



Developmental differentiation of academic motivation in self-determination theory

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Abstract

This study investigates the developmental evolution of motivational specificity within the Self-Determination Theory framework. Motivational regulations range from controlled to autonomous forms, and evidence suggests they become more differentiated with age. Yet, this developmental trajectory remains underexplored. Based on the Specificity Hypothesis, we expected autonomous motivations (intrinsic and identified) to become more specific over time, while controlled motivations would remain stable. We tested this among secondary school students (grades 9–11), assessing motivation across academic subjects. Results show that only autonomous regulations—especially intrinsic motivation—exhibited increasing specificity with age. We also observed stronger correlations between motivation and self-concept within subjects over time. These findings support the Specificity Hypothesis and suggest that the development of autonomous motivation involves growing contextual differentiation. In contrast, controlled regulations remained relatively stable. This study highlights the role of self-concept in motivational development and provides new insights into how motivational regulations evolve. Future research should examine these trajectories in broader contexts to confirm and extend these findings.

Keywords Motivational regulations differentiation · Specificity hypothesis · Multidimensionality · Situational and hierarchical motivation · Developmental differentiation

Introduction

Self-Determination Theory (SDT; Deci & Ryan, 1985; Ryan & Deci, 2017) posits the existence of different types of motivational regulations, ranging from more controlled to more autonomous forms. Numerous studies have confirmed that this motivational differentiation is fundamental for understanding the links between these regulations and various educational outcomes based on their degree of self-determination (e.g., Howard et al., 2021). However, recent research suggests that the structure of motivational regulations is more nuanced than previously thought. In particular, Guay et al. (2010) demonstrated that the intensity of differentiation among these regulations varies according to the

type of regulation and the individuals' age, thereby underscoring the importance of developmental dynamics. In this context, the Specificity Hypothesis (Chanal et al., in press; Chanal & Guay, 2015; Chanal & Paumier, 2020; Paumier & Chanal, 2022) offers new insights, explaining the variability in differentiation between types of regulations. The Specificity Hypothesis proposes that autonomous motivational regulations are more differentiated across contexts than controlled regulations, reflecting their stronger alignment with context-specific experiences and values. Nevertheless, it remains to be explored how this specificity varies across age cohorts and whether it could account for age-related differences identified in seminal studies.

A thorough investigation into age-related differences in the specificity of motivational regulations is therefore important for several reasons. First, it may clarify how different types of motivational regulation become organized across domains during schooling. Understanding whether autonomous and controlled regulations differ in their degree of specificity can provide insights into how motivational systems are structured rather than simply how strong they are. Second, examining these differences may shed light

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on how students differentiate their engagement across academic domains. If motivation is not uniformly distributed across contexts, but instead varies in its degree of domain specificity, this has implications for how contextual influences shape motivation. Finally, exploring age-related patterns in motivational specificity can help bridge the gap between SDT research and developmental perspectives by considering how the organization of motivational regulations varies across domains rather than focusing solely on changes in motivational levels. Thus, this article aims to test the hypothesis that the specificity of SDT motivational regulations differs across age cohorts. More specifically, we postulate that the more autonomous regulations (those associated with a higher degree of self-determination) should exhibit greater differences in specificity across cohorts, as they are already more differentiated than less autonomous regulations. In this study, we investigate academic motivation among secondary school adolescents, analyzing both their general motivation for school and their motivation for various specific subjects. In particular, we focus on motivation toward mathematics and French. These subjects were selected because they represent distinct academic domains that have been widely used in prior research on the differentiation of academic self-concept and motivational constructs (e.g., Marsh, 1986). Mathematics and language-based subjects typically involve different cognitive demands and are associated with distinct patterns of self-perception and engagement. Examining motivational specificity across these contrasting domains provides a meaningful context for assessing whether domain-related differentiation in motivation aligns with patterns observed in the differentiation of academic self-concept.

Within-context differentiation of motivational regulations in SDT

SDT posits the existence of different types of motivation that vary according to their level of self-determination. This level refers to the extent to which an individual perceives themselves as the source of their own behavior (Ryan, 2023). Intrinsic motivation is considered the most self-determined type of motivation, manifesting when individuals engage in an activity purely for the enjoyment and satisfaction it brings, rather than for external consequences (Deci & Ryan, 2000). When intrinsically motivated, individuals experience a sense of autonomy and control over their behavior (Ryan & Deci, 2017). In contrast, extrinsic motivation involves engaging in an activity for instrumental reasons, independent of the intrinsic characteristics of the activity (Ryan, 2023).

SDT identifies several types of extrinsic regulations that differ according to their level of self-determination and the

degree of internalization within an individual's value system (Ryan & Deci, 2020). External regulation represents the least self-determined and least internalized form of extrinsic motivation, relating to behaviors driven by external pressures (Ryan, 2023). Introjected regulation marks an initial stage of internalization, where behavior is still influenced by internal pressures. Individuals engaged in this form of regulation often act to avoid feelings of guilt or shame, or to maintain a positive self-esteem (Ryan & Deci, 2017). Identified regulation constitutes a second level of internalization, manifested when an individual recognizes the importance or relevance of an activity in relation to their own values or goals (Deci & Ryan, 2000). In this case, behavior is no longer dictated by internal or external expectations but rather by personal understanding of its value (Ryan, 2023). Integrated regulation represents the highest level of internalization, where the individual incorporates the associated values and beliefs of an activity into their own value system (Ryan & Deci, 2002). Integrated regulation requires a well-established identity that enables individuals to align with meaningful behaviors (Deci et al., 1996). Given that this hierarchical self-organization typically emerges only in late adolescence or early adulthood, it was not assessed in this study. Finally, amotivation is characterized by a lack of motivation or interest in a given activity (Ryan & Deci, 2017). Amotivated individuals may feel a lack of control over their environment or believe that their actions do not influence outcomes.

