actually help a student who is not suited to the sciences to become aware of a potential mismatch between their predisposition and the field of study. Some studies have examined the joint effects of motivational orientations (e.g., causality orientations) and contextual factors (Koestner & Zuckerman, 1994, Weinstein, Deci & Ryan, 2011) but none have focused specifically on parent or teacher autonomy support. However, to the best of our knowledge, no study has yet examined whether the effects of autonomy support in a particular domain would be moderated by the recipients' natural inclination for that domain.

The present study examined academic development in terms of changes in science students' autonomous motivation, self-efficacy, and grades. Autonomous motivation is thought to be the key to learning, growth and development according to Self determination theory (Deci & Ryan, 2000). Higher levels of autonomous motivation have consistently been associated with positive academic outcomes (Vansteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009). Autonomous motivation is assessed in terms of intrinsic and identified forms of self-regulation, which refers to pursuing activities because they are interesting or personally meaningful. Autonomous motivation is contrasted with controlled motivation, which refers to pursuing activities because of external or internal pressures. Recent goal research suggests that autonomous motivation is a more important predictor of positive outcomes than controlled motivation, which is usually shown to be unrelated to outcomes (Koestner et al, 2008).

Self-efficacy also functions as an essential factor in self-regulatory mechanisms (Bandura & Wood, 1989). Efficacy beliefs play a key role in how individuals perform because it directly affects factors such as goals and aspirations, affective tendencies, and outcome expectations Bandura (1995, 1997), and are strong predictors of their ability to successfully carry out academic tasks (Skaalvik & Skaalvik, 2008). In addition, we focused on science achievement as an outcome variable since high grades in science courses is both important for students who would like to continue studying in higher education and to get more opportunities in their future lives. We thus directly assessed school performance in terms of obtained grades in science courses.

Present Study

This one-year prospective longitudinal investigation considers how a systemizing cognitive orientation and autonomy support from teachers and parents may influence the

autonomous motivation, self-efficacy, and performance of high school students in science programs. A systemizing cognitive orientation was thought to reflect an intrinsic predisposition to be interested in learning science concepts. A sample of 288 students in their final year of a Science High School program (143 females and 145 males) completed surveys at two times and records on their science achievements were collected. We expected teachers' and parents' support of autonomy to be significantly positively related to students' autonomous motivation, self-efficacy and achievement over time. We also expected students with a systemizing cognitive style to display higher levels of motivation, self-efficacy and performance over the difficult final year of high school science. Finally, we hypothesized that systemizing might moderate the impact of autonomy support such that high levels of autonomy support would energize students who had an innate predisposition to science whereas it might actually allow students who lacked this predisposition to shift their energies away from the science studies which they are not intrinsically predisposed to enjoy. We believe that this study represents the first attempt to examine whether the impact of autonomy support is conditional on individual's predisposition in a given domain. Because previous research has highlighted the importance of parent level of education and parent engagement in school activities as importantly linked to educational outcomes, we controlled for these measures in all of our analyses (e.g. Breen, Luijkx, Müller, & Pollak, 2010; Grolnick & Ryan, 1989; Lekholm & Cliffordson, 2008; Marks, 2011).

Method

Participants

In this study, 288 high school students (143 females and 145 males) who were studying in science programs participated in the data collection on a voluntary basis. High school begins in the students' tenth year, when they are 15 to 16 years old, and lasts for three years

and ends in the middle of June. Students select a high school orientation in the spring of their ninth school year, for example social science, business or science. The students in this study were in their final year of a science program in eight metropolitan schools. The students had the same Math teacher, Physics teacher and Chemistry teacher throughout their three years in high school. Participants' mean age was 18.

Measures

The analyses in this study were based on survey data of students' perceptions of teacher support for autonomy, parental support for autonomy, parent engagement in science, systemizing, motivation, self-efficacy, and achievement in science. In each school, students completed questionnaires during an allotted time during the school day. Questionnaires were administered at two times; Time 1 was in September of 2007, in their fall semester of their final year in high school, and Time 2 was in May, during the spring semester of their final high school year. Thus, the students had been enrolled in high school for two years and had had substantial time to get to know their teachers.

At Time 1, questionnaires were completed by 439 students and of these, 288 completed the second questionnaire as well, which gives a response rate of 66% for both questionnaires. In addition, grades for all courses throughout their school years were collected at the end of their final school year. Grade transcripts were received regarding 247 of the students who completed both surveys.

