Journal of Educational Psychology

How Can the Blow of Math Difficulty on Elementary School Children's Motivational, Cognitive, and Affective Experiences be Dampened? The Critical Role of Autonomy-Supportive Instructions

Elke Baten, Maarten Vansteenkiste, Gert-Jan De Muynck, Eline De Poortere and Annemie Desoete

Online First Publication. http://dx.doi.org/10.1037/edu0000444

CITATION

Baten, E., Vansteenkiste, M., De Muynck, G., De Poortere, E., Desoete, A. (in press). How Can the Blow of Math Difficulty on Elementary School Children's Motivational, Cognitive and Affective Experiences be Dampened? The Critical Role of Autonomy-Supportive Instructions. *Journal of Educational Psychology*. Advance online publication. doi: 10.1037/edu0000444

How Can the Blow of Math Difficulty on Elementary School Children's Motivational, Cognitive, and Affective Experiences be Dampened? The Critical Role of Autonomy-Supportive Instructions

Abstract

Although teachers are recommended to create a stimulating learning environment in which children can use, perfect, and extend their skills, this is far from easy. In many cases, identifying the optimal difficulty level of learning tasks involves a trial-and-error process during which teachers offer children too difficult tasks, with negative outcomes as a result. This experimental study investigated if autonomy-supportive instructions could dampen or even cancel out these presumed negative outcomes associated with math difficulty in elementary school children ($N = 479$; $M_{age} = 9.41$). After varying an autonomy-supportive versus a controlling instructional style through a comic book, children solved a series of either easy-medium or difficult math exercises, followed by the completion of questionnaires and the opportunity to choose the difficulty level of a final set of exercises to work on independently. Children who solved difficult, relative to easier, exercises reported less interest, more irritation, and more cognitive disengagement, while also seeking less challenge when asked to work independently. Need-based experiences of competence and autonomy accounted for these effects. Yet, the impairing impact of task difficulty could, at least partially, be dampened through the use of an autonomy-supportive relative to a controlling instructional style, which led to enhanced autonomy satisfaction. These findings largely occurred independent of children's motives for mathematics. The results have high practical value, especially for poor performers and children with Mathematical Learning Disabilities, who find math to be harder overall. Limitations and implications for practice are discussed.

Educational Impact and Implications Statement

Autonomy-supportive instructions (e.g., inviting language, meaningful rationale) were found to dampen the impairing effects of too difficult math tasks on children's motivational, cognitive, and affective experiences. This is especially important for poor performers and children with Mathematical Learning Disabilities, who find math to be harder overall. An autonomy-supportive environment and avoiding too hard learning material may stimulate children to accept new challenges, thereby possibly improving chances for later academic/job success.

Imagine an elementary school child, Anna, in a mathematics class who is asked to solve a series of exercises. Although her teacher is sincerely concerned with helping Anna in applying, perfecting, and extending her knowledge and skills, this is not an easy endeavor. Theoretically, the teacher is encouraged to monitor the child's learning process as to offer exercises in Anna's zone of proximal development ((Moll, 2013; Vygotsky, 1978, 1987). Yet, because different children develop at a different pace (Claessens, Duncan, & Engel, 2009; Claessens & Engel, 2013), with each of them thus having a different zone of proximal development, the offered exercises by the teacher will at times be too difficult for some children, while being too easy for others. Unfortunately, too difficult math exercises may come with a cost, such as decreased perceived competence and increased emotional and behavioral disengagement (Patall, Hooper, Vasquez, Pituch, & Steingut, 2018). In addition, research indicates that children's intrinsic motivation (i.e., pure interest and enjoyment) for mathematics gradually declines throughout elementary school (Gottfried, Fleming, & Gottfried, 2001; Lepper, Corpus, & Iyengar, 2005). The increasing difficulty in math exercises as elementary school progresses (Ashcraft, Krause, & Hopko, 2007) may be one of the reasons for this.

Grounded in Self-Determination Theory (SDT; Ryan & Deci, 2017), the first aim of the present experimental study was to examine the presumed motivational (i.e., reduced interest/enjoyment), cognitive (i.e. thoughts on disengagement), affective (i.e. irritation) and behavioral (i.e., reduced challenge seeking) costs associated with offering too difficult tasks to elementary school children, as well as identifying the mechanisms that can account for these effects. Second, we sought to examine if an autonomy-supportive, relative to a controlling, style of introducing difficult exercises would dampen or even cancel out the hypothesized impairing effects of too difficult tasks. We pursued both aims in the context of mathematics since mathematics achievement in the first year of elementary school is a key predictor for future academic and job success (Duncan et al., 2007; Duncan & Magnuson, 2011). Hence, it is critical to find effective motivational pathways to not only avoid children losing interest in mathematics, but also to stimulate them to extend their skills during math development.

The Competence-Relevant Role of Task Difficulty

Despite teachers doing their best in classrooms to offer optimally challenging exercises that fall within all children's zone of proximal development, for many of them this will involve a trial-and-error process through which they need to continuously calibrate their approach. As a result, children will at certain moments be offered too difficult tasks, which has been found to relate negatively to individuals' perceived competence (Patall et al., 2018; Schmierbach, Chung, Wu, & Kim, 2014). Within SDT, competence represents one of three basic psychological needs, in addition to autonomy and relatedness (Ryan & Deci, 2017; Vansteenkiste, Ryan, & Soenens, 2019). When satisfied, children feel capable to meet the standards and they feel that they could use and extend their skills during task completion. As a result, positive outcomes such as intrinsic motivation, engagement and well-being are elicited (Vansteenkiste & Ryan, 2013). Competence frustration, on the other hand, denotes the presence of feelings of failure and inadequacy and has been found to robustly and independently predict maladaptive outcomes, including amotivation (Haerens, Aelterman, Vansteenkiste, Soenens, & Van Petegem, 2015), help-avoidance (Bartholomew et al., 2018), and ill-being (Vandenkerckhove et al., 2019; Vansteenkiste & Ryan, 2013).

One factor feeding into learners' competence is the difficulty level of the offered task. Previous research has found that overly difficult tasks are associated with various negative consequences, presumably because they elicit feelings of competence frustration. For instance, at the motivational level, too difficult tasks were found to predict lower goal-setting (Horvath et al., 2006) and undermine productivity (Goemaere, Beyers, De Muynck, & Vansteenkiste, 2018). Also, on days that science students perceived their class to be more difficult than usual, they reported more disengagement than usual (Patall et al., 2018). On the affective level, more difficult tasks were shown to relate not only to more negative affect, tension (van der Kaap-Deeder et al., 2016) and self-reported test anxiety (Eunsook, 1999), but also to higher heart rate and elevated blood pressure (Richter, Baeriswyl, & Roets, 2012).

Finally, on the cognitive level, too difficult tasks may provoke negative thinking, as indexed through the engagement in negative inner speech or self-talk (Vygotsky, 1987). Preliminary evidence for this claim comes from an experimental study among tennis players (De Muynck et al., 2017), in which the provision of normative negative, relative to positive, feedback produced more negative self-talk (e.g., worrying, thoughts on disengagement). Similarly, Eunsook (1999) reported students to worry more when filling out a difficult relative to an easier math test. Thus, the engagement in negative self-talk would represent a strategy to regulate their thinking and behavior when solving difficult math exercises, albeit a maladaptive one (Dolcos & Albarracin, 2014).

The Autonomy-Relevant Role of Instructional Style

Given the presumed costs associated with assigning children too difficult exercises, the question is how these pitfalls can be avoided. One possibility is that teachers are very careful with how they introduce these exercises. From an SDT perspective, teachers could adopt either a more autonomy-supportive or a more controlling style to communicate their instruction for these difficult tasks, thereby impacting upon learners' psychological need for autonomy (Reeve & Jang, 2006). Autonomy is defined as acting with a sense of volition, psychological freedom, and authenticity (Ryan & Deci, 2017). Autonomy frustration instead denotes the presence of pressure and internal conflict, with both the satisfaction and frustration of autonomy carrying unique predictive power (Van Assche, van der Kaap-Deeder, Audenaert, De Schryver, & Vansteenkiste, 2018).

Autonomy-supportive teachers build in choices, provide meaningful rationales, validate the learners' perspective, and use an inviting instead of a pressuring communication style (Reeve, 2009, 2016). A sense of pressure can be conveyed through the use of forceful language and demands (e.g., “you should”; Vansteenkiste, Simons, Lens, Sheldon, & Deci, 2004) or through the use of guilt-, anxiety and shame-inducing language (Soenens & Vansteenkiste, 2010; Vansteenkiste, Simons, Lens, Soenens, & Matos, 2005). Studies show that explaining children why learning activities are self-relevant by offering a meaningful rationale promotes a greater willingness to learn and fosters engagement (Jang, 2008; Reeve, Jang, Hardre, & Omura, 2002), especially if the offer of a rationale is embedded within a more general autonomy-supportive approach (Steingut, Patall, & Trimble, 2017). Similarly, the provision of choice has shown to contribute to autonomy satisfaction in children, especially in combination with connecting the task to students’ personal goals and interests (Assor, Kaplan, & Roth, 2002). Extensive research has documented the benefits of an autonomy-supportive teaching style for students' engagement (e.g., Wang et al., 2017), self-regulated learning (e.g., Aelterman et al., 2019), performance (e.g., Froiland, Davison, & Worrell, 2016) and well-being (e.g., Soenens & Vansteenkiste, 2005).

The present study sought to examine if autonomy-supportive instructions could potentially buffer the hypothesized negative effects associated with too difficult math exercises. Autonomy-supportive instructions may play such a role because such instructions alter the functional significance or attributed meaning to the exercises (Ryan & Deci, 2017), with the difficult exercises being appraised as more informational and yielding an opportunity for growth instead of being appraised as evaluative and competence-forestalling. As a result of this different attributed meaning, autonomy-supportive instructions may help dampen the negative impact of difficult exercises. Preliminary evidence for this hypothesis was reported by Sierens, Vansteenkiste, Goossens, Soenens, and Dochy (2009), who found student perceived teacher autonomy-support to interact with teacher structure in the prediction of self-regulated learning (see also Curran, Hill, & Niemiec, 2013). Further, in their diary study, Patall and colleagues

(2018) reported that a perceived autonomy-supportive teaching style minimized the competence- and engagement-impairing effect if the class was perceived to be more difficult than usual on a given day. Finally, experimental work by Mabbe and colleagues (2018) indicates that autonomy-supportive instructions partially buffered (yet did not completely cancel out) the adverse effects of negative feedback on reduced competence satisfaction and intrinsic motivation.

The Role of Students' Motivation for Mathematics

Teachers do not only face the challenge of continuously adjusting the difficulty level of a task as a function of children's developing skills, they may also need to take motivational differences between children into account. Motivational tailoring, which has received limited attention (Soenens, Vansteenkiste, & Van Petegem, 2015; Vansteenkiste, Aelterman, Haerens, & Soenens, 2019), requires teachers to search for the most appropriate need-conducive motivational strategy as a function of different student characteristics, such as motivation (e.g., Flunger, Mayer, & Umbach, 2019).

It has been widely documented that the type of motivation that learners display, either being more autonomous or more controlled in nature, is a robust predictor of their self-regulated learning, well-being, and performance (Cerasoli, Nicklin, & Ford, 2014; Vansteenkiste, Lens, & Deci, 2006). When autonomously motivated, children learn math out of interest and curiosity or because they fully endorse the personal significance of math tasks. In contrast, when controlled motivated, children experience math tasks as a daunting duty, either because they feel pressured to meet external demands or because their activity engagement is buttressed with internal pressures, including feelings of guilt, shame and self-worth (Ryan & Deci, 2000). Previous research among elementary school children has shown that autonomous, relative to controlled, motivation predicts greater enjoyment (Ryan & Connell, 1989), higher engagement and better performance (De Naeghel, Van Keer, Vansteenkiste, & Rosseel, 2012), a finding that also holds in the context of math (Baten & Desoete, 2018).

These motivational differences may interact with the difficulty level of the task in predicting children's learning and adjustment. For instance, children who are already more controlled motivated to begin with may be more sensitive for too difficult tasks, which they appraise more readily as threatening and hard. In contrast, those high in autonomous motivation for math may appraise difficult tasks as more challenging and be more sensitive for the benefits of autonomy-supportive instructions. Findings that deal with the interplay between motivational differences and contextual need-relevant features are mixed to date. For example, experimental studies among adolescents in the context of physical education (Mouratidis, Vansteenkiste, Sideridis, & Lens, 2011) and among judo athletes (Delrue, Soenens, Morbée, Vansteenkiste, & Haerens, 2019) indicated that those participants with higher, relative to those with lower, autonomous motivation derived somewhat more benefits from an autonomy-supportive in comparison with a controlling approach. Yet, other studies have revealed evidence for a different interaction pattern, with especially those being low in autonomous motivation benefiting from a more autonomy-supportive teacher (Black & Deci, 2000).

