Processes of Students' Effort Exertion, Competence Beliefs and Motivation: Cyclic and
Dynamic Effects of Learning Experiences within School Days and School Subjects

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Abstract

We pose a process perspective of learning experiences of effort exertion, competence beliefs, and motivation (autonomous and controlled motivation). Following a process-model of cyclic ("self-sustaining", auto-regressive) and dynamic ("self-enhancing" and "self-diminishing", cross-lagged) associations over time, we investigated the effects of lagged *within-day* and *within-school-subject* constructs, and associations with teacher-perceptions of each student ($n_{teacher} = 22$). In total, 231 students in grade 5 and 6 in primary schools in England (108 boys and 123 girls; $M_{age} = 10.5$ years) responded to the Learning Experience Questionnaire an average of 15.1 time-points during a week ($SD = 3.3$; Range = 10 to 26, in total 3,490 time-points). Multilevel structural equation models (MSEM) showed that effort exertion was the least self-sustaining. Competence beliefs and autonomous motivation were sustained within school-subjects. Controlled motivation was sustained both within days and school subjects. Teachers were more involved with students who felt less competent during the week. Within days controlled motivation showed a self-enhancing effect on effort, while effort showed a self-diminishing effect on controlled motivation. Within school-subjects controlled motivation showed a self-diminishing effect on competence belief and autonomous motivation. Overall our study provides insights into cyclic and dynamic processes of learning experiences in real-time and how these processes are related with student-teacher interactions.

Keywords: engagement; motivation; teacher involvement; intraindividual; multilevel structural equation models

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Introduction

Students' experiences of learning are comprised of dynamic sequences of intraindividual processes and states that take place in real-time throughout the school day and school week. Researchers can investigate these in diary, intensive longitudinal, or micro-analytic studies. Important questions posed by these are (1) whether learning processes are stable or variable, and (2) how instruction can promote such processes (Schmitz, 2006). Indeed, there is a current surge in intraindividual studies using experience sampling or ecological momentary assessment for collecting such real-time data (Hamaker & Wichers, 2017) owing to user-friendly electronic devices (e.g., iPads, tablets). Real-time data have advantages above cross-sectional data for drawing inferences and theorizing (Hattie, 2008) about processes over time in at least two ways. First, retrospective reporting is minimized and contextual closeness maximized (Wilhelm, Perrez, & Pawlik, 2012). Second, appropriate multilevel statistical tools can be used to enable researchers to partition variance due to situations (time), variables and persons (Cattell, 1952). It is not possible to draw conclusions about *intraindividual* variation (e.g., developmental processes, learning processes, and adaptive processes as found in longitudinal data), on the basis of *interindividual* variation (e.g., individual differences, as found in cross-sectional data; Hamaker, 2012; Molenaar, 2004).

Recent intraindividual studies have focused on multi-dimensional aspects of students' real-time learning experiences, e.g., emotions (Goetz, Frenzel, Stoeger, & Hall, 2009), coping with boredom (Nett, Goetz, & Hall, 2011), metacognitive strategies (Nett, Goetz, Hall, & Frenzel, 2012), competence beliefs, effort exertion and task difficulty (Malmberg, Walls, Martin, Little, & Lim, 2013), self-efficacy (Bernacki, Nokes-Malach, & Aleven, 2015), and engagement (Martin et al., 2015). There are also intrindividual studies that focus on students' perceptions of teachers in terms of perceived autonomy support (Tsai, Kunter, Lüdtke, Trautwein, & Ryan, 2008; Tsai, Kunter, Lüdtke, & Trautwein, 2008), autonomy support and thwarting (Patall et al.,

2018), and motivation (Malmberg, Pakarinen, Vasalampi, & Nurmi, 2015). These studies of students' learning experiences focus on (fixed or moderated) effects of concurrent perceptions of the context on experiences, using individuals "as their own controls". As relevant to the present study, however, they did not pose explicit research questions related to the chronological order of time, whereas in the present study we do so. Although Skinner and Schmitz as early as 1993 specified lagged-variable models applied to single cases (Schmitz & Skinner, 1993, pp. 1012-1025), and pooled lagged analysis (Musher-Eizenman, Nesselroade, & Schmitz, 2002), there has been a distinct lack of studies modelling chronologically structured educational data. Such models include focal variables at time T and lagged variables at Time $T-1$ (the preceding time-point). The unique yield these studies offer is to investigate cyclic (or iterative) processes over time (e.g., how effort in one situation predicts effort in the following situation), and dynamic processes over time (e.g., how autonomous motivation in one situation predicts competence belief in the following situation; see Section "Multivariate time-lagged analyses").

Notwithstanding the unique insights this approach offers, modelling real-time lagged associations in educational contexts poses two interesting challenges. The first challenge is how to account for time away from school, such as free time, homework, and sleep. The second challenge is how learning experiences in one subject or lesson can carry over into a following subject or lesson. For example, a learning experience in one lesson may continue to have an effect in the immediately following lesson, indeed, even after controlling for a change in school-subject, teacher, or student group. Or, the learning experience in the previous subject-specific lesson, say science, can have an effect on the subsequent science lesson, even though there may be a time-lag of days in between. To the extent this is the case, it is important for educators to be mindful of the potentially lasting effects of students' positive or negative learning experiences. However, to our knowledge, this has not been investigated. Thus, building on previous studies of students' learning experiences, we investigate the time-lagged associations of students' competence beliefs, engagement and motivation according to the chronological

order of their learning experiences within school-days, and within school-subject. We also investigate how these learning experiences are associated with teacher involvement. In so doing, the present study seeks to further illuminate how learning experiences take place in real-time, and garner a more precise understanding of how student and teacher factors are implicated in this.

Engagement, competence and motivation

The interplay between behavioural and cognitive *engagement* with learning (e.g., effort exertion, task-focus), *competence beliefs* (e.g., how good a student thinks he or she is at school, in a particular subject or at a task), and *motivation* (e.g., the reasons for engaging with learning), is posed in several theoretical models, for example interpersonal (Heider, 1958), engagement (Fredricks, Blumenfeld, & Paris, 2004; Roorda, Koomen, Spilt, & Oort, 2011), self-determination (Ryan & Deci, 2000), and self-regulation (Bernacki et al., 2015; Boekaerts & Corno, 2005) frameworks.

According to self-determination theory, for example, individuals strive to satisfy three basic needs: the need for autonomy, competence, and relatedness (Ryan and Deci, 2000). Importantly, these basic needs can be satisfied in learning contexts where teachers are supportive and the learning tasks are appropriately structured. Students who experience both autonomous (i.e., intrinsic) motivation through tasks and activities that interest them, and controlled (i.e., extrinsic) motivation by adhering to expectations and structures set by teachers, have been related to higher levels of engagement and achievement (Ratelle, Guay, Vallerand, Larose, & Senécal, 2007; Malmberg et al., 2015). Such orientations in which teacher control instruction and its contents, materials, and methods is relatively high, is in the literature referred to as teacher-centred as opposed to student-centered instruction (Cornelius-White, 2007), direct instruction (Flanders, 1970), teacher-directed instruction (Connor, Morrison, & Petrella, 2004), or structure (Jang, Reeve, & Deci, 2010; Skinner & Belmont, 1993).

The ways in which teachers can assist students in integrating these external motives into their internal goals, is described in organismic integration theory (Ryan &

Deci, 2000). According to this theory external demands can be integrated into the individual when the context is conducive, for example through the provision of autonomy support, lack of coercion, direction, and structure, and particularly in situations of both autonomy support and structure (Jang et al., 2010). In such a context students can develop their competences, construe a sense of belonging, and engage in self-directed behaviour, and assimilate external motives into integrated motivation (e.g., accept goals that can be instrumental later on) and identified motivation (e.g., value a goal even if they don't completely endorse it, Ryan & Deci, 2000). Consistent with this conceptualization many studies have found positive association between autonomous and moderately controlled motivation (Deci, Schwartz, Sheinman, & Ryan, 1981), intrinsic, identified, introjected and extrinsic motivation (Ratelle et al., 2007; Walls & Little, 2005), and autonomous and controlled motivation (Malmberg et al., 2015; Patall et al., 2018).