Between-context differentiation of motivational regulations in SDT

Guay et al. (2010) expanded the analysis of the differentiation of motivational regulations described by SDT by examining multiple academic subjects. These researchers studied motivational regulations (intrinsic, identified, and controlled, i.e., introjected and external regulation considered together) across different subjects (i.e., mathematics, reading, and writing) simultaneously in elementary school students (ages 6–9). Their results revealed that intrinsic motivation and identified regulation differentiated more significantly between subjects than controlled motivation, which includes introjected and external regulation. Specifically, these findings suggest that a student with high intrinsic motivation in one subject may display low intrinsic motivation in another. Conversely, a student with high controlled motivation in one subject tends to maintain a similar level across other subjects. These results were unexpected, as nothing in the theory predicted that the extent of differentiation across subjects would vary based on the type of motivational regulation.

To explain these surprising results, Chanal and Guay (2015) proposed the Specificity Hypothesis. They argue that autonomous motivations (those with an internal locus of control, such as intrinsic, integrated, and identified motivation) are more differentiated across academic subjects than controlled motivations (those with an external locus of causality, such as introjected and external regulation). According to this hypothesis, autonomous motivations would be more specific to the academic subjects in which they are measured. More precisely, autonomous motivations would differentiate more between subjects due to the regulatory mechanisms associated with them, which would be specific to the characteristics of each subject (Chanal & Guay, 2015). Thus, as students progress through their educational journey, they may become aware of the importance of each subject, but their identification with a specific discipline could vary based on their cultural background or future career aspirations. In contrast, controlled motivations would be less differentiated because the regulatory mechanisms underlying them are not subject-specific but may manifest across all academic subjects (Chanal & Guay, 2015).

To test their hypothesis, Chanal and Guay (2015) simultaneously measured the motivation of elementary and secondary school students through various motivational regulations (i.e., intrinsic, identified, introjected, and external) for school in general and for several academic subjects (e.g., mathematics, French). Their results confirmed the Specificity Hypothesis, showing that autonomous motivations were indeed more subject-specific than controlled motivations. Recently, studies have replicated these findings by incorporating new motivational regulations (i.e., intrinsic motivation by stimulation, intrinsic motivation by achievement, identified regulation, introjected approach, introjected avoidance, external approach, external avoidance) (Chanal & Paumier, 2020) and focusing on different student populations (i.e., junior high school children) as well as university students (Paumier & Chanal, 2022). The Specificity Hypothesis has recently been validated through a rigorous and robust methodological validation procedure (Chanal et al., in press), generalizing and reinforcing the earlier empirical work conducted.

Developmental aspect of between-context differentiation

Numerous studies have examined age-related differences in the differentiation of various motivational constructs across different academic subjects during adolescence (Bong, 2001; Eccles et al., 1993; Marsh, 1989; Marsh et al., 1991, 1998, 2002; Marsh & Ayotte, 2003; Wigfield et al., 1997). Several pieces of research have demonstrated that the differentiation of the self-concept across different subjects

increases with age, transitioning from elementary to secondary school (Marsh, 1989; Marsh et al., 1991, 1998, 2002; Marsh & Ayotte, 2003). Other studies (Bong, 2001; Eccles et al., 1993; Wigfield et al., 1997) have examined the evolution of the subjective value of tasks. Notably, Wigfield et al. (1997) revealed in a study involving students from Grade 1 to Grade 6 that the link between the subjective value of tasks in mathematics and reading and the associated sense of competence was stronger in older children. Gottfried's work (1985, 1990) also showed that students began to distinguish their intrinsic motivation toward different subjects as early as age 7, with this ability increasing with age. In this context, academic self-concept represents a particularly relevant construct. Beyond reflecting perceived competence, self-concept is conceptualized as a multidimensional and domain-specific representation of the self (Marsh, 1989). Importantly, this differentiation has been shown to strengthen across academic subjects with age, reflecting a progressive structuring of students' perceptions of their abilities and identities across domains. This makes self-concept especially relevant for examining motivational specificity. While competence-related beliefs such as self-efficacy capture perceived capability in specific tasks, self-concept reflects broader domain-related self-perceptions that are closely tied to identity processes. From an SDT perspective, the internalization of values and interests underlying autonomous motivation is likely to be associated with the structuring of the self. Therefore, examining the relationship between motivational regulations and subject-specific self-concept provides an indirect way to assess whether the differentiation of motivation across domains aligns with the differentiation of the self.

Within the framework of the motivational constructs described by SDT, only the study by Guay et al. (2010) has examined age-related patterns in between-subject differentiation among students at different age levels. Regarding intrinsic motivation, their results showed that the average correlations between the three subjects (reading, writing, mathematics) significantly decreased with grade levels, from $r = 0.69$ in Grade 1 to $r = 0.42$ in Grade 2 and $r = .18$ in Grade 3. This pattern is consistent with greater differentiation between academic subjects for intrinsic motivation. In contrast, for identified regulation and controlled motivation (i.e., introjected and external regulation considered together), the results revealed no significant difference in the average correlations between academic subjects across grade levels (from $r = 0.80$ in Grade 1 to $r = 0.79$ in Grade 2 and $r = 0.7$ in Grade 3 for identified, and from $r = 0.84$ in Grade 1 to $r = 0.90$ in Grade 2 and $r = 0.82$ in Grade 3 for controlled), indicating that differentiation remained stable for these motivational regulations. Although their aim was not to compare the specificity of motivational regulations

across educational levels, the findings of the study by Chantal and Guay (2015) showed that the specificity of the four motivational regulations measured (i.e., intrinsic, identified, introjected, and external) was more pronounced in older students. More specifically, the variance accounted for at the situational level was higher among secondary school students (i.e., 0.76, 0.74, 0.26, 0.23 for intrinsic motivation, identified regulation, introjected regulation, and external regulation, respectively) compared to elementary students (i.e., 0.64, 0.55, 0.18, 0.08, respectively).

Our study

The purpose of this study is to examine whether the specificity of motivational regulations described by SDT differs across age cohorts. To date, only one study (Guay et al., 2010) has explored age-related patterns of motivational regulations in this framework. Our research aims to fill this gap by examining differences in the specificity of seven motivational regulations among students in grades 9 to 11. Our primary objective is to test whether the specificity of motivational regulations varies across age cohorts. We hypothesize that the specificity of motivational regulations will vary by age group for autonomous motivations but not for controlled motivations. More specifically, we expect an increase in the specificity of the situationally measured items according to age cohorts for autonomous regulations, while this specificity will remain stable for controlled regulations.