What seems clear from the pattern of obtained interactions to date is that no evidence has been garnered for a matching hypothesis (De Meyer et al., 2016). As such, the hypothesis that the motivating impact of a specific motivation strategy would be reversed depending on students' motivational orientation does not hold. That is, there is no evidence that learners high in autonomous motivation would thrive under an autonomy-supportive approach and that those high in controlled motivation would benefit from a controlling approach. Given the limited research in this area, with no prior study examining the role of motivational differences in relation to task difficulty, we sought to further investigate this topic.

The Present Study

The broader aim of the present experimental study among elementary school children in the context of math education involved examining the impact of task difficulty and instructional style and differences in math motivation as unique and interactive predictors of a broad range of motivational (i.e., interest/enjoyment), cognitive (i.e. thoughts on disengagement), affective (i.e. irritation), and behavioral (i.e., challenge seeking) outcomes. Three more specific research goals were pursued.

The first research goal investigated the main and interaction effects of task difficulty (i.e., easy-medium vs. difficult) and instructional style (i.e., autonomy-supportive vs. controlling). In line with earlier research, it was expected that difficult math problems would provoke more cognitive disengagement (De Muynck et al., 2017; Patall et al., 2018), irritation (Eunsook, 1999), while reducing interest/enjoyment and behavioral challenge seeking during a free-choice period (Mabbe et al., 2018; van der Kaap-Deeder et al., 2016; Hypothesis 1a). As far as instructional style is concerned, we expected that autonomy-supportive, relative to controlling instructions would enhance interest/enjoyment and behavioral challenge seeking, while minimizing irritation and cognitive disengagement (De Muynck et al., 2017; Hypothesis 1b). Finally, one of the more innovative goals was to examine whether autonomy-supportive instructions could dampen or even cancel out some of the presumed impairing effects of high math difficulty (Hypothesis 1c).

The second research goal examined the intervening mechanisms explaining the impact of difficulty level and instructional style. We investigated if need experiences could account for the effects of the manipulations (Jang, Kim, & Reeve, 2012; Jang, Reeve, & Halusic, 2016). In line with prior work (e.g., Mabbe et al., 2018), we hypothesized that difficulty level and instructional style would impact on children's irritation, intrinsic motivation, and behavioral challenge seeking by affecting, respectively, children's experiences of competence and autonomy (Hypothesis 2). Specifically, both need satisfaction and need frustration

(Bartholomew, Ntoumanis, Ryan, & Thøgersen-Ntoumani, 2011; Ryan & Deci, 2017; Vansteenkiste & Ryan, 2013), were examined as either uniquely or in tandem accounting for the effects of difficulty level and instructional style (Jang, Kim, & Reeve, 2016).

Finally, the third research goal explored whether individual differences in children's motives for studying mathematics relate to child outcomes, regardless of task difficulty and instructional style. Congruent with previous studies (e.g., Baten & Desoete, 2018; De Naeghel et al., 2012), we expected that children with higher autonomous motivation, relative to controlled motivation, for mathematics would find the exercises to be more interesting, report less signs of disengagement and irritation, and seek for more challenge when left by themselves (Hypothesis 3). In addition, to draw a more complete and nuanced picture regarding the more general or rather selective impact of task difficulty and instructional style, we examined whether effects of task difficulty and instructional style are dependent on these motives. As noted, the evidence for an interaction pattern as a function of differences in autonomous and controlled motivation has been scanned, leading us to examine this issue in a more explorative way. One possibility, suggested by the sensitization hypothesis (Moller, Deci, & Elliot, 2010), is that especially children with more autonomous motivation would benefit from more need-conducive contexts.

Method

Participants

An experimental study was performed on 479 fourth graders (M_{age} = 9.41; SD = 0.85) stemming from 24 classes of 14 different schools in Flanders, the Dutch-speaking part of Belgium. Every type of Flemish school (community schools, public schools, and free schools) was included, in urban as well as rural areas, in order to have a representative sample.

Procedure

A visual representation of the procedure can be found in Figure 1. The participating children were recruited from a broader pool of children (N = 481) who had participated in an earlier study during which their mathematical abilities were assessed (Desoete et al., 2019). At that time, the children were in Grade 3. In total, 406 children of which we had mathematical abilities available, took part in the new study. In addition, there was an influx of 83 new students in Grade 4, of which we had no information on their mathematical abilities. As such, the sample of the current study originally consisted of 489 participants. As can be noticed in Figure 1, the present investigation involved two school visits, the first involving a baseline assessment and the second the running of the actual experiment. At the start of the first physical visit, school principals gave active informed consent to run the study. Also, passive informed consents, which had been distributed to the potential participants by the teachers (who received them prior to the first visit by e-mail), were collected by the time of the first visit. If parents did not want their child to participate in the study, parents had to return a signed informed consent. In the informed consent, it was clearly stated that children participated on a voluntary and anonymous basis and they could withdraw their participation at any time without needing to provide an explanation and without any consequences. Ten children were not allowed to participate by their parents, resulting in the total sample size of 479. The study was approved by the Ethical Committee of the Faculty of Psychology and Educational Sciences at Ghent University.

During the first visit, children were orally informed about the study by the researchers and they provided active informed consent for participation. Subsequently, background characteristics and motivation for mathematics were measured. Approximately two weeks later, during the second school visit, the experimental part took place. Because eight children were absent during the second visit (due to illness), 471 children took part in the experimental manipulation. The study had a 2 (Task Difficulty: easy-medium vs. difficult) x 2 (Instructional

Style: autonomy-supportive vs. controlling) design, thereby creating four conditions. Children in each class were randomly assigned to one of four experimental conditions, thereby preserving a gender balance within every condition. The randomization thus took place at the individual (and not the class) level, with children within one single class being randomly distributed across the four conditions. The randomization procedure was prepared before the school visit by the researchers, who also secured that participants' test form fitted with the randomly assigned condition. Participants were blind to experimental manipulation.

The experimental protocol consisted of five phases, with the experiment taking place in an entire class group. In Phase 1, the instructional style was manipulated through a vignette methodology (Aguinis & Bradley, 2014), which has been successfully used in similar previous research (e.g., Chang, Chen, Tu, & Chi, 2016; Delrue et al., 2019). Specifically, children read a comic book in which a teacher introduced math exercises in either a more autonomy-supportive or a controlling way (see Figure 2). Before handing out the comic book, the researchers asked children to imagine themselves sitting in the classroom and following the instructions of the teacher such that they got fully immersed in the situation. In the autonomy-supportive condition, the teacher used inviting language (e.g., "You can choose…" rather than "You are obligated …"), provided choice by allowing children to choose how to solve the exercises as well as the order in which they wanted to solve them, and also offered a rationale for solving the exercises (i.e., the exercises were an opportunity to practice and to perfect their skills). In the controlling condition, the teacher placed the children under pressure by using controlling language, thereby also emphasizing that children should solve the exercises in the correct order and in the way they had learned previously. To this end, children had to write down the different steps to reach their answer. Also, the exercises were introduced as a test and no rationale was provided.

After reading the comic book (i.e., the vignette), children filled out a manipulation check of the instructional style (i.e., Phase 2). In Phase 3, difficulty level was manipulated by having children work on either easy-medium or difficult math exercises for 7.5 min. In the easy-medium difficulty condition, children were offered exercises that could be solved by 57.2 to 82.6% of children of their age, whereas children in the difficult condition were offered exercises that could be solved by only 2.9 to 26.2% of children of their age (Desoete et al., 2019).

Phase 4 involved a manipulation check of the difficulty level and a post-experimental assessment, with children filling out questionnaires that measure their need-based experiences, interest/enjoyment, cognitive disengagement and irritation. Finally, Phase 5 involved of a 5-min free-choice period (Wiechman & Gurland, 2009) to measure behavioral challenge seeking.

Two researchers (one doctoral level student and one Master student) went together to every classroom. As for the experimental protocol, the researchers gave standardized instructions in each classroom. Children's regular classroom teacher was present during both the baseline assessment and the actual experiment but did not intervene. Children worked individually, although they could raise their hands to ask questions about the instruments. All questionnaires and math tasks were administered via paper-and-pencil and these materials were thoroughly screened in a pilot study to make sure everything was understandable for the target audience.

Instruments

The instruments used in the current study were presented to participants on three different moments. Pre-experimental measures encompassed participants' mathematical abilities, background characteristics, and motivation for mathematics. Mathematical abilities were retrieved from a pre-existing study when the children were in Grade 3 (Desoete et al., 2019), whereas background characteristics and motivation for mathematics were retrieved during the first school visit (in Grade 4). Post-experimental measures encompassed need experiences, interest/enjoyment, thoughts on disengagement, irritation and behavioral challenge seeking and were all retrieved during the second school visit, after the experimental manipulation took place. Unless indicated otherwise, all instruments relied on a 5-point Likert scale ranging from 1 (not at all) to 5 (very much).

Pre-experimental measures.

Mathematical abilities. Children completed the Kortrijk Arithmetic Test Revision version for the third grade (Kortrijkse Rekentest Revision, KRT-R; Baudonck et al., 2006) when they were in Grade 3 (see Desoete et al., 2019). Because there was an influx of new students in Grade 4, who did not complete the KRT-R, analyses involving math abilities were limited to 406 children (i.e., 84.76% of the sample). The KRT-R is a widely used standardized test in Belgium combining 30 exercises in mental arithmetic and 30 number knowledge exercises. For the current study, the total raw score (range = 0 - 60) was used. The reliability of this total score has proven to be good (Baudonck et al., 2006).

Background characteristics. Information on age and gender was retrieved from the children during the first visit to the classrooms. In addition, the teacher reported whether or not the child had a clinical diagnosis of Mathematical Learning Disabilities (MLD).

Motivation for mathematics. Children's motivation for mathematics was measured using an adapted measure of the Self-Regulation Questionnaire for Reading Motivation (De Naeghel et al., 2012). There were items tapping into autonomous motivation (e.g., "I count because arithmetic is fun"; eight items; $\alpha = .90$) and items tapping into controlled motivation (e.g., “I count because I do not want to disappoint others”; nine items; $\alpha = .77$).

Post-experimental measures.

Manipulation check. The perceived autonomy support (nine items, $\alpha = .90$) of instructions within the comic book was measured with a self-constructed questionnaire closely connected to the story, to serve as a manipulation check. This was done immediately after children finished reading the comic book. Five items tapped into perceived control and four items tapped into perceived autonomy support. For the manipulation check of autonomy support, a difference score was calculated (perceived autonomy support – perceived control). The closer the score to -4, the more controlling the teacher was experienced, whereas the closer the score to +4, the more autonomy-supportive the teacher was experienced. A sample item of perceived autonomy support is “The teacher tells me that learning math is important, for instance, when you want to find out whether you received the correct change in a shop”. A similar manipulation check was used for the difficulty manipulation (four items, α = .91), which children filled out after solving the math exercises. Two items tapped into perceived easiness and two items tapped into perceived difficulty. A difference score was calculated in order to measure perceived difficulty (perceived difficulty – perceived easiness). The closer the score to -4, the easier the exercises were experienced, whereas a score closer to +4 indicated that the exercises were perceived as very difficult. An example item for perceived difficulty is “I found it hard to solve the exercises I got from the teacher”.

Disengagement. The disengagement (e.g., “While solving the exercises, I thought about giving up”) subscale of the Automatic Self-Talk Questionnaire for Sports (Zourbanos, Hatzigeorgiadis, Chroni, Theodorakis, & Papaioannou, 2009) was adapted to the educational context to measure participants' inner speech or thoughts (self-talk) about disengaging while solving the exercises (five items, α = .85). Although self-reported herein, self-reported self-talk has been found to correlate substantially with self-talk as coded by independent raters, while using a thinking-aloud procedure during task conduction (De Muynck et al., 2017).

Need satisfaction and frustration. Autonomy satisfaction (three items, α = .69), autonomy frustration (four items, α = .79), competence satisfaction (four items, α = .79) and competence frustration (four items, α = .81) were measured with a child version of the Basic Psychological Need Satisfaction and Need Frustration Scale (BPNSNFS; Chen et al., 2015; van der Kaap-Deeder et al., 2015). One item for autonomy satisfaction was omitted from the original scale, since reliability analysis revealed that the reliability of the subscale was improved by removing this item ("I had the feeling that the exercises of the teacher were really interesting for me"). Sample items are "I felt like I could choose to solve the exercises" (autonomy satisfaction), "I felt obligated to solve the exercises" (autonomy frustration), "I was confident that I could solve the exercises" (competence satisfaction) and "While I was solving the exercises, I felt uncertain about my performance" (competence frustration).

Intrinsic motivation. A child-friendly version of the Intrinsic Motivation Inventory (Ryan, 1982; Mabbe et al., 2018), adapted to the educational context, was used to measure interest/enjoyment (e.g., "While I was making the exercises, I thought about how much I liked it"; seven items, α = .89) and irritation (e.g., "I was annoyed while solving the exercises"; four items, α = .84).