The sample of the students who dropped out of the study differed somewhat from the sample that participated in this study. The sample of the students who did not complete the questionnaire at Time 2 had 53% male students compared to 50% in the participating sample. There were no significant differences in the level of their parents' education, self-efficacy, systemizing, parents' encouraging support for science or teacher support for autonomy. The

two samples differed, however, in autonomous motivation, $t(437) = 2.37, p < .05$, and in parents' support for autonomy, $t(438) = 2.16, p < .05$, which means that the students who filled in the second questionnaire were more motivated and perceived their parents as being more supportive of their autonomy than the students who only filled in the first questionnaire. Our central analyses control for initial levels of autonomous motivation and autonomy support.

Science teacher support for autonomy (Time 1). This scale consisted of 5 items, developed to measure how the students perceived that their science teachers are supportive of their autonomy when studying science courses (Mathematics, Physics, Chemistry and Biology). These items were adapted from the Perceptions of Science Classes Survey (Kardash & Wallace, 2001). The items refer to teaching acts that are likely to be encountered in science class rooms at a post-secondary level, and were adapted to measure autonomy support. We asked the students to think about one particular class/teacher when answering these questions. An example item is *"I felt that my science teacher provided us with choices and options concerning learning the subject."* The Cronbach alpha was .83.

Parental support for autonomy (Time 1). This scale consisted of 5 items developed to measure how the students perceive that their parents are supportive of their autonomy in general. These items were adapted from the Perceptions of Parents Scale (Grolnick, Ryan, & Deci, 1991). An example item of this scale is *"My parents let me decide for myself whenever possible."* Cronbach alpha was .74.

Parents' science engagement (Time 1) was measured by a five item scale that was developed by adapting items from perceived parental involvement in learning items used by Ratelle, Larose, Guay, and Senécal (2005) and a scale assessing attitudes towards science (Adams et al., 2006). The scale intends to capture parent actions that portray sciences as an exciting endeavor (*e.g., my parents excitedly discussed new scientific discoveries*) or that

stimulate the child's interest (*e.g., my parents and I had debates about science*) and had a Cronbach alpha of .84.

Motivation (Time 1 and 2) was measured with the Academic Motivation Scale (AMS) developed by Vallerand, Pelletier, Blais, and Brière (1992). The AMS consists of 20 items and is composed of five subscales. Each subscale has four items. Two of the sub scales, extrinsic motivation and introjected motivation, refer to controlled motivation ($\alpha = .66$ at Time 1 and $.80$ at Time 2) and two scales, identified motivation and intrinsic motivation, refer to autonomous motivation ($\alpha = .83$ at Time 1 and $.89$ at Time 2), while the fifth subscale measures amotivation ($\alpha = .91$ at Time 1 and $.89$ at Time 2). The present study focuses on autonomous motivation because it has been linked with positive outcomes. A sample item of intrinsic motivation is "*I am enrolled in the Science program because I enjoy learning new things in science*" and a sample item of identified motivation is "*Because I think that knowledge of sciences will help me in my chosen career*".

Self-efficacy (Time 1 and 2) was measured with a 5-item scale adapted from the MSLQ, developed by Garcia and Pintrich (1996). A sample item is "*I am confident that I will be able to correctly solve problems in science courses.*" Cronbach alpha was $.74$ at Time 1 and $.75$ at Time 2.

Systemizing cognitive orientation was measured with an eight item scale adapted from the Systemizing Quotient (Baron-Cohen et al., 2003; see appendix). The Systemizing Quotient questionnaire has 75 items of which many either do not relate to tasks that scientists and students of science are typically involved with, or are very particularly related to British culture. The eight item scale used in this study has previously been validated by the authors in another study (Dedic, Jungert, & Rosenfield, 2010). All items pertained to everyday activities (*e.g., "I am fascinated by how machines work"*). The alpha value was $.67$. The responses for all measures ranged from 1 = Strongly agree to 4 = Strongly disagree.

