

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

©American Psychological Association. This paper is not the copy of record and may not exactly replicate the authoritative document published in the APA journal. Please do not copy or cite without author's permission. The final article is available, upon publication, at: <http://dx.doi.org/10.1037/edu0000444>

1 Running head: How Can the Blow of Math Difficulty be Dampened?

2

3 **How Can the Blow of Math Difficulty on Elementary School Children's Motivational,**

4 **Cognitive, and Affective Experiences be Dampened?**

5 **The Critical Role of Autonomy-Supportive Instructions**

6

7

8

9

Abstract

1
2 Although teachers are recommended to create a stimulating learning environment in which
3 children can use, perfect, and extend their skills, this is far from easy. In many cases, identifying
4 the optimal difficulty level of learning tasks involves a trial-and-error process during which
5 teachers offer children too difficult tasks, with negative outcomes as a result. This experimental
6 study investigated if autonomy-supportive instructions could dampen or even cancel out these
7 presumed negative outcomes associated with math difficulty in elementary school children (N
8 = 479; $M_{\text{age}} = 9.41$). After varying an autonomy-supportive versus a controlling instructional
9 style through a comic book, children solved a series of either easy-medium or difficult math
10 exercises, followed by the completion of questionnaires and the opportunity to choose the
11 difficulty level of a final set of exercises to work on independently. Children who solved
12 difficult, relative to easier, exercises reported less interest, more irritation, and more cognitive
13 disengagement, while also seeking less challenge when asked to work independently. Need-
14 based experiences of competence and autonomy accounted for these effects. Yet, the impairing
15 impact of task difficulty could, at least partially, be dampened through the use of an autonomy-
16 supportive relative to a controlling instructional style, which led to enhanced autonomy
17 satisfaction. These findings largely occurred independent of children's motives for
18 mathematics. The results have high practical value, especially for poor performers and children
19 with Mathematical Learning Disabilities, who find math to be harder overall. Limitations and
20 implications for practice are discussed.

Educational Impact and Implications Statement

21
22 Autonomy-supportive instructions (e.g., inviting language, meaningful rationale) were
23 found to dampen the impairing effects of too difficult math tasks on children's motivational,
24 cognitive, and affective experiences. This is especially important for poor performers and
25 children with Mathematical Learning Disabilities, who find math to be harder overall. An

- 1 autonomy-supportive environment and avoiding too hard learning material may stimulate
- 2 children to accept new challenges, thereby possibly improving chances for later academic/job
- 3 success.

1 Imagine an elementary school child, Anna, in a mathematics class who is asked to solve a series
2 of exercises. Although her teacher is sincerely concerned with helping Anna in applying,
3 perfecting, and extending her knowledge and skills, this is not an easy endeavor. Theoretically,
4 the teacher is encouraged to monitor the child's learning process as to offer exercises in Anna's
5 zone of proximal development ((Moll, 2013; Vygotsky, 1978, 1987). Yet, because different
6 children develop at a different pace (Claessens, Duncan, & Engel, 2009; Claessens & Engel,
7 2013), with each of them thus having a different zone of proximal development, the offered
8 exercises by the teacher will at times be too difficult for some children, while being too easy
9 for others. Unfortunately, too difficult math exercises may come with a cost, such as decreased
10 perceived competence and increased emotional and behavioral disengagement (Patall, Hooper,
11 Vasquez, Pituch, & Steingut, 2018). In addition, research indicates that children's intrinsic
12 motivation (i.e., pure interest and enjoyment) for mathematics gradually declines throughout
13 elementary school (Gottfried, Fleming, & Gottfried, 2001; Lepper, Corpus, & Iyengar, 2005).
14 The increasing difficulty in math exercises as elementary school progresses (Ashcraft, Krause,
15 & Hopko, 2007) may be one of the reasons for this.

16 Grounded in Self-Determination Theory (SDT; Ryan & Deci, 2017), the first aim of the
17 present experimental study was to examine the presumed motivational (i.e., reduced
18 interest/enjoyment), cognitive (i.e. thoughts on disengagement), affective (i.e. irritation) and
19 behavioral (i.e., reduced challenge seeking) costs associated with offering too difficult tasks to
20 elementary school children, as well as identifying the mechanisms that can account for these
21 effects. Second, we sought to examine if an autonomy-supportive, relative to a controlling, style
22 of introducing difficult exercises would dampen or even cancel out the hypothesized impairing
23 effects of too difficult tasks. We pursued both aims in the context of mathematics since
24 mathematics achievement in the first year of elementary school is a key predictor for future
25 academic and job success (Duncan et al., 2007; Duncan & Magnuson, 2011). Hence, it is critical

1 to find effective motivational pathways to not only avoid children losing interest in
2 mathematics, but also to stimulate them to extend their skills during math development.

3 **The Competence-Relevant Role of Task Difficulty**

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

19 One factor feeding into learners' competence is the difficulty level of the offered task.
20 Previous research has found that overly difficult tasks are associated with various negative
21 consequences, presumably because they elicit feelings of competence frustration. For instance,
22 at the motivational level, too difficult tasks were found to predict lower goal-setting (Horvath
23 et al., 2006) and undermine productivity (Goemaere, Beyers, De Muynck, & Vansteenkiste,
24 2018). Also, on days that science students perceived their class to be more difficult than usual,
25 they reported more disengagement than usual (Patall et al., 2018). On the affective level, more

1 difficult tasks were shown to relate not only to more negative affect, tension (van der Kaap-
2 Deeder et al., 2016) and self-reported test anxiety (Eunsook, 1999), but also to higher heart rate
3 and elevated blood pressure (Richter, Baeriswyl, & Roets, 2012).

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

13 **The Autonomy-Relevant Role of Instructional Style**

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

24 Autonomy-supportive teachers build in choices, provide meaningful rationales, validate the
25 learners' perspective, and use an inviting instead of a pressuring communication style (Reeve,

1 2009, 2016). A sense of pressure can be conveyed through the use of forceful language and
2 demands (e.g., “you should”; Vansteenkiste, Simons, Lens, Sheldon, & Deci, 2004) or through
3 the use of guilt-, anxiety and shame-inducing language (Soenens & Vansteenkiste, 2010;
4 Vansteenkiste, Simons, Lens, Soenens, & Matos, 2005). Studies show that explaining children
5 why learning activities are self-relevant by offering a meaningful rationale promotes a greater
6 willingness to learn and fosters engagement (Jang, 2008; Reeve, Jang, Hardre, & Omura, 2002),
7 especially if the offer of a rationale is embedded within a more general autonomy-supportive
8 approach (Steingut, Patall, & Trimble, 2017). Similarly, the provision of choice has shown to
9 contribute to autonomy satisfaction in children, especially in combination with connecting the
10 task to students’ personal goals and interests (Assor, Kaplan, & Roth, 2002). Extensive research
11 has documented the benefits of an autonomy-supportive teaching style for students' engagement
12 (e.g., Wang et al., 2017), self-regulated learning (e.g., Aelterman et al., 2019), performance
13 (e.g., Froiland, Davison, & Worrell, 2016) and well-being (e.g., Soenens & Vansteenkiste,
14 2005).

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

1 (2018) reported that a perceived autonomy-supportive teaching style minimized the
2 competence- and engagement-impairing effect if the class was perceived to be more difficult
3 than usual on a given day. Finally, experimental work by Mabbe and colleagues (2018)
4 indicates that autonomy-supportive instructions partially buffered (yet did not completely
5 cancel out) the adverse effects of negative feedback on reduced competence satisfaction and
6 intrinsic motivation.

7 **The Role of Students' Motivation for Mathematics**

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

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

1 and better performance (De Naeghel, Van Keer, Vansteenkiste, & Rosseel, 2012), a finding that
2 also holds in the context of math (Baten & Desoete, 2018).

3 These motivational differences may interact with the difficulty level of the task in predicting
4 children's learning and adjustment. For instance, children who are already more controlled
5 motivated to begin with may be more sensitive for too difficult tasks, which they appraise more
6 readily as threatening and hard. In contrast, those high in autonomous motivation for math may
7 appraise difficult tasks as more challenging and be more sensitive for the benefits of autonomy-
8 supportive instructions. Findings that deal with the interplay between motivational differences
9 and contextual need-relevant features are mixed to date. For example, experimental studies
10 among adolescents in the context of physical education (Mouratidis, Vansteenkiste, Sideridis,
11 & Lens, 2011) and among judo athletes (Delrue, Soenens, Morbée, Vansteenkiste, & Haerens,
12 2019) indicated that those participants with higher, relative to those with lower, autonomous
13 motivation derived somewhat more benefits from an autonomy-supportive in comparison with
14 a controlling approach. Yet, other studies have revealed evidence for a different interaction
15 pattern, with especially those being low in autonomous motivation benefiting from a more
16 autonomy-supportive teacher (Black & Deci, 2000).