Behavioral challenge seeking. A free-choice paradigm (Wiechman & Gurland, 2009) was implemented as an indicator of behavioral challenge seeking. After having completed the questionnaires, participants were herein provided the choice between exercises of easy (i.e. eligible for third graders), medium (i.e. eligible for fourth graders), or hard (i.e. eligible for fifth graders) difficulty to work on for another 5 min. Every set contained 20 items, selected from the KRT-R (Baudonck et al., 2006), thereby containing 10 items on mental arithmetic and 10 items on number knowledge. Independent of condition, 158 children chose the easy exercises (33.5%), 233 children chose the medium exercises (49.5%), and 80 children chose the difficult exercises (17%).

Plan of Analyses

First, Multivariate Analysis of Variance (MANOVA) was used to examine whether conditions differed from each other before the manipulations took place. Therefore, the two manipulations were entered as fixed factors in the model to investigate their effect on the continuous baseline variables. Chi-square test was used to examine if clinical diagnosis of MLD was equally distributed across conditions. Second, the effectiveness of the manipulations was evaluated by conducting MANOVA with instructional style and difficulty level as between-subject factors and the manipulation check variables as dependent variables. Further, to investigate the main and interaction effects of difficulty level and instructional style on the outcome variables (Research Goal 1), a Multivariate Analysis of Covariance (MANCOVA) was performed with difficulty level and instructional style as between-subjects variables and the outcome variables as dependent variables. Next, to investigate the mediating role of psychological need experiences (Research Goal 2), a latent Structural Equation Model (SEM) was tested using the lavaan package of R (Rosseel, 2012; R Core Team, 2014). Covariances were allowed between all need experiences in the analysis. Regression parameters were estimated using the two-step approach (Hunter & Gerbing, 1982; Lance, Cornwell, & Mulaik, 1988) and bootstrapping (1000 iterations). In the first step, the measurement model was tested. In the second step, the full structural model was tested, fixing the item loadings on the latent factors to the parameter estimates retrieved in the first step of the analysis. Goodness-of-fit was evaluated using the fit measures (cut-off values: .06 for root mean square error of approximation (RMSEA), .08 for standardized root mean square residual (SRMR), .95 for comparative fit index (CFI)) of Hu and Bentler (1999). In all analyses, we controlled for math ability, autonomous motivation and controlled motivation as covariates. Finally, for the third goal it was examined if the autonomous and controlled motivation of the children would alter the impact of our experimental factors and thereby function as a moderator. This was done by regressing the outcome variables separately on difficulty, style, the potential moderator and the interactions between the potential moderator and difficulty and style. Because there were two potential moderators (autonomous motivation, controlled motivation), two experimental factors (task difficulty; instructional style) and eight outcome variables, 32 interactions have been tested (with post hoc Bonferroni correction). The interaction terms were calculated by multiplication of the standardized predictors and the standardized moderators (Aiken, West, & Reno, 1991; Mabbe et al., 2018). When a significant result with one of the moderators emerged, two subgroups were created based on participants scores for the moderator, to get insight into the nature of the interaction effect. More specifically, follow-up ANOVA's were conducted within a group scoring high (≥ *M* + 1*SD*) on the moderator and within a group scoring low on the moderator (≤ *M* - 1*SD*).

Results

Preliminary Analyses

Table 1 presents descriptives and the correlations between study variables. The MANOVA revealed that neither difficulty level, $F(4, 391) = 1.01$, $p = .404$, $\eta_p^2 = .01$, nor instructional style, $F(4, 391) = 0.91$, $p = .460$, $\eta_p^2 = .01$, yielded an effect on autonomous motivation, controlled motivation, math abilities, and age. These findings indicate that children located in different conditions did not differ on these variables at baseline, that is, before the manipulation took place. Furthermore, a chi-squared tests showed that clinical diagnosis of MLD ($n = 28$; 5.8%) and experimental manipulations were unrelated, $\chi^2(3) = 3.86$, $p = .277$, indicating that children with MLD were equally distributed across conditions.

Furthermore, the MANOVA on the manipulation check variables provided evidence for a significant multivariate effect of both difficulty level, $F(2, 464) = 50.83$, $p < .001$, $\eta_p^2 = .18$, and instructional style $F(2, 464) = 942.30$, $p < .001$, $\eta_p^2 = .80$. Follow-up ANOVA's indicated that children in the autonomy-supportive conditions experienced the instructions as more autonomy-supportive ($M = 1.98$, $SD = 1.09$) then did children in the controlling conditions ($M = -2.27$, $SD = 1.03$), whereas children in the easy-medium conditions perceived the exercises as less difficult ($M = -1.17$, $SD = 2.13$) compared to children in the difficult conditions ($M = 0.75$, $SD = 2.01$).

Primary Analyses

Research Goal 1: The role of task difficulty and instructional style. The multivariate results of the MANCOVA revealed that both difficulty level, $F(8, 370) = 10.49$, $p < .001$, $\eta_p^2 = .19$, and instructional style, $F(8, 370) = 2.78$, $p = .005$, $\eta_p^2 = .06$, had a significant multivariate effect, whereas their multivariate interaction was non-significant, $F(8, 370) = 1.53$, $p = .145$, $\eta_p^2 = .03$. These effects emerged after controlling for the multivariate effects of the covariates autonomous motivation, $F(8, 370) = 24.31$, $p < .001$, $\eta_p^2 = .35$, controlled motivation, $F(8, 370) = 3.91$, $p < .001$, $\eta_p^2 = .08$, and math ability, $F(8, 370) = 8.05$, $p < .001$, $\eta_p^2 = .15$. The results of follow-up univariate analyses of each of the manipulated variables and covariates can be found in Table 2, while the means of the different outcomes of the respective conditions are reported in Table 3. Difficulty level had a significant effect in the expected direction on all outcome variables, except for the non-significant effect on autonomy satisfaction. Children solving the more difficult exercises reported more autonomy and competence frustration and less competence satisfaction, they felt more irritated and perceived the exercises to be less enjoyable and interesting. In addition, they reported more cognitive disengagement and chose less difficult exercises in the free-choice period afterwards. The effects for instructional style were limited, with children in the autonomy-supportive conditions reporting greater autonomy satisfaction compared to those in the controlling conditions. Although instructional style tended to have an additional effect on interest/enjoyment, this effect was only marginally significant. As for the interaction, difficulty level and instructional style interacted in the prediction of autonomy frustration (see Figure 3), competence satisfaction (see Figure 4) and competence frustration (see Figure 5). As can be noticed in these figures, the harmful effects (i.e. more need frustration, less competence satisfaction) of having to solve difficult, relative to easy-medium, exercises were dampened when the exercises were introduced in an autonomy-supportive manner. Specifically, when the exercises were introduced in an autonomy-supportive way, the difference between the difficult and easy-medium exercises in autonomy frustration was absent

(p = .999; η_p^2 = .00), while being minimal in the case of competence satisfaction (p < .001; η_p^2 = .08), and competence frustration (p = .010; η_p^2 = .03). In contrast, when introduced in a controlling way, the difference between the difficult and easy-medium exercises in terms of autonomy frustration (p = .002; η_p^2 = .05), competence satisfaction (p < .001; η_p^2 = .22) and competence frustration (p < .001; η_p^2 = .19) was more pronounced. Finally, in a more explorative way, the impact of instructional style and difficulty level on children's performance was examined. See Supplementary material Part 1 (and Supplementary Table 1) for results of these analyses.

Research Goal 2: The explanatory role of need-based experiences. To understand the effects of task difficulty, instructional style and their interaction, need-based experiences were modelled as explanatory variables. The results of the SEM-analysis indicated that the proposed mediation model yielded an acceptable fit, $\chi^2(581) = 1234.34$, p < .001; CFI = .91; RMSEA = .05; SRMR = .07. As can be noticed in Figure 6, instructional style related to autonomy satisfaction, while task difficulty yielded effects on autonomy frustration and both competence satisfaction and frustration. Instructional style and difficulty level interacted in the prediction of autonomy frustration and competence satisfaction as well as frustration, which is in line with the results obtained via the MANCOVA. Several of the need-based experiences related to the various outcomes, with competence satisfaction relating positively and autonomy frustration relating negatively (albeit marginally) to interest/enjoyment. Irritation was predicted by the same set of need-based experiences, albeit in opposite ways, with autonomy frustration thus yielding a positive contribution and competence satisfaction a negative contribution. Cognitive disengagement was predicted by three different need-based experiences, that is, both autonomy and competence frustration (positively) and competence satisfaction (negatively). Finally, competence satisfaction was positively related to behavioral challenge seeking. Thus, the need-based experiences related to the outcomes in hypothesized ways, with the exception of the positive relation between autonomy satisfaction and irritation. This association should be interpreted with caution in light of its non-significance at the correlation level (r = -.01). Subsequent analyses on this specific result can be found in Part 2 of the supplementary materials.

Direct and indirect effects and confidence intervals for the parameters can be found in Table 4. Even though instructional style only predicted autonomy satisfaction, small direct effects were identified with a more controlling style predicting higher disengagement and irritation and relating to less interest/enjoyment. Importantly, as can be noticed in Table 4, all indirect effects from the manipulated variables to interest/enjoyment disengagement, irritation and challenge seeking via one or multiple need measures were (marginally) significant.

Research Goal 3: Do interpersonal differences in motivation matter? As can be noticed in Table 2, several interesting main effects of children's motives for mathematics in the prediction of the task-specific outcomes were obtained. Children with more autonomous motivation for mathematics experienced more need satisfaction and less need frustration, they enjoyed solving the exercises more and reported less irritation and cognitive disengagement. Finally, they also worked on a more challenging set of exercises during the free-choice period. Children with more controlled motivation reported greater frustration of both needs.

Next, through a series of regression analyses, it was examined if autonomous and controlled motivation moderated the relation between instructional style and/or difficulty level on the one hand and on the outcomes on the other hand. Out of 32 tested interactions, only three appeared significant.

First, autonomous motivation moderated the relation between difficulty level and cognitive disengagement, β = -.09, p = .037. More difficult exercises predicted more cognitive disengagement among individuals with lower ($\leq M$ - 1SD; p = .099; η_p^2 = .03) but not among participants with higher levels of autonomous motivation ($\geq M$ + 1SD; p = .511; η_p^2 = .01).

Then, controlled motivation served as a moderator in two additional cases, that is, in the relation between instructional style and autonomy satisfaction, $\beta = .09$, $p = .042$, and in the relation between task difficulty and competence satisfaction, $\beta = .09$, $p = .041$. Follow-up analyses indicated that there was a significant decline in autonomy satisfaction in the controlling, relative to the autonomy-supportive, instructions among participants with lower levels of controlled motivation ($\leq M$ - 1*SD*; $p = .005$; $\eta_p^2 = .11$) but not among participants with higher levels of controlled motivation ($\geq M$ + 1*SD*; $p = .858$; $\eta_p^2 = .00$). Similarly, there was a significant decline in competence satisfaction for difficult, compared to easier, exercises among participants low in controlled motivation ($\leq M$ - 1*SD*; $p < .001$; $\eta_p^2 = .21$), not among participants high in controlled motivation ($\geq M$ + 1*SD*; $p = .099$; $\eta_p^2 = .03$). In addition to the minimal number of interactions, they were no longer significant when a Bonferroni correction (.05/32 = .002) was applied.

Discussion

Given substantial individual differences in the pacing of children's development (Claessens et al., 2009; Claessens & Engel, 2013), it is not easy for teachers to monitor and guide children's learning in a motivating way. Although offered learning tasks can best be situated within children's zone of proximal development (Moll, 2013; Vygotsky, 1978, 1987), for most learners, there will be at least some moments where they will face too difficult tasks. In the current study, we sought to investigate whether such difficult tasks come with a range of motivational, affective, and behavioral costs and whether an autonomy-supportive instructional style serves as a useful strategy to dampen or even overcome the presumed negative consequences of too difficult math tasks. In doing so, we also addressed the role of children's need-based experiences as underlying explanatory mechanisms and children's motivational differences for math as a potential moderator of the effects of manipulated task difficulty and instructional style. A number of interesting findings emerged.

Impairing Effects of Task Difficulty

As we had hypothesized, overly difficult math exercises yielded a host of negative effects. More difficult tasks undermined children's interest in math, elicited more irritation and prompted more thoughts about disengagement. The impact on cognitive disengagement (thoughts such as 'I want to stop', 'I want to get out of here'), is congruent with previous work of Patall and colleagues (2018) who reported that high school students report more emotional and behavioral disengagement on days during which they perceived their science class as more difficult than usual. The present findings extend this body of work by showing that task difficulty *causes* rather than merely covaries with a host of negative outcomes. In addition, the present findings suggest that the reported effects of task difficulty by Patall and colleagues (2018) generalize to elementary children, math education, and indices of cognitive disengagement. Preliminary findings on cognitive disengagement were reported by Eunsook (1999), who found that students worried more when filling out a difficult math task. Also, in an experimental study among adolescent tennis players, negative feedback, another competence-relevant factor, was found to enhance negative inner-speech relative to the provision of positive feedback (De Muynck et al., 2017).