Engagement

Engagement is a multi-dimensional construct (Roorda et al., 2011), with general support for tripartite definitions converging around behavioral engagement (e.g., on-task behavior, participation), emotional engagement (e.g., enjoyment) and cognitive engagement (e.g., cognitive investment in learning, use of metacognitive strategies)(Boekaerts, 2016; Fredricks et al., 2004; Fredricks, Filsecker, & Lawson, 2016). Creating a composite aggregate of all three forms of engagement Roorda et al. (2011) found a medium effect size ($r = .39$) between positive student-teacher relationships and student engagement, and between engagement and achievement ($r = .29$), and positive student-teacher relationship and achievement ($r = .16$). There are some intraindividual studies which have used this tripartite distinction for investigating situation-specific engagement (Pöysä et al., 2018; Shernoff et al., 2015; Vasalampi et al., 2016). Pöysä et al. (2018) found that the three situation-specific (emotional, behavioral, and cognitive) engagement constructs were highly inter-correlated ($r_s = .66$ to $.86$). Shernoff et al. (2015) created a situation-specific engagement construct based on enjoyment (emotional

engagement), concentration (cognitive engagement) and interest (behavioral engagement), which was associated with complexity of, learning support, and challenge in the learning environment. Patall et al. (2018) found associations between situation-specific autonomy support and engagement. We operationalized engagement using the behavioral engagement component as effort exertion, as effort is the most susceptible to volition (Kuhl, 1985). Meta-analyses show that concentration, persistence and engagement are associated with academic performance ($d = 0.48$; Hattie, 2009).

Competence belief

Competence belief is the perception of one's self-related capacity to realize a goal. In the literature these concepts have been referred to as self-efficacy beliefs (Bandura, 2008), agency beliefs (Little, 1998), control and capacity beliefs (Skinner, Zimmer-Gembeck, & Connell, 1998), and self-concept (Marsh, 1990). Despite minute differences in definitions all these beliefs are based on an individuals' sense of agency (Bandura, 2008). Competence beliefs are positively and strongly associated with actual school performance (self-concept: $d = 0.43$; Hattie, 2009), but the specificity of the belief matters (Valentine, Dubois, & Cooper, 2004). For example, competence beliefs can be specified as academic and non-academic domains, with the academic domain further sub-divided into subject-specific self-efficacies (Phan, 2012), and self-concepts (Shavelson, Hubner, & Stanton, 1976). For example, the effects of perceived competence are notably stronger when based on academic self-beliefs (e.g., academic self-concept) rather than global measures (e.g., general self-esteem), and when the perceived competence and achievement measures are matched in subject area (e.g., mathematics achievement and mathematics self-concept).

The situational equivalents of competence beliefs have been termed self-efficacy (Bernacki et al., 2015), mastery experiences (Bandura, 1997), and competence beliefs (Malmberg, Walls, et al., 2013; Tsai, Kunter, Lüdtke, & Trautwein, 2008). Students' gauge their competence belief by their history of drawbacks and mastery, providing a basis for pursuing subsequent optimal or challenging goals. In the longer term sequences

of learning experiences solidify in (trait-level) self-definitions (Shavelson et al., 1976). Consistent with previous studies (Malmberg, Walls, et al., 2013) we operationalized situation-specific competence beliefs as the amount of task-success and understanding (see also Tsai, Kunter, Lüdtke, & Trautwein, 2008). Situation-specific competence beliefs were found to be negatively and differentially associated with task difficulty, and positively and differentially associated with situation-specific effort exertion (Malmberg, Walls, et al., 2013).

Motivation

Motivation can be conceptualized in autonomous or controlled terms (Ryan & Deci, 2000). Autonomous motivation stems from interest, curiosity, enjoyment, and perceived autonomy of learning. Controlled motivation stems from external wishes, demands, structures and imposed goals (Deci & Ryan, 2008). Autonomous motivation energizes individuals to initiate and sustain engagement with a task. Although autonomous motivation plays an important role in pursuing learning goals, most learning activities students engage in at school are controlled, structured or directed by teachers, as they can decide on instructional contents, materials, strategies and modes of support for students (Malmberg et al., 2015). Such orientations in which teacher control of instruction and its contents, materials, and methods is relatively high, is in the literature referred to as teacher-centred as opposed to student-centered instruction (Cornelius-White, 2007), direct instruction (Flanders, 1970), teacher-directed instruction (Connor et al., 2004), or structure (Jang et al., 2010; Skinner & Belmont, 1993).

In the school context, students who develop both autonomous motivation (e.g., subjects, tasks and activities that interest them) and controlled motivations (e.g., adhering to expectations and structures set by teachers and curricula) have been related to higher levels of engagement and achievement (Ratelle et al., 2007). In a study of situation-specific autonomous (i.e., students carrying out a task because they were interested in it, enjoyed it and chose to do it) and controlled motivation (i.e., students

carrying out a task because they had to, or their teacher wanted them to do it), autonomous and controlled motivations were positively associated both across situations and between students (Malmberg et al., 2015). Moreover, an interaction effect showed that lower-performing students felt more autonomous motivation in situations when teachers' expectations (i.e., higher controlled motivation) were higher, while autonomous motivation of higher-performing students was only slightly diminished by higher teacher expectations (i.e., higher controlled motivation). Also Patall et al., 2018 found a daily supports $\times$ thwarts interaction effect on autonomous motivation. These studies suggest that further inspection of cyclic and dynamic associations would be valuable.

Longitudinal studies have shown that intrinsic motivation is stable throughout later childhood and adolescence (Gottfried, Flemming, & Gottfried, 2001). In a longitudinal study (3 time-points) Jang, Kim, & Reeve, 2016 found that a higher level of student disengagement predicted less subsequent teacher autonomy support and more teacher control.

Teacher involvement

Teachers can support students' competence beliefs, engagement and motivation by providing a high level of involvement, defined as the "quality of the interpersonal relationship with teachers and peers" (Skinner & Belmont, 1993). Indeed, positive student-teacher relationships are a buffer against stress and risk, vital for help on (academic) tasks, student engagement, and a foundation for social and emotional development (Collie, Martin, Papworth, & Ginns, 2016; Martin & Dowson, 2009; Pianta, Hamre, & Allen, 2012; Wubbels et al., 2015; Wubbels, Brekelmans, Mainhard, den Brok, & van Tartwijk, 2016). Meta-analyses show that a positive student-teacher relationship is strongly associated with academic performance ($d = 0.72$).

Several concepts are used for describing the ways in which teachers create, maintain and repair student-teacher relationships in order to support students' learning (Roorda et al., 2011). Examples of these concepts are emotional support, classroom organization, and instructional support (Pianta & Hamre, 2009), autonomy support,

structure, and involvement (Skinner & Belmont, 1993), or autonomy-supportive climate, controlling behaviors, and cognitive autonomy support (Tsai, Kunter, Lüdtke, Trautwein, & Ryan, 2008). Emotional support encompasses warmth, lack of negativity, child-centeredness, sensitivity, and responsiveness toward specific children (Pianta & Hamre, 2009), while involvement (Skinner & Belmont, 1993) denotes affection, attunement, dedication of resources, and dependability. Autonomy support includes provision of choice, connections between school activities and children's interests, lack of coercion and external rewards. Such sensitive and responsive teacher-student interaction provides students with experiences that foster motivation and engagement in learning processes. Particularly teachers in primary school are able to dedicate a balance of involvement for each child throughout each day. We used a measure of teacher involvement in our study, as a measure of the time they take for, express affection toward, enjoy interactions with, are attuned to, and dedicate resources to each of their students (Skinner & Belmont, 1993).

