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Self-controlled learning benefits: exploring contributions of self-efficacy and intrinsic motivation via path analysis

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ABSTRACT

Research has shown learning advantages for self-controlled practice contexts relative to yoked (i.e., experimenter-imposed) contexts; yet, explanations for this phenomenon remain relatively untested. We examined, via path analysis, whether self-efficacy and intrinsic motivation are important constructs for explaining self-controlled learning benefits. The path model was created using theory-based and empirically supported relationships to examine causal links between these psychological constructs and physical performance. We hypothesised that self-efficacy and intrinsic motivation would have greater predictive power for learning under self-controlled compared to yoked conditions. Participants learned double-mini trampoline progressions, and measures of physical performance, self-efficacy and intrinsic motivation were collected over two practice days and a delayed retention day. The self-controlled group (M = 2.04, SD = .98) completed significantly more skill progressions in retention than their yoked counterparts (M = 1.3, SD = .65). The path model displayed adequate fit, and similar significant path coefficients were found for both groups wherein each variable was predominantly predicted by its preceding time point (e.g., self-efficacy time 1 predicts self-efficacy time 2). Interestingly, the model was not moderated by group; thus, failing to support the hypothesis that self-efficacy and intrinsic motivation have greater predictive power for learning under self-controlled relative to yoked conditions.

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KEYWORDS
Motor skill learning; learner-controlled; knowledge of performance; video feedback

Introduction

Motor learning researchers invariably search for practice conditions that enhance motor skill acquisition. A practice condition that has clearly emerged as important for motor learning is that of allowing learners to control some features of their learning environment (see Sanli, Patterson, Bray, & Lee, 2013; Wulf, 2007; for reviews). Providing control over features like determining task difficulty (e.g., Andrieux, Danna, & Thon, 2012), practice scheduling (e.g., Wu & Magill, 2011) or when one receives knowledge of results (e.g., Patterson & Carter, 2010) yields superior motor learning compared to an experimenter-imposed condition (i.e., a condition in which a participant is yoked to a self-controlled counterpart). These learning advantages are quite robust given they have been demonstrated for a variety of learning variables and have also been demonstrated with a variety of populations (e.g., Chiviacowsky, Wulf, de Medeiros, Kaefer, & Tani, 2008; Chiviacowsky, Wulf, Lewthwaite, & Campos, 2012).

Despite the amount of research demonstrating the robustness of this finding, little theoretical advancement on the mechanisms underlying the learning benefits of self-controlled practice contexts has occurred. This problem was recently highlighted by Sanli et al. (2013) who encouraged further investigation on this topic from a motivational perspective. Thus, the purpose of this research was to examine the possible contributions of self-efficacy and intrinsic motivation to learning advantages associated with self-controlled learning conditions. The specific self-controlled learning variable of interest in this research involved allowing learners to choose when to watch a video replay of their own performance (self-observation). This research extends Ste-Marie, Vertes, Law, and Rymal's (2013) earlier findings that showed children gained a learning advantage when provided self-control over video self-observation. That research was the first to examine whether self-controlled learning benefits with video observation extended to children given that it had only been studied thus far with adult populations. In addition, Ste-Marie et al. initiated examination into why such learning benefits occurred, and they used Zimmerman (2000) self-regulation of learning model as a theoretical framework.

The self-regulation of learning model (Zimmerman, 2000) is composed of three phases in which one's thoughts, self-regulatory processes and beliefs that precede (forethought phase) occur during (performance-control phase) and after (self-reflection phase) a given action influence one's learning. The phases are assumed to causally influence self-regulatory processes and beliefs in a cyclical manner across the three phases (Zimmerman, 2008). Ste-Marie et al. (2013) examined whether two self-motivational beliefs of the forethought phase, those of self-efficacy and intrinsic interest, were greater when learners controlled the frequency of self-observation viewings (self-controlled learning group) versus when the viewing

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schedule was imposed (yoked group). Self-efficacy, the belief in one's capability to perform a given task (Bandura, 1997), was shown to increase more for the self-controlled learning group across two acquisition days than for the yoked group; however, no self-efficacy differences were found between these groups in retention.