Interestingly, too difficult exercises not only prompted more negative experiences during task engagement, but also when the children had finished working on the assigned exercises. That is, those randomly assigned to the difficult condition, chose less challenging exercises afterwards. Presumably, having experienced a decrement in competence satisfaction and an increase in competence frustration during the experimental phase, children no longer wanted to be exposed to failure experiences and, hence, selected easier tasks, which better guarantee a successful outcome. Alternatively, children who received the easy exercises during the experimental induction may have chosen to set the barrier higher and, therefore, choose a more challenging set of exercises. Without a control group, it is impossible to conclude whether difficult exercises forestall competence and result in reduced challenge seeking or whether easy exercises promote greater challenge seeking by promoting children's sense of confidence. Yet, the present findings indicate that the difficulty level of mathematical tasks not only impacts on children's motivational, cognitive and affective functioning, but even on their behavior as such.

This behavioral finding is in line with a recent study by Mabbe and colleagues (2018) who found that normative, positive feedback, which was competence-affirming, led children to choose more difficult puzzles during a free-choice period compared to those getting negative feedback (see also van der Kaap-Deeder et al., 2016). The present research extends this line of work by showing that another competence-relevant factor, that is, task difficulty, carries similar effects, knowing that math exercises were on average also less intrinsically motivating than the fun puzzles that elementary school children in the Mabbe and colleagues (2018) study were asked to solve.

In terms of the explanatory mechanisms, autonomy frustration as well as both competence satisfaction and frustration accounted for the effects of task difficulty, with less satisfaction and more frustration together explaining why more difficult tasks impaired motivational, cognitive, affective, and behavioral outcomes. The finding that competence need-experiences explain the effects of task difficulty aligns with previous work on perceived difficulty (Patall et al., 2018) and negative feedback (De Muynck et al., 2017; Mabbe et al., 2018), another competence-relevant factor. However, the present study extends this body of work in two ways. First, in the current study, not only need satisfaction but also need frustration was modeled as an explanatory variable, which provided us with more detailed insights into the paths leading to experiences in the mathematics classroom. Second, even though the task difficulty manipulated primarily and most strongly competence need experiences, task difficulty also elicited autonomy frustration, regardless of the instructional style. Presumably, when solving difficult exercises, children may gradually find out that they are incapable to solve them, which may elicit pressure on them to perform well. Such elevated pressure would then be indicative for their increased autonomy frustration.

Dampening Role of Autonomy-Supportive Instructions

One of the most promising and novel findings was the observation that autonomy-supportive instructions helped to dampen the increase of autonomy and competence frustration and the decrease of competence satisfaction when children were asked to solve difficult exercises. Because these need-based experiences were identified as a mechanism for why task difficulty hosts such negative effects, this finding is very promising for teachers dealing with struggling learners. While autonomy-supportive instructions completely cancelled out the autonomy-frustrating effect of difficult exercises, they helped to minimize (but did not cancel out) its competence-impairing impact. Using autonomy-supportive instructions to introduce math exercises thus proves useful to alter the ‘hardiness’ when math tasks get difficult, which yields further benefits. Indeed, by buffering the impairing effects of task difficulty on the mediating need-based experiences, the increase in irritation and cognitive disengagement and the decrease in interest/enjoyment and challenge seeking under conditions of too difficult exercises got indirectly minimized. These findings align with and extend a previous diary study (Patall et al., 2018), which equally reported evidence for the buffering role of an autonomy-supportive communication style in the prediction of competence when students had a hard class. Also, these findings are congruent with prior correlational (Carpentier & Mageau, 2013; Mouratidis, Lens, & Vansteenkiste, 2010) and experimental (De Muynck et al., 2017) work in the context of negative feedback, another competence-relevant factor, where providing negative feedback in an autonomy-supportive, relative to a controlling way was found to yield the best outcomes.

Although instructional style helped to buffer the impairing effects of task difficulty, its main effects were rather limited, with an autonomy-supportive instructional style predicting enhanced autonomy need satisfaction. This finding is congruent with previous correlational (Haerens, Aelterman, Vansteenkiste, Soenens, & Van Petegem, 2015), observational (Reeve & Jang, 2006), and experimental (Grolnick & Ryan, 1987; Mabbe et al., 2018) studies on the role of autonomy support. When compared to the effects observed for task difficulty, the effects of an autonomy-supportive instructional style appeared less robust, presumably because the difficulty manipulation was psychologically more salient to the children for a number of reasons. First, while task difficulty was a "real-life" manipulation as children had to solve exercises of a different difficulty level, instructional style was a vignette-based manipulation in which the children were asked to be personally immersed in the situation of the comic book. Children had to read the instructions in silence, but recent research suggests that socializing agents can also convey a message of control vs. autonomy support via their tone of voice (Weinstein, Zougkou, & Paulmann, 2018). Thus, if the instructions were administered in an interpersonal way, they may have carried a stronger effect. At the same time, by using this experimental vignette methodology, we maintained a maximum amount of control on the instructions given and we were capable of using a within-class randomization procedure. A second reason for the different salience of both manipulations has to do with the differential duration of the two manipulations. Children had to solve math exercises for 7.5 min, while they only read the comic book once. Thus, a one-time exposure to an autonomy-enhancing factor (i.e., instructional style) was pitted against a more ongoing exposure to a competence-thwarting factor (i.e., task difficulty). Taking also the differential timing of both manipulations into account, it is possible that as the experiment progressed, the impact of the instructional style gradually waned as it was overpowered by the more salient competence-decreasing impact of high task difficulty. Future research may repeatedly expose children to a differential instructional and guidance style (see Reeve & Tseng, 2011) to balance both manipulations. Moreover, while the current study used the experimental vignette methodology (Aguinis &

Bradley, 2014), future research should try to replicate our pattern of findings by using real teachers, instead of a teacher depicted in a comic book. Doing this would help to increase the ecological validity of the present findings.

The Role of Children's Motives for Mathematics

We did not only consider an autonomy-supportive, relative to controlling, instructional style as a moderator, but also addressed the role of motivational differences between children in math. As children progress through elementary school, interpersonal differences in their autonomous and controlled motivation for mathematics emerge (Baten & Desoete, 2018). The critical question is then whether teachers need to adjust task difficulty and their communication style according to these differences in motivation. Although the topic of motivational tailoring is of importance from a practical perspective, this issue is under-researched within the SDT-tradition and the motivation literature at large (but see Flunger et al., 2019; Mouratidis et al., 2011). Presumably, because of the universality claims characterizing SDT, there was less of an urgency to examine these issues. Yet, although need satisfaction would be conducive to all children's interest and growth, the pathways towards need satisfaction may somewhat vary (Soenens et al., 2015; Vansteenkiste et al., 2019). Indeed, some teachers are convinced that controlled motivated students would function most optimally when being exposed to a demanding and controlling teacher (De Meyer et al., 2016).

Independent of the manipulated task difficulty and instructional style, children bringing more autonomous motivation to the task felt less irritated during task engagement, found the exercises to be more interesting, picked more challenging exercises to work on when asked to work independently and fewer negative thoughts on disengagement came to their mind. In contrast, those high in controlled motivation reported more need frustration during task engagement; the task was experienced as a daunting duty for which they felt low competence.

Clearly then, while autonomous motivation served as a motivational resource, controlled motivation is a motivational vulnerability factor.

Children's type of motives for mathematics also interacted with the manipulations, even though only small effects were identified and these disappeared when taking multiple testing into account. Specifically, the autonomy-reducing effect of controlling, relative to autonomy-supportive, instructions and the competence-impairing effect of difficult, relative to easier, exercises only appeared for those with lower levels of controlled motivation. Further, especially children with less autonomous motives for mathematics, reported more cognitive disengagement in response to having to solve difficult tasks. These interaction findings need to be interpreted with caution and the limited number of interaction findings contrasts with the robustness of the main effects. A similar limited number of interactions have been reported in previous studies in the context of science (Flunger et al., 2019) and physical education (e.g., De Meyer et al., 2016). Thus, before drawing any strong conclusions regarding the moderating role of motivational differences, the current pattern of findings needs replication.

Practical Implications

The results of the current study indicate that offering too difficult math tasks at school impairs children's motivational, cognitive, and affective experiences in the classroom. Even though teachers may be tempted to offer only easy tasks in light of these findings, thereby lowering their standards all together, such an approach may also come with some disadvantages. Indeed, without sufficient challenge, children's learning process risks to stagnate (Shabani, Khatib, & Ebadi, 2010). For children to not just practice but also to extend their knowledge and skills, assigned exercises need to fall within their zone of proximal development (Moll, 2013; Vygotsky, 1978; Vygotsky, 1987). In many cases, searching for such optimally challenging tasks implies that teachers need to walk on a tightrope, with the risk that children are sometimes provided with too difficult and other times with too easy exercises. The present study then yields the promising message that the motivational, affective, and behavioral costs that too difficult tasks cause can be minimized if teachers pay attention to their communication style. This is a hopeful finding, perhaps especially for children who dispose of less mathematical abilities and who may more easily be confronted with too difficult exercises. Preventing them from disengaging improves their chances for later academic and job success (Duncan et al., 2007; Duncan & Magnuson, 2011) and prevents children with Mathematical Learning Disabilities to even fall further behind (Clements, Fuson, & Sarama, 2017; Clements & Sarama, 2011).

What does it mean specifically to act in an autonomy-supportive way when assigning difficult tasks? First, an autonomy-supportive teacher empathizes with children, thereby highlighting that they may possibly struggle with the activity (Soenens, Deci, & Vansteenkiste, 2017; Vansteenkiste, Niemiec, & Soenens, 2010). Second, they try to provide a meaningful rationale for assigning the more difficult math exercises and, finally, they can build in choices regarding the timing, order, or way of solving the difficult exercises (De Muynck, Soenens, Degraeuwe, Vande Broek, & Vansteenkiste, 2019; Reeve, Nix, & Hamm, 2003). When applying these different autonomy-supportive strategies, the way children cope with the encountered difficult tasks may be altered. Specifically, they may perceive the task as an opportunity for growth rather than as an evaluative and threatening duty. These differential perceptions of challenge versus threat may then encourage them to carry on instead of giving up (Adie, Duda, & Ntoumanis, 2008).

A second recommendation for teachers is to adjust the difficulty level of assigned tasks to children’s capacities (Moll, 2013; Vygotsky, 1978, 1987). This suggestion for scaffolding (Shabani et al., 2010) follows from the observation that an autonomy-supportive instructional style primarily attenuates but does not completely cancel out the adverse impact of too difficult tasks. If teachers want to preserve children’s interest and prevent a drop in disengagement, they do well to offer activities for which children feel competent. In doing so, they may gradually increase the difficulty level of the task such that children increasingly build up a sense of mastery rather than setting the bar too high from the beginning, thereby eliciting a sense of failure. Although some teachers may hold the belief that children would choose the easy way out after making a set of math exercises of easy-medium difficulty, the present study suggests, on the contrary, that they increase their own standards by choosing more challenging exercises when left by themselves. More broadly, the present findings suggest that teachers do well to hold trust in children's capacity to uplift their own learning process, a belief that precisely characterizes need-supportive teachers (Aelterman et al., 2019).

Limitations

As is the case for any study, a number of limitations deserve being mentioned. First, although the vignette-based manipulation appeared effective, such a manipulation may be fairly difficult for elementary school children, especially considering their age, compared to the oral provision of instructions. In addition, oral instructions from an actual math teacher rather than written instructions in a comic book would improve the ecological validity of the study. Because this study revealed a significant moderating effect of even a mild autonomy support, the effect might even be bigger if the instructions were given orally in classrooms. Manipulating communication style in an interpersonal way instead of merely via written vignettes is where a replication study should focus on.

Second, because a neutral condition was not included, either in terms of difficulty level or instructional style, it remains unclear whether the observed differences between conditions are due to the growth-conducive role of autonomy support and easy-medium exercises, or the growth-impeding role of difficult exercises and a controlling communication style, or both. An alternative is to include a condition that contains a mix of different instructional styles instead of a single style, which may be more fitting with the daily teaching reality. Under these ambiguous circumstances, individual differences in motivational orientation may have played a more significant role with control- and autonomy-oriented learners being sensitive for, respectively, the more controlling and autonomy-supportive features of the manipulation. A final methodological improvement would involve deconstructing the global autonomy-supportive approach into its facets (i.e., inviting language, choice, rationale) to examine whether they carry in isolation or in combination the strongest effect (e.g., Deci, Eghrari, Patrick, & Leone, 1994).