The present multivariate time-lagged analyses

Most intraindividual studies use multilevel modelling strategies in which time-points are nested within students (i.e., long or person-period data). This means that individuals are used as "their own controls" particularly in analyses of how individual characteristics predict differences in relationships between situation-specific variables (e.g., cross-level interactions, slopes-as-outcomes models). One way to appropriately model chronologically ordered data is to investigate the associations between measurements at one time-point T and the lagged time-point $T-1$ (i.e., the preceding time-point). While such analyses of (single or multiple) time-lagged variables have been carried out on diary data of parent-child interactions (Aunola, Ruusunen, Viljaranta, & Nurmi, 2015), these have been used to lesser extent for the analysis of educational intraindividual data (but see Patall et al., 2018, who estimated autocorrelated residuals for capturing stability of beliefs from one lesson to another). Such analyses of time-lagged variables can enhance our understanding of the stability of

learning experiences in real-time.

We outline our model of cyclic and dynamic student-teacher interaction and students' processes of engagement, competence and motivation in Fig 1. Following terminology in longer-term longitudinal studies (Guay, Marsh, & Boivin, 2003; Hirvonen, Tolvanen, Aunola, & Nurmi, 2012) we conceptualize three ways in which effort, competence and motivation can be associated over (short-term) time: Cyclical effects can be more or less "self-sustaining" over time. These are captured by the magnitude of the autoregressive paths, also referred to as stability over time. In previous literature on "causal ordering and reciprocal effects" (Guay et al., 2003) between academic performance and competence beliefs (either self-concept or self-efficacy) have posed (1) the "skill-development" path, leading from prior performance (at time T-1) to subsequent competence belief (at time T), and (2) the "self-enhancement" path leading from prior competence belief (at time T-1) to subsequent academic performance (at time T). As we do not have academic performance at the situation level, we propose dynamic effects analogous with the self-enhancement model. But as the cross-lags could potentially be positive (indicating a gain in the variable at Time T), or negative (indicating a drop in the variable at Time T), we call these effects "self-enhancing" (positive cross-lags) or "self-diminishing" effects (negative cross-lags).

More than two decades ago Skinner and Schmitz specified multivariate lagged-variable models applied to single cases of learning experiences (i.e., effort, performance, evaluation and control) in language and mathematics lessons and homework (Schmitz & Skinner, 1993, pp. 1012-1025). The model specified a residual correlation matrix, the associations between the variables at the concurrent time-point T, and a matrix of auto-regressive and cross-lagged associations between the four variables at time-point T and the previous time-point T-1 ("T minus one"). Auto-regressive associations are between the same variable at T and T-1, and cross-lags between one variable at T and another at T-1. Individual differences were observed in associations between concurrent variables, auto-regressive and cross-lagged associations. For example, for some children concurrent effort and performance were unassociated and

for others strongly associated. For some children effort was stable between T-1 and T and for others not. For some children evaluation (teacher report of actual performance) at T-1 was positively associated with effort at T and for some children negatively. In another study using a pooled lagged analysis (Musher-Eizenman et al., 2002), relative to lower-performers higher-performers had more stable control beliefs and perceptions of task ease. Apart from these two studies, there is to the best of our knowledge a lack of studies which have pursued the modelling of chronologically structured data.

Going beyond previous models of intensive longitudinal data (i.e., (Schmitz & Skinner, 1993; Musher-Eizenman et al., 2002)) we include lagged constructs, discriminating between consecutive learning episodes during the day, and the effect of the previous learning episode in that same subject. In Table 1 hypothetical data of one example student is given. During the two days of school the student attends classes in eight different school subjects. The lags of the real-time reports of autonomous motivation in each learning experience are created in two ways. The within-day lag uses the previous report within the day, except for the first report each day, which is coded missing by design (*). The within-subject lag uses the previous report within the same school-subject. For example, the English lesson report in day 3 uses the English report from day 2 as lag. The history lesson in day 2 does not have a previous report and is coded missing.

[insert Table 1 here]

In order to investigate associations between our multivariate constructs: effort exertion, competence belief, and motivation during one school week, and in order to appropriately inspect the chronological sequence of the observations, we propose a model which includes *two* lagged variables, one lag accounting for the previous learning situation within each *day*, and the other the previous learning situation within each *school-subject*. The within-day lags can inform us whether students' learning experiences are self-sustaining (i.e., are consistent or change) within days. The within-subject lags

can provide insight into learning experiences that are self-sustaining (i.e., are consistent or change) within a school-subject. Taken together, our theoretical frame, combined with the multivariate lagged variable method has the potential to enhance our knowledge on real-time processes of learning experiences real-world classrooms.

Research questions

We defined processes of learning experiences as sequences of competence beliefs, effort exertion, and autonomous and controlled motivation in real-time. In order to investigate whether these processes of learning experiences were stable or variable, and how instruction can promote such processes, we posed the following research questions.

(1) What are the cyclic (autoregressive) and dynamic (cross-lagged) associations between learning experiences within days *and* within school-subjects?

(2) How are teacher perceptions and involvement associated with students' learning experiences?

Method

Sample and Procedure

We collected data of 353 students in 16 classrooms in 11 schools. All participants received opt-in parental or guardian consent for participating in the Learning Every Lesson (LEL) study (for more details see Malmberg, Woolgar, & Martin, 2013). During the initial classroom visit students were taught how to use a handheld computer (Personal Digital Assistant, PDA) to complete the electronic Learning Experience Questionnaire (LEQ, Malmberg, Woolgar, & Martin, 2013), after each learning task (i.e., an event triggered response), or at least once every lesson (i.e., a fixed response) for one calendar week. Students were instructed to identify learning episodes. They were given examples of one lesson split into two learning experiences (e.g., individual guitar tutorial at the beginning of a lesson and then returning to do mathematics), and two lessons being treated as one learning episode (e.g., when students had a double lesson in outdoor sports). Researchers monitored compliance of the participants and

performance of the technology during the data collection period. After collecting the PDAs, data were uploaded and error-checked. The study started on Mondays with pick-ups on Friday afternoon, or on Tuesdays with pick-ups the following Monday afternoon. In some cases (e.g., a full day trips or other event that only offered one learning experience a day) students completed the PDA questionnaires on an additional day and the corresponding pick-up was delayed by a day. Of the 5,025 responses, 45 (0.1%) responded to less than 6 of the 19 items and were removed. For the purpose of the lagged analysis here the remaining 4,972 lines of data were scrutinized for time-stamps (i.e., erroneous dates and out-of-school hour time-points, technical errors), odd entries and retrospective reports. Multiple sources of information were screened and cases were hand-picked according to the following logic. We inspected whether the participant (1) had entered the same event twice, duplicating the data, (2) whether one of the two events was a report of an unknown school subject or topic, (3) whether the time-stamp was fixed at 12:00 (the "freeze" mode of this device), and (4) if the report was retrospective. When it was unclear which of the two or more events was the erroneous or the retrospective report, one of the cases were randomly selected. In this way, 491 lines of data (i.e., one line contains the responses to the situation-specific questionnaire for one situation) were excluded. 52 participants who had more than 50% of the lines without time-stamps were also excluded. Then, time-points closer in time than 8 minutes, and participants with less than 10 time-points were excluded from the analysis. This left 3,490 lines of data.

In total there were 231 students who had responded to an average of 15.1 time-points ($SD = 3.3$; Range = 10 to 26). Of these 98 (42.4%) were in Year 5 and 133 (57.6%) in Year 6. There were 108 (46.8%) boys and 123 (53.2%) girls. There were 174 (75.3%) White British, 40 (17.3%) minority students, and 17 (7.4%) unknown. Their mean age was 10.5 years ($SD = 0.64$).