Intrinsic interest within the self-regulation of learning model (Zimmerman, 2000) aligns with Deci's (1975) notions of intrinsic motivation in which one's motivation to do the task is driven by the inherent enjoyment in completing the task versus possible external reward. As per the recommendations of Sanli et al. (2013), Ste-Marie et al. (2013) used subscales from the Intrinsic Motivation Inventory (IMI) (McAuley, Duncan, & Tammen, 1987) to tap into this construct and found the self-controlled learning group self-reported greater intrinsic motivation compared to the yoked group when queried upon completion of the retention phase.

A limitation of Ste-Marie et al. (2013) was that the sample size restricted their analyses and did not allow for the examination of the inter-relationships among self-efficacy, intrinsic motivation and the physical performance outcome. Moreover, a hierarchical regression analysis on retention performance showed that group assignment (i.e., self-controlled versus yoked) was the best predictor, followed by self-efficacy levels; however, intrinsic motivation was not a significant predictor. This was surprising given the fact that self-efficacy showed no significant group differences following retention, whereas intrinsic motivation did. Such findings expose the need for further research on the complex interplay between self-motivational beliefs and motor learning in self-controlled learning environments. Therefore, we continued data collection using the same procedures as Ste-Marie et al. and increased the sample size to better meet the criteria for conducting a path analysis. We anticipated that the contributions of self-efficacy beliefs and intrinsic motivation in predicting physical performance outcomes would be greater for those in the self-controlled learning condition compared to those following an imposed-yoked schedule and thus expected group to moderate the model fit.

Methods

The methods used in this experiment were identical to those used in Ste-Marie et al. (2013), and the reader is directed to that article for specific details not included here. The protocol was approved by the Research Ethics Board at the University of Ottawa (H051009).

Participants

One hundred children (M = 46, F = 54; M_{age} = 11.1, SD = 1.87, range = 7–15 years) with no previous experience on double-mini trampoline participated in this experiment.[1] Based on stem and leaf-plot analysis of the physical performance outcome, four participants were identified as outliers and were excluded from statistical analyses, along with participants that were yoked to these outliers; thus resulting in a final sample size of 92 children. Informed consent sheets from parents and assent forms from participating children were received before children were allowed to participate.

Materials and task

Participants were required to complete a series of skill sequences of increasing difficulty on a double-mini trampoline[2], with the goal of progressing through as many of the 17 sequences as possible. Participants were instructed to move on to the next progression once all criteria (range = 12–17 criteria) for the previous progression were met. All sequences had 10 standard criteria associated with correct execution of the skill sequence (see Table 1); however, each skill sequence also had unique criteria that were specific to the jump. For example, if a tuck jump was being executed, the criteria of the hands grabbing the shins were used, whereas if it was a pike jump, the criteria of legs remaining straight and hands reaching out to touch toes were used.

A Sony video Handycam (model number DCR-HC65/HC85), Toshiba laptop computer and Dartfish software (version 4.5.1.0) were used to create four video sequences of an expert model completing specific progressions of the double mini-trampoline sequences, and to display the self-observation video feedback during the acquisition trials. On day 1, this skilled-model videotape consisted of the 1st skill progression and the 7th skill progression, whereas on day 2 it consisted of the 7th skill progression and the 11th progression. The choice for these progressions was related to the skills being performed. Throughout the entire progressions, there were four basic jumps performed of increasing difficulty (i.e., straight jump, tuck jump, pike jump and straddle jump); and these were combined in varied ways. The skill progressions that were demonstrated on the video enabled all of the criteria for each of the jumps to be explained and viewed; for example, progression one involved executing a straight jump for both the first and second skills in the sequence, whereas,

Table 1. Standard criteria for double-mini progressions 1–17.

Criteria
1. Push off the runway with dominant foot
2. Two foot landing onto the first mini
3. Land in the white area on the first mini
4. Two foot landing onto the second mini
5. Land in the white area on the second mini
6. Arms move up to ears when in the air on first skill
7. Arms move up to ears when in the air on second skill
8. Two foot landing
9. Proper landing (3 s control)
10. Land in box on the mat

Other criteria were used that were specific to each jump that are not listed here.

[1]Of the 100 participants, 60 were included in the data presented in Ste-Marie et al. (2013) and 40 new participants were recruited.