A third limitation concerns generalization across age groups and across teaching areas. As this study only sampled fourth grade elementary school children and focused on mathematics only, the question is whether the current findings generalize to different age groups or different subjects. Finally, it is important to mention that the mediating variables (i.e. autonomy and competence satisfaction/frustration) were measured after instead of during task completion and their assessment co-occurred with the measurement of the outcomes. In ideal circumstances, the presumed mediators are assessed prior to the outcomes, which justifies modelling them as intervening variables in an integrated model. Indeed, given their concurrent assessment, the observed association between the mediators and the outcomes may go in both directions, with the mediators (e.g., competence satisfaction) not only driving the outcomes (e.g., interest) but also the other way around.

Conclusion

Too difficult math exercises appear to result in a loss of interest and challenge seeking as well as increased irritation and cognitive disengagement. However, as children progress through elementary school, a confrontation with increasing math difficulty seems inevitable. In addition, children who dispose of less mathematical abilities or children with MLD may more easily be confronted with too difficult math tasks. This study revealed that even with a subtle manipulation of autonomy-support, the negative effects of too difficult math exercises could be buffered. Providing children with a meaningful rationale, taking their perspective and building in choices, helps to preserve their interest and stimulates them to accept new math challenges and practice in their zone of proximal development, which fosters them to extend their skills. As such, teachers may improve their pupils' chances for later academic and job success.

References

Adie, J. W., Duda, J. L., & Ntoumanis, N. (2008). Autonomy support, basic need satisfaction and the optimal functioning of adult male and female sport participants: A test of basic needs theory. *Motivation and Emotion*, *32*, 189–199. https://doi.org/10.1007/s11031-008-9095-z

Aelterman, N., Vansteenkiste, M., Haerens, L., Soenens, B., Fontaine, J. R. J., & Reeve, J. (2019). Toward an integrative and fine-grained insight in motivating and demotivating teaching styles: The merits of a circumplex approach. *Journal of Educational Psychology*, *111*, 497–521. https://doi.org/10.1037/edu0000293

Aguinis, H., & Bradley, K. J. (2014). Best practice R-recommendations for designing and implementing experimental vignette methodology studies. *Organizational Research Methods*, *17*, 351–371. https://doi.org/10.1177/1094428114547952

Aiken, L. S., West, S. G., & Reno, R. R. (1991). *Multiple regression : testing and interpreting interactions*. Sage Publications.

Ashcraft, M. H., Krause, J. A., & Hopko, D. R. (2007). Is math anxiety a mathematical learning disability? In D. B. Berch & M. M. M. Mazzocco (Eds.), *Why is math so hard for some children? The nature and origins of mathematical learning difficulties and disabilities* (pp. 329–348). Baltimore: Paul H. Brookes.

Assor, A., Kaplan, H., & Roth, G. (2002). Choice is good, but relevance is excellent: Autonomy-enhancing and suppressing teacher behaviours predicting students' engagement in schoolwork. *British Journal of Educational Psychology*, *72*, 261–278.

Bartholomew, K. J., Ntoumanis, N., Mouratidis, A., Katartzi, E., Thøgersen-Ntoumani, C., & Vlachopoulos, S. (2018). Beware of your teaching style: A school-year long investigation of controlling teaching and student motivational experiences. *Learning and Instruction*, *53*, 50–63. https://doi.org/10.1016/j.learninstruc.2017.07.006

Bartholomew, K. J., Ntoumanis, N., Ryan, R. M., & Thøgersen-Ntoumani, C. (2011). Psychological need thwarting in the sport context: Assessing the darker side of athletic experience. *Journal of Sport and Exercise Psychology*, *33*, 75–102. https://doi.org/10.1123/jsep.33.1.75

Baten, E., & Desoete, A. (2018). Mathematical (dis)abilities within the Opportunity-Propensity Model: The choice of math test matters. *Frontiers in Psychology*, *9*, 667. https://doi.org/10.3389/fpsyg.2018.00667

Baudonck, M., Debusschere, A., Dewulf, B., Samyn, F., Vercaemst, V., & Desoete, A. (2006). *De Kortrijkse Rekentest Revision KRT-R. [The Kortrijk Arithmetic Test Revision KRT-R]*. Kortrijk: CAR Overleie.

Black, A. E., & Deci, E. L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination theory perspective. *Science Education*, *84*, 740–756. https://doi.org/10.1002/1098-237X(200011)84:6<740::AID-SCE4>3.0.CO;2-3

Carpentier, J., & Mageau, G. A. (2013). When change-oriented feedback enhances motivation, well-being and performance: A look at autonomy-supportive feedback in sport. *Psychology of Sport and Exercise*, *14*, 423–435. https://doi.org/10.1016/j.psychsport.2013.01.003

Cerasoli, C. P., Nicklin, J. M., & Ford, M. T. (2014). Intrinsic motivation and extrinsic incentives jointly predict performance: A 40-year meta-analysis. *Psychological Bulletin*, *140*, 980–1008. https://doi.org/10.1037/a0035661

Chang, Y.-K., Chen, S., Tu, K.-W., & Chi, L.-K. (2016). Effect of autonomy support on self-determined motivation in elementary physical education. *Journal of Sports Science & Medicine*, *15*, 460–466. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/27803624

Chen, B., Vansteenkiste, M., Beyers, W., Boone, L., Deci, E. L., Van der Kaap-Deeder, J., …

Verstuyf, J. (2015). Basic psychological need satisfaction, need frustration, and need strength across four cultures. *Motivation and Emotion*, *39,* 216–236. https://doi.org/10.1007/s11031-014-9450-1

Claessens, A., Duncan, G., & Engel, M. (2009). Kindergarten skills and fifth-grade achievement: Evidence from the ECLS-K. *Economics of Education Review*, *28*, 415–427. https://doi.org/10.1016/j.econedurev.2008.09.003

Claessens, A., & Engel, M. (2013). How important is where you start? early mathematics knowledge and later school success. *Teachers College Record*, *115*.

Clements, D. H., Fuson, K. C., & Sarama, J. (2017). The research-based balance in early childhood mathematics: A response to Common Core criticisms. *Early Childhood Research Quarterly*, *40*, 150–162. https://doi.org/10.1016/j.ecresq.2017.03.005

Clements, D. H., & Sarama, J. (2011). Early childhood mathematics intervention. *Science (New York, N.Y.)*, *333*, 968–970. https://doi.org/10.1126/science.1204537

Curran, T., Hill, A. P., & Niemiec, C. P. (2013). A conditional process model of children's behavioral engagement and behavioral disaffection in sport based on self-determination theory. *Journal of Sport & Exercise Psychology*, *35*, 30–43.

De Meyer, J., Soenens, B., Vansteenkiste, M., Aelterman, N., Van Petegem, S., & Haerens, L. (2016). Do students with different motives for physical education respond differently to autonomy-supportive and controlling teaching? *Psychology of Sport and Exercise*, *22,* 72–82. https://doi.org/10.1016/j.psychsport.2015.06.001

De Muynck, G.-J., Soenens, B., Degraeuwe, L., Vande Broek, G., & Vansteenkiste, M. (2019). Towards a more refined insight in the critical motivating features of choice: An experimental study among recreational rope skippers. *Psychology of Sport & Exercise*, *in press*.

De Muynck, G.-J., Vansteenkiste, M., Delrue, J., Aelterman, N., Haerens, L., & Soenens, B.

(2017). The effects of feedback valence and style on need satisfaction, self-talk, and perseverance among tennis players: An experimental study. *Journal of Sport and Exercise Psychology*, *39*, 67–80. https://doi.org/10.1123/jsep.2015-0326

De Naeghel, J., Van Keer, H., Vansteenkiste, M., & Rosseel, Y. (2012). The relation between elementary students’ recreational and academic reading motivation, reading frequency, engagement, and comprehension: A Self-Determination Theory perspective. *Journal of Educational Psychology*, *104*, 1006–1021. https://doi.org/10.1037/a0027800

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating internalization: The Self-Determination Theory perspective. *Journal of Personality*, *62*, 119–142. https://doi.org/10.1111/j.1467-6494.1994.tb00797.x

Delrue, J., Soenens, B., Morbée, S., Vansteenkiste, M., & Haerens, L. (2019). Do athletes’ responses to coach autonomy support and control depend on the situation and athletes’ personal motivation? *Psychology of Sport and Exercise*, *43*, 321–332. https://doi.org/10.1016/j.psychsport.2019.04.003

Desoete, A., Baten, E., Vercaemst, V., De Busschere, A., Baudonck, M., & Vanhaeke, J. (2019). Metacognition and motivation as predictors for mathematics performance of Belgian elementary school children. *ZDM Mathematics Education*. https://doi.org/10.1007/s11858-018-01020-w

Dolcos, S., & Albarracin, D. (2014). The inner speech of behavioral regulation: Intentions and task performance strengthen when you talk to yourself as a You. *European Journal of Social Psychology*, *44*, 636–642. https://doi.org/10.1002/ejsp.2048

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., … Japel, C. (2007). School readiness and later achievement. *Developmental Psychology*, *43*, 1428–1446. https://doi.org/10.1037/0012-1649.43.6.1428

Duncan, G. J., & Magnuson, K. (2011). The nature and impact of early achievement skills, attention and behavior problems. In G. J. Duncan & R. J. Murnane (Eds.), *Whither opportunity: Rising inequality, schools, and children's life chances* (pp. 47–69). New York: Russel Sage.

Eunsook, H. (1999). Test anxiety, perceived test difficulty, and test performance: Temporal patterns of their effects. *Learning and Individual Differences*, *11*, 431–447.

Flunger, B., Mayer, A., & Umbach, N. (2019). Beneficial for some or for everyone? Exploring the effects of an autonomy-supportive intervention in the real-life classroom. *Journal of Educational Psychology*, *111*, 210–234. https://doi.org/10.1037/edu0000284

Froiland, M. J., Davison, M. L., & Worrell, F. C. (2016). Aloha teachers: teacher autonomy support promotes Native Hawaiian and Pacific Islander students' motivation, school belonging, course-taking and math achievement. *Social Psychology of Education*, *19*, 879–894. https://doi.org/10.1007/s11218-016-9355-9

Goemaere, S., Beyers, W., De Muynck, G. J., & Vansteenkiste, M. (2018). The paradoxical effect of long instructions on negative affect and performance: When, for whom and why do they backfire? *Acta Astronautica*, *147*, 421–430. https://doi.org/10.1016/j.actaastro.2018.03.047

Gottfried, A. E., Fleming, J. S., & Gottfried, A. W. (2001). Continuity of academic intrinsic motivation from childhood through late adolescence: A longitudinal study. *Journal of Educational Psychology*, *93*, 3–13. https://doi.org/10.1037/0022-0663.93.1.3

Haerens, L., Aelterman, N., Vansteenkiste, M., Soenens, B., & Van Petegem, S. (2015). Do perceived autonomy-supportive and controlling teaching relate to physical education students' motivational experiences through unique pathways? Distinguishing between the bright and dark side of motivation. *Psychology of Sport & Exercise*, *16*, 26–36. https://doi.org/10.1016/j.psychsport.2014.08.013

Horvath, M., Herleman, H. A., Lee Mckie, · R, Horvath, M., Herleman, · H, & Mckie, · R

Lee. (2006). Goal orientation, task difficulty, and task interest: A multilevel analysis. *Motivation and Emotion*, *30*, 171–178. https://doi.org/10.1007/s11031-006-9029-6

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*, 1–55. https://doi.org/10.1080/10705519909540118

Hunter, J. E., & Gerbing, D. W. (1982). Unidimensional measurement, second order factor analysis, and causal models. *Research in Organizational Behavior : An Annual Series of Analytical Essays and Critical Reviews*, *4*.

Jang, H. (2008). Supporting students' motivation, engagement, and learning during an uninteresting activity. *Journal of Educational Psychology*, *100*, 798–811. https://doi.org/10.1037/a0012841

Jang, H., Kim, E. J., & Reeve, J. (2012). Longitudinal test of self-determination theory's motivation mediation model in a naturally occurring classroom context. *Journal of Educational Psychology*, *104*, 1175–1188. https://doi.org/10.1037/a0028089

Jang, H., Kim, E. J., & Reeve, J. (2016). Why students become more engaged or more disengaged during the semester: A self-determination theory dual-process model. *Learning and Instruction*, *43*, 27–38. https://doi.org/10.1016/j.learninstruc.2016.01.002

Jang, H., Reeve, J., & Halusic, M. (2016). A new autonomy-supportive way of teaching that Increases conceptual learning: Teaching in students' preferred ways. *The Journal of Experimental Education*, *84*, 686–701. https://doi.org/10.1080/00220973.2015.1083522

Lance, C. E., Cornwell, J. M., & Mulaik, S. A. (1988). Limited information parameter estimates for latent or mixed manifest and latent variable models. *Multivariate Behavioral Research*, *23*, 171–187. https://doi.org/10.1207/s15327906mbr2302_3

Lepper, M. R., Corpus, J. H., & Iyengar, S. S. (2005). *Intrinsic and extrinsic motivational orientations in the classroom: Age differences and academic correlates*.

https://doi.org/10.1037/0022-0663.97.2.184
Mabbe, E., Soenens, B., De Muynck, G. J., & Vansteenkiste, M. (2018). The impact of feedback valence and communication style on intrinsic motivation in middle childhood: Experimental evidence and generalization across individual differences. *Journal of Experimental Child Psychology*, *170*, 134–160. https://doi.org/10.1016/j.jecp.2018.01.008

Moll, L. C. (2013). *Vygotski and education*. New York: Routledge.