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

25 **The Present Study**

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

7 The first research goal investigated the main and interaction effects of task difficulty (i.e.,
8 easy-medium vs. difficult) and instructional style (i.e., autonomy-supportive vs. controlling).
9 In line with earlier research, it was expected that difficult math problems would provoke more
10 cognitive disengagement (De Muynck et al., 2017; Patall et al., 2018), irritation (Eunsook,
11 1999), while reducing interest/enjoyment and behavioral challenge seeking during a free-choice
12 period (Mabbe et al., 2018; van der Kaap-Deeder et al., 2016; Hypothesis 1a). As far as
13 instructional style is concerned, we expected that autonomy-supportive, relative to controlling
14 instructions would enhance interest/enjoyment and behavioral challenge seeking, while
15 minimizing irritation and cognitive disengagement (De Muynck et al., 2017; Hypothesis 1b).
16 Finally, one of the more innovative goals was to examine whether autonomy-supportive
17 instructions could dampen or even cancel out some of the presumed impairing effects of high
18 math difficulty (Hypothesis 1c).

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

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

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

18 **Method**

19 **Participants**

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

24 **Procedure**

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

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

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

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

1 After reading the comic book (i.e., the vignette), children filled out a manipulation check of
2 the instructional style (i.e., Phase 2). In Phase 3, difficulty level was manipulated by having
3 children work on either easy-medium or difficult math exercises for 7.5 min. In the easy-
4 medium difficulty condition, children were offered exercises that could be solved by 57.2 to
5 82.6% of children of their age, whereas children in the difficult condition were offered exercises
6 that could be solved by only 2.9 to 26.2% of children of their age (Desoete et al., 2019).

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

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

18 **Instruments**

19 The instruments used in the current study were presented to participants on three
20 different moments. Pre-experimental measures encompassed participants' mathematical
21 abilities, background characteristics, and motivation for mathematics. Mathematical abilities
22 were retrieved from a pre-existing study when the children were in Grade 3 (Desoete et al.,
23 2019), whereas background characteristics and motivation for mathematics were retrieved
24 during the first school visit (in Grade 4). Post-experimental measures encompassed need
25 experiences, interest/enjoyment, thoughts on disengagement, irritation and behavioral

1 challenge seeking and were all retrieved during the second school visit, after the experimental
2 manipulation took place. Unless indicated otherwise, all instruments relied on a 5-point Likert
3 scale ranging from 1 (not at all) to 5 (very much).

4 **Pre-experimental measures.**

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

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

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

21 **Post-experimental measures.**

22 **Manipulation check.** The perceived autonomy support (nine items, $\alpha = .90$) of
23 instructions within the comic book was measured with a self-constructed questionnaire closely
24 connected to the story, to serve as a manipulation check. This was done immediately after
25 children finished reading the comic book. Five items tapped into perceived control and four

1 items tapped into perceived autonomy support. For the manipulation check of autonomy
2 support, a difference score was calculated (perceived autonomy support – perceived control).
3 The closer the score to -4, the more controlling the teacher was experienced, whereas the closer
4 the score to +4, the more autonomy-supportive the teacher was experienced. A sample item of
5 perceived autonomy support is “The teacher tells me that learning math is important, for
6 instance, when you want to find out whether you received the correct change in a shop”. A
7 similar manipulation check was used for the difficulty manipulation (four items, $\alpha = .91$), which
8 children filled out after solving the math exercises. Two items tapped into perceived easiness
9 and two items tapped into perceived difficulty. A difference score was calculated in order to
10 measure perceived difficulty (perceived difficulty – perceived easiness). The closer the score
11 to -4, the easier the exercises were experienced, whereas a score closer to +4 indicated that the
12 exercises were perceived as very difficult. An example item for perceived difficulty is “I found
13 it hard to solve the exercises I got from the teacher”.

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

21 ***Need satisfaction and frustration.*** Autonomy satisfaction (three items, $\alpha = .69$),
22 autonomy frustration (four items, $\alpha = .79$), competence satisfaction (four items, $\alpha = .79$) and
23 competence frustration (four items, $\alpha = .81$) were measured with a child version of the Basic
24 Psychological Need Satisfaction and Need Frustration Scale (BPNSNFS; Chen et al., 2015; van
25 der Kaap-Deeder et al., 2015). One item for autonomy satisfaction was omitted from the

1 original scale, since reliability analysis revealed that the reliability of the subscale was improved
2 by removing this item (“I had the feeling that the exercises of the teacher were really interesting
3 for me”). Sample items are "I felt like I could choose to solve the exercises" (autonomy
4 satisfaction), “I felt obligated to solve the exercises” (autonomy frustration), "I was confident
5 that I could solve the exercises" (competence satisfaction) and “While I was solving the
6 exercises, I felt uncertain about my performance” (competence frustration).

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

12 ***Behavioral challenge seeking.*** A free-choice paradigm (Wiechman & Gurland, 2009)
13 was implemented as an indicator of behavioral challenge seeking. After having completed the
14 questionnaires, participants were herein provided the choice between exercises of easy (i.e.
15 eligible for third graders), medium (i.e. eligible for fourth graders), or hard (i.e. eligible for fifth
16 graders) difficulty to work on for another 5 min. Every set contained 20 items, selected from
17 the KRT-R (Baudonck et al., 2006), thereby containing 10 items on mental arithmetic and 10
18 items on number knowledge. Independent of condition, 158 children chose the easy exercises
19 (33.5%), 233 children chose the medium exercises (49.5%), and 80 children chose the difficult
20 exercises (17%).

21 **Plan of Analyses**

22 First, Multivariate Analysis of Variance (MANOVA) was used to examine whether
23 conditions differed from each other before the manipulations took place. Therefore, the two
24 manipulations were entered as fixed factors in the model to investigate their effect on the
25 continuous baseline variables. Chi-square test was used to examine if clinical diagnosis of MLD

1 was equally distributed across conditions. Second, the effectiveness of the manipulations was
2 evaluated by conducting MANOVA with instructional style and difficulty level as between-
3 subject factors and the manipulation check variables as dependent variables. Further, to
4 investigate the main and interaction effects of difficulty level and instructional style on the
5 outcome variables (Research Goal 1), a Multivariate Analysis of Covariance (MANCOVA)
6 was performed with difficulty level and instructional style as between-subjects variables and
7 the outcome variables as dependent variables. Next, to investigate the mediating role of
8 psychological need experiences (Research Goal 2), a latent Structural Equation Model (SEM)
9 was tested using the lavaan package of R (Rosseel, 2012; R Core Team, 2014). Covariances
10 were allowed between all need experiences in the analysis. Regression parameters were
11 estimated using the two-step approach (Hunter & Gerbing, 1982; Lance, Cornwell, & Mulaik,
12 1988) and bootstrapping (1000 iterations). In the first step, the measurement model was tested.
13 In the second step, the full structural model was tested, fixing the item loadings on the latent
14 factors to the parameter estimates retrieved in the first step of the analysis. Goodness-of-fit was
15 evaluated using the fit measures (cut-off values: .06 for root mean square error of approximation
16 (RMSEA), .08 for standardized root mean square residual (SRMR), .95 for comparative fit
17 index (CFI)) of Hu and Bentler (1999). In all analyses, we controlled for math ability,
18 autonomous motivation and controlled motivation as covariates. Finally, for the third goal it
19 was examined if the autonomous and controlled motivation of the children would alter the
20 impact of our experimental factors and thereby function as a moderator. This was done by
21 regressing the outcome variables separately on difficulty, style, the potential moderator and the
22 interactions between the potential moderator and difficulty and style. Because there were two
23 potential moderators (autonomous motivation, controlled motivation), two experimental factors
24 (task difficulty; instructional style) and eight outcome variables, 32 interactions have been
25 tested (with post hoc Bonferroni correction). The interaction terms were calculated by

1 multiplication of the standardized predictors and the standardized moderators (Aiken, West, &
2 Reno, 1991; Mabbe et al., 2018). When a significant result with one of the moderators emerged,
3 two subgroups were created based on participants scores for the moderator, to get insight into
4 the nature of the interaction effect. More specifically, follow-up ANOVA's were conducted
5 within a group scoring high ($\geq M + 1SD$) on the moderator and within a group scoring low on
6 the moderator ($\leq M - 1SD$).

7 **Results**

8 **Preliminary Analyses**

9 Table 1 presents descriptives and the correlations between study variables. The MANOVA
10 revealed that neither difficulty level, $F(4, 391) = 1.01, p = .404, \eta_p^2 = .01$, nor instructional style,
11 $F(4, 391) = 0.91, p = .460, \eta_p^2 = .01$, yielded an effect on autonomous motivation, controlled
12 motivation, math abilities, and age. These findings indicate that children located in different
13 conditions did not differ on these variables at baseline, that is, before the manipulation took
14 place. Furthermore, a chi-squared tests showed that clinical diagnosis of MLD ($n = 28; 5.8\%$)
15 and experimental manipulations were unrelated, $\chi^2(3) = 3.86, p = .277$, indicating that children
16 with MLD were equally distributed across conditions.