Science achievement (Time 1 and 2). The grading system uses letter grades for each course. These letter grades were converted to a numerical scale: Fail = 1; Pass = 2; Pass with distinction = 3; and, Pass with great distinction = 4. Science achievement at Time 1 was calculated as the mean of grades in the two Mathematics courses that students take in their second year in high school and a course in basic Physics that they take during their first two years in high school. The students received their grades in these three courses during their second year, and grades in them would thus represent science achievement at Time 1. Achievement at Time 2 was calculated as the mean of an advanced course in Mathematics, an advanced course in Physics and a course in Chemistry of their final year of high school.

Parents' level of education. Students responded to a question that read “*Keeping in mind your parent who has the highest level of education, the highest level of courses that this parent followed were in: 1. High-school 2. College 3. University 4. Post-graduate studies.*”

Results

Descriptive results and Pearson's correlations between the main variables are presented in Table 2. It can be seen that the correlations between parent engagement in science, parental support for autonomy and teacher support for autonomy were small; between .12 and .20, which indicates that support and engagement from these sources are perceived as distinct from each other. Furthermore, autonomous motivation at Time 1 was significantly correlated with autonomous motivation at Time 2 ($r = .71$), self-efficacy at Time 1 correlated significantly with self-efficacy at Time 2 ($r = .56$) and the grades in science were moderately, but significantly correlated with grades at Time 2 ($r = .45$). In addition, autonomous motivation at Time 1 and Time 2 had medium to large correlations with self-efficacy at Time 1 and 2 (r 's between .43 and .56). It can also be seen that systemizing correlated moderately with autonomous motivation ($r = .35$) and self-efficacy ($r = .35$) at Time 2. Achievement in

science in the final year was moderately correlated with autonomous motivation, both at Time 1 ($r = .36$) and Time 2 ($r = .29$) and largely with self-efficacy, at Time 1 ($r = .59$) and moderately at Time 2 ($r = .45$). However, systemizing was not related to achievement at Time 1 and only weakly, positively to achievement ($r = .15$) at Time 2.

Insert Table 2 About Here

Regressions

Hierarchical multiple regressions were performed with the dependent variables at Time 2. The first set of predictors in each regression was gender and parents' level of education. In each regression, we controlled for values of the outcome variable at Time 1. By entering the baseline measure in the first block, we were essentially using our independent variables to predict residual change scores in our dependent variable (e.g., scores reflecting a change in school achievement from the initial to the follow-up assessment). Systemizing cognitive orientation was entered as a second set. In the third set, parent engagement in science, parental support for autonomy, and teacher support for autonomy were entered. Finally, three two-way interactions of systemizing with the support values and three two-way interactions of education level of parents with the support values were entered. All predictors were standardized before entry in the regression equation. The interaction terms were created by calculating products. Table 3 presents the results of these regression analyses. Preliminary analyses showed that there were no two-way interactions involving gender, so we did not include them in our main analyses.

The regression for autonomous motivation at Time 2 was significant, multiple $R = .75$, $R^2 = .56$, $F(10, 274) = 34.57$, $p < .001$. Neither gender nor parents' level of education was significantly related to autonomous motivation at Time 2. Systemizing cognitive orientation ($\beta = .20$, $t = 4.23$, $p < .001$) and autonomy support from science teachers ($\beta = .14$, $t = 3.25$, $p < .001$) were significantly positively related to autonomous motivation at Time 2.

Thus, students high in systemizing cognitive orientation and students who perceived the autonomy support from their science teachers as high had higher autonomous motivation over time, than students who were low in systemizing and who perceived the autonomy support from their science teachers as low. Finally, there was one significant interaction. A systemizing cognitive orientation interacted significantly with autonomy support from parents ($\beta = .09$, $t = 1.98$, $p < .05$). The pattern of this interaction is shown in Figure 1. It can be seen that for autonomous motivation, students with a high systemizing cognitive orientation (compared to students with a low systemizing cognitive orientation) showed an especially positive response to autonomy support from their parents. This interaction suggests that autonomy support from parents is more important for high systemizers than low systemizers, which later has a positive effect on their autonomous motivation.