Moller, A. C., Deci, E. L., & Elliot, A. J. (2010). Person-level relatedness and the incremental value of relating. *Personality and Social Psychology Bulletin*, *36*, 754–767. https://doi.org/10.1177/0146167210371622

Mouratidis, A. A., Vansteenkiste, M., Sideridis, G., & Lens, W. (2011). Vitality and interest–enjoyment as a function of class-to-class variation in need-supportive teaching and pupils' autonomous motivation. *Journal of Educational Psychology*, *103,* 353–366. https://doi.org/10.1037/a0022773

Mouratidis, A., Lens, W., & Vansteenkiste, M. (2010). How you provide corrective feedback makes a difference: the motivating role of communicating in an autonomy-supporting way. *Journal of Sport & Exercise Psychology*, *32*, 619–637.

Patall, E. A., Hooper, S., Vasquez, A. C., Pituch, K. A., & Steingut, R. R. (2018). Science class is too hard: Perceived difficulty, disengagement, and the role of teacher autonomy support from a daily diary perspective. *Learning and Instruction*, *58,* 220–231. https://doi.org/10.1016/j.learninstruc.2018.07.004

Reeve, J. (2009). Why teachers adopt a controlling motivating style toward students and how they can become more autonomy supportive. *Educational Psychologist*, *44*, 159–175. https://doi.org/10.1080/00461520903028990

Reeve, J. (2016). Autonomy-supportive teaching: What it is, how to do it. In *Building*

Autonomous Learners (pp. 129–152). https://doi.org/10.1007/978-981-287-630-0_7
Reeve, J., & Jang, H. (2006). What teachers say and do to support students' autonomy during a learning activity. *Journal of Educational Psychology, 98*, 209–218. https://doi.org/10.1037/0022-0663.98.1.209
Reeve, J., Jang, H., Hardre, P., & Omura, M. (2002). Providing a rationale in an autonomy-supportive way as a strategy to motivate others during an uninteresting activity. *Motivation and Emotion*, *26*, 183–207. https://doi.org/10.1023/A:1021711629417
Reeve, J., Nix, G., & Hamm, D. (2003). Testing models of the experience of self-determination in intrinsic motivation and the conundrum of choice. *Journal of Educational Psychology*, *95*, 375–392. https://doi.org/10.1037/0022-0663.95.2.375
Reeve, J., & Tseng, C.-M. (2011). Cortisol reactivity to a teacher's motivating style: the biology of being controlled versus supporting autonomy. *Motivation and Emotion*, *35*, 63–74. https://doi.org/10.1007/s11031-011-9204-2
Richter, M., Baeriswyl, E., & Roets, A. (2012). Personality effects on cardiovascular reactivity: Need for closure moderates the impact of task difficulty on engagement-related myocardial beta-adrenergic activity. *Psychophysiology*, *49*, 704–707. https://doi.org/10.1111/j.1469-8986.2011.01350.x
Rosseel, Y. (2012). lavaan : An R Package for Structural Equation Modeling. *Journal of Statistical Software*, *48*, 1–36. https://doi.org/10.18637/jss.v048.i02
Ryan, R., & Connell, J. (1989). Perceived locus of causality and internalization: Examining reasons for acting in two domains. *Journal of Personality and Social Psychology*, *57*, 749–761. https://doi.org/10.1037/0022-3514.57.5.749
Ryan, R., & Deci, E. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *The American Psychologist*, *55*, 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Ryan, R., & Deci, E. (2017). *Self-determination theory. Basic psychological needs in motivation, development and wellness*. New York, NY: Guilford Press.

Ryan, R. M. (1982). Control and information in the intrapersonal sphere: An extension of cognitive evaluation theory. *Journal of Personality and Social Psychology*. https://doi.org/10.1037/0022-3514.43.3.450

Schmierbach, M., Chung, M. Y., Wu, M., & Kim, K. (2014). No one likes to lose: The effect of game difficulty on competency, flow, and enjoyment. *Journal of Media Psychology*, *26*, 105–110. https://doi.org/10.1027/1864-1105/a000120

Shabani, K., Khatib, M., & Ebadi, S. (2010). Vygotsky's Zone of Proximal Development: Instructional implications and teachers' professional development. *English Language Teaching*, *3*. https://doi.org/10.5539/elt.v3n4p237

Sierens, E., Vansteenkiste, M., Goossens, L., Soenens, B., & Dochy, F. (2009). The synergistic relationship of perceived autonomy support and structure in the prediction of self-regulated learning. *British Journal of Educational Psychology*, *79*, 57–68. https://doi.org/10.1348/000709908X304398

Soenens, B., Deci, E. L., & Vansteenkiste, M. (2017). How Parents Contribute to Children's Psychological Health: The Critical Role of Psychological Need Support. In *Development of Self-Determination Through the Life-Course* (pp. 171–187). https://doi.org/10.1007/978-94-024-1042-6_13

Soenens, B., & Vansteenkiste, M. (2010). A theoretical upgrade of the concept of parental psychological control: Proposing new insights on the basis of self-determination theory. *Developmental Review*, *30*, 74–99. https://doi.org/10.1016/j.dr.2009.11.001

Soenens, B., Vansteenkiste, M., & Van Petegem, S. (2015). Let us not throw out the baby with the bathwater: Applying the principle of universalism without uniformity to autonomy-supportive and controlling parenting. *Child Development Perspectives*, *9*, 44–

49. https://doi.org/10.1111/cdep.12103

Steingut, R. R., Patall, E. A., & Trimble, S. S. (2017). The effect of rationale provision on motivation and performance outcomes: A meta-analysis. *Motivation Science*, *3*, 19–50. https://doi.org/10.1037/mot0000039

Van Assche, J., van der Kaap-Deeder, J., Audenaert, E., De Schryver, M., & Vansteenkiste, M. (2018). Are the benefits of autonomy satisfaction and the costs of autonomy frustration dependent on individuals' autonomy strength? *Journal of Personality*, *86*, 1017–1036. https://doi.org/10.1111/jopy.12372

van der Kaap-Deeder, J., Soenens, B., Boone, L., Vandenkerckhove, B., Stemgée, E., & Vansteenkiste, M. (2016). Evaluative concerns perfectionism and coping with failure: Effects on rumination, avoidance, and acceptance. *Personality and Individual Differences, 101*, 114–119. https://doi.org/10.1016/j.paid.2016.05.063

van der Kaap-Deeder, J., Vansteenkiste, M., Soenens, B., Loeys, T., Mabbe, E., & Gargurevich, R. (2015). Autonomy-supportive parenting and autonomy-supportive sibling interactions. *Personality and Social Psychology Bulletin*, *41*, 1590–1604. https://doi.org/10.1177/0146167215602225

Vandenkerckhove, B., Soenens, B., Van der Kaap-Deeder, J., Brenning, K., Luyten, P., & Vansteenkiste, M. (2019). The role of weekly need-based experiences and self-criticism in predicting weekly academic (mal)adjustment. *Learning and Individual Differences*, *69*, 69–83. https://doi.org/10.1016/j.lindif.2018.11.009

Vansteenkiste, M., Aelterman, N., Haerens, L., & Soenens, B. (2019). Seeking stability in stormy educational times: A need-based perspective on (de)motivating teaching grounded in selfdetermination theory. In E. Gonida & M. Lemos (Eds.), *Motivation in education at a time of global change: Theory, research, and implications for practice*. Bingley, UK: Emerald.

Vansteenkiste, M., Lens, W., & Deci, E. L. (2006). Intrinsic versus extrinsic goal contents in Self-Determination Theory: Another look at the quality of academic motivation. *Educational Psychologist*, *41*, 19–31. https://doi.org/10.1207/s15326985ep4101_4

Vansteenkiste, M., Niemiec, C. P., & Soenens, B. (2010). The development of the five mini-theories of self-determination theory: an historical overview, emerging trends, and future directions. In T. C. Urdan & S. A. Karabenick (Eds.), *The decade ahead: Theoretical perspectives on motivation and achievement* (Vol. 16A, pp. 105–165). https://doi.org/10.1108/S0749-7423(2010)000016A007

Vansteenkiste, M., & Ryan, R. M. (2013). On psychological growth and vulnerability: Basic psychological need satisfaction and need frustration as a unifying principle. *Journal of Psychotherapy Integration*, *23*, 263–280. https://doi.org/10.1037/a0032359

Vansteenkiste, M., Ryan, R. M., & Soenens, B. (2019). Basic Psychological Need Theory: Advancements, critical themes, and future directions. *Manuscript Submitted for Publication.*

Vansteenkiste, M., Simons, J., Lens, W., Sheldon, K. M., & Deci, E. L. (2004). Motivating learning, performance, and persistence: The synergistic effects of intrinsic goal contents and autonomy-supportive contexts. *Journal of Personality and Social Psychology*, *87*, 246–260. https://doi.org/10.1037/0022-3514.87.2.246

Vansteenkiste, M., Simons, J., Lens, W., Soenens, B., & Matos, L. (2005). Examining the motivational impact of intrinsic versus extrinsic goal framing and autonomy-supportive versus internally controlling communication style on early adolescents' academic achievement. *Child Development*, *76*, 483–501. https://doi.org/10.1111/j.1467-8624.2005.00858.x

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Vygotsky, L. S. (1987). Thinking and Speech. In E. Zavershneva & R. van der Veer (Eds.), *The Collected Works of L. S. Vygotsky, Problems of General Psychology* (pp. 353–366). https://doi.org/10.1007/978-981-10-4625-4_21

Wang, J., Liu, R.-D., Ding, Y., Xu, L., Liu, Y., & Zhen, R. (2017). Teacher's autonomy support and engagement in math: Multiple mediating roles of self-efficacy, intrinsic value, and boredom. *Frontiers in Psychology*, *8*, 1006. https://doi.org/10.3389/fpsyg.2017.01006

Weinstein, N., Zougkou, K., & Paulmann, S. (2018). You "have" to hear this: Using tone of voice to motivate others. *Journal of Experimental Psychology: Human Perception and Performance*, *44*, 898–913. https://doi.org/10.1037/xhp0000502

Wiechman, B. M., & Gurland, S. T. (2009). What happens during the free-choice period? Evidence of a polarizing effect of extrinsic rewards on intrinsic motivation. *Journal of Research in Personality*, *43*, 716–719. https://doi.org/10.1016/j.jrp.2009.03.008

Zourbanos, N., Hatzigeorgiadis, A., Chroni, S., Theodorakis, Y., & Papaioannou, A. (2009). Automatic self-talk questionnaire for sports (ASTQS): Development and preliminary validation of a measure identifying the structure of athletes' self-talk. *The Sport Psychologist*, *23*, 233–251. https://doi.org/10.1123/tsp.23.2.233

Table 1. Pearson Correlations Among Study Variables and Descriptive Statistics

	M (*SD*)	1	2	3	4	5	6	7	8	9	10	11	12
1. Math abilities	28.00 (10.14)												
2. Autonomous motivation	3.69 (0.98)	.28***											
3. Controlled motivation	2.78 (0.78)	-.23***	-.05										
4. Disengagement	2.06 (0.97)	-.33***	-.40***	.18***									
5. Autonomy satisfaction	2.55 (0.99)	.07	.14**	.10*	-.09^{+}								
6. Autonomy frustration	2.43 (0.98)	-.14**	-.19***	.24***	.44***	-.12**							
7. Competence satisfaction	3.21 (0.97)	.34***	.37***	-.10*	-.54***	.25***	-.33***						
8. Competence frustration	2.55 (1.01)	-.28***	-.22***	.22***	.50***	-.02	.49***	-.53***					
9. Interest/Enjoyment	3.04 (1.05)	.25***	.57***	-.06	-.62***	.18***	-.38***	.58***	-.36***				
10. Irritation	1.99 (0.98)	-.25***	-.36***	.18***	.70***	-.01	.50***	-.49***	.47***	-.63***			
11. Behavioral challenge seeking	1.83 (0.69)	.39***	.49***	-.14**	-.45***	.11*	-.27***	.46***	-.38***	.52***	-.45***		
12. Difficulty	-	-.03	-.00	.05	.23***	-.00	.12*	-.32***	.27***	-.21***	.19***	-.16***	
13. Instructional style	-	.02	.02	-.05	.05	-.20***	-.05	-.01	-.01	-.04	-.04	.02	-.01

Note: *M* = Mean, *SD* = Standard Deviation;
Difficulty coded as '0' for easy-medium and '1' for difficult; Instructional style coded as '0' for autonomy-support and '1' for control
$^{*}p < .050$, $^{**} p < .010$, $^{***} p < .001$, $^{+} p < .10$