17 Furthermore, the MANOVA on the manipulation check variables provided evidence for a
18 significant multivariate effect of both difficulty level, $F(2, 464) = 50.83, p < .001, \eta_p^2 = .18$, and
19 instructional style $F(2, 464) = 942.30, p < .001, \eta_p^2 = .80$. Follow-up ANOVA's indicated that
20 children in the autonomy-supportive conditions experienced the instructions as more
21 autonomy-supportive ($M = 1.98, SD = 1.09$) than did children in the controlling conditions (M
22 $= -2.27, SD = 1.03$), whereas children in the easy-medium conditions perceived the exercises
23 as less difficult ($M = -1.17, SD = 2.13$) compared to children in the difficult conditions ($M =$
24 $0.75, SD = 2.01$).

25 **Primary Analyses**

1 **Research Goal 1: The role of task difficulty and instructional style.** The multivariate
2 results of the MANCOVA revealed that both difficulty level, $F(8, 370) = 10.49, p < .001, \eta_p^2 =$
3 $.19$, and instructional style, $F(8, 370) = 2.78, p = .005, \eta_p^2 = .06$, had a significant multivariate
4 effect, whereas their multivariate interaction was non-significant, $F(8, 370) = 1.53, p = .145,$
5 $\eta_p^2 = .03$. These effects emerged after controlling for the multivariate effects of the covariates
6 autonomous motivation, $F(8, 370) = 24.31, p < .001, \eta_p^2 = .35$, controlled motivation, $F(8, 370)$
7 $= 3.91, p < .001, \eta_p^2 = .08$, and math ability, $F(8, 370) = 8.05, p < .001, \eta_p^2 = .15$. The results of
8 follow-up univariate analyses of each of the manipulated variables and covariates can be found
9 in Table 2, while the means of the different outcomes of the respective conditions are reported
10 in Table 3. Difficulty level had a significant effect in the expected direction on all outcome
11 variables, except for the non-significant effect on autonomy satisfaction. Children solving the
12 more difficult exercises reported more autonomy and competence frustration and less
13 competence satisfaction, they felt more irritated and perceived the exercises to be less enjoyable
14 and interesting. In addition, they reported more cognitive disengagement and chose less difficult
15 exercises in the free-choice period afterwards. The effects for instructional style were limited,
16 with children in the autonomy-supportive conditions reporting greater autonomy satisfaction
17 compared to those in the controlling conditions. Although instructional style tended to have an
18 additional effect on interest/enjoyment, this effect was only marginally significant. As for the
19 interaction, difficulty level and instructional style interacted in the prediction of autonomy
20 frustration (see Figure 3), competence satisfaction (see Figure 4) and competence frustration
21 (see Figure 5). As can be noticed in these figures, the harmful effects (i.e. more need frustration,
22 less competence satisfaction) of having to solve difficult, relative to easy-medium, exercises
23 were dampened when the exercises were introduced in an autonomy-supportive manner.
24 Specifically, when the exercises were introduced in an autonomy-supportive way, the
25 difference between the difficult and easy-medium exercises in autonomy frustration was absent

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

9 **Research Goal 2: The explanatory role of need-based experiences.** To understand the
10 effects of task difficulty, instructional style and their interaction, need-based experiences were
11 modelled as explanatory variables. The results of the SEM-analysis indicated that the proposed
12 mediation model yielded an acceptable fit, $\chi^2(581) = 1234.34$, $p < .001$; CFI = .91; RMSEA =
13 .05; SRMR = .07. As can be noticed in Figure 6, instructional style related to autonomy
14 satisfaction, while task difficulty yielded effects on autonomy frustration and both competence
15 satisfaction and frustration. Instructional style and difficulty level interacted in the prediction
16 of autonomy frustration and competence satisfaction as well as frustration, which is in line with
17 the results obtained via the MANCOVA. Several of the need-based experiences related to the
18 various outcomes, with competence satisfaction relating positively and autonomy frustration
19 relating negatively (albeit marginally) to interest/enjoyment. Irritation was predicted by the
20 same set of need-based experiences, albeit in opposite ways, with autonomy frustration thus
21 yielding a positive contribution and competence satisfaction a negative contribution. Cognitive
22 disengagement was predicted by three different need-based experiences, that is, both autonomy
23 and competence frustration (positively) and competence satisfaction (negatively). Finally,
24 competence satisfaction was positively related to behavioral challenge seeking. Thus, the need-
25 based experiences related to the outcomes in hypothesized ways, with the exception of the

1 positive relation between autonomy satisfaction and irritation. This association should be
2 interpreted with caution in light of its non-significance at the correlation level ($r = -.01$).
3 Subsequent analyses on this specific result can be found in Part 2 of the supplementary
4 materials.

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

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

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

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

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

13 Discussion

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

1 **Impairing Effects of Task Difficulty**

2 As we had hypothesized, overly difficult math exercises yielded a host of negative effects.
3 More difficult tasks undermined children's interest in math, elicited more irritation and
4 prompted more thoughts about disengagement. The impact on cognitive disengagement
5 (thoughts such as 'I want to stop', 'I want to get out of here'), is congruent with previous work
6 of Patall and colleagues (2018) who reported that high school students report more emotional
7 and behavioral disengagement on days during which they perceived their science class as more
8 difficult than usual. The present findings extend this body of work by showing that task
9 difficulty *causes* rather than merely covaries with a host of negative outcomes. In addition, the
10 present findings suggest that the reported effects of task difficulty by Patall and colleagues
11 (2018) generalize to elementary children, math education, and indices of cognitive
12 disengagement. Preliminary findings on cognitive disengagement were reported by Eunsook
13 (1999), who found that students worried more when filling out a difficult math task. Also, in an
14 experimental study among adolescent tennis players, negative feedback, another competence-
15 relevant factor, was found to enhance negative inner-speech relative to the provision of positive
16 feedback (De Muynck et al., 2017).

17 Interestingly, too difficult exercises not only prompted more negative experiences during
18 task engagement, but also when the children had finished working on the assigned exercises.
19 That is, those randomly assigned to the difficult condition, chose less challenging exercises
20 afterwards. Presumably, having experienced a decrement in competence satisfaction and an
21 increase in competence frustration during the experimental phase, children no longer wanted to
22 be exposed to failure experiences and, hence, selected easier tasks, which better guarantee a
23 successful outcome. Alternatively, children who received the easy exercises during the
24 experimental induction may have chosen to set the barrier higher and, therefore, choose a more
25 challenging set of exercises. Without a control group, it is impossible to conclude whether

1 difficult exercises forestall competence and result in reduced challenge seeking or whether easy
2 exercises promote greater challenge seeking by promoting children's sense of confidence. Yet,
3 the present findings indicate that the difficulty level of mathematical tasks not only impacts on
4 children's motivational, cognitive and affective functioning, but even on their behavior as such.

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

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

1 elicit pressure on them to perform well. Such elevated pressure would then be indicative for
2 their increased autonomy frustration.

3 **Dampening Role of Autonomy-Supportive Instructions**

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

24 Although instructional style helped to buffer the impairing effects of task difficulty, its main
25 effects were rather limited, with an autonomy-supportive instructional style predicting

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

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

4 **The Role of Children's Motives for Mathematics**

5 We did not only consider an autonomy-supportive, relative to controlling, instructional style
6 as a moderator, but also addressed the role of motivational differences between children in
7 math. As children progress through elementary school, interpersonal differences in their
8 autonomous and controlled motivation for mathematics emerge (Baten & Desoete, 2018). The
9 critical question is then whether teachers need to adjust task difficulty and their communication
10 style according to these differences in motivation. Although the topic of motivational tailoring
11 is of importance from a practical perspective, this issue is under-researched within the SDT-
12 tradition and the motivation literature at large (but see Flunger et al., 2019; Mouratidis et al.,
13 2011). Presumably, because of the universality claims characterizing SDT, there was less of an
14 urgency to examine these issues. Yet, although need satisfaction would be conducive to all
15 children's interest and growth, the pathways towards need satisfaction may somewhat vary
16 (Soenens et al., 2015; Vansteenkiste et al., 2019). Indeed, some teachers are convinced that
17 controlled motivated students would function most optimally when being exposed to a
18 demanding and controlling teacher (De Meyer et al., 2016).

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

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

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

15 **Practical Implications**

16 The results of the current study indicate that offering too difficult math tasks at school
17 impairs children's motivational, cognitive, and affective experiences in the classroom. Even
18 though teachers may be tempted to offer only easy tasks in light of these findings, thereby
19 lowering their standards all together, such an approach may also come with some
20 disadvantages. Indeed, without sufficient challenge, children's learning process risks to
21 stagnate (Shabani, Khatib, & Ebadi, 2010). For children to not just practice but also to extend
22 their knowledge and skills, assigned exercises need to fall within their zone of proximal
23 development (Moll, 2013; Vygotsky, 1978; Vygotsky, 1987). In many cases, searching for such
24 optimally challenging tasks implies that teachers need to walk on a tightrope, with the risk that
25 children are sometimes provided with too difficult and other times with too easy exercises. The

1 present study then yields the promising message that the motivational, affective, and behavioral
2 costs that too difficult tasks cause can be minimized if teachers pay attention to their
3 communication style. This is a hopeful finding, perhaps especially for children who dispose of
4 less mathematical abilities and who may more easily be confronted with too difficult exercises.
5 Preventing them from disengaging improves their chances for later academic and job success
6 (Duncan et al., 2007; Duncan & Magnuson, 2011) and prevents children with Mathematical
7 Learning Disabilities to even fall further behind (Clements, Fuson, & Sarama, 2017; Clements
8 & Sarama, 2011).