Differences in the specificity of intrinsic motivation across cohorts may reflect maturational processes, during which experiences and exposure to different academic subjects multiply as students progress through school levels. This allows for the development of more pronounced interests and preferences for certain subjects. As Deci and Ryan (1985) explain, “at the beginning, interests are relatively undifferentiated, and gradually through accumulated experiences they become more differentiated” (p. 127). Regarding identified regulation, although Guay et al. (2010) did not find a significant difference in between-subject differentiation across educational levels, it is plausible that this regulation reflects maturational processes, becoming more specific with development. Indeed, the accumulation of diverse educational experiences encourages students to reflect on what is important to them and how this aligns with their personal and academic aspirations. Therefore, students at later stages may show clearer distinctions in how they value academic subjects, potentially reflecting a more articulated understanding of their goals and priorities. Thus, over the course of their schooling, they would become increasingly capable of identifying and valuing subjects differently based on their relevance to their personal goals or values, resulting in an increase in the specificity of identified regulation.

Given that the underlying mechanisms of controlled motivations are not specific to any particular academic discipline, we expect that the specificity of these regulations will not increase across educational levels, consistent with the findings of Guay et al. (2010).

To strengthen our conclusions, we will also assess differences in the relationships between the subject-specific factors across different subjects. In this context, subject-specific factors refer to latent components capturing the portion of motivational regulation that is uniquely associated with each academic subject, beyond what is shared across subjects. We therefore expect differences in these relationships across cohorts, but only for autonomous motivations. Finally, we will also examine the correlations between the subject-specific factors and the self-concept in these subjects. Indeed, self-concept has been shown to be specific to academic subjects, providing an interesting proxy to determine the level of specificity of the different motivational regulations and their evolution. Since autonomous regulations are more specific than controlled motivations, we first anticipate stronger links between these regulations and self-concept within each subject, according to the level of self-determination. Furthermore, if specificity is greater in later cohorts for autonomous motivations as posited, we anticipate that the relationships between these constructs will also be stronger in later cohorts, but solely for autonomous regulations.

Methods

Participants and procedure

The sample for this study was derived from two data collection waves conducted between 2013 and 2016 in various secondary schools within the Canton of Geneva. The total sample comprised 1,675 students, of whom 48.15% were male and 51.85% were female ($M_{age}=13.99$ years, $SD=0.92$). This sample included 484 students in the 9th grade ($M_{age}=12.99$ years, $SD=0.49$), 709 students in the 10th grade ($M_{age}=13.02$ years, $SD=0.56$), and 482 students in the 11th grade ($M_{age}=14.93$ years, $SD=0.58$). The participants were drawn from three secondary schools and were distributed across 106 classes. In the Geneva school system, Grades 9 to 11 correspond to lower secondary education, typically attended by students aged approximately 12 to 15. These grades are part of compulsory schooling and precede upper secondary pathways, which may include academic or vocational tracks.

Both studies received ethical approval from the Ethics Committee of the University of Geneva. Written consent was obtained from both students and their parents prior to

participation in the research. Approval to conduct the study was granted by the Ethics Committee of the Faculty of Psychology at the University of Geneva. Data collection and analysis were conducted anonymously. Students completed a paper-based questionnaire during school hours. Research assistants visited the schools to administer the questionnaire, providing uniform instructions for all administrations. They were also present to assist students as needed, ensuring clarity regarding any items in the questionnaire.

Measures

The various motivational regulations of the students were assessed using the questionnaire developed by Chanal et al. (2019). This questionnaire consists of seven subscales, each measuring one of the following motivational regulations: intrinsic motivation to experience stimulation (e.g., “because the class... brings me pleasure”), intrinsic motivation for achievement (i.e., a combination of intrinsic motivation to know and intrinsic motivation toward accomplishments; e.g., “because I discover new things in...”), identified regulation (e.g., “because I consider it important for the future”), introjected regulation (approach; e.g., “to be proud of myself”), introjected regulation (avoidance; e.g., “because I would be ashamed of myself if I did not do it”), external regulation (approach; e.g., “to please other people”), and external regulation (avoidance; e.g., “to avoid being punished”). Participants indicated the frequency with which each statement corresponded to their reasons for participating in school and specific subjects on a seven-point Likert scale, ranging from 1 (“never”) to 7 (“always”). For this study, the questionnaire was used to measure motivations related to school as well as for French and mathematics. McDonald’s omega coefficients indicated good internal consistency for autonomous regulations (ω s ranging from 0.83 to 0.93), acceptable consistency for introjected regulations (ω s ranging from 0.63 to 0.80), and acceptable to good consistency for external regulations (ω s ranging from 0.64 to 0.80). Reliability coefficients were slightly at the school-general level compared to subject-specific contexts. Omega coefficients were computed based on the standardized factor loadings derived from the confirmatory factor analyses.

Students’ self-concept was evaluated using the questionnaire developed by Gu erin et al. (2003). This questionnaire, consisting of six items, was adapted to measure self-concept related to school, mathematics, and French. For each of the six items (e.g., “I do well in...”), students rated their level of agreement on a seven-point Likert scale, ranging from 1 (strongly disagree) to 7 (strongly agree). Internal consistency was assessed using McDonald’s omega coefficients. Reliability was excellent for the self-concept scales

in mathematics ($\omega=0.97$), French ($\omega=0.94$), and school in general ($\omega=0.93$).