Table 2. Univariate Effects of Contextual and Interpersonal Difference Variables on Outcome Variables

	Difficulty level			Instructional style			Difficulty x Style		Autonomous motivation		Controlled motivation	
	F	η_p^2	d	F	η_p^2	d	F	η_p^2	F	η_p^2	F	η_p^2
Mediating variables												
Autonomy satisfaction	.04	.00	0.02	16.48***	.04	-0.42	0.54	.00	9.46**	.02	3.52	.01
Autonomy frustration	5.51**	.01	0.26	2.22	.01	0.09	4.44*	.01	13.47***	.00	19.52***	.05
Competence satisfaction	62.30***	.14	-0.73	0.12	.00	-0.01	4.62*	.01	52.52***	.12	0.41	.00
Competence frustration	43.13***	.10	0.65	0.09	.00	-0.01	7.91**	.02	13.14***	.03	7.52**	.02
Outcome variables												
Interest/enjoyment	26.41***	.07	-0.45	2.59	.01	-0.12	0.18	.00	155.62***	.29	0.02	.00
Disengagement	27.29***	.07	0.51	1.96	.01	0.08	0.76	.00	57.26***	.13	2.97	.01
Irritation	22.15***	.06	0.47	2.50	.01	0.12	1.41	.00	35.81***	.09	3.24	.01
Behavioral challenge seeking	12.48***	.03	-0.32	0.26	.00	0.07	3.05	.01	87.29***	.19	0.50	.00

Note: d = Cohen's d

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Table 3. Means and Standard Deviations of Outcome Variables per Condition

	Autonomy-supportive Style (*n* = 242)		Controlling Style (*n* = 237)	
	Easy *n* = 120	Difficult *n* = 122	Easy *n* = 120	Difficult *n* = 117
Mediating variables				
Autonomy satisfaction	2.70 (0.94)	2.79 (1.00)	2.36 (1.03)	2.33 (0.84)
Autonomy frustration	2.32 (0.92)	2.38 (0.97)	2.23 (0.87)	2.67 (1.08)
Competence satisfaction	3.50 (0.90)	2.99 (0.91)	3.64 (0.87)	2.83 (0.93)
Competence frustration	2.32 (0.96)	2.71 (0.95)	2.07 (0.94)	2.94 (0.92)
Outcome variables				
Interest/Enjoyment	3.38 (1.04)	2.93 (0.97)	3.27 (1.04)	2.81 (1.00)
Disengagement	1.77 (0.90)	2.19 (0.97)	1.80 (0.84)	2.32 (0.98)
Irritation	1.70 (0.87)	2.05 (0.93)	1.72 (0.91)	2.24 (0.96)
Behavioral challenge seeking	1.93 (0.64)	1.78 (0.70)	2.06 (0.71)	1.75 (0.67)

Table 4. Direct and Indirect Effects in the Structural Model, together with Confidence Intervals (Bootstrapped – 1000 iterations)

		β	*p*	95% CI
Direct Effects	Style → Autonomy Satisfaction	-.23	.001	[-.52, -.14]
	Style → Interest/Enjoyment	-.09	.019	[-.34, -.03]
	Style → Disengagement	.08	.076	[-.02, .31]
	Style → Irritation	.09	.045	[.00, .30]
	Style x Difficulty → Autonomy Frustration	.13	.011	[.02, .19]
	Style x Difficulty → Competence Satisfaction	-.09	.048	[-.18, -.00]
	Style x Difficulty → Competence Frustration	.14	.004	[.04, .22]
	Difficulty → Autonomy Frustration	.13	.011	[.05, .37]
	Difficulty → Competence Satisfaction	-.42	<.001	[-.99, -.62]
	Difficulty → Competence Frustration	.35	<.001	[.46, .83]
	Autonomy Satisfaction → Irritation	.13	.035	[.01, .31]
	Autonomy Frustration → Interest/Enjoyment	-.12	.064	[-.32, .01]
	Autonomy Frustration → Disengagement	.21	.003	[.09, .44]
	Autonomy Frustration → Irritation	.39	<.001	[.25, .60]
	Competence Satisfaction → Interest/Enjoyment	.64	<.001	[.49, .85]
	Competence Satisfaction → Disengagement	-.34	<.001	[-.51, -.17]
	Competence Satisfaction → Irritation	-.37	<.001	[-.49, -.17]
	Competence Satisfaction → Challenge Seeking	.29	.001	[.09, .32]
	Competence Frustration → Disengagement	.21	.032	[.02, .41]
Indirect Effects	Style → Autonomy Satisfaction → Irritation	-.03	.076	[-.11, .01]
	Style x Difficulty → Autonomy Frustration → Interest/Enjoyment	-.02	.131	[-.04, .01]
	Style x Difficulty → Autonomy Frustration → Disengagement	.03	.051	[.00, .06]
	Style x Difficulty → Autonomy Frustration → Irritation	.05	.021	[.01, .08]
	Style x Difficulty → Competence Satisfaction →Interest/Enjoyment	-.06	.056	[-.12, .00]
	Style x Difficulty → Competence Satisfaction → Disengagement	.03	.079	[-.00, .06]
	Style x Difficulty → Competence Satisfaction → Irritation	.03	.076	[-.00, .06]
	Style x Difficulty → Competence Satisfaction → Challenge Seeking	-.03	.086	[-.04, .00]
	Style x Difficulty → Competence Frustration → Disengagement	.03	.083	[-.00, .06]
	Difficulty → Autonomy Frustration → Interest/Enjoyment	-.02	.131	[-.07, .01]
	Difficulty → Autonomy Frustration → Disengagement	.03	.051	[.00, .11]
	Difficulty → Autonomy Frustration → Irritation	.05	.021	[.01, .17]
	Difficulty → Competence Satisfaction → Interest/Enjoyment	-.27	<.001	[-.73, -.35]
	Difficulty → Competence Satisfaction → Disengagement	.14	<.001	[.12, .43]
	Difficulty → Competence Satisfaction → Irritation	.15	<.001	[.12, .41]
	Difficulty → Competence Satisfaction → Challenge Seeking	-.12	.001	[-.26, -.06]
	Difficulty → Competence Frustration → Disengagement	.07	.039	[.01, .27]

Note: 95% CI = 95% Confidence Interval

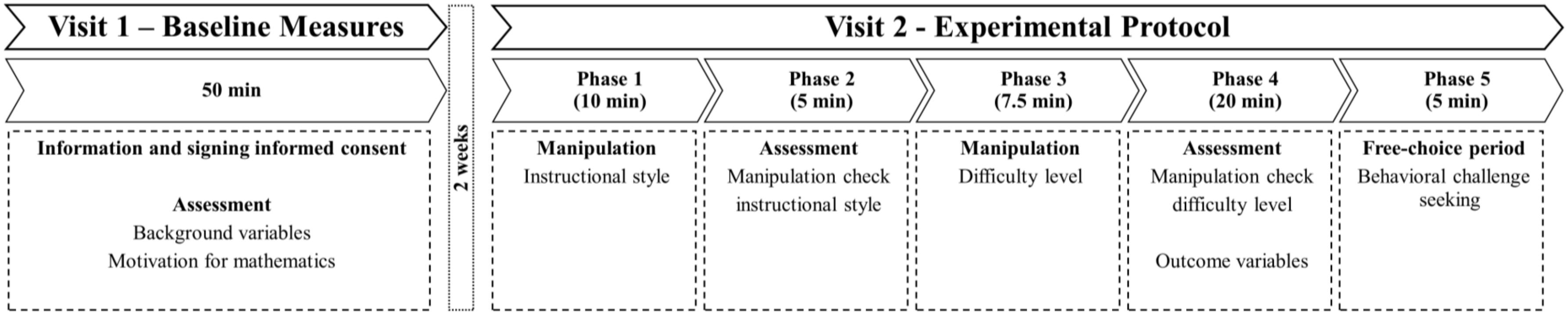


Figure 1. Study Procedure

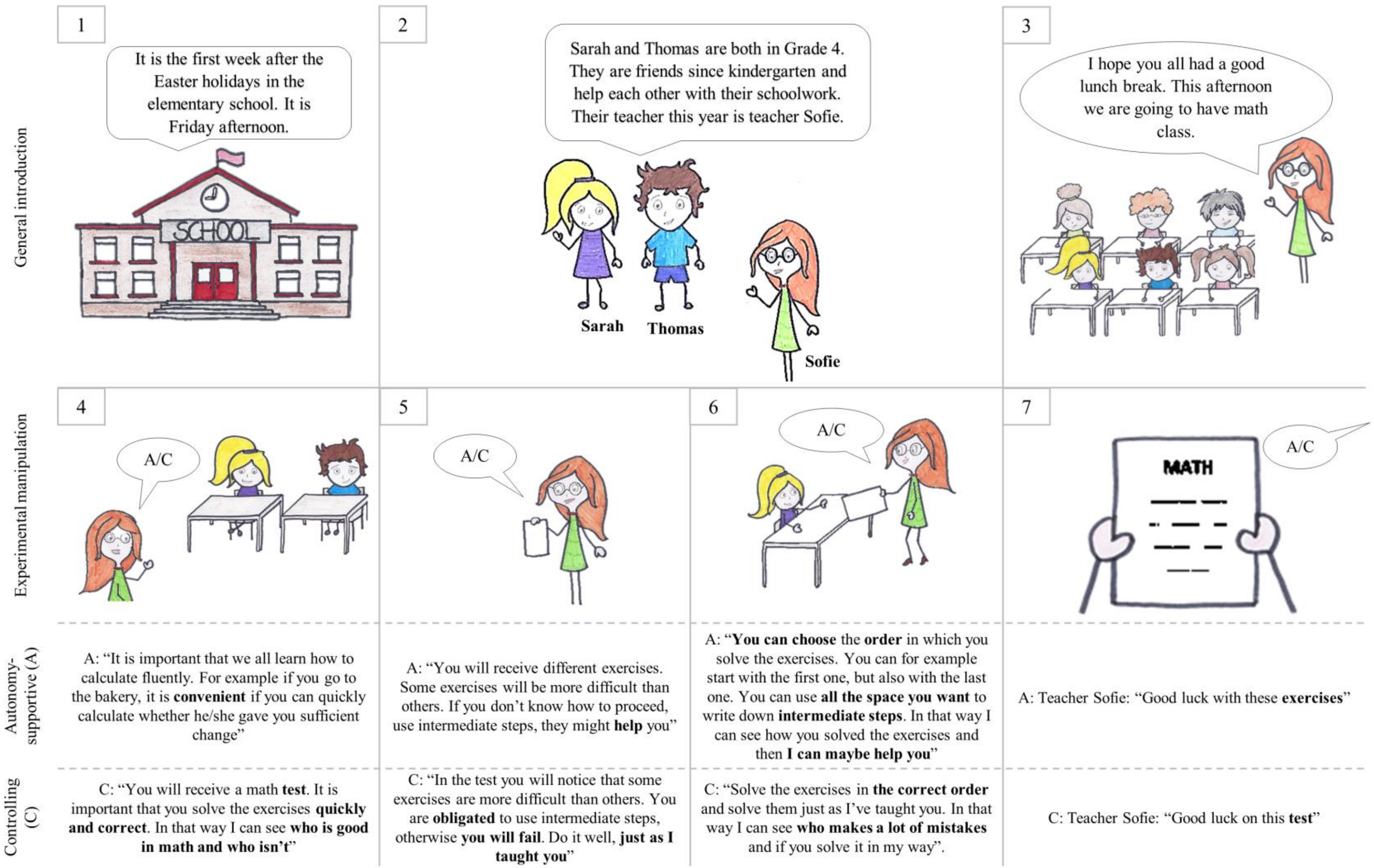
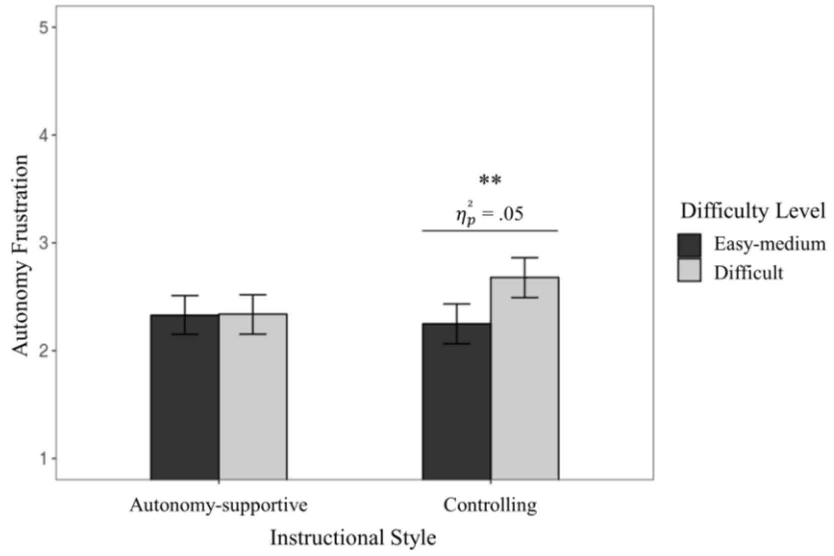
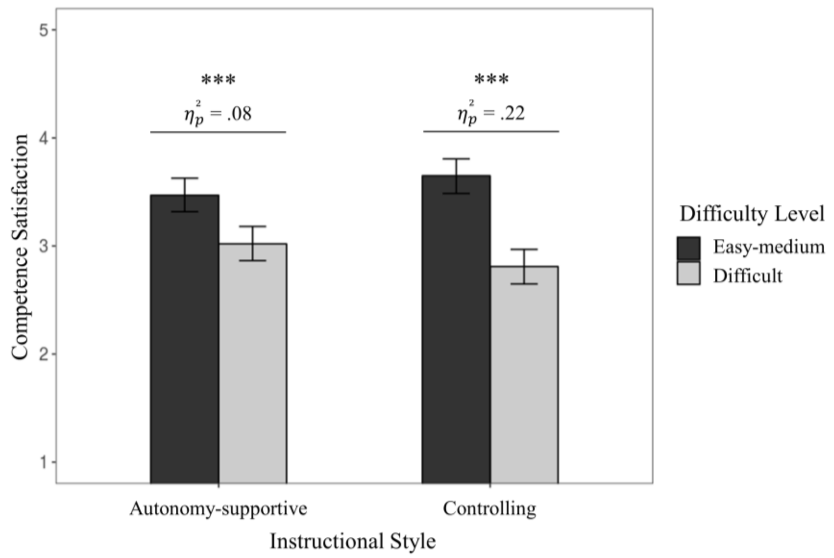