9 What does it mean specifically to act in an autonomy-supportive way when assigning
10 difficult tasks? First, an autonomy-supportive teacher empathizes with children, thereby
11 highlighting that they may possibly struggle with the activity (Soenens, Deci, & Vansteenkiste,
12 2017; Vansteenkiste, Niemiec, & Soenens, 2010). Second, they try to provide a meaningful
13 rationale for assigning the more difficult math exercises and, finally, they can build in choices
14 regarding the timing, order, or way of solving the difficult exercises (De Muynck, Soenens,
15 Degraeuwe, Vande Broek, & Vansteenkiste, 2019; Reeve, Nix, & Hamm, 2003). When
16 applying these different autonomy-supportive strategies, the way children cope with the
17 encountered difficult tasks may be altered. Specifically, they may perceive the task as an
18 opportunity for growth rather than as an evaluative and threatening duty. These differential
19 perceptions of challenge versus threat may then encourage them to carry on instead of giving
20 up (Adie, Duda, & Ntoumanis, 2008).

21 A second recommendation for teachers is to adjust the difficulty level of assigned tasks to
22 children's capacities (Moll, 2013; Vygotsky, 1978, 1987). This suggestion for scaffolding
23 (Shabani et al., 2010) follows from the observation that an autonomy-supportive instructional
24 style primarily attenuates but does not completely cancel out the adverse impact of too difficult
25 tasks. If teachers want to preserve children's interest and prevent a drop in disengagement, they

1 do well to offer activities for which children feel competent. In doing so, they may gradually
2 increase the difficulty level of the task such that children increasingly build up a sense of
3 mastery rather than setting the bar too high from the beginning, thereby eliciting a sense of
4 failure. Although some teachers may hold the belief that children would choose the easy way
5 out after making a set of math exercises of easy-medium difficulty, the present study suggests,
6 on the contrary, that they increase their own standards by choosing more challenging exercises
7 when left by themselves. More broadly, the present findings suggest that teachers do well to
8 hold trust in children's capacity to uplift their own learning process, a belief that precisely
9 characterizes need-supportive teachers (Aelterman et al., 2019).

10 **Limitations**

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

20 Second, because a neutral condition was not included, either in terms of difficulty level or
21 instructional style, it remains unclear whether the observed differences between conditions are
22 due to the growth-conducive role of autonomy support and easy-medium exercises, or the
23 growth-impeding role of difficult exercises and a controlling communication style, or both. An
24 alternative is to include a condition that contains a mix of different instructional styles instead
25 of a single style, which may be more fitting with the daily teaching reality. Under these

1 ambiguous circumstances, individual differences in motivational orientation may have played
2 a more significant role with control- and autonomy-oriented learners being sensitive for,
3 respectively, the more controlling and autonomy-supportive features of the manipulation. A
4 final methodological improvement would involve deconstructing the global autonomy-
5 supportive approach into its facets (i.e., inviting language, choice, rationale) to examine
6 whether they carry in isolation or in combination the strongest effect (e.g., Deci, Eghrari,
7 Patrick, & Leone, 1994).

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

19 **Conclusion**

20 Too difficult math exercises appear to result in a loss of interest and challenge seeking as
21 well as increased irritation and cognitive disengagement. However, as children progress
22 through elementary school, a confrontation with increasing math difficulty seems inevitable. In
23 addition, children who dispose of less mathematical abilities or children with MLD may more
24 easily be confronted with too difficult math tasks. This study revealed that even with a subtle
25 manipulation of autonomy-support, the negative effects of too difficult math exercises could be

- 1 buffered. Providing children with a meaningful rationale, taking their perspective and building
- 2 in choices, helps to preserve their interest and stimulates them to accept new math challenges
- 3 and practice in their zone of proximal development, which fosters them to extend their skills.
- 4 As such, teachers may improve their pupils' chances for later academic and job success.

References

- 1
2 Adie, J. W., Duda, J. L., & Ntoumanis, N. (2008). Autonomy support, basic need satisfaction
3 and the optimal functioning of adult male and female sport participants: A test of basic
4 needs theory. *Motivation and Emotion*, *32*, 189–199. [https://doi.org/10.1007/s11031-](https://doi.org/10.1007/s11031-008-9095-z)
5 008-9095-z
- 6 Aelterman, N., Vansteenkiste, M., Haerens, L., Soenens, B., Fontaine, J. R. J., & Reeve, J.
7 (2019). Toward an integrative and fine-grained insight in motivating and demotivating
8 teaching styles: The merits of a circumplex approach. *Journal of Educational*
9 *Psychology*, *111*, 497–521. <https://doi.org/10.1037/edu0000293>
- 10 Aguinis, H., & Bradley, K. J. (2014). Best practice R-recommendations for designing and
11 implementing experimental vignette methodology studies. *Organizational Research*
12 *Methods*, *17*, 351–371. <https://doi.org/10.1177/1094428114547952>
- 13 Aiken, L. S., West, S. G., & Reno, R. R. (1991). *Multiple regression : testing and interpreting*
14 *interactions*. Sage Publications.
- 15 Ashcraft, M. H., Krause, J. A., & Hopko, D. R. (2007). Is math anxiety a mathematical
16 learning disability? In D. B. Berch & M. M. M. Mazzocco (Eds.), *Why is math so hard*
17 *for some children? The nature and origins of mathematical learning difficulties and*
18 *disabilities* (pp. 329–348). Baltimore: Paul H. Brookes.
- 19 Assor, A., Kaplan, H., & Roth, G. (2002). Choice is good, but relevance is excellent:
20 Autonomy-enhancing and suppressing teacher behaviours predicting students’
21 engagement in schoolwork. *British Journal of Educational Psychology*, *72*, 261–278.
- 22 Bartholomew, K. J., Ntoumanis, N., Mouratidis, A., Katartzi, E., Thøgersen-Ntoumani, C., &
23 Vlachopoulos, S. (2018). Beware of your teaching style: A school-year long
24 investigation of controlling teaching and student motivational experiences. *Learning and*
25 *Instruction*, *53*, 50–63. <https://doi.org/10.1016/j.learninstruc.2017.07.006>

- 1 Bartholomew, K. J., Ntoumanis, N., Ryan, R. M., & Thøgersen-Ntoumani, C. (2011).
2 Psychological need thwarting in the sport context: Assessing the darker side of athletic
3 experience. *Journal of Sport and Exercise Psychology*, *33*, 75–102.
4 <https://doi.org/10.1123/jsep.33.1.75>
- 5 Baten, E., & Desoete, A. (2018). Mathematical (dis)abilities within the Opportunity-
6 Propensity Model: The choice of math test matters. *Frontiers in Psychology*, *9*, 667.
7 <https://doi.org/10.3389/fpsyg.2018.00667>
- 8 Baudonck, M., Debusschere, A., Dewulf, B., Samyn, F., Vercaemst, V., & Desoete, A.
9 (2006). *De Kortrijkse Rekentest Revision KRT-R. [The Kortrijk Arithmetic Test Revision*
10 *KRT-R]*. Kortrijk: CAR Overleie.
- 11 Black, A. E., & Deci, E. L. (2000). The effects of instructors' autonomy support and students'
12 autonomous motivation on learning organic chemistry: A self-determination theory
13 perspective. *Science Education*, *84*, 740–756. [https://doi.org/10.1002/1098-](https://doi.org/10.1002/1098-237X(200011)84:6<740::AID-SCE4>3.0.CO;2-3)
14 [237X\(200011\)84:6<740::AID-SCE4>3.0.CO;2-3](https://doi.org/10.1002/1098-237X(200011)84:6<740::AID-SCE4>3.0.CO;2-3)
- 15 Carpentier, J., & Mageau, G. A. (2013). When change-oriented feedback enhances
16 motivation, well-being and performance: A look at autonomy-supportive feedback in
17 sport. *Psychology of Sport and Exercise*, *14*, 423–435.
18 <https://doi.org/10.1016/j.psychsport.2013.01.003>
- 19 Cerasoli, C. P., Nicklin, J. M., & Ford, M. T. (2014). Intrinsic motivation and extrinsic
20 incentives jointly predict performance: A 40-year meta-analysis. *Psychological Bulletin*,
21 *140*, 980–1008. <https://doi.org/10.1037/a0035661>
- 22 Chang, Y.-K., Chen, S., Tu, K.-W., & Chi, L.-K. (2016). Effect of autonomy support on self-
23 determined motivation in elementary physical education. *Journal of Sports Science &*
24 *Medicine*, *15*, 460–466. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/27803624>
- 25 Chen, B., Vansteenkiste, M., Beyers, W., Boone, L., Deci, E. L., Van der Kaap-Deeder, J., ...