Teacher reports were provided by 22 teachers of whom 18 were females (81.8%). Their mean age was 35.7 years ($SD = 10.9$, Range = 24-61). Their teaching experience was on average 11.7 years ($SD = 11.7$; Range = 1.5-40.0) of which 4.7 years at their

current school (SD = 5.2; Range = 0.06-21.00 years).

Students in the diminished sample for data-analysis and those who were excluded did not differ in teacher-rated task-focus ($t_{[325]} = 0.44$; $p = .66$), involvement ($t_{[325]} = -0.70$; $p = .48$) or academic performance ($t_{[322]} = 0.40$; $p = .69$).

Lagged variables. We created two lagged variables of each item used for the analysis (see Table 1). The within-day lag was based on the chronological time-sequence within each day, so each lagged event was the previous learning experience within that day. The first learning experience each day was coded as missing, in order to account for events that have taken place since students were in school a previous day (i.e., the day before or the day before a weekend), e.g., extra-curricular activities, play, home-work, rest and sleep. The median within-day lag was 1 h 26 min. The within-school-subject lag was based on the succession of learning episodes in the same subject. Students had indicated in a drop-down menu of the standard subjects in the curriculum which subject "they were doing right now" (1 = history, 2 = geography, 3 = art, 4 = math, 5 = English, 6 = science, 7 physical education, and 8 = other). In case students had selected the "other" option they were asked to write in their own words what the topic was about, and the total list of subjects was recoded into a new variable (1 = history, 2 = geography, 3 = arts and crafts, 4 = math, 5 = English, 6 = science, 7 physical education, 8 = music, 9 = computer technology, 10 = modern languages, 11 = religious education, 12 = health, and 13 = other). The time-points were sorted according to school subject and lagged variables created which used the previous learning experience in that subject as observation. The first occurrence of each subject was coded missing. The missing data-points of both lagged variables are construed as Missing Completely at Random (MCAR; Schafer & Graham, 2002), as the week we observed students in the year, provides arbitrary start and end points of the time-span students took part in the study. The median within school-subject lag was 24 hours 14 minutes.

Student instruments

Students' real-time experiences of learning were measured using the LEQ, (Malmberg, Woolgar, & Martin, 2013). In that study we demonstrated adequate structural validity of our key constructs using multilevel confirmatory factor analysis, and convergence with external validity measures.

Effort exertion was a one-item indicator, "How much effort did you put in?", 1 = none at all, 4 = a lot). *Competence belief* was operationalized with two items "how well were you doing at this task" 1 = poorly, 5 = very well, and "how much did you understand" 1 = all of it, 4 = none (reverse coded, and rescaled to 1-5). We estimated internal consistencies (Cronbach's α) across time-points $M_a = .69$; $SD_a = .11$), and McDonald's omegas: $\omega_W = .69$; $\omega_B = .89$; based on standardized factor loadings $\lambda_{WS} = .68-.77$; $\lambda_{BS} = .82-.98$. Autonomous motivation included three items in response to the opening phrase "why were you doing this task?...I enjoyed it", "I was interested" and "I chose it" (1 = not at all, 4 = very much; $\omega_W = .83$; $\omega_B = .89$; $\lambda_{WS} = .64-.86$; $\lambda_{BS} = .61-1.00$; $M_a = .84$; $SD_a = .07$). controlled motivation included two items "I had to do it" and "my teacher wanted me to do it" (1 = not at all, 4 = very much; $\omega_W = .76$; $\omega_B = .94$; $\lambda_{WS} = .73-.83$; $\lambda_{BS} = .88-1.00$; $M_a = .83$; $SD_a = .08$). While our definition of autonomous motivation clearly overlaps with the definition of autonomous motivation of Ryan & Deci, 2000, our controlled motivation construct refers to the ways in which the teacher sets expectations and demand-level (Malmberg et al., 2015), and organizes instruction and structures the teaching contents (Jang et al., 2010), rather than coercion (Patall et al., 2018; Tsai, Kunter, Lüdtke, Trautwein, & Ryan, 2008). Intraclass correlations (r_{ICC}) for our four constructs were substantive so we specified multilevel models to take account of the clustering: effort exertion $r_{ICC} = .28$, competence belief $r_{ICC} = .28$, autonomous motivation $r_{ICC} = .37$, and controlled motivation $r_{ICC} = .55$. Structural validity was tested using two-level confirmatory factor analysis in the current sub-sample (see below).

Teacher reports

Twenty-two teachers reported on their involvement with students, provided information on students' academic performance, and rated the students' task-focus. On average teachers reported on 16.1 students ($SD = 10.1$; Range = 1-44). For the current analyses we averaged the teacher-reports for each student.

Teacher involvement with students

Teacher involvement was measured using items of dedication of resources (aid, time, energy), modified from previous studies (e.g., Wellborn, Connell, Skinner, & Pierson, 1988), particularly the Dedication of Resources items, e.g., "I spend time with this student" and "I talk with this student". We used six items characterizing the student-teacher relationship (0 = not at all, 4 = very often): "I spend one-to-one time with him / her", "We talk often with each other", "I give him / her a lot of attention", "I put in time and energy with him / her", "I provide thorough explanations for him / her", and "I put a lot of thought into my education of him/her"; $\alpha = .84$; $\omega_B = .84$; $\lambda_{BS} = .43$ to $.89$. The associations between academic performance, task-focus and teacher involvement presented in Table 3 support its construct validity, teachers being more involved with lower performing and less task-focused students.

Students' academic performance

Teachers reported on students' performance in mathematics, English, and science, the three key subjects students sit in their 6th year of primary school in England (the Key Stage 2 exam). They did so using each student's curriculum levels, that we subsequently used to grade performance by way of integer values ranging from 1 to 5 (1a = 1.67, 2c = 2, 2b = 2.33, 2a = 2.67, 3c = 3, 3b = 3.33, 3a = 3.67, 4c = 4, 4b = 4.33, 4a = 4.67, 5c = 5). These are absolute measures of performance in relation to curriculum standards. Each sub-step (e.g., "2a" to "2b") represents one term of progress. Each full scale-step (e.g., "2" to "3") represents a school-year of progress (see also Malmberg et al., 2015). As the 6th grade students had higher curriculum levels in

mathematics ($t_{[209]} = -5.73$; $p < .001$), English ($t_{[220.8]} = -6.91$; $p < .001$), and science ($t_{[199.1]} = -8.75$; $p < .001$), we standardised each performance measure within classrooms prior to analysis ($M = 0$, $SD = 1$). The quality of the construct was adequate: $\alpha = .90$, and $\omega_B = .90$; $\lambda_{BS} = .86-.88$).

Students' task-focused behavior

We used teacher-reports of each student's task-focus in school in general. Task-focus was measured with six items modified from the Behavioural Strategy Rating Scale II (Zhang, Nurmi, Kiuru, Lerkkanen, & Aunola, 2011). Teachers were asked to think about each student's behaviour and work habits in class, and respond on five-point scales (0 = not at all, 1 = rarely, 2 = sometimes, 3 = often, 4 = very often), to what extent each of the six statements characterize the way each student typically behaves in learning situations. Half of the items were positively worded (indicating task-focus) "actively attempts to solve even difficult tasks", "demonstrates initiative and persistence in activities and tasks", and "tries hard to finish even difficult tasks". The three negatively worded items (indicating task-avoidance) were: "has a tendency to find something else to do, instead of focusing on the task at hand", "gives up easily", and "loses focus if a task or activity is not going well" ($\alpha = .94$; $\omega_B = .95$; $\lambda_{BS} = .72-.93$). We specified the construct so that higher values indicated more focus on tasks. The three negatively worded items were specified to form a method-construct for wording (Zhang et al., 2011).