The regression for self-efficacy at Time 2 was also significant, multiple $R = .64$, $R^2 = .41$, $F(10, 274) = 18.81$, $p < .001$. Self-efficacy at Time 1 was significantly positively related to self-efficacy at Time 2 ($\beta = .55$, $t = 10.81$, $p < .001$). Systemizing cognitive orientation ($\beta = .22$, $t = 4.02$, $p < .001$) and science teacher support for autonomy ($\beta = .18$, $t = 3.73$, $p < .001$) both related to later self-efficacy. Thus, we found the same pattern for students' self-efficacy as for their autonomous motivation, as students high in systemizing cognitive orientation and students who perceived the autonomy support from their science teachers as high had higher self-efficacy over time, than students who were low in systemizing and who perceived the autonomy support from their science teachers as low. In addition, a systemizing cognitive

orientation interacted significantly with autonomy support from parents ($\beta = .11, t = 2.10, p < .05$). The patterns of this interaction are shown in Figure 2. It can be seen the same pattern appeared for self-efficacy as for autonomous motivation; students with a high systemizing cognitive orientation showed an especially positive response to autonomy support from their parents, which suggests that autonomy support from parents is more important for high systemizers than low systemizers, which later on has a positive effect on their self-efficacy.

Insert Figures 1 to 2 About Here

The regression for science achievement at Time 2 was also significant, multiple $R = .52$, $R^2 = .27, F(10, 244) = 9.04, p < .001$. Science achievement at Time 1 was significantly positively related to science achievement at Time 2 ($\beta = .43, t = 7.71, p < .001$). The level of education of the students' parents was significantly positively related to their achievement in science ($\beta = .17, t = 3.05, p < .01$). In addition, systemizing cognitive orientation ($\beta = .15, t = 2.31, p < .05$) and science teacher support for autonomy ($\beta = .12, t = 2.18, p < .05$) both related to later achievement in science. There were no interaction effects approaching significance.

Thus, students high in systemizing cognitive orientation and students who perceived the autonomy support from their science teachers as high received higher grades in science over time, than students who were low in systemizing and who perceived the autonomy support from their science teachers as low.

Finally, as controlled motivation and amotivation also were assessed in the present research we performed hierarchical multiple regressions with them as dependent variables

too. Even if the purpose of this study was not to investigate controlled motivation and amotivation, we found it valuable to do so. The regression for amotivation at Time 2 was significant, multiple $R = .66$, $R^2 = .43$, $F(10, 274) = 20.63$, $p < .001$. Amotivation at Time 1 was significantly positively related to amotivation at Time 2 ($\beta = .58$, $t = 11.95$, $p < .001$), while systemizing cognitive orientation was significantly negatively related to amotivation at Time 2 ($\beta = -.30$, $t = -5.78$, $p < .001$). Controlled motivation at Time 2 was significant, multiple $R = .54$, $R^2 = .29$, $F(10, 274) = 11.01$, $p < .001$. Controlled motivation at Time 1 was significantly positively related to controlled motivation at Time 2 ($\beta = .49$, $t = 9.47$, $p < .001$) and teacher autonomy support was positively related to controlled motivation at T2 ($\beta = .12$, $t = 2.31$, $p < .05$). No other variables were related to controlled motivation at Time 2 and there were no interaction effects approaching significance.

 Insert Table 3 About Here

In summary, Table 3 shows the standardized regression effects for autonomous motivation, self-efficacy and achievement at Time 1 and at Time 2 and the predictor variables at the point they were entered in the regression equation. It can be seen that for all of the three important outcomes, there were main effects for a systemizing cognitive orientation and teacher support for autonomy, whereas parents' support for autonomy interacted with systemizing cognitive orientation.

General Discussion and Conclusions

The present investigation was designed primarily to explore the idea that a systemizing cognitive orientation, as well as parental and teacher support for autonomy, is associated with positive outcomes in students who study science in high school. Autonomy support from many sources and across different domains has consistently been linked with positive outcomes (Deci & Ryan, 2008). No previous research, to the best of our knowledge, has

explored whether differences in an intrinsic disposition in a domain together with support for autonomy will be associated with outcomes.

Our findings showed that a strong systemizing orientation, irrespective of gender, was a factor that explains how well science students adjust to their studies, across all three of our dependent measures. Youth who are high in systemizing have a drive to try to deduce rules governing the behaviour of inanimate systems, which in turn motivates them to seek more challenging problems, and hence to improve their skills in such domains and to engage in science studies. It is likely that small differences in these dispositions increase through chosen activities. For example, people with a low systemizing drive probably avoid thinking of systems and numbers and consequently lack confidence and motivation that is needed when studying science. We also found that autonomy support from science teachers was significantly positively related to autonomous motivation, self-efficacy, and achievement in science of the students over time, whereas parental support was not directly related to any of those outcomes over time. This result confirms studies from several countries that have found that teachers play an important and distinctive role for their students (Alivernini & Lucidi, 2011; Chirkov & Ryan, 2001, Ferguson, Kasser, & Jahng, 2011; Vallerand et al., 1997).