- 1 Verstuyf, J. (2015). Basic psychological need satisfaction, need frustration, and need
2 strength across four cultures. *Motivation and Emotion*, *39*, 216–236.
3 <https://doi.org/10.1007/s11031-014-9450-1>
- 4 Claessens, A., Duncan, G., & Engel, M. (2009). Kindergarten skills and fifth-grade
5 achievement: Evidence from the ECLS-K. *Economics of Education Review*, *28*, 415–
6 427. <https://doi.org/10.1016/j.econedurev.2008.09.003>
- 7 Claessens, A., & Engel, M. (2013). How important is where you start? early mathematics
8 knowledge and later school success. *Teachers College Record*, *115*.
- 9 Clements, D. H., Fuson, K. C., & Sarama, J. (2017). The research-based balance in early
10 childhood mathematics: A response to Common Core criticisms. *Early Childhood*
11 *Research Quarterly*, *40*, 150–162. <https://doi.org/10.1016/j.ecresq.2017.03.005>
- 12 Clements, D. H., & Sarama, J. (2011). Early childhood mathematics intervention. *Science*
13 *(New York, N.Y.)*, *333*, 968–970. <https://doi.org/10.1126/science.1204537>
- 14 Curran, T., Hill, A. P., & Niemiec, C. P. (2013). A conditional process model of children’s
15 behavioral engagement and behavioral disaffection in sport based on self-determination
16 theory. *Journal of Sport & Exercise Psychology*, *35*, 30–43.
- 17 De Meyer, J., Soenens, B., Vansteenkiste, M., Aelterman, N., Van Petegem, S., & Haerens, L.
18 (2016). Do students with different motives for physical education respond differently to
19 autonomy-supportive and controlling teaching? *Psychology of Sport and Exercise*, *22*,
20 72–82. <https://doi.org/10.1016/j.psychsport.2015.06.001>
- 21 De Muynck, G.-J., Soenens, B., Degraeuwe, L., Vande Broek, G., & Vansteenkiste, M.
22 (2019). Towards a more refined insight in the critical motivating features of choice: An
23 experimental study among recreational rope skippers. *Psychology of Sport & Exercise*, *in*
24 *press*.
- 25 De Muynck, G.-J., Vansteenkiste, M., Delrue, J., Aelterman, N., Haerens, L., & Soenens, B.

- 1 (2017). The effects of feedback valence and style on need satisfaction, self-talk, and
2 perseverance among tennis players: An experimental study. *Journal of Sport and*
3 *Exercise Psychology*, 39, 67–80. <https://doi.org/10.1123/jsep.2015-0326>
- 4 De Naeghel, J., Van Keer, H., Vansteenkiste, M., & Rosseel, Y. (2012). The relation between
5 elementary students' recreational and academic reading motivation, reading frequency,
6 engagement, and comprehension: A Self-Determination Theory perspective. *Journal of*
7 *Educational Psychology*, 104, 1006–1021. <https://doi.org/10.1037/a0027800>
- 8 Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating internalization:
9 The Self-Determination Theory perspective. *Journal of Personality*, 62, 119–142.
10 <https://doi.org/10.1111/j.1467-6494.1994.tb00797.x>
- 11 Delrue, J., Soenens, B., Morbée, S., Vansteenkiste, M., & Haerens, L. (2019). Do athletes'
12 responses to coach autonomy support and control depend on the situation and athletes'
13 personal motivation? *Psychology of Sport and Exercise*, 43, 321–332.
14 <https://doi.org/10.1016/j.psychsport.2019.04.003>
- 15 Desoete, A., Baten, E., Vercaemst, V., De Busschere, A., Baudonck, M., & Vanhaeke, J.
16 (2019). Metacognition and motivation as predictors for mathematics performance of
17 Belgian elementary school children. *ZDM Mathematics Education*.
18 <https://doi.org/10.1007/s11858-018-01020-w>
- 19 Dolcos, S., & Albarracín, D. (2014). The inner speech of behavioral regulation: Intentions and
20 task performance strengthen when you talk to yourself as a You. *European Journal of*
21 *Social Psychology*, 44, 636–642. <https://doi.org/10.1002/ejsp.2048>
- 22 Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., ...
23 Japel, C. (2007). School readiness and later achievement. *Developmental Psychology*,
24 43, 1428–1446. <https://doi.org/10.1037/0012-1649.43.6.1428>
- 25 Duncan, G. J., & Magnuson, K. (2011). The nature and impact of early achievement skills,

- 1 attention and behavior problems. In G. J. Duncan & R. J. Murnane (Eds.), *Whither*
2 *opportunity: Rising inequality, schools, and children's life chances* (pp. 47–69). New
3 York: Russel Sage.
- 4 Eunsook, H. (1999). Test anxiety, perceived test difficulty, and test performance: Temporal
5 patterns of their effects. *Learning and Individual Differences, 11*, 431–447.
- 6 Flunger, B., Mayer, A., & Umbach, N. (2019). Beneficial for some or for everyone?
7 Exploring the effects of an autonomy-supportive intervention in the real-life classroom.
8 *Journal of Educational Psychology, 111*, 210–234. <https://doi.org/10.1037/edu0000284>
- 9 Froiland, M. J., Davison, M. L., & Worrell, F. C. (2016). Aloha teachers: teacher autonomy
10 support promotes Native Hawaiian and Pacific Islander students' motivation, school
11 belonging, course-taking and math achievement. *Social Psychology of Education, 19*,
12 879–894. <https://doi.org/10.1007/s11218-016-9355-9>
- 13 Goemaere, S., Beyers, W., De Muynck, G. J., & Vansteenkiste, M. (2018). The paradoxical
14 effect of long instructions on negative affect and performance: When, for whom and why
15 do they backfire? *Acta Astronautica, 147*, 421–430.
16 <https://doi.org/10.1016/j.actaastro.2018.03.047>
- 17 Gottfried, A. E., Fleming, J. S., & Gottfried, A. W. (2001). Continuity of academic intrinsic
18 motivation from childhood through late adolescence: A longitudinal study. *Journal of*
19 *Educational Psychology, 93*, 3–13. <https://doi.org/10.1037/0022-0663.93.1.3>
- 20 Haerens, L., Aelterman, N., Vansteenkiste, M., Soenens, B., & Van Petegem, S. (2015). Do
21 perceived autonomy-supportive and controlling teaching relate to physical education
22 students' motivational experiences through unique pathways? Distinguishing between
23 the bright and dark side of motivation. *Psychology of Sport & Exercise, 16*, 26–36.
24 <https://doi.org/10.1016/j.psychsport.2014.08.013>
- 25 Horvath, M., Herleman, H. A., Lee Mckie, · R, Horvath, M., Herleman, · H, & Mckie, · R

- 1 Lee. (2006). Goal orientation, task difficulty, and task interest: A multilevel analysis.
2 *Motivation and Emotion*, 30, 171–178. <https://doi.org/10.1007/s11031-006-9029-6>
- 3 Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure
4 analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A*
5 *Multidisciplinary Journal*, 6, 1–55. <https://doi.org/10.1080/10705519909540118>
- 6 Hunter, J. E., & Gerbing, D. W. (1982). Unidimensional measurement, second order factor
7 analysis, and causal models. *Research in Organizational Behavior : An Annual Series of*
8 *Analytical Essays and Critical Reviews*, 4.
- 9 Jang, H. (2008). Supporting students' motivation, engagement, and learning during an
10 uninteresting activity. *Journal of Educational Psychology*, 100, 798–811.
11 <https://doi.org/10.1037/a0012841>
- 12 Jang, H., Kim, E. J., & Reeve, J. (2012). Longitudinal test of self-determination theory's
13 motivation mediation model in a naturally occurring classroom context. *Journal of*
14 *Educational Psychology*, 104, 1175–1188. <https://doi.org/10.1037/a0028089>
- 15 Jang, H., Kim, E. J., & Reeve, J. (2016). Why students become more engaged or more
16 disengaged during the semester: A self-determination theory dual-process model.
17 *Learning and Instruction*, 43, 27–38. <https://doi.org/10.1016/j.learninstruc.2016.01.002>
- 18 Jang, H., Reeve, J., & Halusic, M. (2016). A new autonomy-supportive way of teaching that
19 increases conceptual learning: Teaching in students' preferred ways. *The Journal of*
20 *Experimental Education*, 84, 686–701. <https://doi.org/10.1080/00220973.2015.1083522>
- 21 Lance, C. E., Cornwell, J. M., & Mulaik, S. A. (1988). Limited information parameter
22 estimates for latent or mixed manifest and latent variable models. *Multivariate*
23 *Behavioral Research*, 23, 171–187. https://doi.org/10.1207/s15327906mbr2302_3
- 24 Lepper, M. R., Corpus, J. H., & Iyengar, S. S. (2005). *Intrinsic and extrinsic motivational*
25 *orientations in the classroom: Age differences and academic correlates.*