[2]Double-mini trampoline is an apparatus composed of two connected trampolines. Participants run up to the trampoline and jump onto the first trampoline, which is slanted upwards from the ground, and perform a skill in the air (e.g., pike jump). The landing of this skill is done on the second trampoline, and followed by a second skill (e.g., tuck jump) from the second trampoline onto a gymnastics mat located on the ground by the double-mini apparatus.

progression seven was executing a tuck jump as the first skill and the pike jump as the second skill. With just these two video demonstrations, the learner was able to view the proper execution of three of the four jumps (progression 11 included the straddle jump).

Measures

Physical performance

Physical performance scores in acquisition were taken as the progression level the participant reached at the end of each block of trials. The specific criteria for each progression level ranged from 12 to 17, with 10 of the criteria consistent for each progression (see Table 1). For acquisition, physical performance scores were based on the progression level attained at the end of each trial block. Physical performance scores for retention were the number of progression levels advanced during the retention test, plus the percentage value of the number of criteria attained at the current progression for the remaining trials. For example, if the participant started at level 6 and advanced to level 8 and had attained 7 of the 14 criteria in that sequence, the retention score would be 2.50. To determine the percentage of the criteria obtained, a former national level competitor in double-mini trampoline, aware of the criteria, scored approximately 50% of the retention trials, and a trained research assistant scored the remaining performances. Given we had two different raters involved in assessing the retention performance scores, we determined agreement between the two raters using the procedures outlined by Bland and Altman (1986). Ensuring the scorers were blind to experimental group, the retention trials of 25 participants were scored by both raters. The Bland–Altman analysis indicated a mean difference of .06 (SD = .46) between the two raters, and the 95% limits of agreement ranged from −.84 to .96.

Self-efficacy

A self-efficacy questionnaire was created for this experiment in accordance with Bandura's guidelines (2006). The instructions on the questionnaire required participants to state their belief in their ability to meet all the criteria for seven progressions of increasing difficulty that were in the set of 17 progressions to be learned; specifically, progression sequences numbered 3, 5, 7, 9, 11 and 15. Underneath each statement was a Likert scale ranging from 0 to 100, where 0 represented "cannot do at all" and 100 represented "highly certain I can do". The mean of all seven self-efficacy statements was calculated and used to represent participants' self-efficacy. Cronbach alpha values were considered good for both days of practice and for retention (i.e., all three time points; α-values = .94–.96).

Intrinsic motivation

The interest/enjoyment subscale of the IMI, validated by McAuley et al. (1987), was used as the intrinsic motivation measure. This subscale included seven statements related to participants' interest and enjoyment of the task that were modified to apply to the double-mini trampoline task. Likert scales ranging from one to seven where a "one" represented "not true at all" and a "seven" represented "very much true" were under each statement. Mean scores across the seven items were generated for intrinsic motivation. Cronbach alpha values were considered good at all three time points (α-values = .87–.89).

Procedure

Participants were assigned to one of two experimental groups The self-controlled group was started first, and then participants in the experimenter-imposed group (hereafter referred to as the yoked group) were paired to a self-controlled group participant. This was done because the self-controlled groups' self-observation schedule was required in order to assign the yoked group participants their feedback schedule. Groups were also matched such that the participant yoked to the self-controlled counterpart was of the same gender and approximately the same age (i.e., ±6 months). Participants were tested in small groups of typically 3–5 children (range 2–7). The experiment transpired over three consecutive days with 2 days involving acquisition trials and 1 day of retention. Figure 1 provides an overview of the procedures used.

Acquisition

Day 1 of acquisition began with participants seeing a list of the full progression sequence and then viewing the video of a skilled-model performing two of the to-be-learned progression sequences, specifically progression 1 and 7. Verbal cues were provided about the necessary criteria needed to advance through the progressions while watching the skilled model video. Participants then completed a jumping activity, which consisted of them jumping progressively further distances and evaluating their capability to jump the distance. This provided them with a concrete analogy of how to evaluate self-efficacy perceptions prior to completing the self-efficacy questionnaire with regard to the to-be-learned progressions. Upon completion of the self-efficacy questionnaire, participants were informed the task goal was to move through as many skill sequence progressions as possible. The self-controlled group was informed they could ask for feedback, in the form of video self-observation, after any trial they wanted and that they would also receive information about what to focus on while viewing the video in addition to a prescriptive statement about how to do it correctly next trial. Those in the yoked group were told that they would be informed when they could observe their video feedback (as well as the cueing information and prescriptive knowledge of performance), and it would occur after a random selection of trials.

