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An integrative analytical framework for understanding the effects of autonomous and controlled motivation

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ABSTRACT

Purpose: To use polynomial regression analysis with response surface methodology to examine the extent to which autonomous motivation (AM) and controlled motivation (CM) as separate constructs, as well as how the degree of agreement/differentiation and the direction of differentiation among them, can predict outcomes in academic and health contexts.
Methods: Data from two studies with university students and one study with breast cancer survivors were used.
Results: In general, AM predicted positive academic and health outcomes, whereas CM positively predicted negative outcomes. Positive outcomes were generally higher whereas negative outcomes were generally lower when AM was greater than CM and when agreement between AM and CM increased.
Conclusions: Consideration of the degree of agreement and the direction of differentiation between AM and CM adds to the interpretation of the associations between motivation and outcomes in academic and health contexts that is not captured by simply examining AM or CM separately or using a combined AM–CM score.

Over the last 30 years, organismic integration theory (OIT), which is part of self-determination theory (SDT; Deci & Ryan, 1985; Deci & Ryan, 2000), has gained widespread attention as an integrative model for the study of human motivation. OIT theorists have developed a model of motivation that focuses on the quality of motivation underlying behavior, which includes six core motivational regulations that vary in the degree of self-determination. Researchers have employed various scoring approaches in order to study the antecedents, processes, and outcomes of the six motivational regulations (see Pelletier & Sarrazin, 2007; Wilson, Sabiston, Mack, & Blanchard, 2012 for discussion). Each scoring approach has provided distinct, yet complementary, perspectives that have been helpful to improve our understanding of the complex role of motivation across different contexts. However, some researchers have highlighted limitations with the traditional analytical approaches to studying motivation (e.g., Bono & Judge, 2003; Chemolli & Gagné, 2014; Gaudreau, Carraro, & Miranda, 2012; Koestner, 2008; Wilson et al., 2012). In this paper, we discuss these limitations and use polynomial regression analysis with response surface methodology as an analytical tool to examine how autonomous motivation (AM) and controlled motivation (CM), as well as the degree of agreement/differentiation and direction of differentiation of these two dimensions of motivations, can predict outcomes in academic and health contexts across three studies. Specifically, we aimed to show that this analytical approach can be used to better understand what happens when individuals have increasingly similar levels of AM and CM (i.e., high agreement; low differentiation), as well as what happens when individuals have higher or lower levels of AM than CM (i.e., direction of differentiation). We selected health and academic contexts because they: (a) reflect areas in which OIT has been used extensively, (b) are of public importance, and (c) are relatively independent, and thus issues of generality of the findings can been considered.

1. Conceptual organization of the six core motivational regulations

Deci and Ryan (1985) proposed a self-determination continuum that includes six core motivational regulations ranging from non-regulated to self-determined forms of motivation. Adjacent regulations on the continuum have been postulated to be sequentially

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ordered according to their increasing amount of self-determination and internalization. Intrinsic motivation is the most self-determined type of motivation because the individual pursues the activity for the inherent pleasure and enjoyment of the activity. Extrinsic motivation encompasses four of the regulations that differ in their level of self-determination. Moving from most to least self-determined, integrated regulation involves participation in an activity because it is fully integrated with the individual's sense of self and congruent with his/her personal beliefs. Identified regulation involves participation in an activity that the individual deems personally valuable and important to attain a desired outcome. Introjected regulation involves participation in an activity to avoid feelings of guilt and shame and/or protect feelings of worth and ego. External regulation involves participation in an activity because of external demands (e.g., punishments, threats) and/or possible rewards. Finally, when the individual has a relative absence of intrinsic or extrinsic motivation and lacks a reason to act, he/she is said to be amotivated (Deci & Ryan, 2002).

Although there is some evidence supporting the self-determination continuum proposed by Deci and Ryan (1985), its validity has recently been questioned (Chemolli & Gagné, 2014). Indeed, researchers have suggested that caution should be heeded because the structure of motivation is potentially more complex. On the one hand, a continuum suggests that self-determined and non self-determined motivation should be negatively correlated, which is not always the case. On the other hand, a continuum offers little to explain that individuals can possess comparable scores of self-determined and non self-determined motivation, a finding that has been often supported through the different combinations of motivation identified in cluster analytical studies (Haerens, Kirk, Cardon, De Bourdeaudhuij, & Vansteenkiste, 2010; Hayenga & Corpus, 2010; Ratelle, Guay, Vallerand, Larose, & Senécal, 2007; Vansteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009). One way of exploring motivation more cautiously is to study broader dimensions of motivation such as AM and CM (Grant, Nurmohamed, Ashford, & Dekas, 2011; Vansteenkiste, Zhou, Lens, & Soenens, 2005).

2. Assessment of motivation

As indicated above, researchers have adopted various scoring approaches to assess the antecedents, processes, and outcomes of the six motivational regulations. Some have used the scores from each of the motivational regulations to determine their unique effect on different outcomes (e.g., Sabiston et al., 2010; Taylor et al., 2014). However, multicollinearity issues associated with this approach have been reported (e.g., Brunet, Sabiston, Castonguay, Ferguson, & Bessette, 2012). For this reason, a second approach has been to group the regulations into two theoretically-driven dimensions of motivation, namely AM and CM, which according to Vansteenkiste and colleagues (2005, p. 472) are "the two primary types of motivation within SDT." Intrinsic motivation and the two self-determined extrinsic regulations (i.e., integrated and identified) are regrouped in the AM dimension, whereas the two non-self-determined regulations (i.e., introjection and external) are regrouped in the CM dimension[1]. Accordingly, AM represents motivation that stems from an internal locus of causality and it captures the underlying agentic, volitional, and self-endorsed properties entailed in each of the self-determined motivational regulations. CM represents motivation that originates from an external locus of causality and it captures the underlying sense of heteronomy stemming from the interpersonal and intrapersonal pressure entailed in the non-self-determined motivational regulations (Deci & Ryan, 2000).

A third common scoring approach has been to create a variable called the *Relative Autonomy Index* (RAI; Ryan & Connell, 1989). The RAI is created by weighting each motivational regulation and summing the weighted scores to obtain one score. Similarly, Martin-Albo, González-Cutre, and Núña (2014) have recently proposed the *Positive Motivation Index* (PMI), in which the weight of each motivational regulation is derived from the factor loadings estimated in a confirmatory factor analysis. Finally, researchers have used difference scores whereby CM scores are subtracted from AM scores (e.g., Sheldon & Elliot, 1998). The RAI, PMI, and difference scoring methods can offer valuable insight about the direction of differentiation and the degree of agreement/differentiation of these two dimensions of motivations. For example, positive scores indicate that individuals have higher AM than CM, and negative scores indicate they have lower AM than CM. Further, scores of zero indicate that individuals have the same amount of AM and CM (i.e., perfect agreement). Last, higher scores (positive or negative) reflect an increasing degree of differentiation between AM and CM.

Despite the widespread use of these aforementioned formulas, researchers have questioned these scoring methods (Bono & Judge, 2003; Vansteenkiste et al., 2005; Wilson et al., 2012). Technically, these scoring procedures represent the combination of theoretically distinct constructs which makes their interpretation conceptually ambiguous and prone to bias (Edwards, 2002). This can limit the understanding of the differential antecedents, processes, and outcomes of AM and CM. From a theoretical standpoint, this is a major limitation considering that the distinction between AM and CM has heuristic value to characterize and differentiate the phenomenological and functional features of distinct core dimensions of motivations.

3. Autonomous and controlled motivations as separate constructs

It is important to disentangle the *absolute amount* of AM and CM as well as their relative difference or the lack thereof because individuals with different absolute amounts of AM and CM may end up with the same difference or relative motivation scores. To illustrate this problem, consider the hypothetical cases of John, Tim, and Stan. John has low scores of 2, 2, 1, 1, 2, and 2 on intrinsic, integrated, identified, introjection, external, and amotivation subscales whereas Tim and Stan respectively have medium (i.e., 3, 4, 3, 3, 4, and 3) and high scores (i.e., 6, 7, 6, 6, 7, and 6) on all subscales. Using either the traditional weighted formulas or the difference scores, these three fictitious persons would have a score of zero. This example shows that using these formulas does not allow researchers to take into consideration the absolute levels of AM and CM as they remain conflated within one single score.