Statistical analyses

SEM models regarding the specificity hypothesis

To address our two objectives, we conducted correlated trait-correlated method minus one (CTCM-1) structural equation modeling (SEM) analyses (Eid et al., 2003). CTCM-1 models have been identified as the optimal framework for capturing the multidimensional and hierarchical structure of all motivational regulations (Chanal et al., in press). This model effectively differentiates the item variance associated with the contextual level (e.g., motivation toward school) from that associated with specific academic subjects. At the contextual level, motivation is perceived as a unique trait, while in relation to academic subjects, it is viewed as correlated methods or deviations from the overall trait, as illustrated in Fig. 1 for intrinsic motivation. Thus, each specific factor for each academic subject reflects deviations from the global factor, identifying the item-specific variance related to each subject that exceeds the shared variance at the contextual level. For each CTCM-1 model, correlated uniquenesses (CU) were incorporated to account for the residual covariance among similar items administered across different subjects (see Fig. 1). CTCM-1 models were estimated for each of the motivational regulations using the data from the total sample. The item variance decomposition of these models was conducted to replicate the classical results supporting the Specificity Hypothesis for the various motivational regulations.

Multi-group analyses regarding the specificity hypothesis across cohorts

Multi-group analyses were conducted for each motivational regulation using students’ grade levels (9, 10, and 11) as the grouping variable. First, we estimated a configural invariance model (M1) without constraints across groups to establish a baseline model for comparison. Next, we compared this configural invariance model to a model in which factor loadings were constrained to be equivalent across the three groups (M2). This comparison aimed to test whether the factorial structure of motivational regulations was similar across different grade levels, and by extension, to determine if there were differences in specificity among the grades. The item variance decomposition of these models was then conducted to determine if specificity was increasing across the different cohorts. Subsequently, we compared model M2 to a model in which an additional constraint was added on the correlation between specific subject-related factors

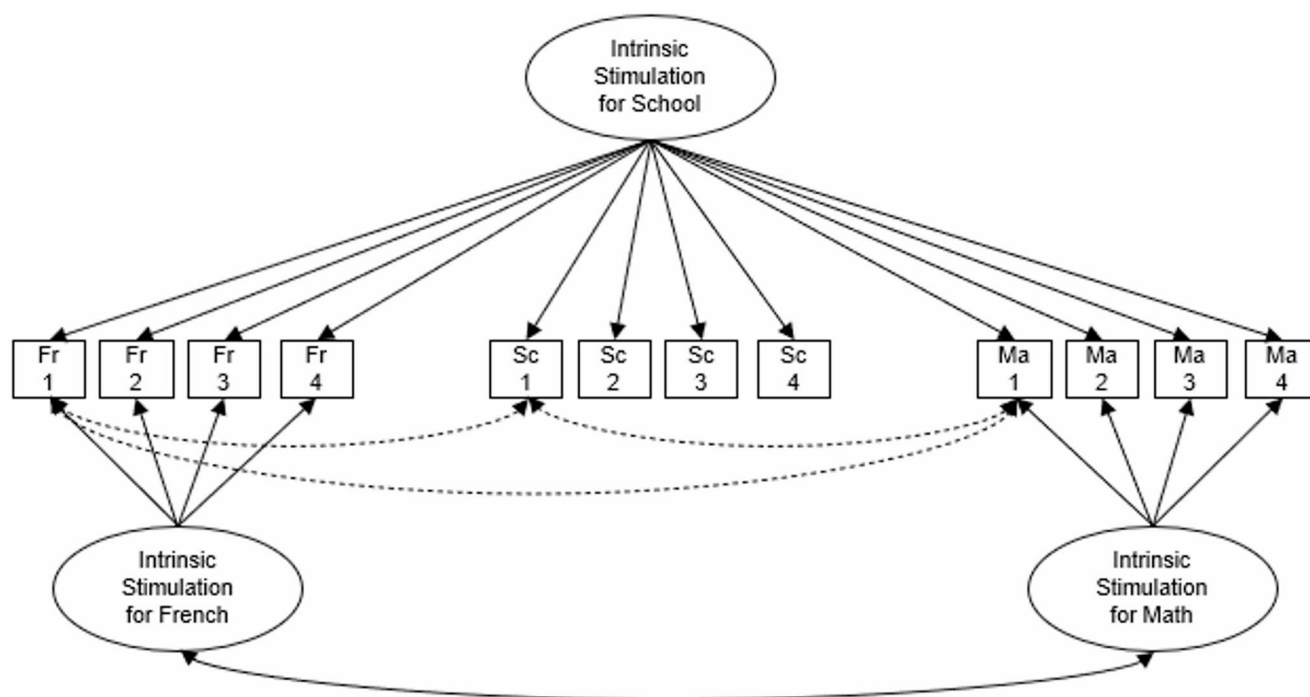


Fig. 1 Graphical representation of CTCM-1 modeling. Fr=item for French, Sc=item for School, Ma=item for Mathematics. 1 to 4=number of items. Dashed arrows represent correlated uniqueness (CU), displayed only for item 1 for clarity

(M3). This last comparison sought to determine whether the relationships among the specific factors were similar across cohorts.

To further support our argument regarding the evolution of specificity over time, we examined the relationships between motivational regulations and self-concept across cohorts. To achieve this, we extracted the factor scores for motivational regulations from the CTCM-1 models, as well as for self-concept, and then performed correlations among the different constructs for each cohort separately.

Model estimation and fit indices

We employed full information maximum likelihood (FIML) estimation using Mplus version 7 (Muthén & Muthén, 2012). All models were tested using maximum likelihood estimation, incorporating robust standard errors (MLR estimation). Missing data represented less than 1% of the total dataset.

To evaluate model fit, we utilized various fit indices, including chi-square values, comparative fit index (CFI), Tucker-Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). In accordance with established guidelines (Hu & Bentler, 1999; Marsh et al., 2005), CFI and TLI values close to or exceeding 0.90 and 0.95 indicate acceptable and excellent fit to the data, respectively. RMSEA values close to or below 0.08 suggest good model

fit, while an SRMR value of 0.08 or less indicates a good fit (Hu & Bentler, 1999). To test the significance of the differences between models in the multi-group analyses, we employed corrected chi-square difference tests ($\Delta\chi^2$). Given that our models were estimated using the MLR method, we applied the scale correction method for difference testing proposed by Satorra and Bentler (2010) to adequately compare differences between models.

Results

Differences in specificity according to regulations

The fit indices for the correlated trait-correlated method minus one (CTCM-1) models for each regulation are presented in Table 1. For the seven motivational regulations considered, the models demonstrate acceptable fit, with the exception of intrinsic motivation for achievement, which exhibited an RMSEA exceeding the threshold (i.e., 0.096) and a TLI below the acceptable level (i.e., 0.870).