Figure 2. Comic book used to manipulate the instructional style of the teacher.
Note: A = Autonomy-supportive language used in the autonomy-supportive condition; C = Controlling language used in the controlling condition



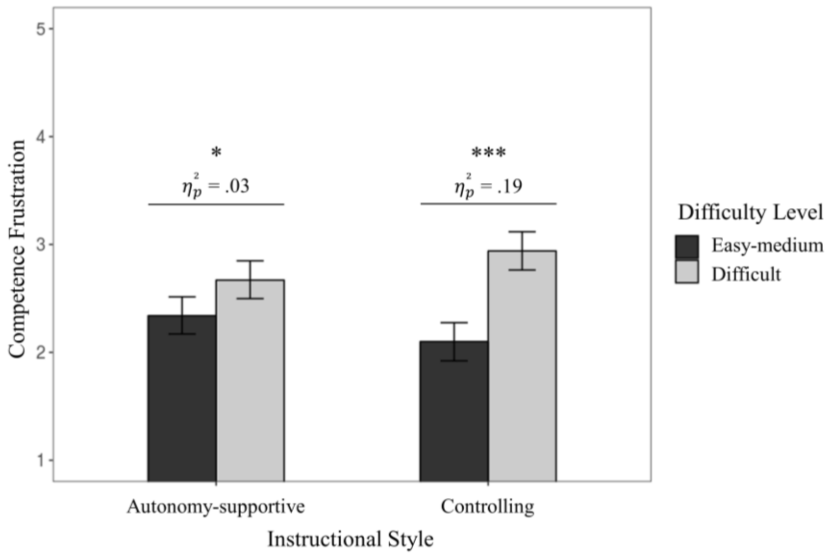
Note: ** $p < .01$

Figure 3. Interaction effect between manipulated task difficulty and instructional style in the prediction of autonomy frustration.



Note: *** $p < .001$

Figure 4. Interaction effect between manipulated task difficulty and instructional style in the prediction of competence satisfaction.



Note: $^{*}p < .05$, $^{***}\, p < .001$

Figure 5. Interaction effect between manipulated task difficulty and instructional style in the prediction of competence frustration.

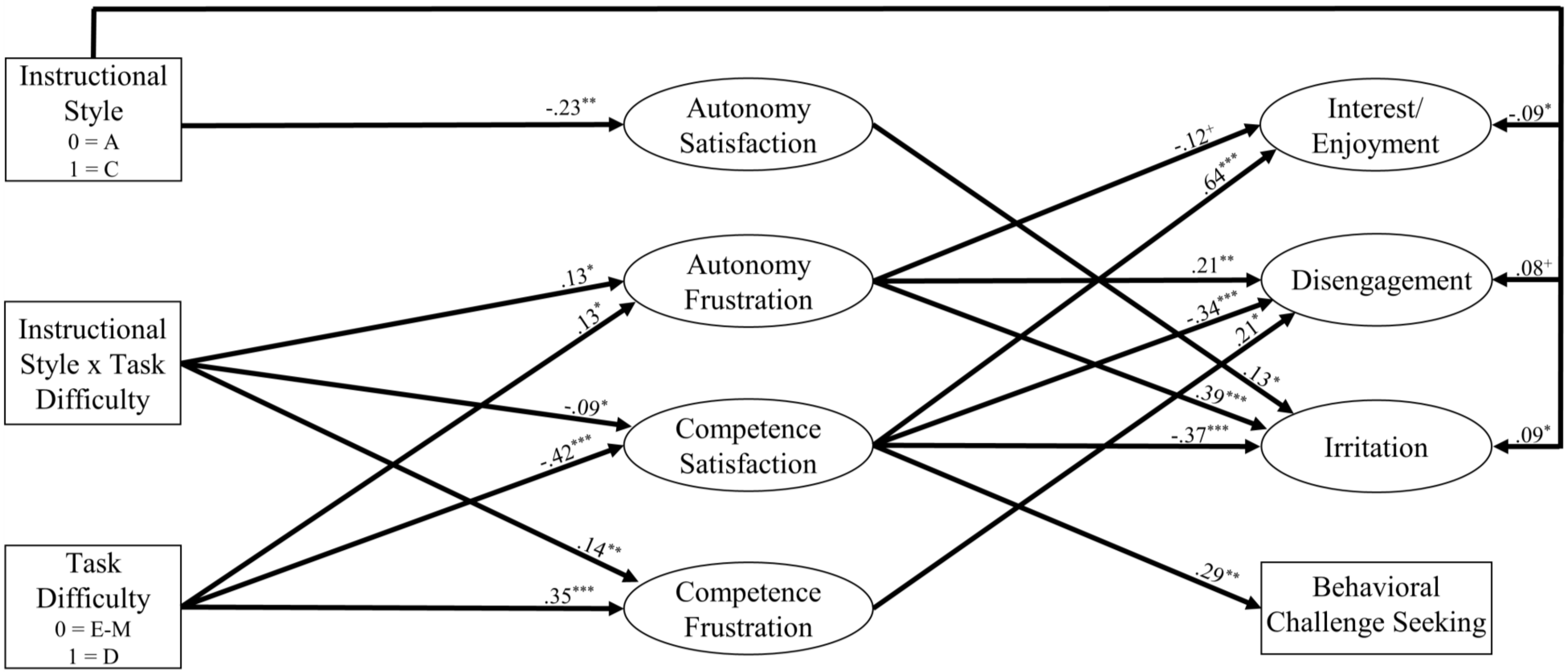


Figure 6. Structural model depicting the mediating role of need-based experiences in the relation between manipulated instructional style, task difficulty and outcomes

Note: A = Autonomy-supportive language used in the autonomy-supportive condition; C = Controlling language used in the controlling condition; E-M = Easy-medium exercises; D = Difficult exercises

$^{*}p < .05$, $^{**}\, p < .01$, $^{***}\, p < .001$, $^{+}\, p < .10$

How Can the Blow of Math Difficulty on Elementary School Children's Motivational, Cognitive and Affective Experiences be Dampened? The Critical Role of Autonomy-Supportive Instructions

Supplementary Material

Part 1. The Role of Task Difficulty and Instructional Style on Performance

Method. To explore the effect of the manipulations on performance, Univariate Analyses of Variance (ANOVA) were performed. Performances within one difficulty level (either easy-medium or difficult) during the experimental phase were compared between those receiving autonomy-supportive vs. controlling instructions. Also during the free-choice period afterwards, performance was compared between conditions. Two outcome measures were considered: accuracy (= number of items correct/number of items solved) and number of items correct.

Results. The analyses revealed that instructional style did not impact on children's performance, not immediately, but also not afterwards. For difficulty, a small effect on the performance in the free-choice period was found, namely children in the difficult condition during the experimental phase, performed slightly worse (*M* = .58, *SD* = .25) in the free-choice period, compared to those in the easy-medium condition (*M* = .63, *SD* = .24). However, this effect was small (η_p^2 = .02) and was only found when accuracy (items correct/items solved) was chosen as an outcome measure for performance. This effect was absent with the number of items correct as outcome and emerged after controlling for the main effects of math ability, autonomous and controlled motivation. Math ability was strongly and positively related to all outcomes, with smaller effect sizes for the difficult exercises in the free-choice period. The effect on these difficult exercises was only marginally significant when taking the accuracy as outcome and non-significant with the number of items correct as outcome. Autonomous motivation was found to relate positively to performance in the medium difficulty level of the free-choice period, whereas there was a negative relationship (marginally significant) with controlled motivation. In addition, controlled motivation yielded negative effects on performance (accuracy) in the difficult exercises of the free-choice period. Details of these analyses can be found in Supplementary Table 1.

Discussion. We found more autonomously motivated children to perform better on medium difficult tasks than compared to children with less autonomous motivation, regardless of their abilities. This is a very important finding that demonstrates the crucial role of autonomous motivation for performance outcomes, over and above the effect of ability. This finding is completely in line with a recent meta-analysis on 74 studies (n = 80.145), which concluded that 16.6% of the variation in school achievement could be explained by differences in motivation, over and above intelligence which explained 66.6% of the variance (Kriegbaum, Becker, & Spinath, 2018). Furthermore, we found that for very difficult tasks, performance gets undermined for children with high levels of controlled motivation. It seems to be the case that when tasks get more difficult, autonomous motivation functions as an enhancer for performance, but only for medium difficulty. For very difficult tasks, autonomous motivation does not contribute anymore, but controlled motivation seems then to impair performance.

Part 2. Subsequent Analyses on SEM-Results (Hypothesis 2)

The positive relation between autonomy satisfaction and irritation in the SEM-results was explored in further detail. Subsequent analyses revealed that a model involving a composite score of need satisfaction and need frustration, thus collapsing across both autonomy and competence items, and a model with only competence satisfaction and competence frustration as mediators revealed significant negative parameter estimates between need satisfaction and irritation. When only autonomy satisfaction and frustration were included as mediators, a positive, albeit non-significant association was found between need satisfaction and irritation, a finding congruent with the correlational results. Presumably, the final structural model involving all four mediators may have caused problems of multicollinearity, thereby producing more unstable results. In addition, the internal consistency of autonomy satisfaction was the lowest of the four need measures, indicating that this measure contains more error variance which could additionally have affected the parameter estimates.

Table 1. Univariate Effects of contextual and interpersonal difference variables on performance

	Difficulty level			Instructional style			Difficulty x Style		Math ability		Autonomous motivation		Controlled motivation	
	F	η_p^2	d	F	η_p^2	d	F	η_p^2	F	η_p^2	F	η_p^2	F	η_p^2
Performance in the experimental phase														
Easy-medium (n = 198)	-	-	-	0.00	.00	-.03	-	-	78.75***	.29	1.80	.01	2.62	.01
Difficult (n = 192)	-	-	-	1.80	.01	-.14	-	-	33.52***	.15	2.78^{+}	.02	0.35	.00
Performance in the free-choice period (# correct)														
Choice 1 = easy (n = 120)	0.48	.00	-.02	0.00	.00	.09	0.50	.00	20.83***	.16	0.00	.00	0.06	.00
Choice 2 = medium (n = 201)	0.74	.00	-.08	0.22	.00	.06	0.08	.00	54.14***	.22	4.64*	.02	3.58^{+}	.02
Choice 3 = difficult (n = 71)	1.26	.02	.19	1.36	.02	.17	0.59	.01	2.65	.04	2.50	.04	1.32	.02
Performance in the free-choice period (accuracy)														
Choice 1 = easy (n = 120)	2.36	.02	-.16	0.00	.00	.04	0.01	.00	24.71***	.18	1.45	.01	0.09	.00
Choice 2 = medium (n = 201)	4.10*	.02	-.20	0.02	.00	.00	0.47	.00	45.60***	.19	5.39*	.03	0.54	.00
Choice 3 = difficult (n = 71)	0.13	.00	.08	0.05	.00	.00	0.32	.01	3.94^{+}	.06	0.03	.00	4.58*	.07

Note: d = Cohen's d; $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$, $^{+}p < .100$; '# correct' = number of items answered correctly; 'accuracy' = number of items answered correctly divided by number of items answered in total.
For performance in the experimental phase, only main effects of instructional style and covariates are reported since difficulty level differed between instructional style conditions.