As a way of addressing these issues, AM and CM have been modeled as independent predictors that are distinctly associated with various outcomes – an approach referred to as the bifurcated scoring method (Wilson et al., 2012). In general, researchers using this method have found positive associations for AM with health and well-being (Brunet, Burke, & Sabiston, 2013; Miquelon & Vallerand, 2006), goal progress (Koestner, Otis, Powers, Pelletier, & Gagnon, 2008), and behavioral outcomes such as fruit and vegetable intake (Shaikh, Vinokur, Yaroch, Williams, & Resnicow, 2011) and exercise (Wilson et al., 2012). For CM, the associations are mixed in that both negative and non-significant associations have commonly been reported for CM with exercise (Teixeira,

[1] Integrated regulation is rarely measured in studies because many instruments do not contain an integrated regulation subscale. Also, amotivation is not included in either AM or CM because it reflects a lack or absence of motivation (Ratelle et al., 2007).

Carraca, Markland, Silva, & Ryan, 2012), goal progress (Koestner et al., 2008), and a range of negative affective and cognitive outcomes (Simons, Dewitte, & Lens, 2004).

Despite the conceptual clarity afforded by the bifurcated scoring method, the results of traditional regression-based analyses (e.g., multiple regression, structural equation modeling, multilevel modeling) are often interpreted in a way that creates the impression that AM and CM are merely competing sources that explain unique variance in the outcomes. Furthermore, this approach does not allow researchers to examine the effects of the degree of agreement/differentiation and direction of differentiation between the two dimensions of motivations. As demonstrated in the fictitious cases of John, Tim and Stan and in empirical studies (Ratelle et al., 2007; Vansteenkiste et al., 2009), individuals can have different within-person combinations of AM and CM. Some individuals can possess comparable amounts of AM and CM (i.e., high agreement; low differentiation), whereas others can have divergent amounts of AM and CM (i.e., low agreement; high differentiation). The extent to which levels of AM and CM are similar or dissimilar remains largely concealed in traditional regression-based analyses. One solution is to apply *polynomial regression analysis with response surface methodology* to the scores of AM and CM in order to unpack different types of effects that have remained largely obscured in our past efforts to disentangle the role of different dimensions of motivation in human functioning.

4. Polynomial regression analysis with response surface methodology

Polynomial regression analysis (Edwards, 1994; Edwards & Parry, 1993), coupled with response surface methodology (see Shanock, Baran, Gentry, Pattison, & Heggestad, 2010 for an empirical example), offers researchers an alternative approach to examine the effects of AM and CM on an outcome within the confines of the variable-centered research tradition. Polynomial regression analysis can be used to test a set of linear and non-linear (i.e., quadratic) equations derived from a regression-based model in which AM and CM are included as separate variables, along with their squared and product terms. This approach will be valuable to SDT researchers as it can be used to investigate theoretically-driven questions of upmost importance within a single variable-centered statistical model: (a) the unique effects associated with the *absolute amount* of AM and CM; (b) the effects associated with the *degree of agreement* between AM and CM; (c) the effects associated with the *direction of the differentiation* between AM and CM; and (d) the effects associated with the *degree of differentiation* between AM and CM[2]. Although this approach has yet to be examined in the extant SDT literature, researchers examining other variables in different contexts have embraced polynomial regression analysis with response surface methodology as a way of dealing with the problems associated with difference scores and the need to differentiate the respective effects of the degree of differentiation and agreement (e.g., Brunet, Sabiston, et al., 2012; Shanock et al., 2010; Yang, Levine, Smith, Ispas, & Rossi, 2008).

5. Purpose and hypotheses

The goal of our research was to illustrate how polynomial regression analysis with response surface methodology can be used to test the effects of AM and CM on a range of outcomes in academic and health contexts. In Study 1, we tested the effects of AM and CM on academic and physical activity outcomes in university students. In Study 2 and Study 3, we used contextual measures of motivation to re-examine the effects of AM and CM on academic, physical activity, and health outcomes in a different sample of university students and a sample of breast cancer survivors, respectively. Based on theoretical perspectives and previous research grounded in SDT and other fields that have used polynomial regression analysis with response surface methodology (Cable & Edwards, 2004; Edwards & Cable, 2009; Shanock et al., 2010; van Vuuren, Veldkamp, de Jong, & Seydel, 2007), we hypothesized that:

(a) AM will be positively associated with positively-valenced outcomes and negatively associated with negatively-valenced outcomes, whereas CM will be negatively associated with positively-valenced outcomes and positively associated with negatively-valenced outcomes (*absolute level of motivation hypothesis*).
(b) Having higher AM than CM will be positively associated with positively-valenced outcomes and negatively associated with negatively-valenced outcomes, whereas having lower AM than CM will be negatively associated with positively-valenced outcomes and positively associated with negatively-valenced outcomes (*direction of differentiation hypothesis*).
(c) Greater agreement between AM and CM will be positively associated with positively-valenced outcomes and negatively associated with negatively-valenced outcomes (*degree of agreement hypothesis*).
(d) Greater positive differentiation (i.e., AM is much higher than CM) will be positively associated with positively-valenced outcomes and negatively associated with negatively-valenced outcomes, whereas having a greater negative differentiation (i.e., AM is much lower than CM) will be negatively associated with positively-valenced outcomes and positively associated with negatively-valenced outcomes (*degree of differentiation hypothesis*).

6. Study 1

Polynomial regression analysis with response surface methodology has been predominantly used in the context of organizational and body image studies (e.g., Brunet, Sabiston, et al., 2012; Cafri, van den Berg, & Brannick, 2010; Shanock et al., 2010; Yang et al., 2008). In this short-term prospective study, our goal was to demonstrate how this approach can be applied to academic and health contexts using data drawn from Carraro and Gaudreau's (2011) study.

6.1. Participants and procedures

Participants were 214 undergraduate students enrolled at a Canadian university (80.4% female; M_{age} = 19.12 years, SD = 3.50). Most (65.9%) were in their freshman year. Participants were recruited from either a university-based participant pool (who received course credit for their participation) or from first and second year undergraduate psychology courses (who received $5 compensation). Participants were not required to be physically active at the time of the study, but were asked to participate in the study only if they were interested in setting a physical activity goal. Participants completed a questionnaire in September/October 2006 (Time 1), and a follow-up questionnaire approximately 1 month later (Time 2). The timing of questionnaire administration coincided with the beginning and end of one academic semester and is comparable to other research in which a one-month period was sufficient for individual differences to occur in goal progress (e.g., Gaudreau et al., 2012). This study was approved by the ethics committee at the University of Ottawa, and participants provided informed consent.

[2] Polynomial regression analysis can also estimate the non-linear effect of the degree of agreement between AM and CM.

6.2. Measures

6.2.1. Personal goals (Time 1)

Participants were provided with Koestner, Lekes, Powers, and Chicoine's (2002, p. 235) definition of personal goals (i.e., "Projects and concerns that people think about, plan for, carry out, and sometimes [though not always] complete or succeed at"). Then, they were asked to list one personal academic and one personal physical activity goal they had for the semester. These instructions were adapted from Koestner et al. (2002) to focus on academic and physical activity goals. Examples the goals participants listed are: "I would like to do a full-body workout at the gym three times per week" and "I want to keep ahead of all my reading."

6.2.2. Motivation (Time 1)

To assess participants' motivation to achieve each of their two goals, participants were asked to rate the degree to which five statements reflected their motivation to pursue their academic and physical activity goals (Sheldon & Kasser, 1998). The statements reflected five motivational regulations: intrinsic ("Because of the fun and enjoyment that this goal provides me; simply for the interest in the experience itself"), identified ("Because I am valuing this goal wholeheartedly; it is important for my personal development"), introjected ("I would feel ashamed, guilty or anxious if I didn't; I feel obligated to have this goal"), external ("Somebody else is putting pressure on me; I will get something from somebody if I do"), and amotivation ("I don't really know why I would want to pursue this goal; this goal is not really a source of motivation for me"). Participants were asked to rate the extent to which they were pursuing their goal for each of the five reasons using a 9-point scale ranging from 1 (*not at all for this reason*) to 9 (*completely for this reason*). Participants rated each statement separately for their academic and physical activity goals. Intrinsic and identified items for each goal were averaged to obtain an AM score for each goal. Introjected and external items were averaged to obtain a CM score for each goal. Not including the amotivation item in these calculations is consistent with previous research (e.g., Ratelle et al., 2007) and theoretical tenets that amotivation is characterized by a lack of motivation, and is therefore neither autonomous nor controlled (Deci & Ryan, 2000). In the past, researchers have used these indicators and similar scoring methods to study goal motivation from a SDT perspective (e.g., Gaudreau et al., 2012; Sheldon & Kasser, 1998).