Interestingly, autonomous motivation and self-efficacy of students who were high in systemizing cognitive orientation were especially linked with parental support for autonomy. Students with strong innate predispositions to involve themselves in the field of science and whose parents encourage choice and self- initiation will feel more motivated and competent in studying science. In other words, it is likely that highly systemizing students with autonomy supportive parents will seek ever more challenging problems, and hence improve their skills in such domains. Children who are high systemizers, but whose parents are not as autonomy supportive, may feel a pressure to study science, and might lose their drive and autonomous motivation, if they feel that they have not freely chosen their academic orientation. Students

with low systemizing orientations who have autonomy supportive parents will, instead, feel that they have the choice to freely choose other academic fields that they are more interested in and that they feel a higher predisposition to succeed in. A question that remains is how (and if) parents could increase the autonomous motivation, self-efficacy, and achievement in science of children who study science but who are low in systemizing.

Contrary to previous research by Grolnick and Ryan (1989) and Joussemet et al (2004), the present study failed to obtain evidence for a significant direct relation of parental autonomy support with school outcomes. This null finding was unexpected. It should be noted however, that parental autonomy support was significantly positively associated with contemporaneous time 1 variables, it was only in terms of predicting change over the final year of study that no effect for parental autonomy support emerged. Perhaps the direct impact of parental autonomy support reaches its limits toward the end of high school and this motivational factor then has impact only in conjunction with students' intrinsic disposition. Future research will need to examine this question.

Parent engagement in science was unrelated to change in academic outcomes. Previous studies (Soucy & Larose, 2000; Strage & Brandt, 1999) have indicated that parents' scaffolding, which was operationalized as discussing science topics with children or taking them to science museums, can be beneficial for student learning and achievement. Parental engagement in science, like parental autonomy support, was significantly associated with all three baseline measures of academic development, but it failed to predict further changes in any of the outcomes. In the present investigation we obtained a weak correlation between reports of parental and teacher support of autonomy, suggesting that these sources do not overlap much. In combination with our other results, this suggests that these two sources of autonomy support are not redundant. Stated differently, the low correlations between parental

autonomy support and teacher autonomy support, suggests that students' perceptions of support are highly differentiated and are unlikely to simply reflect a student's perceptual bias.

The present study suffered from several limitations such as our reliance on a correlation design and self-reports of the receipt of support from parents and teachers. Furthermore, systemizing cognitive orientation was only measured with a self-report measure rather than a behavioral test.. We also focused only on students in a science stream, while future research could study students in other academic orientations. It would be particularly interesting to identify predisposing personality features in fields such as language arts or social sciences and to determine whether they moderate the effects of autonomy support. A future longitudinal study could also follow students after high school, in higher education and in their working life to see how it is related to outcomes such as autonomous motivation, self-efficacy and performance in other contexts over time.

Conclusion

In conclusion, this is the first study to demonstrate that parental autonomy support may be especially helpful for individuals with an intrinsic disposition in a domain. Our findings provide evidence for the importance of a strong systemizing drive for students who study science, as well as teacher and parental support for autonomy. The prospective nature of our findings is relatively unique for studies that assessed both teacher and parent support of students' school pursuits. Our findings may have implications for parents, schools and teachers. For example, parents should try to be both involved and engaged in their children's science studies in high school, but also give them meaningful rationales for why it is important to study science and doing homework, acknowledging their children's feelings about studying science and use language that convey choice rather than control. It is also important that parents acknowledge children who lack a systemizing drive and let them choose other possible fields to study after high school. For teachers and schools, it is also

important to be autonomy supportive of students by promoting satisfaction of their need for autonomy by offering meaningful choices in school. Schools and teachers should also be acknowledging of the students' feelings about studying science and giving them various meaningful rationales for the importance of school assignments.

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Table 1

Correlations of student school outcomes with teacher and parental autonomy support for studies that included both predictors.