The results of the variance decomposition for each motivational regulation across the total sample are shown in Table 2. These findings indicate that the variance explained at the situational level is higher for autonomous regulations compared to controlled regulations. On average, the variance at the situational level was 0.49 (67% of the explained variance) for intrinsic motivation to stimulation, 0.28 (45% of

Table 1 Fit Indices for CTCM-1 Models for Each Motivational Regulation in the Whole Sample ($N=1675$)

	χ^2	df	RMSEA	CFI	TLI	SRMR	AIC	BIC
Intrinsic Stimulation	132.451	33	0.042	0.989	0.979	0.023	65488.248	65797.391
Intrinsic Achievement	541.756	33	0.096	0.935	0.870	0.038	66907.707	67216.85
Identified	171.023	33	0.05	0.982	0.964	0.029	65662.035	65971.178
Introjected Approach	114.947	33	0.039	0.99	0.98	0.024	69449.402	69758.545
Introjected Avoidance	151.933	33	0.046	0.982	0.964	0.036	70439.195	70748.338
External Approach	198.537	64	0.035	0.986	0.976	0.035	85432.23	85817.303
External Avoidance	74.988	33	0.028	0.994	0.988	0.02	70912.616	71221.76

Table 2 Variance decomposition attributable to contextual and situational levels in CTCM-1 models, including variance explained by the specific level, for each grade

	Residual	Contextual	Situational	%Specific
Intrinsic Stimulation	0.26	0.24	0.49	67
9	0.25	0.31	0.45	59
10	0.27	0.24	0.48	66
11	0.27	0.18	0.55	75
Intrinsic achievement	0.37	0.35	0.28	45
9	0.37	0.37	0.25	40
10	0.38	0.34	0.27	44
11	0.34	0.33	0.34	51
Identified	0.40	0.24	0.37	61
9	0.39	0.24	0.37	60
10	0.40	0.25	0.35	58
11	0.39	0.21	0.40	66
Introjected approach	0.47	0.37	0.16	31
9	0.46	0.37	0.16	31
10	0.47	0.37	0.16	30
11	0.49	0.35	0.16	32
Introjected avoidance	0.60	0.28	0.12	31
9	0.60	0.26	0.14	35
10	0.60	0.27	0.13	32
11	0.60	0.30	0.10	26
External approach	0.64	0.27	0.09	25
9	0.64	0.26	0.11	30
10	0.65	0.27	0.08	24
11	0.63	0.28	0.08	23
External avoidance	0.57	0.31	0.12	28
9	0.54	0.34	0.12	26
10	0.57	0.31	0.13	29
11	0.60	0.28	0.12	31

the explained variance) for intrinsic motivation to achievement, and 0.37 (61% of the explained variance) for identified regulation. Conversely, for controlled regulations, only 0.16 and 0.12 (31% of the explained variance) were related to introjected regulation approach and avoidance respectively, and 0.09 and 0.12 (28% and 31% of the explained variance) for external regulation approach and avoidance respectively. These results corroborate previous findings on the Specificity Hypothesis for the overall sample, indicating that autonomous motivations are more specific to academic subjects than controlled motivations.

Differences in specificity across cohorts

The results of the model comparisons between the configural invariance models (M1) and the models with constrained factor loadings (M2) are presented in Table 3. The results of the chi-square difference test reveal significant differences for intrinsic motivation to stimulation ($\Delta\chi^2(34)=60.027, p < .01$) and intrinsic motivation to achievement ($\Delta\chi^2(34)=60.258, p < .01$). These findings suggest that the factor loadings differ significantly across cohorts by grade level. For identified, introjected approach and avoidance regulations, as well as external approach and avoidance regulations, the chi-square difference test indicates no significant differences between the M1 and M2 models. Thus, the results demonstrate that the factor loadings do not vary significantly across cohorts for these five regulations. In summary, the analyses indicate significant differences in factor loadings between grades for intrinsic motivation to stimulation and achievement, but not for the other regulations.

The results of the item variance decomposition for each motivational regulation by cohort are presented in Table 2. For intrinsic motivation to stimulation, the situational variance increases across grades from 0.45 in Grade 9 to 0.48 in Grade 10, and to 0.55 in Grade 11 (corresponding to 59%, 66%, and 75% of the explained variance). A similar trend is observed for intrinsic motivation to achievement, where the situational variance rises from 0.25 in Grade 9 to 0.27 in Grade 10, and then to 0.34 in Grade 11 (40%, 44%, and 51% of the explained variance). These results indicate an increase in the specificity of intrinsic motivations from Grades 9 to 11, aligning with our hypothesis.

Correlations between specific factors

The correlations between the same motivational regulation towards French and mathematics for the total sample and by cohort are presented in Table 4.

Total sample

For the total sample, the results indicate that the correlation pattern between the same motivational regulations

Table 3 Comparison of multigroup models across grades 9, 10, and 11p for each motivational regulation