6.2.3. Planning (Time 2)

Planning for academic and physical activity goals was assessed using the implementation plans questionnaire adapted to academic and physical activity contexts (Rise, Thompson, & Verplanken, 2003). Participants reported the extent to which they had formulated a detailed action plan specifying the when ("I made detailed plans about the day or days on which to perform my academic [or physical activity] goal" and "I made detailed plans about the time of day on which to perform my academic [or physical activity] goal"), how ("I made detailed plans about how to find the time to work on my academic [or physical activity] goal"), where ("I made detailed plans about where to perform my academic [or physical activity] goal"), and what ("I made detailed plans about what to do to perform my academic [or physical activity] goal") aspects related to their academic and physical activity goals. Participants rated each statement separately for their academic and physical activity goals using a 9-point scale ranging from 1 (*not at all*) to 9 (*totally*). Items relating to academic goals and physical activity goals were presented separately. Score reliability has been demonstrated for this measure in academic (Rise et al., 2003) and physical activity contexts (Dugas, Gaudreau, & Carraro, 2012). Average scores for academic and physical activity planning were created by averaging their respective items.

6.2.4. Goal progress (Time 2)

Progress toward academic and physical activity goals was assessed using three items each for physical activity and academic goals. An example item is "Please rate the extent to which you progressed on this goal." Participants were asked to indicate the extent to which they had progressed on both their academic and physical activity goals on a 9-point scale ranging from 1 (*not at all*) to 9 (*totally*). Average scores for academic and physical activity goal progress were created by averaging their respective items.

6.2.5. Average grade (Time 2)

Participants were asked to self-report what level of performance best described their grades, in general, for the semester. Specifically, they were asked " What level of academic performance best describes the grade you have obtained so far in your classes for the semester". Response options ranged from 1 (*F: 0–49%*) to 9 (*A+: 90–100%*).

6.3. Data analyses

Following data screening procedures and calculation of descriptive statistics and estimates of internal consistency (see Table 1), data were analyzed using polynomial regression analyses with response surface methodology. First, AM and CM were centered and modeled as separate predictors (x_1 and x_2), along with the square of these centered variables (x_1^2 and x_2^2) and the cross-product of these centered variables ($x_1 \times x_2$) to assess the linear, nonlinear, and interactive relationships between motivation and each outcome. The centering of the scores reduces multicollinearity between AM and CM and their higher-order terms (Cohen, Cohen, West, & Aiken, 2013). Next, the regression coefficients were transformed into four surface values (a_1 to a_4; see Kazén & Kuhl, 2011 for a methodological review). These values were used to examine how the degree of agreement/differentiation and the direction of the differentiation between AM and CM related to each outcome. The formulas used to compute the surface values were those provided by Kazén and Kuhl (2011) and are presented in Table 2, along with their meaning and how to interpret each surface value. Finally, a three-dimensional graph corresponding to combinations of the regression coefficients was created to aid in interpreting the a_1 to a_4 values (Edwards, 1994; Shanock et al., 2010). Results of the polynomial regression analyses and response surface methodology are presented in Table 3 and Fig. 1.

6.4. Results

6.4.1. Academic planning

The regression model was significant, $F(5, 208) = 5.26$, $p < .001$, $R^2 = .11$. AM positively predicted academic planning. Interpretation of the response surface values indicated that the degree of agreement between AM and CM was linearly and positively associated with academic planning (a_1). Academic planning was higher when AM was higher than CM (a_3).

6.4.2. Academic goal progress

The regression model was significant, $F(5, 208) = 5.00$, $p < .001$, $R^2 = .11$. AM and CM positively and negatively predicted academic goal progress, respectively. Academic goal progress was higher when AM was higher than CM (a_3).

6.4.3. Average grade

The regression model was significant, $F(5, 208) = 3.75$, $p < .01$, $R^2 = .08$. AM positively predicted average grade. Degree of

Table 1
Descriptive statistics for main variables in the three studies.

	N	Cronbach alpha	Scale range	Mean	SD
Study 1					
Academic autonomous motivation (Time 1)	214	–	1–9	5.75	1.71
Academic controlled motivation (Time 1)	214	–	1–9	3.55	1.96
Academic planning (Time 2)	214	.94	1–9	5.34	2.01
Academic goal progress (Time 2)	214	.85	1–9	5.28	1.90
Self-reported average grade (Time 2)	214	–	1–9	3.92	1.65
Physical activity autonomous motivation (Time 1)	214	–	1–9	6.76	1.68
Physical activity controlled motivation (Time 1)	214	–	1–9	2.88	1.81
Physical activity planning (Time 2)	214	.95	1–9	4.19	2.11
Physical activity goal progress (Time 2)	214	.94	1–9	4.06	2.06
Study 2					
Academic autonomous motivation (Time 1)	290	.89	1–7	4.94	1.26
Academic controlled motivation (Time 1)	290	.81	1–7	2.87	1.47
Average grade (Time 2)	290	–	1–10	6.10	2.02
Burnout (Time 2)	290	.92	1–7	3.46	1.02
Engagement (Time 2)	290	.91	1–7	4.23	.96
Satisfaction with life (Time 2)	290	.90	1–7	4.63	1.23
Joy (Time 2)	290	.83	1–7	4.65	1.08
Hope (Time 2)	290	.88	1–7	4.29	1.12
Boredom (Time 2)	290	.87	1–7	3.37	1.18
Anxiety (Time 2)	290	.85	1–7	3.71	1.23
Study 3					
Physical activity autonomous motivation	180	.91	0–4	2.61	.95
Physical activity controlled motivation	180	.72	0–4	.81	.68
Moderate-to-vigorous physical activity (min/week)	180	–	0–720	181.40	178.56
Depressive symptoms	180	.81	0–3	.75	.51
Cancer worries	180	.87	1–4	2.65	.82
Negative affect	180	.88	1–5	1.72	.66
Positive affect	180	.88	1–5	3.26	.69

Notes. SD = standard deviation. All subscale scores were created by averaging items.

agreement between AM and CM was linearly and positively related to average grade (a_1). Average grade was higher when AM was higher than CM (a_3).

6.4.4. Physical activity planning

The regression model was significant, $F(5, 208) = 4.62$, $p < .01$, $R^2 = .10$. AM and CM squared positively and negatively predicted physical activity planning, respectively. Degree of agreement between AM and CM was linearly and positively associated with physical activity planning (a_1). Physical activity planning was higher when AM was higher than CM (a_3).

6.4.5. Physical activity goal progress

The regression model was not significant, $F(5, 208) = 1.22$, $p = .30$, $R^2 = .03$, although AM positively predicted physical activity goal progress. Therefore, response surface values were not computed.

6.5. Brief discussion

Researchers have typically focused either on the effect of absolute level of AM and CM or on the effect of AM relative to CM. Consistent with the first research tradition, we found that higher absolute level of AM was associated with higher academic planning, academic goal progress, self-reported average grade, physical activity planning, and physical activity goal progress. Consistent with the second research tradition, the results from the response surface values indicated that higher AM relative to CM predicted higher academic planning, academic goal progress, and self-reported average grade as a_3 was significant. Across the academic and health contexts, our results clearly demonstrated the usefulness of polynomial regression analysis with response surface methodology to retain, integrate, and capitalize on the advantages of these two research traditions.

7. Study 2

In Study 1, polynomial regression analysis with response surface methodology was used to study the associations between university students' AM and CM and their self-set academic and physical activity goals. Studies on goal motivation represent one particular case of research that has examined the outcomes

Table 2
Surface values formulas, meaning, and interpretation.