Analytic procedure

In order to analyze the first research question, to investigate cyclic (autoregressive) and dynamic (cross-lagged) associations between our focal variables, we in our person-period (long) dataset (i.e., time-points nested in persons) created two lagged variables (time T-1D within each day and time T-1S within each subject; see Table 2) for each indicator (i.e., each learning experience item). We then specified multilevel structural equation models (B. Muthén, 1994) in order to account for time-points (t) nested in individuals (i), and disattenuate substantive parameters of

measurement error (see Supplementary Materials). This set-up is analogous to the dynamic SEM (DSEM) approach (Asparouhov, Hamaker, & Muthén, 2018). However, we explicitly created our lagged dataset as it contains two lagged variables, one of which was non-conventional (i.e., the within-school-subject lag). We also explicitly parameterized correlated uniquenesses.

In the measurement model (Model 1 in the Supplementary Materials) we specified latent constructs based on one (effort exertion), two (competence belief and controlled motivation) and three indicators (autonomous motivation). We equated factor loadings across levels and time-points, creating metric invariance of the constructs (Marsh et al., 2009), taking care that the invariance constraints were not unreasonable (Van de Schoot, Lugtig, & Hox, 2012).

Following Figure 1 we then specified multivariate multilevel lagged-construct models in order to investigate both lagged, cross-lagged, and within time-point relationships between the constructs (Model 2 in the Supplementary Materials). We *a priori* allowed like indicators of constructs at T and T-1 to have correlated uniquenesses. The structural part of the model was specified so that latent constructs at time T (η_T) were first regressed on within-day constructs at T-1 (η_{T-D1} ; see Figure 2, left), then on within school-subject constructs (η_{T-S1})(see Figure 2, right). Finally we specified a full model in which the latent constructs at time T were regressed on both lagged constructs together (see Figure 3). This model also included teachers' involvement (and students' academic performance and task-focus) at the between level (see Model 3 in the Supplementary Materials). It thus answered the second research question - what are the associations between teacher involvement and students' learning experiences. The covariance coverage for the resulting dataset, which by design had lagged data-points assumed to be Missing Completely at Random (MCAR), was between 0.32 to 1.00 (see Table 2).

Models fit was assessed using the Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and the Standardized Root Mean Square Residual for the within-level ($SRMR_W$) and between-level ($SRMR_B$). For our baseline

model (Model 1) we in addition report the level-specific partially saturated ("PS") indices: $RMSEA_{PSW}$ and $RMSEA_{PSB}$, and CFI_{PSW} and CFI_{PSB} (Ryu & West, 2009). We report the Satorra-Bentler corrected χ^2 as we adjusted standard errors for non-normalities using the Robust Maximum Likelihood estimator (for individual items the skewness was from -1.64 to 0.05, and kurtosis from -1.39 to 2.18).

We carried out all analyses in Mplus 7.4 (L. K. Muthén & B. Muthén, 2015), adjusting standard errors for clustering between classrooms ($n_{class} = 14$) as intraclass correlations were $r_{ICC} = .004$ for effort exertion, $r_{ICC} = .091$ for competence belief, $r_{ICC} = .090$ for autonomous motivation, and $r_{ICC} = .015$ for controlled motivation. There was an insufficient number of classrooms for modelling at the highest level. Effect sizes were calculated using recommendations by Marsh et al. (2009), $ES = (2 \times B \times SD_{predictor}) / \psi$, where B is the unstandardised regression coefficient, $SD_{predictor}$ the standard deviation of the predictor variable and ψ the total variance of the dependent variable.

Results

We first tested structural validity of our constructs at the within and between levels following Equation 1 (see Supplementray Materials). A model in which factor loadings were allowed to vary across the levels fitted data well ($SB\chi^2_{[30]} = 75.27$; $p < .001$, $RMSEA = .021$, $CFI = .989$, $SRMR_W = .017$, $SRMR_B = .034$, $L0 = 15175.66$, $AIC = 60802.62$, $BIC = 61110.50$, adjusted $BIC = 60951.63$). The metric invariance model also fitted data well ($SB\chi^2_{[34]} = 86.88$; $p < .001$, $RMSEA = .021$, $CFI = .987$, $SRMR_W = .017$, $SRMR_B = .038$, $RMSEA_{PSW} = .022$, $CFI_{PSW} = .988$, $RMSEA_{PSB} = .042$, $CFI_{PSB} = .988$, $L0 = 15179.63$, $AIC = 60810.53$, $BIC = 61093.78$, adjusted $BIC = 60947.62$). Negligible differences were found between the freely estimated and the metric invariant model suggesting the invariance constraints were reasonable (Van de Schoot et al., 2012): $\Delta SB\chi^2_4 = 11.80$; $p = .019$, $\Delta SB-2LL\chi^2_4 = -11.58$; $p = .021$, $\Delta RMSEA = .000$, $\Delta CFI = .002$, $\Delta AIC = 7.91$, $\Delta BIC = -16.72$, $\Delta BIC_{adj} = -4.01$. We thus proceeded by adding the lagged constructs to this baseline model.

Cyclic and dynamic effects within days

In order to answer the first research question, what are the within-day and within school-subject cyclic effects of each construct. Following Model 2 (see Supplementary Materials) we specified a model for within-day lags (see left in Fig 2)

The within-day model fitted data well ($SB\chi^2_{[94]} = 187.57$, RMSEA = .017, CFI = .988, SRMR_W = .019, SRMR_B = .044). As we can see to the left in Fig 2 autonomous motivation ($B = .11$, $\beta = .14$; $p = .002$; $ES = 0.25$) and controlled motivation ($B = .19$, $\beta = .28$; $p < .001$; $ES = 0.41$) were self-sustaining within days. The following dynamic effects were found: Higher previous competence belief predicted diminished autonomous motivation ($B = -.08$, $\beta = -.09$; $p = .023$; $ES = -0.16$). Higher previous effort exertion predicted diminished controlled motivation from the teacher ($B = -.07$, $\beta = -.10$; $p = .001$; $ES = -0.15$). Higher controlled motivation the previous learning situation predicted *more* enhanced effort the following situation ($B = .09$, $\beta = .10$; $p = .003$; $ES = 0.18$).

Cyclic and dynamic effects within school subjects

Model 2 for within-school-subject effects also fitted the data well ($SB\chi^2_{[94]} = 181.25$, RMSEA = .016, CFI = .988, SRMR_B = .021, SRMR_W = .041). To the right in Figure 2 we see that competence belief, autonomous and controlled motivation were sustained from the previous lesson to the following lesson within a particular subject. Autonomous motivation was most sustained ($B = .28$, $\beta = .34$; $p < .001$; $ES = 0.61$). Controlled motivation ($B = .18$, $\beta = .26$; $p < .001$; $ES = 0.37$) and competence belief ($B = .20$, $\beta = .23$; $p < .001$; $ES = 0.50$) were equally sustained.

Higher controlled motivation in the preceding situation predicted a *diminished* competence belief the subsequent lesson ($B = -.08$, $\beta = -.10$; $p = .010$; $ES = -0.21$). A higher level of autonomous motivation in the previous situation predicted *diminished* controlled motivation subsequent situation ($B = -.07$, $\beta = -.11$; $p = .041$; $ES = -0.16$).

[insert Table 2 here]

[insert Figure 2 here]

Joint cyclic and dynamic effects within days and school-subjects

We then investigated the joint effects of the within-day and within-subject lags, following the within-part of Model 3 (see Supplementary Materials). This model fitted the data well ($SB\chi^2_{[387]} = 774.25$, RMSEA = .017, CFI = .978, SRMR_W = .021, SRMR_B = .066). As shown in Figure 3 we found patterns of associations consistent with the previous models of within-day and within-subject effects separately (see Figure 2). Going beyond the separate analyses in Figure 2, we now tested whether the within-day or within-school-subject self-sustaining effect was stronger. To do so we observed the associations between T and D1, and T and S1 respectively (see Table 2), and then tested if the auto-regression parameters were significantly different from each other, by specifying additional parameters in the MSEM.