On trials in which feedback was requested (or provided for the yoked group), the experimenter first provided an attentional cue related to the most important error based on a predetermined knowledge of performance priority list. The participant would then view the trial and subsequently be provided with a transitional statement to reinforce how to correct the error identified in the video. For example, if the researcher cued the observer to watch how he/she landed in the wrong spot on the trampoline bed, the transition statement would be: "On your next jump make sure you land in the middle of the trampoline."

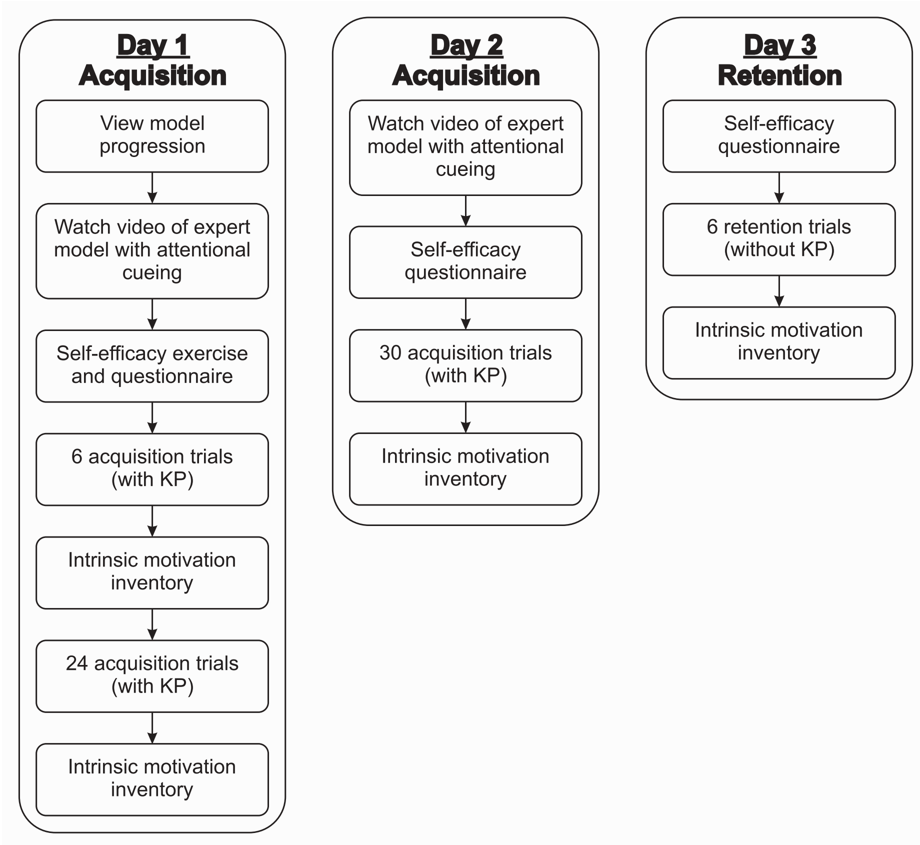

Figure 1. Overview of the experimental procedure for the acquisition phase (Days 1 and 2) and the retention phase (Day 3).

The intrinsic interest subscale of the IMI was completed after the first block of 6 trials, and after 30 trials were completed. The first administration was to ensure that the groups were not different in intrinsic motivation at the outset of the acquisition trials. Day 2 of acquisition followed the same procedures as Day 1 with a few modifications: (1) the skilled-model video showed two progressions (7 and 11) that were further along the progression list to ensure the learners were reminded of the criteria associated with the more difficult skill sequences, (2) the children did not complete the self-efficacy jumping activity and (3) the IMI was only completed at the end of the day.