Value	Formula	Meaning	Interpretation
a_1	$bx_1 + bx_2$	Reflects the linear relationship between the degree of agreement between AM and CM and the outcome	+ a_1 = as the degree of agreement between AM and CM increases so does the outcome − a_1 = as the degree of agreement between AM and CM increases the outcome decreases
a_2	$bx_3 + bx_4 + bx_5$	Reflects the nonlinear relationship between the degree of agreement between AM and CM and the outcome	+ a_2 = the effect of agreement between AM and CM becomes even more pronounced at higher levels of agreement − a_2 = the effect of agreement between AM and CM diminishes at higher levels of agreement
a_3	$bx_1 - bx_2$	Reflects how the *direction* of the differentiation between AM and CM is related to the outcome	+ a_3 = higher AM relative to CM is associated with higher scores on the outcome − a_4 = higher AM relative to CM is associated with lower scores on the outcome
a_4	$bx_3 - bx_4 + bx_5$	Reflects how the *degree* of differentiation in AM and CM is related to the outcome	+ a_4 = a greater positive differentiation between AM and CM (i.e., AM is much higher than CM) is associated with higher scores on the outcome − a_4 = a greater negative differentiation between AM and CM (i.e., AM is much lower than CM) is associated with lower scores on the outcome

Notes. AM = autonomous motivation. CM = controlled motivation. bx_1 = beta coefficient for autonomous motivation. bx_2 = beta coefficient for controlled motivation. bx_3 = beta coefficient for autonomous motivation squared. bx_4 = beta coefficient for controlled motivation squared. bx_5 = beta coefficient for the cross-product of autonomous and controlled motivations. All betas taken to calculate the surface values are unstandardized.

Table 3
Results of the polynomial regression analyses in Study 1.

	Academic planning beta (SE) [95% CI]	Academic goal progress beta (SE) [95% CI]	Average grade beta (SE) [95% CI]	Physical activity planning beta (SE) [95% CI]	Physical activity goal progress beta (SE) [95% CI]
Autonomous motivation (bx_1)	.37(.08)* [.22, .53]	.28(.08)* [.13, .43]	.28(.07)* [.14, .41]	.37(.09)* [.19, .55]	.19(.09)* [.01, .38]
Controlled motivation (bx_2)	−.08(.08) [−.23, .07]	−.19(.07)* [−.33, −.04]	−.04(.06) [−.17, .08]	.06(.10) [−.14, .26]	−.05(.10) [−.25, .15]
Autonomous squared (bx_3)	.02(.04) [−.05, .10]	−.04(.04) [−.11, .03]	0(.03) [−.06, .06]	.07(.05) [−.03, .16]	.04(.05) [−.06, .13]
Controlled squared (bx_4)	−.03(.03) [−.09, .03]	.02(.03) [−.04,.08]	−.01(.03) [−.06, .04]	−.08(.04)* [−.14, −.01]	−.01(.04) [−.08, .06]
Autonomous × controlled (bx_5)	.01(.04) [−.06, .08]	−.01(.04) [−.08, .06]	.01(.03) [−.05, .07]	−.05(.05) [−.14, .04]	−.02(.05) [−.11, .08]
Surface values					
a_1	.29(.12)*	.09(.11)	.23(.09)*	.43(.15)*	–
a_2	0(.06)	−.03(.06)	.01(.05)	−.06(.07)	–
a_3	.45(.10)*	.46(.09)*	.32(.09)*	.31(.12)*	–
a_4	−.02(.06)	0(.06)	−.02(.05)	.04(.07)	–

Notes. $a_1 = bx_1 + bx_2$. $a_2 = bx_3 + bx_4 + bx_5$. $a_3 = bx_1 - bx_2$. $a_4 = bx_3 - bx_4 + bx_5$. beta = unstandardized coefficient; SE = standard error; 95% CI = 95% confidence interval.
* $p < .05$.

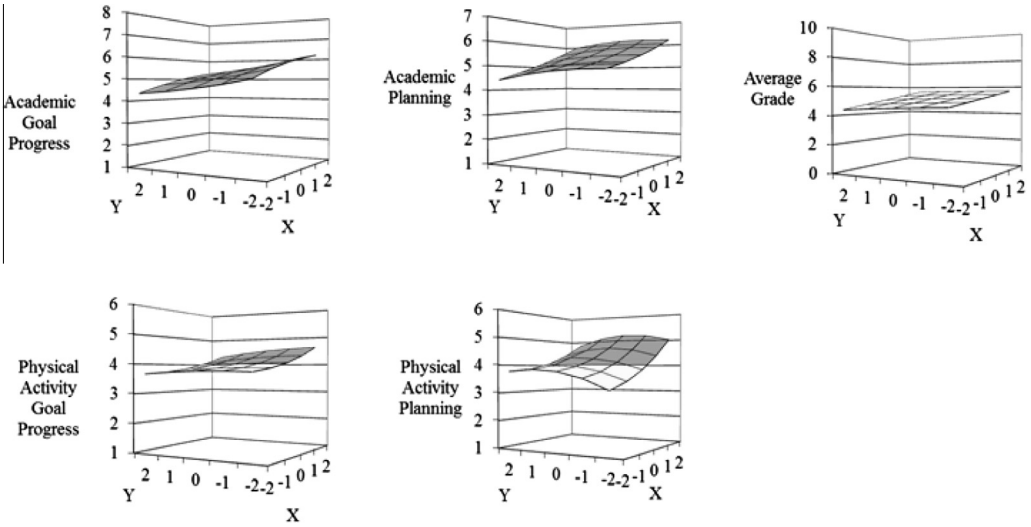

Fig. 1. Study 1 outcomes as predicted by autonomous and controlled motivations. *Notes.* Y = controlled motivation; X = autonomous motivation. While the same surface values may be significant across dependent outcomes, the shape of the surface varies because of differences in the (1) magnitude and/or direction of the surface values, and (2) estimated regression parameters, which are used to plot the graphs.

associated to AM and CM (e.g., Koestner et al., 2008; Sheldon & Elliot, 1998). Many researchers in educational psychology have operationalized motivation at the contextual level whereby students are asked to assess why they go to school or participate in school-related activities (Guay, Ratelle, & Chanal, 2008). In Study 2, one of our goals was to demonstrate that polynomial regression analysis with response surface methodology could extend to the study of motivation at the contextual level of analysis. Therefore, we analyzed data from a new study to illustrate the potential of this analytical approach to predict an objective indicator of performance – semester grade point average (semester GPA) – used by university administrators to benchmark the academic success of students. Furthermore, because students experience different emotions toward school (Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011), we also examined academic emotions, engagement, and burnout as outcomes of AM and CM.

7.1. Participants and procedures

The sample was 290 undergraduate students (70.7% female; M_{age} = 19.08 years, *SD* = 3.20). Most (77.2%) were in their freshman year and self-identified as Caucasian (62.8%). Participants were recruited from either a university-based participant pool (who received course credit for their participation) or from first and second year undergraduate psychology courses (who received $5 compensation). Data were collected in November 2011 (Time 1) using an online questionnaire located on a secured research server. At this time, participants also provided authorization for the researchers to access their student record to view their semester GPA at the end of the 2011 Fall semester (Time 2). Participants provided informed consent to participate in the study and to grant us access to their semester GPA. This study was approved by the University of Ottawa research ethics board.

7.2. Measures

7.2.1. Motivation (Time 1)

Participants were asked to think about why they study at university and report the extent to which 15 statements reflected their academic motivation using items employed in previous research (Gaudreau, 2015). The statements reflected six motivational regulations: intrinsic (e.g., "Because I truly love it"),

integrated (e.g., "It is part of who I am as a person"), identified (e.g., "I feel that it is important for me"), introjected (e.g., "In order not to feel ashamed"), external (e.g., "Somebody is putting pressure on me"), and amotivation (e.g., "I do it, but it is not motivating"). Response options ranged from 1 (*not at all for this reason*) to 7 (*totally for this reason*). To remain consistent with Study 1, the amotivation items were not analyzed in this study. An AM score was created by averaging scores for intrinsic, integrated, and identified regulation items. A CM score was created by averaging scores for introjected and external regulation items.

7.2.2. Academic burnout and engagement (Time 1)

Academic burnout and engagement were assessed using items from the Maslach Burnout Inventory for students (MBI-student) and the Utrech Work Engagement scale for students (UWES-student), respectively, presented in Schaufeli Martínez, Pinto, Salanova, and Bakker (2002). The MBI-student consisted of 15 items that assessed exhaustion (5 items; e.g., "I feel burned out from my studies"), cynicism (4 items; e.g., "I have become less enthusiastic about my studies"), and efficacy (6 items; e.g., "I can effectively solve the problems that arise in my studies"; reverse-coded). The UWES-student included 14 items that assessed absorption (4 items; "Time flies when I'm studying"), dedication (5 items; e.g., "I find my studies to be full of meaning and purpose), and vigor (5 items; e.g., "when I am studying, I feel mentally strong"). Response options ranged from 1 (*never*) to 7 (*always*). Schaufeli et al. (2002) have demonstrated score reliability and validity for these items. We used global burnout and engagement scores that combined all the item responses to the MBI-student subscales and all the responses to the UWES-student subscales, respectively.