Effort exertion at time T was not sustained within days or within school-subjects (with D1 and S1 $\rho = .07$; $p = .043$, and $\rho = .08$; $p = .071$). The effects were not significantly different ($\Delta_B = -.02$; $p = .723$). Competence belief at time T was sustained more strongly within school-subjects ($\rho = .25$; $p < .001$) than within days ($\rho = .08$; $p = .118$), a difference that was significant ($\Delta_B = -.18$; $p < .001$). Autonomous motivation at time T was more strongly sustained within school-subjects ($\rho = .33$; $p < .001$) than within days ($\rho = .19$; $p < .001$), a difference that was significant ($\Delta_B = -.22$; $p = 0.045$). Interestingly, controlled motivation at time T was equally sustained within days ($\rho = .37$; $p < .001$) as within school-subjects ($\rho = .34$; $p < .001$), not significantly different from each other ($\Delta_B = .05$; $p = .662$).

The following dynamic effects were found: A higher level of within-day controlled motivation enhanced effort ($B = .10$, $\beta = .12$, $p = .019$; $ES = 0.22$), and autonomous motivation ($B = .09$, $\beta = .11$, $p = .046$; $ES = 0.20$) in the following situation. A higher level of within-day effort exertion ($B = -.07$, $\beta = -.10$, $p < .001$; $ES = -0.16$) and higher level of school-subject autonomous motivation in the previous situation ($B = -.09$, $\beta = -.13$, $p = .030$; $ES = -0.21$) predicted a *diminished* controlled motivation in the

following situation. A higher level of subject-specific prior controlled motivation diminished subsequent competence beliefs ($B = -.11$, $\beta = -.14$, $p = .018$; $ES = -0.29$), and autonomous motivation ($B = -.11$, $\beta = -.13$, $p = .038$; $ES = -0.23$).

[insert Table 3 here]

[insert Figure 2 here]

Teacher involvement and learning experiences

In order to answer our second research question, what are the associations between teacher involvement and learning experiences, we in Model 3 (see Supplementary Materials) observed associations between teacher-reported perceptions of the students and of their interaction with the student, and learning experiences (effort exertion, competence belief, intrinsic and extrinsic motivation) at the between level. At the between-level, learning experiences are the student average learning experiences during a week. As we treated the teacher-reports as contemporaneous with the student-reports we observed associations, and not directional effects. Prior to fitting Model 3, a CFA of the teacher-report measures on their own (i.e., all at the between level of the model) also fitted the data well ($SB\chi^2_{[84]} = 238.00$, $RMSEA = .023$, $CFI = .905$, $SRMR_B = .067$).

As we can see in Table 3 teacher involvement was higher with lower performing students, $\rho = -.45$; $p < .001$, and with less task-focused students $\rho = -.42$; $p < .001$, academic performance and task-focus being strongly positively associated $\rho = .71$; $p < .001$. During the week, higher performance was unrelated with effort exertion ($\rho = .07$; $p = .285$) and intrinsic motivation ($\rho = .08$; $p = .194$) during the week. Higher performance was positively related with competence beliefs ($\rho = .49$; $p < .001$) and controlled motivation ($\rho = .24$; $p = .002$) during the week.

Higher task-focus was associated with more effort exertion ($\rho = .14$; $p = .027$) and autonomous motivation ($\rho = .21$; $p = .006$) during the week. Higher task-focus was

strongly associated with competence beliefs ($\rho = .41$; $p < .001$) and controlled motivation ($\rho = .21$; $p < .001$) during the week. Teachers were more involved with students who felt less competent ($\rho = -.28$; $p < .001$) and those who exerted less effort ($\rho = -.21$; although $p = .067$).

Discussion

Following a process perspective of learning and instruction (Schmitz, 2006), we first investigated cyclic and dynamic learning experiences (i.e., effort exertion, competence beliefs, and motivation) within days and within school-subjects, and second, how teacher perceptions and involvement were associated with students' learning experiences. We went beyond previous intraindividual studies of students' learning experiences in four ways, providing a unique window into real-time processes in schools. First, we went beyond previous models of engagement and motivation by applying a theoretical model of cyclic (self-sustaining), and dynamic (self-enhancing and self-diminishing) effects within the microcosm of time (see Fig 1). Second, we conceptualized the chronological ordering of learning experiences using two *innovative* lagged variables contextually relevant for primary school: the sequence of learning experiences within school days, and within each school subject (even though these can be one or more days apart). Third, to appropriately model the chronologically ordered data, we specified autoregressive and cross-lagged associations between learning experiences over time (Schmitz & Skinner, 1993). Fourth, we associated teacher perceptions and involvement with students' learning experiences. Novel cyclic effects (i.e., lagged autoregressive paths), and dynamic effects (cross-lagged paths) emerged, indicating self-sustaining, self-enhancing and self-diminishing relationships between effort exertion, competence beliefs and motivation in real-time. Teachers were more involved with lower-performing, less task-focused students who felt less competent. We discuss these in turn.

Self-sustaining cycles within days or within school subjects?

We investigated self-sustaining effects within days and within school subjects separately (Fig 2) and jointly (Fig 3). Consistent across the three models the following cyclic patterns emerged. As no self-sustaining effects of lagged effort exertion was found, it appeared as the most situation-specific experience of the four included learning experience constructs. This was consistent with the conceptualization that effort is subject to volition (Kuhl, 1985) and thus susceptible to situational affordances and constraints. The lack of self-sustaining effect in our short-term study was different from that of longer-term longitudinal studies. For example Jang et al., 2016 found self-sustaining effects of engagement (behavioral, emotional, agentic and cognitive engagement) $\beta = .32$ and $.34$ over three time-points eight weeks apart. Intraclass coefficients (within individuals) of $r_{ICC_{within}}=.40$ were found for a 7-item behavioral/cognitive engagement construct (Pöysä et al., 2018).

In our study self-sustaining effects of competence beliefs and autonomous motivation were consistent within school-subject model (Fig 2, right), and in the joint model (Fig 3): competence beliefs and autonomous motivation were sustained within school-subjects, from one lesson to the following. Previous (cross-sectional) studies have shown that academic performance in a school subject is more strongly associated with subject-specific self-concept or self-efficacy (Valentine et al., 2004). Theoretically such a self-sustaining loop was consistent with the hypothesized links (Bandura, 1997) between mastery experience (i.e., sense of success in a prior learning task) and self-efficacy (i.e., competence to realize the subsequent learning task), also found empirically (i.e., evaluation as a predictor of control; Schmitz & Skinner, 1993). Competent individuals are not derailed by momentary failures, while less competent individuals could be disengaged.

Autonomous motivation (i.e., enjoying, choosing to, and being interested in a subject) from one episode to the next was as consistent over time as was competence belief. Longitudinal studies have shown that intrinsic motivation is stable in the longer term (Gottfried et al., 2001), and in the shorter term (Patall et al., 2018). Although

competence beliefs and autonomous motivation were clearly associated stable aspects of learning a particular school subject, most learning situations students were engaged in were not autonomously motivated but controlled, structured or directed by teachers (Cornelius-White, 2007; Connor et al., 2004; Skinner & Belmont, 1993). We found effects of *both* lagged within-school-subject and lagged within-day controlled motivation on concurrent controlled motivation. Our measure of controlled motivation (i.e., Why were you doing the task? "I had to" and "I wanted to") tapped into the way teachers set expectations for students, consistent with the ways in which teachers can structure and engage students, without coercion.