Intrinsic stimulation	χ^2	df	SCF	χ^2 corr	df corr	cd	$\Delta\chi^2$	Δ df	<i>p</i>
M1 Configural	220.646	99	1.212	267.335	119.948				
M1-M2 Factor loading invariance	282.631	133	1.162	328.417	154.546	1.018	60.027	34.000	0.004
M2-M3 Factor loading and correlation invariance	289.781	135	1.163	337.073	157.032	1.243	6.964	2.000	0.031
Intrinsic achievement									
M1 Configural	643.278	99	1.193	767.431	118.107				
M1-M2 Factor loading invariance	691.055	133	1.226	847.026	163.018	1.321	60.258	34.000	0.004
M2-M3 Factor loading and correlation invariance	689.606	135	1.229	847.802	165.969	1.475	0.526	2.000	0.769
Identified									
M1 Configural	239.062	99	1.216	290.628	120.354				
M1-M2 Factor loading invariance	278.699	133	1.207	336.501	160.584	1.183	38.770	34.000	0.263
M2-M3 Factor loading and correlation invariance	279.321	135	1.209	337.643	163.188	1.302	0.877	2.000	0.645
Introjected approach									
M1 Configural	199.830	99	1.216	243.073	120.424				
M1-M2 Factor loading invariance	223.115	133	1.199	267.403	159.401	1.146	21.223	34.000	0.957
M2-M3 Factor loading and correlation invariance	228.039	135	1.203	274.399	162.446	1.523	4.595	2.000	0.101
Introjected avoidance									
M1 Configural	217.126	99	1.145	248.501	113.306				
M1-M2 Factor loading invariance	254.652	133	1.176	299.420	156.381	1.267	40.191	34.000	0.215
M2-M3 Factor loading and correlation invariance	256.114	135	1.179	301.907	159.138	1.378	1.805	2.000	0.406
External approach									
M1 Configural	303.715	192	1.195	362.788	229.344				
M1-M2 Factor loading invariance	342.085	236	1.221	417.788	288.227	1.338	41.099	44.000	0.597
M2-M3 Factor loading and correlation invariance	350.710	238	1.220	427.971	290.431	1.102	9.238	2.000	0.010
External avoidance									
M1 Configural	163.663	99	1.136	185.970	112.494				
M1-M2 Factor loading invariance	163.663	133	1.178	192.762	156.647	1.299	5.230	34.000	1.000
M2-M3 Factor loading and correlation invariance	205.387	135	1.183	242.891	159.651	1.502	33.379	2.000	0.000

Table 4 Correlations between the same motivational regulation for French and mathematics

	Whole sample	9	10	11
Intrinsic stimulation	-0.16	-0.36	-0.18	0.02
Intrinsic achievement	-0.14	-0.16	-0.19	-0.01
Identified	0.12	0.16	0.10	0.13
Introjected approach	0.24	0.40	0.12	0.22
Introjected avoidance	0.26	0.43	0.24	0.13
External approach	0.54	0.80	0.35	0.36
External avoidance	0.74	0.76	0.73	0.79

towards different school-subjects follows the specificity pattern demonstrated across regulations. Specifically, correlations are stronger and increase systematically along the continuum of self-determination. The correlations along the regulations from intrinsic stimulation to external avoidance are $r = -.016$, $r = -.014$, $r = 0.12$, $r = 0.24$, $r = 0.26$, $r = 0.54$, and $r = 0.74$.

By cohorts

The results of the model comparisons between the models with constrained factor loadings (M2) and the models with constrained correlations among specific factors (M3) are presented in Table 3. The results of the chi-square difference

test reveal significant differences for intrinsic motivation to stimulation ($\Delta\chi^2(2) = 6.964$, $p < .05$), external approach regulation ($\Delta\chi^2(2) = 9.238$, $p < .001$), and external avoidance regulation ($\Delta\chi^2(2) = 33.379$, $p < .001$), indicating that the correlation among specific factors differs across cohorts. In contrast, for intrinsic motivation to achievement, identified regulation, introjected approach and avoidance regulations, the chi-square difference test shows no significant differences between the M2 and M3 models. For these four regulations, the results indicate that the correlation among specific factors remains stable across cohorts.

The results show that inter-subject correlations tend to become less negative with increasing grades for intrinsic motivation to stimulation. The correlation shifts from $r = -.36$ in Grade 9 to $r = -.18$ in Grade 10, and is no longer significant in Grade 11 ($r = .02$). For external approach regulation, the correlation in Grade 9 is substantially higher ($r = .80$) than in Grade 10 ($r = .35$) or in Grade 11 ($r = .36$). Finally, for external avoidance regulation, the correlation shows a slight decrease from $r = .76$ in Grade 9 to $r = .73$ in Grade 10, and then increases to $r = .79$ in Grade 11. In summary, intrinsic motivations in French and mathematics become less interdependent. External regulations exhibit

Table 5 Correlations between each motivational regulation and self-concept for mathematics, French, and the average

Mathematics	Whole Sample (N=1642)	9 (N=473)	10 (N=693)	11 (N=476)
Intrinsic stimulation	0.63	0.63	0.62	0.65
Intrinsic achievement	0.41	0.37	0.42	0.48
Identified	0.37	0.30	0.38	0.41
Introjected approach	0.20	0.17	0.24	0.18
Introjected avoidance	0.03	0.01	0.07	-0.01
External approach	0.13	0.14	0.09	0.18
External avoidance	-0.02	0.02	-0.02	-0.04
French	Whole Sample	9	10	11
Intrinsic stimulation	0.48	0.45	0.50	0.48
Intrinsic achievement	0.33	0.32	0.34	0.32
Identified	0.26	0.20	0.31	0.21
Introjected approach	0.21	0.22	0.19	0.24
Introjected avoidance	0.11	0.04	0.15	0.10
External approach	0.11	0.02	0.17	0.10
External avoidance	-0.02	-0.08	0.06	-0.07
Average	Whole Sample	9	10	11
Intrinsic stimulation	0.55	0.54	0.56	0.56
Intrinsic achievement	0.37	0.34	0.38	0.40
Identified	0.31	0.25	0.35	0.31
Introjected approach	0.21	0.19	0.22	0.21
Introjected avoidance	0.07	0.03	0.11	0.05
External approach	0.12	0.08	0.13	0.14
External avoidance	-0.02	-0.03	0.02	-0.06

a low degree of differentiation across academic subjects, without a clear trend over the grades.

Correlations between motivational regulations and self-concept

The convergent correlations for each motivational regulation for the total sample and by cohort are presented in Table 5, for both French and mathematics, as well as the average across the two subjects.

Total sample

For the total sample, the results indicate that the correlation pattern between motivational regulations and self-concept follows the specificity pattern demonstrated across regulations. Specifically, correlations are weaker and decrease systematically along the continuum of self-determination. The correlations for mathematics are $r = .63$, $r = .41$, $r = .37$,

$r = .20$, $r = .03$, $r = .13$, and $r = -.02$; for French, they are $r = .48$, $r = .33$, $r = .26$, $r = .21$, $r = .11$, $r = .11$, and $r = -.02$; and on average across both subjects, $r = .55$, $r = .37$, $r = .31$, $r = .21$, $r = .07$, $r = .12$, and $r = -.02$. Notably, correlations are stronger for mathematics than for French concerning autonomous motivations.