7.2.3. Academic emotions (Time 1)

Academic emotions of joy (e.g., "I enjoy learning new things"), hope (e.g., "I have an optimistic view toward studying"), boredom (e.g., "When studying for my courses, I feel bored"), and anxiety (e.g., "Before I start studying material for this course, I feel tense and nervous") were assessed using six items each drawn from the Achievement Emotions Questionnaire (AEQ; Pekrun et al., 2011). Participants were asked to report the degree to which they experienced each emotion on a 7-point scale from 1 (*not at all*) to 7 (*totally agree*). An average score was computed. Pekrun et al. (2011) have provided evidence of score reliability and validity for the AEQ.

7.2.4. Life satisfaction (Time 1)

The Satisfaction With Life Scale (SWLS) was used to assess life satisfaction (Diener, Emmons, Larsen, & Griffin, 1985). An example item is "In most ways my life is close to my ideal." Participants rated the degree to which each item reflected their level of satisfaction using a 7-point scale ranging from 1 (*not at all*) to 7 (*totally*). An average score was computed. The SWLS has been used extensively in research and has demonstrated score reliability and validity (Pavot & Diener, 2008).

7.2.5. Objective semester GPA (Time 2)

Participants' official semester GPA was obtained with the help of officers at the Institutional Research and Planning office. Scores ranged from 0 (*F*) to 10 (*A+*).

7.3. Results

Data were analyzed following the same procedures described for Study 1. Descriptive statistics and estimates of internal consistency are reported in Table 1. Results of the polynomial regression analyses and response surface methodology are presented in Table 4 and Fig. 2.

7.3.1. Semester GPA

The regression model was significant, $F(5, 284) = 4.70$, $p < .001$, $R^2 = .08$. AM and CM positively and negatively predicted semester GPA, respectively. Interpretation of the response surface values indicated that semester GPA was higher when AM was higher than CM (a_3).

7.3.2. Academic burnout

The regression model was significant, $F(5, 284) = 13.60$, $p < .001$, $R^2 = .19$. AM and CM negatively and positively predicted academic burnout, respectively. Academic burnout was lower when AM was higher than CM (a_3).

7.3.3. Academic engagement

The regression model was significant, $F(5, 284) = 13.20$, $p < .001$, $R^2 = .19$. AM positively predicted academic engagement. Degree of agreement between AM and CM was linearly and positively associated with academic engagement (a_1). Academic engagement was higher when AM was higher than CM (a_3).

7.3.4. Academic joy

The regression model was significant, $F(5, 284) = 11.05$, $p < .001$, $R^2 = .16$. AM positively predicted academic joy. Degree of agreement between AM and CM linearly and positively predicted academic joy (a_1). Academic joy was higher when AM was higher than CM (a_3).

7.3.5. Academic hope

The regression model was significant, $F(5, 284) = 11.86$, $p < .001$, $R^2 = .17$. AM positively predicted academic hope. Degree of agreement between AM and CM linearly and positively predicted academic hope (a_1). Academic hope was higher when AM was higher than CM (a_3).

7.3.6. Academic anxiety

The regression model was significant, $F(5, 284) = 3.73$, $p < .01$, $R^2 = .06$. CM positively predicted academic anxiety. Academic anxiety was lower when AM was higher than CM (a_3).

7.3.7. Academic boredom

The regression model was significant, $F(5, 284) = 10.50$, $p < .001$, $R^2 = .16$. AM and CM negatively and positively predicted academic boredom, respectively. Academic boredom was lower when AM was higher than CM (a_3).

7.3.8. Satisfaction with life

The regression model was significant, $F(5, 284) = 8.51$, $p < .001$, $R^2 = .13$. AM and CM positively and negatively predicted satisfaction with life, respectively. Satisfaction with life was higher when AM was higher than CM (a_3).

7.4. Brief discussion

In this study, we provided further evidence for the use of polynomial regression analysis with response surface methodology for examining the associations of academic motivation at the contextual level with a series of academic adjustment indicators, including an objective measure of academic achievement (i.e., semester GPA). Our findings were consistent with the view that AM fosters positively-valenced outcomes because it was positively associated with semester GPA, satisfaction with life, and academic engagement, joy, and hope. Conversely, the associations between CM and the outcomes were less consistent. The interesting pattern that warrants attention, however, was that those participants who reported greater AM relative to CM had higher semester GPA, satisfaction with life, and academic engagement, joy, and hope as

Table 4
Results of the polynomial regression analyses in Study 2.

	Average Grade beta (SE) [95% CI]	Burnout beta (SE) [95% CI]	Engagement beta (SE) [95% CI]	SWL beta (SE) [95% CI]	Joy beta (SE) [95% CI]	Hope beta (SE) [95% CI]	Anxiety beta (SE) [95% CI]	Boredom beta (SE) [95% CI]
Autonomous motivation (bx_1)	.53(.21)* [.11, .95]	−.34(.10)* [−.54, −.14]	.35(.10)* [.16, .54]	.23(.13)† [−.02, .47]	.43(.11)* [.22, .64]	.46(.11)* [.24, .69]	−.13(.13) [−.39, .13]	−.29(.12)* [−.53, −.06]
Controlled motivation (bx_2)	−.28(.09)* [−.46, −.10]	.17(.04)* [.09, .26]	−.02(.04) [−.10, .06]	−.11(.05)* [−.22, −.01]	.02(.05) [−.07, .11]	.01(.05) [−.09, .10]	.19(.06)* [.09, .30]	.21(.05)* [.11, .31]
Autonomous squared (bx_3)	.02(.09) [−.16, .20]	0(.04) [−.09, .08]	.03(.04) [−.05, .11]	.09(.05) [−.02, .19]	.01(.05) [−.08, .10]	.05(.05) [−.04, .14]	−.01(.06) [−.12, .10]	.01(.05) [−.09, .11]
Controlled squared (bx_4)	.05(.05) [−.05, .14]	.01(.02) [−.03, .06]	−.01(.02) [−.05, .04]	.01(.03) [−.05, .06]	−.01(.02) [−.06, .04]	−.02(.03) [−.07, .03]	−.01(.03) [−.06, .05]	.02(.03) [−.03, .08]
Autonomous × controlled (bx_5)	−.06(.07) [−.19, .07]	.01(.03) [−.05, .07]	.01(.03) [−.05, .07]	.05(.04) [−.02, .13]	−.01(.03) [−.07, .06]	−.01(.03) [−.08, .06]	.01(.04) [−.07, .09]	.01(.04) [−.06, .08]
Surface values								
a_1	.25(.23)	−.17(.11)	.33(.10)*	.11(.14)	.45(.12)*	.47(.12)*	.06(.14)	−.08(.13)
a_2	0(.14)	.02(.07)	.04(.07)	.14(.09)	−.01(.08)	.02(.08)	0(.09)	.04(.08)
a_3	.80(.23)*	−.51(.11)*	.37(.10)*	.34(.14)*	.41(.12)*	.46(.12)*	−.32(.14)*	−.50(.13)*
a_4	.12(.09)	0(.04)	.02(.03)	.04(.06)	.01(.04)	.04(.05)	−.03(.06)	.02(.05)

Notes. $a_1 = bx_1 + bx_2$. $a_2 = bx_3 + bx_4 + bx_5$. $a_3 = bx_1 - bx_2$. $a_4 = bx_3 - bx_4 + bx_5$. SWL = satisfaction with life; beta = unstandardized coefficient; SE = standard error; [95% CI] = 95% confidence interval.
* $p < .05$.
† $p < .08$.