Retention

The retention test was completed on Day 3, approximately 24 h after the end of Day 2 of acquisition. The sequence of events was as follows: (1) complete self-efficacy measure, (2) perform six trials of the sequence, with the starting progression being two levels lower than that attained in the last block of acquisition and (3) complete IMI subscales.

Model analysis

A path analysis using maximum likelihood estimation was performed to examine the causal links between the self-reported psychological variables of self-efficacy and interest/enjoyment, and the physical performance measure used during acquisition and retention. The model was created using relationships based on theoretical and empirical support (e.g., Bandura, 1997; Deci, 1975). The model analysed direct relationships among self-efficacy, physical performance and interest/enjoyment as a function of time. The fit of the path model was evaluated using a combination of indices which included the Tucker–Lewis index (TLI), the comparative fit index (CFI), the standardised root mean square residual (SRMR), the root mean square error of approximation (RMSEA) and the chi-squared (χ^2) likelihood ratio statistic (Bryne, 2010; Hu & Bentler, 1999). A good model fit is denoted by a non-significant χ^2-value; however, this is not often found (MacCallum, 2003) and this statistic has been criticised for being too sensitive to sample size, resulting in a higher likelihood of Type 1 errors. As a result, the χ^2/df statistic was also used as a measure of model fit (Bryne, 2010). Fit indices were deemed to indicate good model fit if: TLI and CFI values ≥ .90, SRMR values ≤ .08, and RMSEA values ≤ .06, and χ^2/df < 3.00 (Bryne, 2010; Hu & Bentler, 1999; Tabachnick & Fidell, 2013). A multi-group moderation analysis was performed using the critical ratio difference test which uses *z*-scores to identify any significant differences between groups on each path of the model (Bryne, 2010). For the *z*-score, values greater than 1.96 and 2.58 are considered significant at $P < .05$ and $P < .01$, respectively.

Results

Before exploring the path analysis, we first wanted to ensure that the self-controlled learning benefits that were found by Ste-Marie et al. (2013) were maintained with the addition of 40 new participants. The delayed retention test scores were used for this given delayed retention is considered the gold standard for assessing the relative permanence of a previously practiced skill (Kantak & Winstein, 2012).[3] An independent samples *t*-test, $t(90) = 4.10$, $P < .001$, $d = 83$, revealed that the self-controlled group ($M = 2.04$, SD = .98) completed a significantly higher number of progressions in retention than their yoked counterparts ($M = 1.35$, SD = .65). Knowing that the typical self-controlled learning advantages occurred, we next performed the path analysis to determine model fit and the multi-group moderation analysis which tested our main hypothesis regarding self-efficacy and intrinsic motivation as possible underlying mechanisms of these learning advantages.

Model fit

The results of the path analysis indicated adequate fit for the model (Figure 2), $\chi^2 = 114.47$, $P < .001$, $\chi^2/df = 1.66$, TLI = .93, CFI = .96, SRMR = .10, RMSEA = .06. Self-efficacy at time 1 was positively related self-efficacy at time 2 ($\beta = .51$, $P < .001$), which itself was positively related to self-efficacy at time 3 ($\beta = .66$, $P < .001$). Physical performance at time 1 was positively related to both self-efficacy at time 2 ($\beta = .35$, $P < .001$) and physical performance at time 2 ($\beta = .83$, $P < .001$). Physical performance at time 2 was positively related to self-efficacy at time 3 ($\beta = .23$, $P < .01$) as well as physical performance at time 3 ($\beta = .43$, $P < .001$). Intrinsic motivation at time 1 was negatively related to physical performance at time 2 ($\beta = -.16$, $P < .01$), but positively related to intrinsic motivation at time 2 ($\beta = .72$, $P < .001$). Lastly, intrinsic motivation at time 2 was positively related to intrinsic motivation at time 3 ($\beta = .90$, $P < .001$). All other paths in the model failed to reach significance (*P*-values > .05).