In our study self-sustaining effects of controlling motivation ("teacher expectations") were consistent across the within-day model (Fig 2, left), within school-subject model (Fig 2, right), and in the joint model (Fig 3): controlled motivation was self-sustained *both* within days *and* school subjects. The sustained within-school-day effect was interesting as it reflected the role of *consistency* of teachers' expectations of students. In another framework, Skinner et al., 1998 found a positive "ambient effect" of average teacher support aggregated over six time-points (half a year apart) on enhancing students' trajectories of capacity and strategy beliefs. Thinking of the consistency within school-day as a contextual (ambient) effect (Skinner et al., 1998), makes sense in primary school classrooms, in which most lessons during the week are taught by the same teacher (as was the case in our study). This was consistent with the idea that teachers can create a stable context in which development of students' competence beliefs and engagement with school work can be supported (Skinner et al., 1998). Teachers being consistent from one school-subject to another allows teachers to follow up on situational behaviours, give more attention when needed (e.g., a particular student needs assistance in one subject is autonomous in another), intervene early when students are "having a bad day", and allow students to catch up on topics they need to during the day. The teacher consistency enables some degree of individualization, not possible if teachers do not interact with a particular student throughout the day. Although Skinner et al. (1998) used an aggregate of repeated measures of perceived

support over three years of primary schooling, we suggest our within-person lag provided an analogous account of such stability each day, within the one-week microcosm we investigated. We will still reflect on the within time-point associations between the residualized constructs (i.e., associations between constructs, net of variance predicted by the prior learning experience).

In our study, associations between residualized learning experiences (at Time T) within that time-point (controlling for prior experiences) more effort exertion was associated with a higher competence belief ($\rho = .18$; cf. Malmberg, Woolgar, & Martin, 2013) consistent with previous cross-sectional findings that competent and agentic students exert more effort (Little, 1998; Schmitz & Skinner, 1993). In our study more effort exertion was also related with higher levels of autonomous motivation ($\rho = .19$), as motivation is required for initiating and maintaining goal-oriented behavior and sustaining engagement (Patall et al., 2018; Sheldon & Elliot, 1998; Zimmerman, 2008). In our study more effort exertion was also related to a higher level of controlled motivation ($\rho = 0.11$), as teacher expectations, demands, and established structures provide external regulation of goal-directed behavior and engagement (Patall et al., 2018; Sheldon & Elliot, 1998; Schmitz & Skinner, 1993). Some forms of "moderately" controlled motivation (Deci et al., 1981), such as introjected (e.g., wanting not to disappoint the teacher) and extrinsic motivation (e.g., being rewarded by good marks), can be instrumental for achieving learning goals (Deci & Ryan, 2008). Previous studies have shown that a mixture of high levels of both autonomous and controlled motivation were associated with positive academic outcomes (Ratelle et al., 2007). In our study concurrent controlling motivation was associated with concurrent autonomous motivation ($\rho = .17$, compared with .13 found by Patall et al., 2018, indicating that these two motivational patterns were not antagonistic, but instead form a simplex structure of motivational beliefs in which intrinsic and extrinsic motivation form a continuum (Deci, Koestner, & Ryan, 1999).

Dynamic self-enhancing and self-diminishing effects

We discuss self-enhancing and self-diminishing (cross-lagged) effects presented in Fig 3. We found an interesting constellation (i.e., "loops") of within-day effects, and another within school-subjects.

Within-day loops The within-day loops were: more prior effort diminished subsequent controlled motivation (-.07). Higher prior teacher expectations (i.e., controlled motivation) enhanced subsequent effort (.10) and autonomous motivation (.09). As we also found (see Table 3) that student effort exertion was positively associated with teacher-perceptions of students' task-focus, the above within-day finding suggested that teachers make judgements of how much to expect from students, on the basis of their visible on-task behavior and overt behavioral engagement (Nurmi, 2012). In the case students exerted less than optimal engagement with tasks, teachers could in the subsequent learning situation, increase the expectation, redirect students who got off-task, or encourage students to try again. In the case students, in the eyes of the teacher exerted an appropriate amount of effort on a task, the teachers could relax expectations of students. The extent to which the expectations and redirections were carried out in an autonomy supportive rather than in a coercive manner, would be reflected in higher levels of students' engagement and motivation. The extent to which the expectations were implemented using e.g., threats of punishments or denials of rewards, could be reflected in lower levels of students' engagement and motivation (Patall et al., 2018).

Within-school-subject loops The within-school-subject loops were: higher prior autonomous diminished subsequent teacher expectations (-.09; i.e., controlled motivation). Higher teacher expectations diminished competence beliefs (-.11) and autonomous motivation (-.11). This finding indicates a negative loop of subject-specific expectations and pressures, consistent with studies on the thwarting effects of extrinsic motivation (Patall et al., 2018), particularly the role of extrinsic rewards on intrinsic motivation (Deci et al., 1999). Here competence might have played a crucial role: if students experience an increase in pressure and expectations from the teacher, this may

signal to the students that the teacher considers they not currently up to the task demand and that more effort is needed. From attribution and self-worth theory perspectives (e.g., Covington, 2000), the fact that more effort is expected may be interpreted as implying low ability, manifesting in our study as lower perceived competence self-ratings by students. As higher teacher involvement was associated with lower average competence beliefs during the week, we next inspect the role of teacher involvement in this process.

Teacher involvement and learning experiences

Consistent with previous studies which have found that higher task-focus was associated with higher academic performance (Hirvonen et al., 2012) and with a higher level of teacher support (Nurmi et al., 2013), we found that (see Table 3) teachers were more involved with students who were relatively lower-performers, who were less task-focused, and felt less competent on average during the week. A higher level of task-focus was associated with higher levels of all four student-reported learning experiences (effort exertion, competence belief, and autonomous and controlled motivation). As the association between teacher involvement and students' competence beliefs was bi-directional, it could be interpreted in two ways. First, teachers were involved with and dedicated time, resources and affect toward students, because students actively sought the teachers' involvement (Nurmi, 2012). This could be based on students' experiences of positive and meaningful student-teacher relationships in the past (Pianta et al., 2012). Second, teachers could have used their knowledge of students' low performance as a cue for monitoring student progress and engagement with tasks. This could have enhanced the sense of a controlling or punitive environment (Pianta et al., 2012), in which focus was on performance, rather than on building positive relationships (Collie et al., 2016). However, in our study teacher involvement was unassociated with autonomous and controlled motivation, suggesting that different teachers might get involved with students in different ways. It would be important in future studies to incorporate reports of whether students actively seek the teachers'

involvement or not, or to what extent teachers' use controlling messages, suppressing student perspectives, or using uninteresting activities (Patall et al., 2018).

Limitations

There are some limitations of this study that were important to contextualize findings and that provide direction for future research. First, the sample was English school students. As differences in students' real-time engagement have been found between countries (Salmela-Aro, Moeller, Schneider, Spicer, & Lavonen, 2016), future replication of the current findings in other contexts are necessary. Second, our study was focused on primary (elementary) school students and their teachers. As secondary school students are taught by multiple teachers, future research might explore similar questions as ours using multiple teacher ratings. Third, the lagged analysis included data of students who reported between 10 and 26 times. Although lagged analyses can be carried out using fewer than 10 time-points, more time-points are needed for any future time-series types of analyses. Fourth, while our discrete time approach was consistent with the organization of students' lesson time-tables in school during a week, a continuous time approach could reveal interesting effects of actual distances in time-lags between educational experiences (Voelkle & Oud, 2013). Finally, while Bayesian estimation for intraindividual data has been made available using DSEM (Asparouhov et al., 2018; B. Muthén & Asparouhov, 2012; Pöysä et al., 2018), our datasets required bespoke set-up and specification. Future studies could compare the maximum likelihood based approach to a Bayesian approach in which the role of prior information is emphasized and the role of large-sample-theory is de-emphasized.

Conclusion

Following a process perspective of learning experiences (competence belief, effort exertion, autonomous and controlled motivation) during a week of school, we investigated cyclic (auto-regressive, self-sustaining) and dynamic (cross-lagged self-enhancing and self-diminishing) effects within school days and school subjects. We found self-sustained competence belief and autonomous motivation within

school-subjects, and self-sustained controlled motivation both within days and school-subjects. Dynamic within-day controlled motivation predicted self-enhanced effort exertion and autonomous motivation, reflecting a protective role of teacher expectations throughout days. Within school-subjects controlled motivation had a self-diminishing effect on competence beliefs and autonomous motivation, reflecting the cost of teacher expectations.