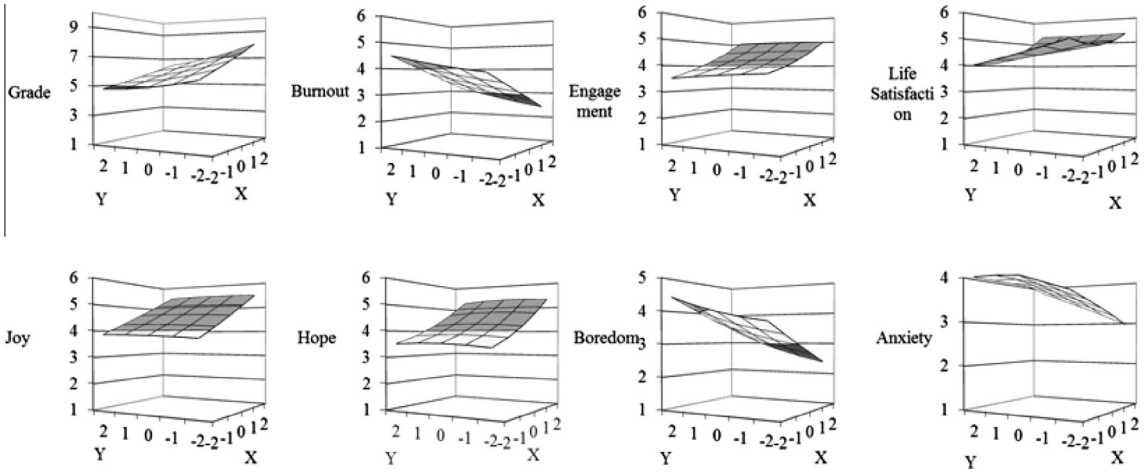

Fig. 2. Study 2 outcomes as predicted by autonomous and controlled motivations. *Notes.* Y = controlled motivation; X = autonomous motivation. While the same surface values may be significant across dependent outcomes, the shape of the surface varies because of differences in the (1) magnitude and/or direction of the surface values, and (2) estimated regression parameters, which are used to plot the graphs.

reflected by significant a_3 values. They also had lower academic burnout, boredom, and anxiety – results that would have remained concealed without a closer inspection of the response surface values. These findings indicate that the advantages of the polynomial regression analysis with response surface methodology do generalize to the study of motivation at the contextual level to predict indicators of academic adjustment and success.

8. Study 3

In Studies 1 and 2, we showed that polynomial regression analysis with response surface methodology offers a useful platform to retain, integrate, and capitalize on the advantages of the two scoring traditions used in the SDT literature to predict academic and health outcomes in university-based samples. For this analytical approach to have greater influence across various areas of psychological sciences, it is important to show that it is applicable across normative and clinical populations. To this end, we sought to replicate and extend our findings while showing this approach can be used to study motivation and its associations with physical activity and health outcomes in breast cancer survivors.

While there are over 1.4 million new cases of breast cancer diagnosed each year worldwide, most women will survive the disease (Jemal et al., 2011). This life event can serve as a 'teachable moment' and increase women's motivation to adopt health-promoting behaviors to reduce the physical and psychological health threats of the disease (Demark-Wahnefried, Aziz, Rowland, & Pinto, 2005). Breast cancer survivors therefore represent an ideal population to study motivation and its associations with behavioral and psychological health outcomes. Indeed, there has been growing interest in linking motivation to physical activity (e.g., Finnegan et al., 2007; Milne, Wallman, Guilfoyle, Gordon, & Courneya, 2008; Wilson, Blanchard, Nehl, & Baker, 2006) and health outcomes (e.g., Brunet et al., 2013) in cancer survivors. To move this research forward, we explored whether the results of our polynomial regression analysis with response surface methodology in Studies 1 and 2 hold in a sample of breast cancer survivors. We conducted cross-sectional analyses of data collected as part of an ongoing longitudinal study investigating the natural changes in lifestyle behaviors in breast cancer survivors. While the cross-sectional analyses will not allow us to draw conclusions about the directions of the associations, it will allow us to

determine if the findings of Study 3 are consistent with theoretical propositions, findings from Studies 1 and 2, and findings from previous studies.

8.1. Participants and procedures

The sample included 180 women (M_{age} = 54.78, *SD* = 10.99 years) who completed self-report questionnaires and provided valid accelerometer data at baseline of a longitudinal study. Participants completed treatment for breast cancer 3.34 (*SD* = 2.28) years prior to the start of the study for stage I (40%), II (38.9%), or III (21.1%) breast cancer. Most participants were Caucasian (85%), married or living with life partner (65.6%), and had either a university degree (28.3%) or a post graduate degree (23.9%). Treatments received were as follows: lumpectomy (57.8%), single mastectomy (28.3%), double mastectomy (16.7%), chemotherapy (66.7%), radiotherapy (89.4%), and/or hormonal therapy (49.4%). This study was approved by the ethics committees at McGill University and hospitals/clinics where participants were recruited from, and informed consent was obtained from participants.

8.2. Measures

8.2.1. Motivation

The Behavioral Regulation in Exercise Questionnaire-2 (BREQ-2; Markland & Tobin, 2004) was used to assess motivation for physical activity. It included five subscales: amotivation (4 items; e.g., "I can't see why I should bother exercising"), extrinsic (4 items; e.g., "I feel under pressure from my friends/family to exercise"), introjected (3 items; e.g., "I feel ashamed when I miss an exercise session"), identified (4 items; e.g., "I value the benefits of exercise"), and intrinsic (4 items; e.g., "I exercise because it's fun") regulations. However, in keeping with Studies 1 and 2, the amotivation items were not analyzed in this study. Participants were asked to indicate to what extent each of the items was true for them using a 5-point scale ranging from 0 (*not true for me*) to 4 (*very true for me*). Average scores for each motivational regulation were created by averaging their respective items. Support for the reliability and validity of BREQ-2 scores have been demonstrated (e.g., Rose, Markland, & Parfitt, 2001; Wilson, Rodgers, Blanchard, & Gessell, 2003).

8.2.2. Depressive symptoms

The 10-item Center for Epidemiological Studies Depression (CES-D; Radloff, 1977) was used to assess depressive symptoms. Participants were asked to report the frequency with which they experienced 10 depressive symptoms in the past seven days using a 4-point scale ranging from 0 (*rarely or none of the time* [*<1 day*]) to 3 (*all of the time* [*5–7 days*]). An example item is "I was bothered by things that usually don't bother me." An average score was calculated by averaging the items. Scores from the CES-D are valid and reliable and this measure has been used in cancer populations (Hann, Winter, & Jacobsen, 1999; Vodermaier, Linden, & Siu, 2009).

8.2.3. Affect

The Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) was used to assess affect. Participants were asked to report the extent to which they experienced 10 positive emotions/feelings (e.g., interested) and 10 negative emotions/feelings (e.g., upset) during the past week using on a 5-point scale ranging from 1 (*very slightly or not at all*) to 5 (*extremely*). Average scores for positive and negative affect were created by averaging their respective items. This scale has been used with cancer patients, and scores have shown satisfactory reliability and validity (Badger, Braden, Mishel, & Longman, 2004; Watson et al., 1988).

8.2.4. Cancer worry

The Assessment of Survivors Concerns (ASC) scale (Gotay & Pagano, 2007) was used to assess cancer-related and general health worries. Participants were asked to report the degree to which they worry about "... future diagnostic tests", "... another type of cancer", "... a recurrence", "... dying", "... their health", and "concerns about my child's health" using a 4-point scale ranging from 1 (*not at all*) to 4 (*very much*). Following Gotay and Pagano's (2007) recommendation to remove the last item (i.e., "concerns about my child's health") as it does not apply to all participants, an average score was calculated using the first five items. ASC scores have demonstrated reliability and validity with cancer survivors (Gotay & Pagano, 2007).

8.2.5. Moderate-to-vigorous physical activity (MVPA)

In addition to completing the self-report questionnaires, participants wore a GT3M accelerometer (ActiGraph, Pensicola, Florida) to assess physical activity. Participants were asked to wear the device for 7 days from awakening to bedtime, with the exception of water activities. Data were downloaded in 60-s epochs. Data were included in the analysis if data were available for at least 500 min on 4 days. The median for accelerometer wearing compliance was 6.55 (*SD* = 1.04) days. Previously established cut-points were used to calculate daily minutes of moderate (1952–5724 counts•minute^{-1}) plus vigorous physical activity (> 5725 counts•minute^{-1}; Freedson, Melanson, & Sirard, 1998), while controlling for the number of days the device was worn. In light of recently published physical activity guidelines recommending moderate and vigorous intensities (Brunet, Sabiston, & Meterissian, 2012; Schmitz et al., 2010), this study focused on MVPA. Score reliability of the ActiGraph accelerometer has been established (McClain, Sisson, & Tudor-Locke, 2007), as well as score validity against other objective physical activity measures (Focht, Sanders, Brubaker, & Rejeski, 2003; Plasqui & Westerterp, 2007).