Multi-group moderation

The estimates as standardised regression weights with the corresponding *P*-values of each path are shown in Table 2 for the self-controlled group and the yoked group. Overall, similar patterns were noted for both the groups, with each variable (i.e., self-efficacy, physical performance and intrinsic motivation) being predominantly predicted by its preceding time point (e.g., time *n* of a variable predicts time $n + 1$ for that variable). Although most of the estimates for both the self-controlled and the yoked group were significant, there were only a few differences between the groups that were significant. The positive relationship between physical performance at times 1 and 2 was moderated by group with a stronger effect found in the yoked group. The positive relationship between intrinsic motivation at times 1 and 2 was moderated by group and also revealed a stronger effect in the yoked group compared to the self-controlled group. The last path that was moderated by group was the negative relationship of intrinsic motivation at time 1 on physical performance at time 2, with this effect being stronger in the self-controlled group.

Discussion

The primary purpose of this experiment was to investigate the contributions of self-efficacy and intrinsic motivation, via path analysis, to the learning advantages associated with practising in a self-controlled learning condition compared to yoked learning condition. We hypothesised that a person's self-efficacy and intrinsic motivation would show stronger predictive power towards one's physical performance under self-controlled as compared to yoked learning conditions. The results of the path analysis, however, do not support this hypothesis. Instead, similar results were obtained for the two learning conditions as the model was not moderated by experimental group. Although

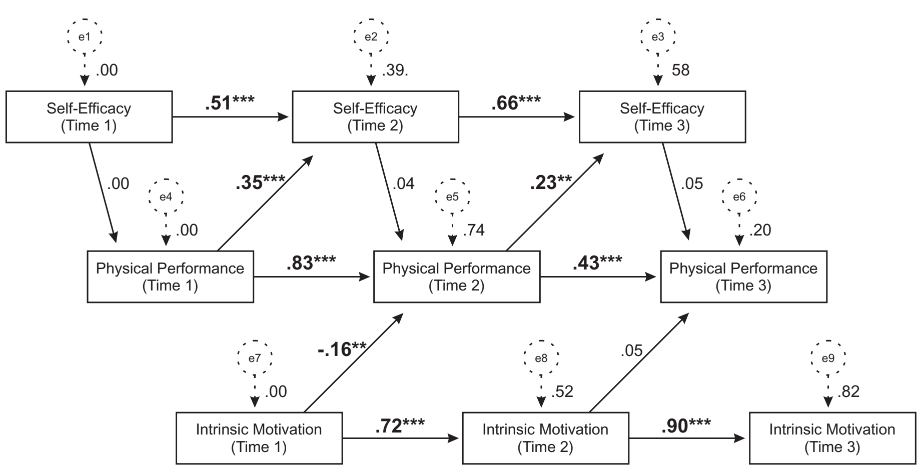

Figure 2. Standardised regression weights for the model based on the full data set with significant (large and bold font) and non-significant (small font). Time 1 and 2 represent acquisition blocks 5 and 10, respectively, while time 3 represents retention. The single-headed arrows represent hypothesised predictive relationships in the model. Note: *$P < .05$; **$P < .01$; ***$P < .001$.

[3]An analysis of the final block of acquisition was analysed to ensure that physical performance between the self-Controlled and the yoked groups revealed that they were not significantly different from each other in their physical performance scores ($P > .05$). This eliminates any concern that one group may have had an easier or harder retention test based on the starting skill progression they experienced as both groups were at a comparable physical performance level at the end of the practice phase.

Table 2. Multi-group (self-controlled and yoked) analysis comparing the different paths of the model.

Path of interest			Self-controlled		Yoked		
			Estimate	*P*-value	Estimate	*P*-value	*z*-Score
Self-efficacy time 1	→	Self-efficacy time 2	.46	<.001	.58	<.001	1.506
Self-efficacy time 2	→	Self-efficacy time 3	.56	<.001	.79	<.001	1.133
Self-efficacy time 1	→	Physical performance time 1	−.02	.909	.21	.140	1.126
Self-efficacy time 2	→	Physical performance time 2	.16	.041	.00	.975	−1.372
Self-efficacy time 3	→	Physical performance time 3	.22	.144	−.18	.228	−1.893
Physical performance time 1	→	Self-efficacy time 2	.45	<.001	.18	.131	−1.242
Physical performance time 2	→	Self-efficacy time 3	.24	.029	.20	.008	−.493
Physical performance time 1	→	Physical performance time 2	**.76**	<.001	**.84**	<.001	**2.267***
Physical performance time 2	→	Physical performance time 3	.41	.004	.30	.05	−.959
Intrinsic motivation time 1	→	Intrinsic motivation time 2	**.41**	.002	**.82**	<.001	**2.675****
Intrinsic motivation time 2	→	Intrinsic motivation time 3	.76	<.001	.96	<.001	.531
Intrinsic motivation time 1	→	Physical performance time 2	**−.32**	<.001	**−.08**	.321	**3.408****
Intrinsic motivation time 2	→	Physical performance time 3	.05	.691	−.18	.203	−.867