- 1 <https://doi.org/10.1037/0022-0663.97.2.184>
- 2 Mabbe, E., Soenens, B., De Muynck, G. J., & Vansteenkiste, M. (2018). The impact of
3 feedback valence and communication style on intrinsic motivation in middle childhood:
4 Experimental evidence and generalization across individual differences. *Journal of*
5 *Experimental Child Psychology*, *170*, 134–160.
6 <https://doi.org/10.1016/j.jecp.2018.01.008>
- 7 Moll, L. C. (2013). *Vygotski and education*. New York: Routledge.
- 8 Moller, A. C., Deci, E. L., & Elliot, A. J. (2010). Person-level relatedness and the incremental
9 value of relating. *Personality and Social Psychology Bulletin*, *36*, 754–767.
10 <https://doi.org/10.1177/0146167210371622>
- 11 Mouratidis, A. A., Vansteenkiste, M., Sideridis, G., & Lens, W. (2011). Vitality and interest–
12 enjoyment as a function of class-to-class variation in need-supportive teaching and
13 pupils’ autonomous motivation. *Journal of Educational Psychology*, *103*, 353–366.
14 <https://doi.org/10.1037/a0022773>
- 15 Mouratidis, A., Lens, W., & Vansteenkiste, M. (2010). How you provide corrective feedback
16 makes a difference: the motivating role of communicating in an autonomy-supporting
17 way. *Journal of Sport & Exercise Psychology*, *32*, 619–637.
- 18 Patall, E. A., Hooper, S., Vasquez, A. C., Pituch, K. A., & Steingut, R. R. (2018). Science
19 class is too hard: Perceived difficulty, disengagement, and the role of teacher autonomy
20 support from a daily diary perspective. *Learning and Instruction*, *58*, 220–231.
21 <https://doi.org/10.1016/j.learninstruc.2018.07.004>
- 22 Reeve, J. (2009). Why teachers adopt a controlling motivating style toward students and how
23 they can become more autonomy supportive. *Educational Psychologist*, *44*, 159–175.
24 <https://doi.org/10.1080/00461520903028990>
- 25 Reeve, J. (2016). Autonomy-supportive teaching: What it is, how to do it. In *Building*

1 *Autonomous Learners* (pp. 129–152). https://doi.org/10.1007/978-981-287-630-0_7

2 Reeve, J., & Jang, H. (2006). What teachers say and do to support students' autonomy during
3 a learning activity. *Journal of Educational Psychology*, *98*, 209–218.
4 <https://doi.org/10.1037/0022-0663.98.1.209>

5 Reeve, J., Jang, H., Hardre, P., & Omura, M. (2002). Providing a rationale in an autonomy-
6 supportive way as a strategy to motivate others during an uninteresting activity.
7 *Motivation and Emotion*, *26*, 183–207. <https://doi.org/10.1023/A:1021711629417>

8 Reeve, J., Nix, G., & Hamm, D. (2003). Testing models of the experience of self-
9 determination in intrinsic motivation and the conundrum of choice. *Journal of*
10 *Educational Psychology*, *95*, 375–392. <https://doi.org/10.1037/0022-0663.95.2.375>

11 Reeve, J., & Tseng, C.-M. (2011). Cortisol reactivity to a teacher's motivating style: the
12 biology of being controlled versus supporting autonomy. *Motivation and Emotion*, *35*,
13 63–74. <https://doi.org/10.1007/s11031-011-9204-2>

14 Richter, M., Baeriswyl, E., & Roets, A. (2012). Personality effects on cardiovascular
15 reactivity: Need for closure moderates the impact of task difficulty on engagement-
16 related myocardial beta-adrenergic activity. *Psychophysiology*, *49*, 704–707.
17 <https://doi.org/10.1111/j.1469-8986.2011.01350.x>

18 Rosseel, Y. (2012). lavaan : An R Package for Structural Equation Modeling. *Journal of*
19 *Statistical Software*, *48*, 1–36. <https://doi.org/10.18637/jss.v048.i02>

20 Ryan, R., & Connell, J. (1989). Perceived locus of causality and internalization: Examining
21 reasons for acting in two domains. *Journal of Personality and Social Psychology*, *57*,
22 749–761. <https://doi.org/10.1037/0022-3514.57.5.749>

23 Ryan, R., & Deci, E. (2000). Self-determination theory and the facilitation of intrinsic
24 motivation, social development, and well-being. *The American Psychologist*, *55*, 68–78.
25 <https://doi.org/10.1037/0003-066X.55.1.68>

- 1 Ryan, R., & Deci, E. (2017). *Self-determination theory. Basic psychological needs in*
2 *motivation, development and wellness*. New York, NY: Guilford Press.
- 3 Ryan, R. M. (1982). Control and information in the intrapersonal sphere: An extension of
4 cognitive evaluation theory. *Journal of Personality and Social Psychology*.
5 <https://doi.org/10.1037/0022-3514.43.3.450>
- 6 Schmierbach, M., Chung, M. Y., Wu, M., & Kim, K. (2014). No one likes to lose: The effect
7 of game difficulty on competency, flow, and enjoyment. *Journal of Media Psychology*,
8 26, 105–110. <https://doi.org/10.1027/1864-1105/a000120>
- 9 Shabani, K., Khatib, M., & Ebadi, S. (2010). Vygotsky's Zone of Proximal Development:
10 Instructional implications and teachers' professional development. *English Language*
11 *Teaching*, 3. <https://doi.org/10.5539/elt.v3n4p237>
- 12 Sierens, E., Vansteenkiste, M., Goossens, L., Soenens, B., & Dochy, F. (2009). The
13 synergistic relationship of perceived autonomy support and structure in the prediction of
14 self-regulated learning. *British Journal of Educational Psychology*, 79, 57–68.
15 <https://doi.org/10.1348/000709908X304398>
- 16 Soenens, B., Deci, E. L., & Vansteenkiste, M. (2017). How Parents Contribute to Children's
17 Psychological Health: The Critical Role of Psychological Need Support. In *Development*
18 *of Self-Determination Through the Life-Course* (pp. 171–187).
19 https://doi.org/10.1007/978-94-024-1042-6_13
- 20 Soenens, B., & Vansteenkiste, M. (2010). A theoretical upgrade of the concept of parental
21 psychological control: Proposing new insights on the basis of self-determination theory.
22 *Developmental Review*, 30, 74–99. <https://doi.org/10.1016/j.dr.2009.11.001>
- 23 Soenens, B., Vansteenkiste, M., & Van Petegem, S. (2015). Let us not throw out the baby
24 with the bathwater: Applying the principle of universalism without uniformity to
25 autonomy-supportive and controlling parenting. *Child Development Perspectives*, 9, 44–

1 49. <https://doi.org/10.1111/cdep.12103>

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

5 Van Assche, J., van der Kaap-Deeder, J., Audenaert, E., De Schryver, M., & Vansteenkiste,
6 M. (2018). Are the benefits of autonomy satisfaction and the costs of autonomy
7 frustration dependent on individuals' autonomy strength? *Journal of Personality*, 86,
8 1017–1036. <https://doi.org/10.1111/jopy.12372>

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

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

17 Vandenkerckhove, B., Soenens, B., Van der Kaap-Deeder, J., Brenning, K., Luyten, P., &
18 Vansteenkiste, M. (2019). The role of weekly need-based experiences and self-criticism
19 in predicting weekly academic (mal)adjustment. *Learning and Individual Differences*,
20 69, 69–83. <https://doi.org/10.1016/j.lindif.2018.11.009>

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

- 1 Vansteenkiste, M., Lens, W., & Deci, E. L. (2006). Intrinsic versus extrinsic goal contents in
2 Self-Determination Theory: Another look at the quality of academic motivation.
3 *Educational Psychologist, 41*, 19–31. https://doi.org/10.1207/s15326985ep4101_4
- 4 Vansteenkiste, M., Niemiec, C. P., & Soenens, B. (2010). The development of the five mini-
5 theories of self-determination theory: an historical overview, emerging trends, and future
6 directions. In T. C. Urdan & S. A. Karabenick (Eds.), *The decade ahead: Theoretical*
7 *perspectives on motivation and achievement* (Vol. 16A, pp. 105–165).
8 [https://doi.org/10.1108/S0749-7423\(2010\)000016A007](https://doi.org/10.1108/S0749-7423(2010)000016A007)
- 9 Vansteenkiste, M., & Ryan, R. M. (2013). On psychological growth and vulnerability: Basic
10 psychological need satisfaction and need frustration as a unifying principle. *Journal of*
11 *Psychotherapy Integration, 23*, 263–280. <https://doi.org/10.1037/a0032359>
- 12 Vansteenkiste, M., Ryan, R. M., & Soenens, B. (2019). Basic Psychological Need Theory:
13 Advancements, critical themes, and future directions. *Manuscript Submitted for*
14 *Publication*.
- 15 Vansteenkiste, M., Simons, J., Lens, W., Sheldon, K. M., & Deci, E. L. (2004). Motivating
16 learning, performance, and persistence: The synergistic effects of intrinsic goal contents
17 and autonomy-supportive contexts. *Journal of Personality and Social Psychology, 87*,
18 246–260. <https://doi.org/10.1037/0022-3514.87.2.246>
- 19 Vansteenkiste, M., Simons, J., Lens, W., Soenens, B., & Matos, L. (2005). Examining the
20 motivational impact of intrinsic versus extrinsic goal framing and autonomy-supportive
21 versus internally controlling communication style on early adolescents' academic
22 achievement. *Child Development, 76*, 483–501. [https://doi.org/10.1111/j.1467-](https://doi.org/10.1111/j.1467-8624.2005.00858.x)
23 [8624.2005.00858.x](https://doi.org/10.1111/j.1467-8624.2005.00858.x)
- 24 Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*.
25 Cambridge, MA: Harvard University Press.