8.3. Results

Data were analyzed following the same procedures described for Study 1. Descriptive statistics and estimates of internal consistency are reported in Table 1. Results of the polynomial regression analyses and response surface methodology are presented in Table 5 and Fig. 3.

8.3.1. MVPA

The regression model was significant, $F(5, 174) = 11.91$, $p < .001$, $R^2 = .26$. AM was a positive correlate of MVPA. Degree of agreement between AM and CM was linearly and positively associated with MVPA (a_1). MVPA levels were higher when AM was higher than CM (a_3).

8.3.2. Cancer worry

The regression model was significant, $F(5, 174) = 2.11$, $p < .01$, $R^2 = .09$. CM was positively associated with cancer worry. Degree of agreement between AM and CM was linearly and positively associated with cancer worry (a_1). Cancer worry was lower when AM was higher than CM (a_3).

8.3.3. Positive affect

The regression model was significant, $F(5, 174) = 4.08$, $p < .01$, $R^2 = .11$. AM was positively associated with positive affect. Positive affect was higher when AM was higher than CM (a_3).

8.3.4. Negative affect

The regression model was significant, $F(5, 174) = 4.04$, $p < .01$, $R^2 = .10$. CM was positively associated with negative affect. Degree of agreement between AM and CM was linearly and

Table 5
Results of the polynomial regression analyses in Study 3.

	MVPA beta (SE) [95% CI]	Depressive symptoms beta (SE) [95% CI]	Cancer worries beta (SE) [95% CI]	Negative affect beta (SE) [95% CI]	Positive affect beta (SE) [95% CI]
Autonomous motivation (bx_1)	49.84(6.75)* [36.51, 63.16]	−.03(.02) [−.07, .01]	.01(.03) [−.05, .08]	.01(.03) [−.05, .06]	.11(.03)* [.05, .16]
Controlled motivation (bx_2)	−.70(10.43) [−21.28, 19.89]	.11(.03)* [.05, .18]	.17(.05)* [.06, .27]	.16(.04)* [.08, .25]	−.08(.04) [−.16, .01]
Autonomous squared (bx_3)	6.46(3.39)† [−.23, 13.15]	0(.01) [−.02, .02]	0(.02) [−.04, .03]	0(.01) [−.03, .03]	0(.01) [−.03, .03]
Controlled squared (bx_4)	−7.41(7.21) [−21.65, 6.83]	−.01(.02) [−.05, .04]	.01(.04) [−.06, .08]	−.01(.03) [−.07, .05]	−.01(.03) [−.07, .05]
Autonomous × controlled (bx_5)	−4.37(5.40) [−15.02, 6.29]	.01(.02) [−.02, .05]	0(.03) [−.06, .05]	.01(.02) [−.03, .06]	−.01(.02) [−.06, .03]
Surface values					
a_1	49.14(11.61)*	.08(.04)*	.18(.06)*	.17(.05)*	.03(.05)
a_2	−5.31(7.69)	.01(.03)	0(.05)	0(.04)	−.02(.04)
a_3	50.53(13.18)*	−.14(.04)*	−.15(.06)*	−.16(.05)*	.18(.05)*
a_4	3.42(9.89)	−.02(.03)	.01(.05)	−.02(.04)	0(.04)

Notes. $a_1 = bx_1 + bx_2$. $a_2 = bx_3 + bx_4 + bx_5$. $a_3 = bx_1 - bx_2$. $a_4 = bx_3 - bx_4 + bx_5$. MVPA = moderate-to-vigorous physical activity, beta = unstandardized coefficient, SE = standard error, [95% CI] = 95% confidence interval.
* $p < .05$.
† $p < .08$.

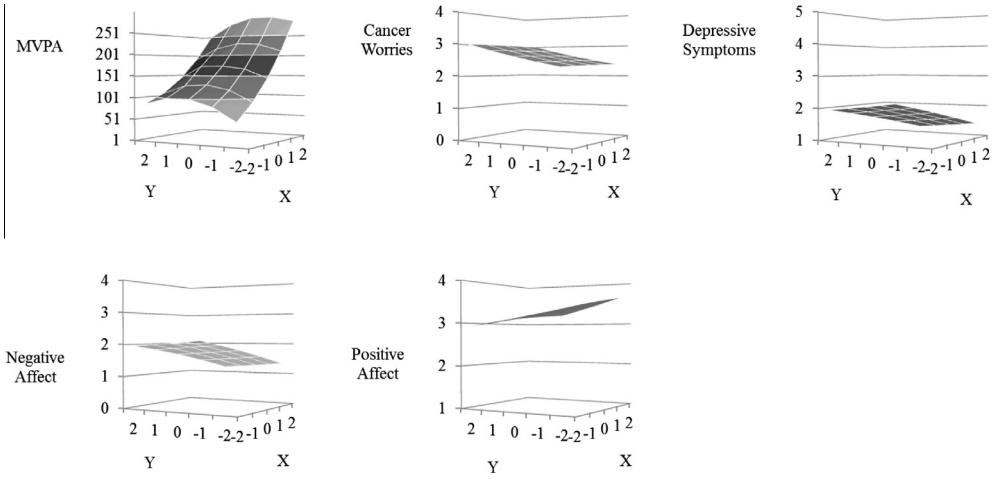

Fig. 3. Study 3 outcomes as predicted by autonomous and controlled motivations. *Notes.* Y = controlled motivation; X = autonomous motivation; MVPA = moderate-to-vigorous physical activity. While the same surface values may be significant across dependent outcomes, the shape of the surface varies because of differences in the (1) magnitude and/or direction of the surface values, and (2) estimated regression parameters, which are used to plot the graphs.

positively associated with negative affect (a_1). Negative affect was lower when AM was higher than CM (a_3).

8.3.5. Depressive symptoms

The regression model was significant, $F(5, 174) = 3.47$, $p < .01$, $R^2 = .09$. CM was positively associated with depressive symptoms. Degree of agreement between AM and CM was linearly and positively associated with depressive symptoms (a_1). Depressive symptoms were lower when AM was higher than CM (a_3).

8.4. Brief discussion

Polynomial regression analysis with response surface methodology was again helpful in understanding the complex relationships of AM and CM with accelerometer assessed physical activity and self-reported health outcomes. The results in this study supported those found in Studies 1 and 2 by showing that both AM and CM are relevant individually and in combination. Specifically, the present findings were consistent with the OIT assumption (Deci & Ryan, 1985) in that AM was associated with positively-valenced outcomes (e.g., positive affect, MVPA), whereas CM was associated with negatively-valenced outcomes (e.g., depressive symptoms, cancer worry). Consistent with Studies 1 and 2, the response surface values offered a novel perspective by showing that a_3 was steadily significant such that better outcomes were associated with having higher AM relative to CM – a result that would have remained concealed without the use of this analytical approach.

9. General discussion

From a theoretical standpoint, the distinction between AM and CM has heuristic value because it characterizes and differentiates the phenomenological and functional features of distinct dimensions of motivation. However, attributable to the lack of an alternative approach, researchers using traditional regression-based analyses have focused either on the unique effects of AM and CM (e.g., Brunet et al., 2013; Koestner et al., 2008; Miquelon & Vallerand, 2006; Shaikh et al., 2011; Wilson et al., 2012) or on the effect of AM relative to CM (e.g., Brunet & Sabiston, 2009;

Guay & Vallerand, 1997; Soenens & Vansteenkiste, 2005). In our research, we tried to offer a solution by first arguing for the use of separate scores of AM and CM (i.e., bifurcated scoring method) in order to subsequently analyze them within the confines of polynomial regression analysis with response surface methodology. In line with our *absolute level of motivation* hypothesis and empirical findings (Brunet et al., 2013; Koestner et al., 2008; Ng et al., 2012), AM and CM were distinctively associated with various academic and health outcomes measured across three studies with university students and breast cancer survivors. More importantly, our *degree of agreement* and *direction of differentiation* hypotheses were largely supported by the findings showing that the degree of agreement between AM and CM (a_1) and the direction of differentiation between AM and CM (a_3) can contribute to the prediction of academic, physical activity, and health outcomes. While our final hypothesis (*degree of differentiation hypothesis*) was not supported, our collective findings helped showcase the advantages of using an analytical approach that can retain and unpack different types of effects within the confines of a single statistical model from the variable-centered research tradition.