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Table captions (with notes)

Table 1: Hypothetical lagged data.

Note: The within-day lag is based on the successive order of learning experiences through the day. Each day starts with a missing data-point to account for the events that have taken place since students were previously at school, the day, before or before a weekend, e.g., extra-curricular activities, play, home-work, rest and sleep. The within-subject lag is based on the succession of learning episodes in the same subject. The first occurrence of each subject is coded missing. The missing data-points of both lagged variables were considered Missing Completely at Random (MCAR), as the week we observed students in the year, provides arbitrary start and end points of the observations sequence.

Table 2: Within-level (time-points) correlation matrix.

Note: Eff = effort exertion, Comp = competence belief, Auto = autonomous motivation, Cntr = controlled motivation; T = time-point zero, D1 = lagged within-day time-point T-1, S1 = lagged within-school-subject time-point T-1. Descriptives are based on raw data. Estimates are standardized coefficients from Mplus 7.4. Standard errors are adjusted for clustering between classrooms.

Table 3: Between-level (students) correlation matrix.

Note: Eff = effort exertion, Comp = competence belief, Auto = autonomous motivation, Cntr = controlled motivation; i = student average during the week; Perf = student academic performance, Focus = student task-focus, Inv = teacher involvement with each student. Descriptives are based on raw data. Estimates are standardized coefficients from Mplus 7.4. Coefficients in *italics* were not significant at $p \leq .05$. Standard errors were adjusted for clustering between classrooms.

Figure captions (with notes)

Figure 2: Cyclic and dynamic effects within days (left) and within school subjects (right).

Note: Eff = effort exertion, Comp = competence belief, Auto = autonomous motivation, Cntr = controlled motivation. T = time-point zero, D1 = lagged within-day time-point T-1, S1 = lagged within-school-subject time-point T-1. All parameters were estimated but only significant ($p \leq .05$) unstandardized regression coefficients and standardized residual correlations from from Mplus 7.4 are included in the figure.

Figure 3: Joint cyclic and dynamic effects within days and school subjects.

Note: Note: Eff = effort exertion, Comp = competence belief, Auto = autonomous motivation, Cntr = controlled motivation. All parameters were estimated but only significant ($p \leq .05$) unstandardized regression coefficients and standardized residual correlations from from Mplus 7.4 are included in the figure.

Table 1

Day	Lesson	Subject	Autonomous	Day lag	Subject lag
2	1	Eng	3.00	*	2.67
2	2	Maths	1.67	3.00	2.00
2	3	Arts	2.00	1.67	*
2	4	PE	1.67	2.00	*
2	5	History	2.33	1.67	*
3	1	Maths	2.00	*	1.67
3	2	Language	3.00	2.00	*
3	3	English	2.67	3.00	3.00
3	4	Science	2.00	2.67	2.33
3	5	Computer	2.67	2.00	*

Note: The within-day lag is based on the successive order of learning experiences through the day. Each day starts with a missing data-point to account for the events that have taken place since students were previously at school, the day, before or before a weekend, e.g., extra-curricular activities, play, home-work, rest and sleep. The within-subject lag is based on the succession of learning episodes in the same subject. The first occurrence of each subject is coded missing. The missing data-points of both lagged variables were considered Missing Completely at Random (MCAR), as the week we observed students in the year, provides arbitrary start and end points of the observations sequence.

Table 2

			Eff			Comp			Auto			Cntr			Descriptives			
	T	D1	S1	T	D1	S1	T	D1	S1	T	D1	S1	T	D1	S1	n	M	SD
Eff	T															3,295	3.28	0.90
	D1	.07														2,337	3.29	0.89
	S1	.08	.38													1,765	3.27	0.89
Comp	T	.18	.02	.00												3,490	4.30	0.85
	D1	.02	.19	.08	.08											2,467	4.27	0.87
	S1	.03	.08	.18	.25	.28										1,890	4.27	0.84
Auto	T	.19	.03	.03	.49	.02	.13									3,373	2.78	0.96
	D1	.02	.23	.11	.03	.48	.14	.19								2,380	2.75	0.97
	S1	.04	.13	.22	.14	.21	.47	.33	.49							1,818	2.78	0.95
Cntr	T	.12	-.04	-.01	.02	.03	-.07	.15	.11	-.02						3,436	3.20	0.87
	D1	.08	.13	.08	-.01	.07	.11	.10	.24	.21	.37					2,432	3.20	0.87
	S1	.03	.09	.12	-.07	.09	.11	.03	.20	.25	.34	.68				1,862	3.21	0.86

Note: Eff = effort exertion, Comp = competence belief, Auto = autonomous motivation, Cntr = controlled motivation; T = time-point zero, D1 = lagged within-day time-point T-1, S1 = lagged within-school-subject time-point T-1. Descriptives are based on raw data. Estimates are standardized coefficients from Mplus 7.4. Standard errors are adjusted for clustering between classrooms.

Table 3

	Effort _{<i>i</i>}	Comp _{<i>i</i>}	Auto _{<i>i</i>}	Cntr _{<i>i</i>}	Perf	Focus	n	M	SD
Effort _{<i>i</i>}							221	3.26	0.53
Comp _{<i>i</i>}	.23						231	4.28	0.46
Auto _{<i>i</i>}	.29	.50					231	2.77	0.64
Cntr _{<i>i</i>}	.20	.30	.44				231	3.19	0.63
Perf	.07	.49	.08	.24			224	0.12	0.86
Focus	.14	.41	.21	.21	.71		227	2.58	0.51
Inv	-.21	-.28	-.03	.01	-.45	-.42	227	2.46	0.95

Note: Eff = effort exertion, Comp = competence belief, Auto = autonomous motivation, Cntr = controlled motivation; *i* = student average during the week; Perf = student academic performance, Focus = student task-focus, Inv = teacher involvement with each student. Descriptives are based on raw data. Estimates are standardized coefficients from Mplus 7.4. Coefficients in *italics* were not significant at $p \leq .05$. Standard errors were adjusted for clustering between classrooms.

Figure 1. Student-teacher interaction and students' cyclic and dynamic processes of engagement, competence and motivation

Note: Time is conceptualized at the concurrent time-point (T) and the preceding (lagged) time-point ($T-1$). Autoregressive paths (i.e., paths from the preceding to the concurrent time-point of the same construct) indicate cyclical self-sustaining effects, indicated with bold ("thick") arrows. Cross-lagged paths (i.e., paths from a preceding construct to a different concurrent construct) indicate dynamic effects which can be either self-enhancing or self-diminishing, indicated with "thin" arrows. Double-headed paths denote four associated constructs at each time-point. Eff = effort exertion, Comp = competence belief, Auto = autonomous motivation, Cntr = controlled motivation. The associations between the constructs at time T are associations between residuals of the constructs (i.e., the associations between the constructs controlling for the auto-regressive and all cross-lagged associations).

Figure 2. Cyclic and dynamic effects within days (left) and within school subjects (right).

Note: Eff = effort exertion, Comp = competence belief, Auto = autonomous motivation, Cntr = controlled motivation. T = time-point zero, D1 = lagged within-day time-point T-1, S1 = lagged within-school-subject time-point T-1. All parameters were estimated but only significant ($p \leq .05$) unstandardized regression coefficients and standardized residual correlations from from Mplus 7.4 are included in the figure.

Figure 3. Joint cyclic and dynamic effects within days and school subjects.

Note: Note: Eff = effort exertion, Comp = competence belief, Auto = autonomous motivation, Cntr = controlled motivation. All parameters were estimated but only significant ($p \leq .05$) unstandardized regression coefficients and standardized residual correlations from Mplus 7.4 are included in the figure.