By cohorts

The correlations with self-concept generally trend upward with grade levels for autonomous motivations only, while no such trend is observed for controlled motivations across both subjects. In mathematics, this pattern appears consistent for all autonomous motivations, including identified regulation. However, in French, this pattern is less clear. The patterns for the three autonomous regulations show greater specificity between Grades 9 and 10, with varying trends observed between Grades 10 and 11. Specifically, for intrinsic motivation to stimulation and for intrinsic motivation to achievement there is a slight decrease, whereas for identified regulation, a more pronounced decrease is observed. For controlled regulations, no clear trend of increase is noted across cohorts.

In summary, as expected, autonomous regulations are more closely related to self-concept within a corresponding subject than controlled regulations. Over the grades, correlations with self-concept increase for both types of intrinsic motivations, and to a lesser extent for identified regulation while no such increase is evident for the more controlled motivations.

Discussion

This study aimed to explore age-related differences in motivational regulations according to SDT, adopting a perspective centered on the specificity of regulations at the situational level. Our results reveal a differentiated structure of motivational regulations, suggesting that situational specificity varies according to the level of self-determination associated with the regulation, thereby replicating findings related to the Specificity Hypothesis. These results are further supported by the correlations observed among different academic subjects as well as the relationships between regulations and the self-concept within the same subject across our entire sample. In accordance with our hypotheses, the findings demonstrate that only the specificity of autonomous motivational regulations differed across age cohorts. More specifically, higher levels of specificity were observed across the three age cohorts studied for the two forms of intrinsic motivation, while other regulations did not show significant changes in their specificity. The correlations

between academic subjects also illustrate age-related differences specific to intrinsic motivation for stimulation, whereas the connections with the self-concept were stronger in later cohorts for autonomous motivations. One possible explanation for this pattern is that autonomous motivations are more closely tied to personally endorsed values and interests, which are likely to become more differentiated across domains as students gain experience with different academic subjects. Interestingly, correlations between autonomous motivation and self-concept were somewhat stronger in mathematics than in French. This difference may reflect subject-specific characteristics, as mathematics and language-based subjects may engage students in distinct ways, potentially leading to stronger alignment between motivational processes and self-representations in certain domains. Given the exploratory nature of this finding, this interpretation should be considered cautiously. In contrast, controlled motivations are often driven by more general pressures or expectations that may operate similarly across contexts. This interpretation is consistent with SDT, which posits that autonomous forms of motivation are grounded in internalized values and personal relevance. As these values become more clearly articulated across domains, autonomous motivations may show greater differentiation. Controlled motivations, by contrast, may remain more context-general because their regulatory basis is less dependent on domain-specific alignment. This pattern may suggest that motivational differentiation is not uniform across regulatory types but instead reflects the degree to which motivation is anchored in personally endorsed values. In this sense, specificity may be understood as an indicator of how strongly motivational processes are integrated within the self.

The results of our study provide new insights into understanding the development of motivational regulations within the framework of SDT. By demonstrating that differences in the differentiation of regulations are linked to the specificity of these regulations across different contexts, our findings suggest greater variability in age-related patterns of autonomous motivations compared to controlled motivations within a given domain. This interpretation is consistent with prior findings suggesting that autonomous forms of motivation tend to be more context-sensitive than controlled forms (e.g., Chanal & Guay, 2015; Guay et al., 2010). Although our study does not focus on the temporal evolution of motivational regulations within the academic subjects investigated or in the school environment, this approach has been largely favored in SDT research across its traditional application fields (such as academic, physical activity, work, or vocational decision-making). Developmental research within the SDT domain has almost exclusively examined the evolution of motivation in terms of motivational trajectories observed over varying periods,

primarily within a single domain or context at a time (e.g., Corpus et al., 2020; Guay et al., 2021; Leroy & Bressoux, 2016; Li et al., 2024). Our study contributes new insights to this body of work by highlighting that the existing literature has certainly not adequately accounted for the differences in differentiation among types of motivational regulations.

Our study offers a novel perspective on the development of motivation within the framework of SDT by adopting a developmental lens. By examining the differentiation of types of motivational regulations across various domains, it explores the structuring of these regulations from an angle that has been relatively underexplored in SDT research. This approach opens new avenues for research that can enhance our understanding of motivational development across different contexts. The findings from this initial study also allow for the consideration of distinct processes and developmental mechanisms that may underlie these differences and differentiation of types of regulations. Indeed, if autonomous and controlled motivations do not achieve the same level of differentiation across contexts, this suggests that the developmental processes at play within these two types of motivation could differ. A central hypothesis in this regard pertains to the relationships between motivational regulations and the self-concept. The development of the self-concept as a hierarchical and multidimensional structure is well-established (e.g., Arens et al., 2021; Brunner et al., 2010; Schmidt et al., 2017). In SDT, the system of motivational regulation is linked to the progressive internalization of both internal and external contingencies within the self-concept throughout development. Consequently, the higher level of specificity observed in autonomous motivations may reflect the developmental influence of the self-concept on these motivations as it differentiates. Thus, the self-concept may play a structuring role in the differentiation of autonomous motivations across various life contexts, as suggested by research on the progressive differentiation of self-concept across domains (e.g., Marsh, 1986; Brunner et al., 2010; Arens et al., 2021). This interpretation is also consistent with research on the development of executive functions and cognitive differentiation in childhood, which highlights increasing capacities for cognitive flexibility and domain-specific structuring of representations across development (e.g., Yanguéz et al., 2025).

This perspective also paves the way for studying the cross-influences between different domains in the development of autonomous motivation, an area that has been relatively underexplored in SDT research. In self-concept studies, the Internal/External reference model (Marsh, 1986) has been extensively studied and validated across diverse cultures, ages, and populations (e.g., Marsh et al., 2015; Möller et al., 2020; Wu et al., 2021). This model identifies two types of comparisons: internal comparisons between

academic domains that students make in school contexts (for instance, between scientific and verbal domains), and external or social comparisons that students engage in when comparing themselves to others in their environment, such as their classmates or school. Specifically, this model demonstrates that students' self-concept in mathematics is negatively affected by their performance in verbal subjects, and conversely, their self-concept in verbal is influenced by their proficiency in mathematics.