Polynomial regression analysis with response surface methodology bears some similarity to traditional regression analyses because it retains the capacity to examine the unique associations of AM and CM with specific outcomes. Consistent with past research (Brunet et al., 2013; Koestner et al., 2008; Ng et al., 2012) and theoretical hypotheses (Deci & Ryan, 1985), our results showed that AM was a consistent predictor of positively-valenced behavioral (i.e., goal progress and objective physical activity), performance (i.e., semester GPA), self-regulation (i.e., planning and engagement), and emotional outcomes (i.e., positive affect, joy, and hope). In contrast, CM was a more consistent predictor of negatively-valenced outcomes (i.e., burnout, negative affect, anxiety, depressive symptoms, boredom, and cancer worry). Overall, the absolute amount of AM and CM does matter.

Furthermore, we demonstrated in our research that polynomial regression analysis with response surface methodology can extend the typical regression-based analyses by showing that complementary theoretically-driven hypotheses can be tested within one statistical model. Specifically, our findings showed that the direction of differentiation between AM and CM can offer a more comprehensive understanding of the complex role of motivation in predicting academic and health outcomes. Indeed, across 17 of the 18 outcomes measured in three studies, the surface values revealed that having more AM than CM was related to more positively-valenced and less negatively-valenced outcomes as reflected by significant a_3 values (see Table 6). This is consistent with theoretical propositions regarding the quality of motivation (Deci & Ryan, 1985), which suggest that AM is of high quality and leads to better outcomes than CM which is of lower quality (Deci & Ryan, 2000). Findings are also in line with previous studies using cluster analysis to investigate how different motivations combine within one individual and showing that individuals who report high AM and low CM report the most optimal set of outcomes in academic and health contexts (Haerens et al., 2010; Hayenga & Corpus, 2010; Ratelle et al., 2007; Vansteenkiste et al., 2009). However, unlike cluster analysis which conflates differentiation and level of AM and CM, the current analyses show that the direction of the differentiation between AM and CM influences academic and health outcomes. In other words, they showed that having higher AM than CM matters irrespective of whether participants reported low or high levels of AM and CM. Accordingly, the application of polynomial regression analysis with response surface methodology can assist researchers and theorists in distinguishing the effects of the level of AM and CM from the effects of the direction of differentiation of their scores.

Table 6
Summary table for the response surface values across three studies.

	a_1	a_2	a_3	a_4
Study 1				
Academic planning	√	X	√	X
Academic goal progress	X	X	√	X
Average grade	√	X	√	X
Physical activity planning	√	X	√	X
Physical activity goal progress	–	–	–	–
Study 2				
Average grade	X	X	√	X
Burnout	X	X	√	X
Engagement	√	X	√	X
Satisfaction with life	X	X	√	X
Joy	√	X	√	X
Hope	√	X	√	X
Anxiety	X	X	√	X
Boredom	X	X	√	X
Study 3				
Moderate-to-vigorous physical activity	√	X	√	X
Depressive symptoms	√	X	√	X
Cancer worries	√	X	√	X
Negative affect	√	X	√	X
Positive affect	X	X	√	X

Notes. √ = surface value was significant at $p < .05$, X = surface value was not significant at $p < .05$. a_1 = linear association with degree of agreement between AM and CM. a_2 = nonlinear association with degree of agreement between AM and CM. a_3 = association with direction of the differentiation between AM and CM. a_4 = association with degree of differentiation in AM and CM.

Degree of agreement between AM and CM had a significant linear effect on 10 of the 18 outcomes variables measured in our three studies as reflected by significant a_1 values (see Table 6). These findings, which only became apparent by computing the response surface values, revealed that knowing how comparable AM and CM scores are, can help predict certain outcomes in academic and health contexts among university students and breast cancer survivors. Thus, it appears that the relationship between CM and academic and health outcomes is more complex than the interpretation typically afforded by traditional regression-like analyses of bifurcated scores. For instance, goal planning and self-reported grades (Study 1), academic engagement, joy, and hope (Study 2), and objectively measured physical activity behavior (Study 3) were higher when there was a greater degree of agreement between AM and CM, suggesting greater agreement between AM and CM can be beneficial for these specific outcomes. However, in Study 3, a different pattern of findings emerged whereby depressive symptoms, cancer worry, and negative affect of breast cancer survivors were higher when there was a greater degree of agreement between AM and CM. Thus, greater agreement between AM and CM appears to be harmful for these other outcomes. Although speculative, these divergent results could be attributable to the normative versus clinical samples used in the first two studies and in Study 3, respectively. It is possible that the added social and self-imposed pressure inherent to CM is more emotionally detrimental when women face a life-threatening cancer diagnostic (Brunet et al., 2013). Future research using polynomial regression analysis could open the door to a new line of SDT investigations to delineate for whom and under which particular life situations a greater degree of agreement between AM and CM relates to more desirable outcomes, on the one hand, and to less desirable outcomes, on the other hand. It is also possible to speculate that the effects of the degree of agreement between AM and CM differ depending on whether outcomes are positively- or negatively-valenced. Thus, another important next step in this field of research is to examine possible reasons underlying the different effects of agreement uncovered in our study.

Despite the contributions and implications of this research, our studies have limitations. First, most of the data were collected by self-report questionnaires, which may have resulted in reporting bias. Nonetheless, this potential bias was limited in Studies 2 and 3 by incorporating objective measures of academic performance and physical activity behavior. Future studies should try to incorporate clinical interviews (e.g., depression) to triangulate findings using a mixture of self-reported and informant-reported outcomes. Second, the sample sizes were moderate, though comparable with other studies in the field, which might affect the statistical power of our analyses. Therefore, our findings should be replicated with larger samples. Third, polynomial regression analyses were conducted using manifest variables in which the parameter estimates are attenuated by measurement error (Fan, 2003). Recent advancements in latent variable analysis of interactive and non-linear terms (e.g., Kelava et al., 2011) could eventually lead the way to estimating polynomial regression models with latent variables. Such an approach would enable researchers to estimate true effects not attenuated by measurement error. Finally, the observational study designs do not allow for causal inferences. Researchers should employ experimental study designs to examine if manipulating AM and CM causes change in academic, physical activity, and health outcomes.

10. Implications

While the choice of the analytical approach is ultimately dependent on the research question, we have tried to illustrate the types of research questions that could be answered and what new knowledge could be gleaned if researchers were to adopt polynomial regression analysis with response surface methodology in future research. Indeed, it allows researchers to retain the advantages of the traditional scoring methods used in the extant SDT literature by examining, within one statistical model: (a) the unique effects associated with the *absolute amount* of AM and CM, (b) the linear and non-linear effects associated with the *degree of agreement* between AM and CM (a_1 and a_2, respectively), (c) the effects associated with the *direction of the differentiation* between AM and CM (a_3), and (d) the effects associated with the *degree of differentiation* between AM and CM (a_4).

11. Conclusion

Polynomial regression analysis with surface response methodology has been discussed as a potentially useful approach to examine the effects of AM and CM (e.g., Chemolli & Gagné, 2014; Judge, Bono, Erez, & Locke, 2005). On the basis of our results in the academic and health contexts, we offered an initial demonstration of how polynomial regression analysis with response surface methodology can be used to test various hypotheses relating to motivation within the confines of one statistical model stemming from a variable-centered research tradition. Specifically, across three studies, we demonstrated that the absolute amounts of AM and CM were differentially associated with positively- and negatively-valenced outcomes in a way that generally matched the extent literature and theoretical hypotheses of SDT. This analytical approach also revealed that the degree of agreement between AM and CM (a_1) and the direction of differentiation between AM and CM (a_3) added to the interpretation of the associations between motivation and several behavioral, self-regulation, and emotional outcomes in academic and health contexts. This underscores the importance of considering surface value methodology in order to understand the effects of AM and CM over and above the typical parameters estimated in a traditional regression-based analyses.

Conflicts of interest

The authors have no conflicts of interest or financial disclosures to report.

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