	<i>Country</i>	<i>Age</i>	<i>n</i>	<i>Parental Aut-Support</i>	<i>Teacher Aut-Support</i>
<i>Alivernini et al., 2011</i>	<i>Italy</i>	<i>16</i>	<i>421</i>	<i>.13</i>	<i>.27</i>
<i>Chirkov & Ryan, 2001</i>	<i>USA</i>	<i>16</i>	<i>116</i>	<i>.17</i>	<i>.30</i>
	<i>Russia</i>	<i>16</i>	<i>120</i>	<i>.26</i>	<i>.28</i>
<i>Ferguson et al., 2011</i>	<i>Denmark</i>	<i>16</i>	<i>99</i>	<i>.45</i>	<i>.46</i>
	<i>USA</i>	<i>16</i>	<i>98</i>	<i>.16</i>	<i>.51</i>
	<i>South Korea</i>	<i>16</i>	<i>125</i>	<i>.22</i>	<i>.36</i>
<i>Vallerand et al., 1997</i>	<i>Canada</i>	<i>15</i>	<i>4537</i>	<i>.46</i>	<i>.29</i>

Table 2

Correlations, means and standard deviations for systemizing, support measures, parent engagement, autonomous motivation, self-efficacy and science achievement.

	1	2	3	4	5	6	7	8	9	10	M	SD
1.	-	.07	.15*	.27*	.35*	.35*	.36*	.35*	.05	.15*	2.94	0.48
<i>Systemizing</i>												
2. Parental		-	.13*	.20*	.21*	.20*	.19*	.20*	.13*	.14*	3.39	0.55
<i>Autonomy support</i>												
3. Teacher			-	.12*	.17*	.27*	.16*	.30*	.11*	.26*	2.80	0.73
<i>Autonomy support</i>												
4. Parental Engagement				-	.35*	.35*	.24*	.24*	.08	.14*	2.27	0.74
5. Motivation T1					-	.71*	.46*	.44*	.08	.36*	2.91	0.70
6. Motivation T2						-	.43*	.56*	.04	.29*	2.93	0.70
7. Self-efficacy T1							-	.56*	.28*	.59*	2.88	0.70
8. Self-efficacy T2								-	.09	.45*	2.80	0.51
9. Achivement T1									-	.45*	3.14	0.76
10. Achivement T2										-	2.98	0.84

* $p < .05$

Table 3

Standardized regression coefficients and t-tests for autonomous motivation, self-efficacy, and achievement.

	Motivation T2			Self-efficacy T2			Achievement		
	β	t-test	$pr^{2\dagger}$	β	t-test	$pr^{\dagger}$	β	t-test	$pr^{\dagger}$
Controlling var.	.70***	16.25	.47	.55***	10.81	.28	.43***	7.71	.18
Gender	.00	0.10	.00	.04	0.79	.00	-.00	-0.07	.00
Parent education	.06	1.30	.00	.03	0.63	.00	.17**	3.05	.03
Systemizing	.20***	4.23	.03	.22***	4.02	.04	.15*	2.31	.02
Parental Autonomy support	.03	0.74	.00	.06	1.13	.00	.07	1.14	.00
Teacher Parental Engagement	.14***	3.25	.02	.18***	3.73	.03	.12*	2.18	.01
Systemizing *	.02	.48	.00	.04	0.79	.00	-.01	-.16	.00
Parental Autonomy support	.09*	1.98	.01	.11*	2.10	.01	.08	1.24	.00
Systemizing *									
Teacher Autonomy support	-.02	-0.48	.00	.01	0.19	.00	.02	0.33	.00
Systemizing *									
Parental Engagement	-.07	-1.72	.00	-.02	-.48	.00	-.02	-.30	.00

$\dagger pr^2$ = Squared part correlations, represents the unique contribution for each variable

*** $p < .001$; ** $p < .01$; * $p < .05$

Appendix A

Systemizing cognitive orientation items

1. I am not interested in understanding how new technology (*e.g.*, wireless communication) works. (R)
2. I am fascinated by how machines work.
3. I find it easy to read and understand maps.
4. I do not tend to watch science documentaries on TV or read articles about science. (R)
5. I find it easy to understand instruction manuals for putting things together.
6. I rarely read web pages or articles about new technology. (R)
7. If I were buying a computer, I would want to know the exact details of its technical specifications (*e.g.*, hard drive capacity or processor speed).
8. I find it difficult to interpret a graph if it does not have an explanation. (R)