- 1 Vygotsky, L. S. (1987). Thinking and Speech. In E. Zavershneva & R. van der Veer (Eds.),
2 *The Collected Works of L. S. Vygotsky, Problems of General Psychology* (pp. 353–366).
3 https://doi.org/10.1007/978-981-10-4625-4_21
- 4 Wang, J., Liu, R.-D., Ding, Y., Xu, L., Liu, Y., & Zhen, R. (2017). Teacher’s autonomy
5 support and engagement in math: Multiple mediating roles of self-efficacy, intrinsic
6 value, and boredom. *Frontiers in Psychology*, 8, 1006.
7 <https://doi.org/10.3389/fpsyg.2017.01006>
- 8 Weinstein, N., Zougkou, K., & Paulmann, S. (2018). You “have” to hear this: Using tone of
9 voice to motivate others. *Journal of Experimental Psychology: Human Perception and*
10 *Performance*, 44, 898–913. <https://doi.org/10.1037/xhp0000502>
- 11 Wiechman, B. M., & Gurland, S. T. (2009). What happens during the free-choice period?
12 Evidence of a polarizing effect of extrinsic rewards on intrinsic motivation. *Journal of*
13 *Research in Personality*, 43, 716–719. <https://doi.org/10.1016/j.jrp.2009.03.008>
- 14 Zourbanos, N., Hatzigeorgiadis, A., Chroni, S., Theodorakis, Y., & Papaioannou, A. (2009).
15 Automatic self-talk questionnaire for sports (ASTQS): Development and preliminary
16 validation of a measure identifying the structure of athletes’ self-talk. *The Sport*
17 *Psychologist*, 23, 233–251. <https://doi.org/10.1123/tsp.23.2.233>
18

1 **Table 1.** Pearson Correlations Among Study Variables and Descriptive Statistics

	<i>M (SD)</i>	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

2 Note: *M* = Mean, *SD* = Standard Deviation;

3 Difficulty coded as ‘0’ for easy-medium and ‘1’ for difficult; Instructional style coded as ‘0’ for autonomy-support and ‘1’ for control

4 **p* < .050, ***p* < .010, ****p* < .001, +*p* < .10

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

	Difficulty level			Instructional style			Difficulty x Style		Autonomous motivation		Controlled motivation	
	<i>F</i>	η_p^2	<i>d</i>	<i>F</i>	η_p^2	<i>d</i>	<i>F</i>	η_p^2	<i>F</i>	η_p^2	<i>F</i>	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

2 Note: *d* = Cohen's *d*
 3 **p* < .05, ***p* < .01, ****p* < .001
 4
 5
 6

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

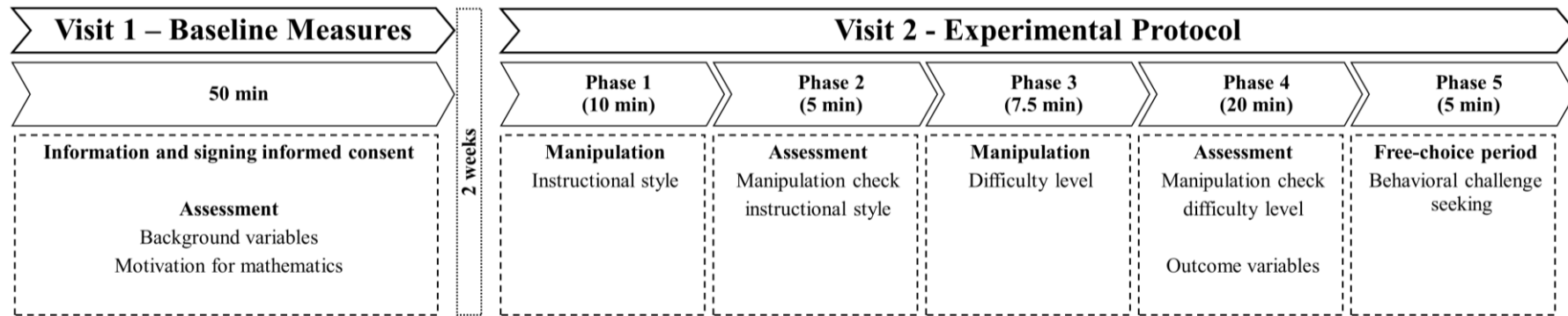
	Autonomy-supportive Style (<i>n</i> = 242)		Controlling Style (<i>n</i> = 237)	
	Easy <i>n</i> = 120	Difficult <i>n</i> = 122	Easy <i>n</i> = 120	Difficult <i>n</i> = 117
Mediating variables				
Autonomy satisfaction	2.70 (0.94)	2.79 (1.00)	2.36 (1.03)	2.33 (0.84)
Autonomy frustration	2.32 (0.92)	2.38 (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)

2


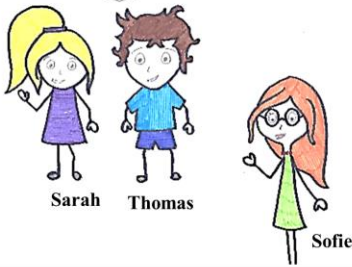

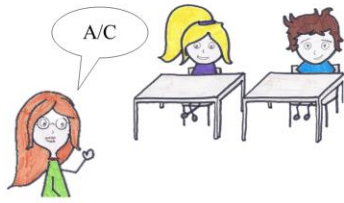

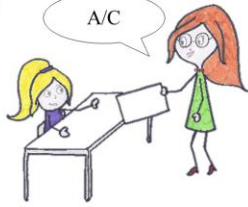
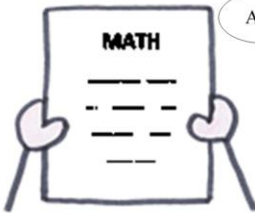
1 **Table 4.** Direct and Indirect Effects in the Structural Model, together with Confidence
 2 Intervals (Bootstrapped – 1000 iterations)

		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]	

3 Note: 95% CI = 95% Confidence Interval



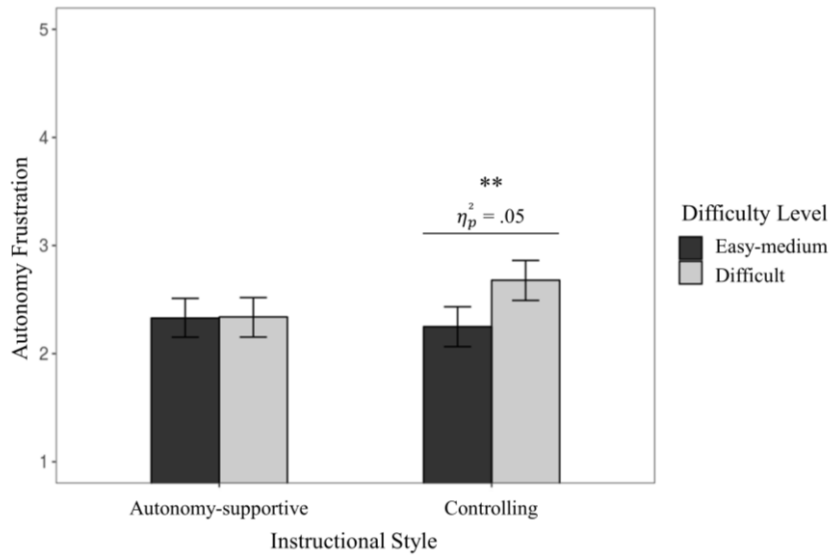
1
2 *Figure 1. Study Procedure*

General introduction	<p>1</p> <p>It is the first week after the Easter holidays in the elementary school. It is Friday afternoon.</p> 	<p>2</p> <p>Sarah and Thomas are both in Grade 4. They are friends since kindergarten and help each other with their schoolwork. Their teacher this year is teacher Sofie.</p>  <p>Sarah Thomas Sofie</p>	<p>3</p> <p>I hope you all had a good lunch break. This afternoon we are going to have math class.</p> 	
Experimental manipulation	<p>4</p> <p>A/C</p> 	<p>5</p> <p>A/C</p> 	<p>6</p> <p>A/C</p> 	<p>7</p> <p>A/C</p> 
Autonomy-supportive (A)	<p>A: "It is important that we all learn how to calculate fluently. For example if you go to the bakery, it is convenient if you can quickly calculate whether he/she gave you sufficient change"</p>	<p>A: "You will receive different exercises. Some exercises will be more difficult than others. If you don't know how to proceed, use intermediate steps, they might help you"</p>	<p>A: "You can choose the order in which you solve the exercises. You can for example start with the first one, but also with the last one. You can use all the space you want to write down intermediate steps. In that way I can see how you solved the exercises and then I can maybe help you"</p>	<p>A: Teacher Sofie: "Good luck with these exercises"</p>
Controlling (C)	<p>C: "You will receive a math test. It is important that you solve the exercises quickly and correct. In that way I can see who is good in math and who isn't"</p>	<p>C: "In the test you will notice that some exercises are more difficult than others. You are obligated to use intermediate steps, otherwise you will fail. Do it well, just as I taught you"</p>	<p>C: "Solve the exercises in the correct order and solve them just as I've taught you. In that way I can see who makes a lot of mistakes and if you solve it in my way".</p>	<p>C: Teacher Sofie: "Good luck on this test"</p>