Estimates represent the standardised regression weights and *P*-value indicates whether that path of interest was significant for the group. For the *z*-scores: $*P < .05$ (critical ratio > 1.96); $**P < .01$ (critical ratio > 2.58). Paths that were significantly moderated by group are made bold for emphasis.

physical performance and self-efficacy beliefs showed a cyclical relationship during acquisition, a finding that coincides with much of the self-efficacy literature (Bandura, 1997; Feltz, Short, & Sullivan, 2008), these beliefs and intrinsic motivation had little explanatory power for the advantages noted in the physical performance scores.

The lack of support for our hypotheses could be due to varied reasons. One factor concerns whether we selected the most appropriate form of motivation to assess. The self-determination continuum ranges from a complete absence of motivation (i.e., amotivation) to a series of motivations that are considered more externally regulated and reflect motives driven by tangible external rewards or the avoidance of punishment and disapproval (i.e., external regulation, introjected regulation). Further along the continuum are motives driven by the desire to act in a way that is aligned with one's identity and psychological needs (i.e., identified regulation, integrated regulation) but that are not purely intrinsically motivated (Deci & Ryan, 1985; Ryan & Deci, 2000). It may be that self-control encourages a shift from more externally regulated motives for task engagement to more self-determined motives, but may not result in purely intrinsic motives. Perhaps examining other forms of motivation along the self-determination continuum would be worthwhile.

The absence of a relationship between self-efficacy and performance during retention also suggests that other factors may drive the performance benefits. As an example, and staying within Self-determination Theory (Deci & Ryan, 1985; Ryan & Deci, 2000), it may be that the self-control group perceives greater choice (i.e., autonomy), which in turn leads to improved performance early in acquisition. The element of self-control over an aspect of practice may also engage learners in a more intrinsic (i.e., autonomous) rather than extrinsic (i.e., controlled) goal focus, leading to enhanced performance. These suppositions are in line with Sanli et al.'s (2013) encouragements to integrate Self-determination Theory, and thus considerations on perceptions of autonomy and subsequent goal focus would be useful. We also note the limitation that the small sample size did not allow the incorporation of further variables into the model nor additional relationships. Exploration of the inter-relationships between variables could help to improve the fit of the model, as evidenced by the modification indices suggested for both the self-controlled and yoked groups.

While we do encourage further inquiry from this motivational approach, another viable line of research is one which examines how self-controlled conditions may engage the learner in greater or more varied information-processing activities than that of imposed-learning conditions. Increasing the processing demands of a practice context has been argued to be more effective for skill acquisition than less demanding contexts (Guadagnoli & Lee, 2004; Lee, Swinnen, & Serrien, 1994; Schmidt & Bjork, 1992). Increased information-processing has, for example, been said to occur within self-controlled learning conditions because participants are more engaged in adopting new or better learning strategies (Hartman, 2007; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997), increased metacognitive processing (Patterson, Carter, & Sanli, 2011), or more engaged in error estimation and/or feedback processing (Carter, Carlsen, & Ste-Marie, 2014; Grand et al., 2015). Thus, research examining more information-processing based mechanisms is well warranted.

To conclude, path analysis results that were obtained for participants in self-controlled and yoked learning conditions indicated that self-efficacy and intrinsic motivation, as measured here, likely do not contribute to the physical performance benefits obtained for self-controlled self-observation of double mini-trampoline skills. Further research that considers other measures within Self-determination Theory or more cognitive-based mechanisms are still needed to better understand the learning advantages associated with self-controlled learning. Only with a complete understanding of self-controlled learning will we be able to optimise its use for motor learning across varied populations and motor skills.

Disclosure statement

No potential conflict of interest was reported by the authors.

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