Longitudinal studies (e.g., Chen et al., 2013; Marsh et al., 2018; Möller et al., 2014; Wu et al., 2021) have confirmed the robustness of this effect and its generalizability within the school context. In light of our findings regarding the differentiation of autonomous motivation and the differences in specificity across cohorts, it seems pertinent to suggest that other sources of differentiation for similar motivational regulations (for example, intrinsic motivation) across different domains (such as mathematics and French) may also arise from mechanisms of internal (cross-domain) and external (social) comparison, as described in the Internal/External Frame of Reference model (Marsh, 1986). Our results are consistent with this hypothesis, particularly through the correlations observed in the cohort-related differences in intrinsic motivation to stimulation. While the correlations reveal a notable differentiation ($r = -.16$) between these constructs across the entire sample and differences in this pattern over cohorts ($r = -.36$, $r = -.18$, and $r = -.02$), these variations raise questions about their significance during the secondary education period covered by our study. Exploring the gradual decrease of negative links between these constructs could shed light on the potential processes of internal comparison between subjects, as depicted by Marsh's internal/external model in the context of self-concept.

A final theoretical implication of our results pertains to the genesis of the multidimensionality of SDT constructs from a young age, both across academic subjects and within each subject. The study by Guay et al. (2010), conducted with young children (from age 6), focused solely on intrinsic motivation, identified motivation, and controlled motivation (the latter encompassing introjection and external regulation). In first graders (6 years old), the findings indicated low differentiation of constructs, both within subjects (average correlations between intrinsic, identified, and controlled motivation were $r = .66$, $r = .66$, and $r = .68$, respectively) and between subjects (average correlations for intrinsic motivation were $r = .69$, for identified motivation $r = .80$, and for controlled motivation $r = .84$). While this study demonstrated a rapid increase in intra- and inter-subject differentiation in the next two age cohorts, the initial process of differentiation between types of regulations and then between subjects remains an open question, especially

since the links with motivation at the contextual level were not examined in that study. The question of whether this differentiation first occurs within a subject or between subjects remains to be elucidated.

According to our perspective of the Specificity Hypothesis, the most coherent hypothesis would be a pattern of differentiation along the continuum of self-determination across subjects, which would progressively foster differentiation within subjects between the various regulations. The differentiation of motivational regulations could thus emerge gradually, with an increasing specificity that distinguishes subject-specific motivation from broader contextual motivation. This process might begin with autonomous motivations, which are more deeply rooted in daily school experiences. Upon entering school, external contingencies may play a relatively minor role for young children, for whom formal evaluation and behavioral regulation exercised by parents or educational supervision remain limited, and performance is not yet at the forefront of expectations. It is important to note, however, that this developmental interpretation may depend on the cultural and educational context. In systems where performance and formal evaluation are emphasized from early schooling, external contingencies may become salient at much earlier stages. Accordingly, the present findings should be understood within the Swiss educational context, and future cross-cultural research would be valuable to examine the robustness of these patterns. Thus, one might envision a developmental model in which children's school motivation begins to differentiate along the continuum of self-determination, initially marked by specificity for intrinsic motivation before extending to extrinsic motivations, which may vary in their degree of autonomy. However, as noted above, such a developmental sequence may depend on the broader cultural and educational context and should not be assumed to generalize uniformly across systems.

This hierarchical and multidimensional perspective on motivation diverges from the approach that has dominated SDT research over the past fifty years (see Chanal et al., in press), where the emphasis was placed on differentiating regulations within the same context without considering the hierarchical structure of constructs. Recent empirical data supporting the Specificity Hypothesis provide strong evidence for the idea of structural development based on differentiation relative to a higher-order contextual or global construct, at least for autonomous regulations. Our results indicate greater specificity in later cohorts, although further studies are necessary to draw definitive conclusions. The question of structural development and the developmental mechanisms underlying controlled motivations across contexts, as well as within each context, remains a crucial area of research that our work helps to open.

Limitations and future directions

Although this study represents a significant advancement, several limitations must be acknowledged. First, as the study was conducted within a school context, the generalization of the findings to other domains remains limited. It would be pertinent to explore these dynamics in other contexts where contextual and situational motivations are also at play. Additionally, the results rely on cross-sectional cohort analyses, and the lack of longitudinal data prevents us from clearly distinguishing between cohort effects and developmental effects. Longitudinal studies will therefore be necessary to confirm and refine the observed results. Finally, while the proposed hierarchical differentiation model of motivational regulations is promising, its modeling remains complex. We had to restrict our analyses to simplified models that excluded additional factors related to the measured items. The methods of correlated uniqueness employed in this study yielded reliable adjustments; however, previous research (Chanal et al., in press) indicates that incorporating item-related factors may further enhance the model's accuracy, albeit with convergence challenges—difficulties we encountered with our own data. Consequently, it is possible that our results, particularly concerning controlled motivations, might vary slightly when accounting for item-specific variance.

Conclusion

This study provides original insights into the structuring of motivational regulations from SDT by examining differences in their specificity across age cohorts. Our findings support the Specificity Hypothesis, revealing that autonomous motivational regulations, particularly intrinsic motivation, are more differentiated in later age cohorts. This work represents a significant contribution to the field of developmental psychology by integrating the perspective of specificity within a multidimensional and hierarchical view of motivational regulations. This approach reflects an effort toward theoretical and methodological renewal, aiming to better understand the developmental dynamics of motivation and their potential applications, both in education and in other everyday contexts.

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Data availability The data that support the findings of this study are available from the corresponding author, JC, upon reasonable request.

Declarations

Competing interests The authors declare no competing interests.

Declarations of generative AI and AI-assisted technologies in the writing process During the preparation of this work the author(s) used ChatGPT in order to improve language and readability.

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