1
2
3

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



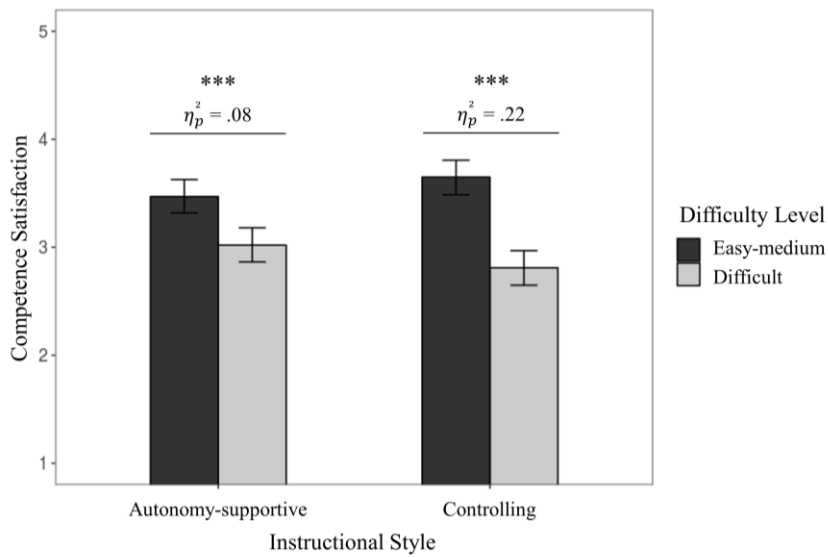
1

2 Note: ** $p < .01$

3

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

6

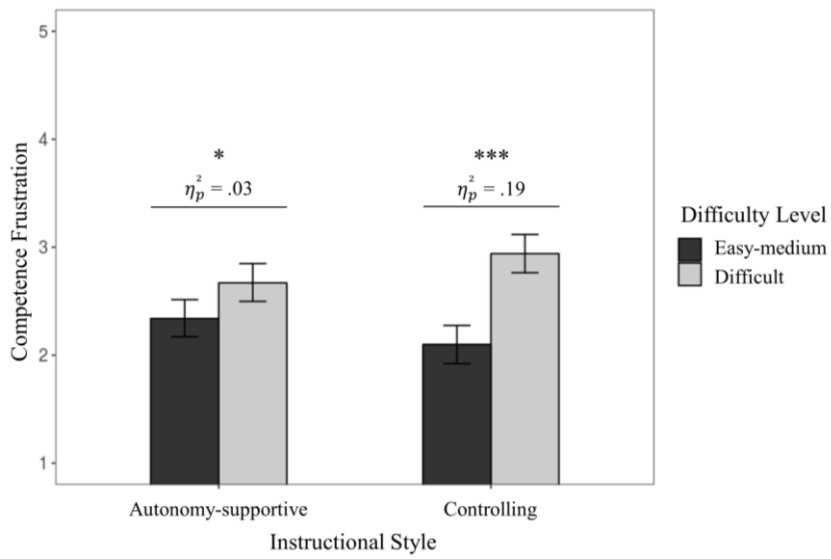


7

8 Note: *** $p < .001$

9

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

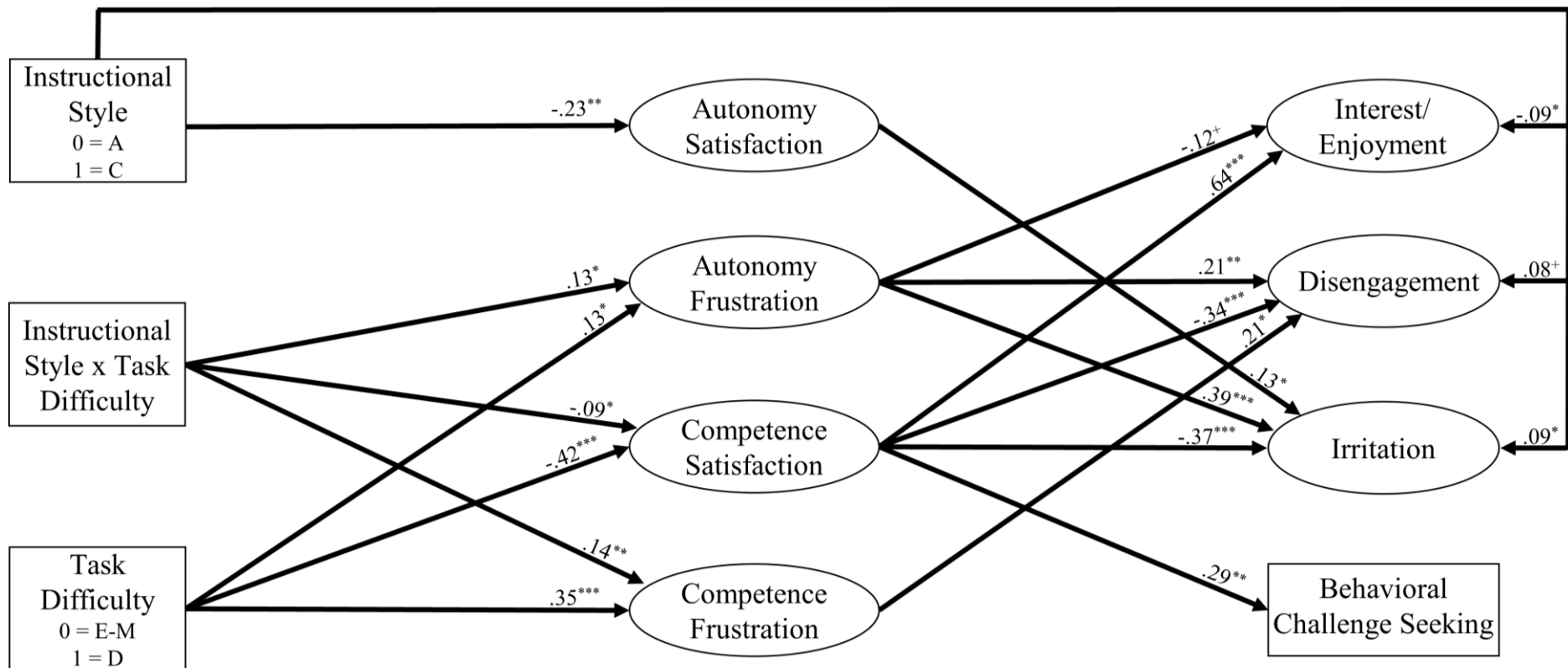


1

2 Note: * $p < .05$, *** $p < .001$

3

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



1

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

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

5 * $p < .05$, ** $p < .01$, *** $p < .001$, + $p < .10$

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 ($\eta_p^2 = .02$) 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	
	<i>F</i>	η_p^2	<i>d</i>	<i>F</i>	η_p^2	<i>d</i>	<i>F</i>	η_p^2	<i>F</i>	η_p^2	<i>F</i>	η_p^2	<i>F</i>	η_p^2
Performance in the experimental phase														
Easy-medium (<i>n</i> = 198)	-	-	-	0.00	.00	-.03	-	-	78.75***	.29	1.80	.01	2.62	.01
Difficult (<i>n</i> = 192)	-	-	-	1.80	.01	-.14	-	-	33.52***	.15	2.78 ⁺	.02	0.35	.00
Performance in the free-choice period (# correct)														
Choice 1 = easy (<i>n</i> = 120)	0.48	.00	-.02	0.00	.00	.09	0.50	.00	20.83***	.16	0.00	.00	0.06	.00
Choice 2 = medium (<i>n</i> = 201)	0.74	.00	-.08	0.22	.00	.06	0.08	.00	54.14***	.22	4.64*	.02	3.58 ⁺	.02
Choice 3 = difficult (<i>n</i> = 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 (<i>n</i> = 120)	2.36	.02	-.16	0.00	.00	.04	0.01	.00	24.71***	.18	1.45	.01	0.09	.00
Choice 2 = medium (<i>n</i> = 201)	4.10*	.02	-.20	0.02	.00	.00	0.47	.00	45.60***	.19	5.39*	.03	0.54	.00
Choice 3 = difficult (<i>n</i> = 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.