

PAPER

Improving Students' Motivation for Physical Activity Using Digital Media: A Quasi-Experimental Study in Physical Education Using Smartphones and Tablets

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ABSTRACT

Based on the potential of digital media (DM) to increase students' motivation in physical education (PE), this study investigated the effects of a theory-based tablet and smartphone intervention on students' motivation in PE. A total of 309 students (8th and 9th grade) participated over five weeks. The intervention group ($n = 161$) carried out DM-supported PE lessons. Basic psychological need satisfaction (BPNS) and behavioral regulation were assessed. Results show no significant differences between groups on BPNS and behavioral regulation. However, BPNS moderated behavioral regulation regardless of the group. The non-significant results on BPNS and behavioral regulation show that the intervention did not lead to a significant improvement in motivation, which may be due to too little autonomy support, too little attractive content, and too little fun for the students. Future studies should investigate students' preferences for DM in PE and use these findings to develop interventions to support BPNS in PE.

KEYWORDS

self-determination theory, basic psychological needs, behavioral regulation, smartphones, tablets, students, mobile technology

1 INTRODUCTION

Motivational processes are crucial for improving the physical activity (PA) of children and adolescents [1]. One setting in which children's and adolescents' PA can be improved is school and, in particular, physical education (PE), as they are obligated to participate regardless of socio-economic status [2]. Thus, opportunities to make PE motivating must be found. One way to enhance motivation in PE could be the use of digital media (DM). Therefore, the purpose of the present study is to examine the potential of DM in order to motivate children and adolescents in PE.

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To describe the motivational potential of DM in PE, Deci and Ryan's Self-Determination Theory (SDT) [3] can serve as a theoretical framework, as it is one of the most used theories regarding motivation in PA. SDT is a macro-theory including six mini-theories [3, 4], of which two mini-theories are particularly used in PE [5, 6]: Basic Psychological Needs Theory (BPNT) and Organismic Integration Theory (OIT).

BPNT focuses on the three innate basic psychological needs (BPNs) of people: autonomy, competence, and relatedness [7]. Autonomy refers to being able to make decisions about one's own behavior that are consistent with one's own interests and integrated values. Competence means feeling effective in interactions and challenges in one's environment. Relatedness refers to belonging to something or someone and caring for others or being cared for by others [8]. People consciously or unconsciously strive to satisfy these BPNs [8] in different situations, different contexts, and their global life [9], with exercise or the use of DM being specific contexts.

Besides BPNT, OIT is another mini-theory within SDT. OIT describes behavior as amotivated, extrinsically motivated, or intrinsically motivated [7]. While amotivation is defined by a lack of behavioral intention, extrinsically motivated behavior is distinguished into more controlled and more self-determined types of behavioral regulation [7]. With increasing levels of self-determination, these types are external regulation (e.g., behavior to avoid punishment), introjected regulation (e.g., following social norms), identified regulation (e.g., following rational beliefs), and integrated regulation (e.g., reaching internal and personally significant values and attitudes). Finally, intrinsically motivated individuals are fully self-determined, focusing on a behavior itself (e.g., because of fun or interest) rather than its consequences [3, 7, 10].

According to Deci and Ryan [7], BPNS and the internalization of behavior are connected. Specifically, the more the BPNs are supported, the more self-determined a behavior is [11].

The SDT research on students' motivation in PE is summarized in several literature reviews. Vasconcellos et al. [5] analyzed 265 quantitative studies on students' motivation in PE in a systematic review and meta-analysis. One important result from this analysis is the strong correlation between BPNS and self-determined types of behavioral regulation in PE, which fits the theoretical assumptions of Deci and Ryan [7]. The relevance of BPNS is also reflected in a systematic review by White et al. [6] who summarized 34 qualitative studies on motivation in PE. Given this review, providing exercise choices (need for autonomy), individual challenges (need for competence), and possibilities for team activities (need for relatedness) can lead to more BPNS and increased self-determination in PE. In this regard, White et al. [6] emphasize that novelty, choices, and challenges are necessary to promote BPNS and enhance self-determined behavioral regulation, especially intrinsic motivation in PE.

In addition to the reviews by Vasconcellos et al. [5] and White et al. [6], a systematic review and meta-analysis of Kelso et al. [1] provides specific information on the effectiveness of interventions aiming to improve students' PA motivation in school. Kelso et al. [1] included 57 studies, 47 of which related to PE. The studies focused on different motivational variables, including BPNS (competence $n = 30$, autonomy $n = 18$, relatedness $n = 16$), intrinsic motivation ($n = 18$), and internalization ($n = 10$). The results of the meta-analysis showed small to moderate effects of interventions on perceived autonomy, intrinsic motivation, identified regulation, and the self-determination index (weighted score of behavioral regulation; [12]). Kelso et al. [1] concluded that school-based interventions have the potential to

increase children's and adolescents' motivation for PA, but that the effects vary within the interventions.

Considering the limited impact of intervention approaches on PA, it seems necessary to find new ways to motivate students within school-based PE interventions. One promising approach may be the use of DM as an innovative and multifaceted approach to improve PA motivation [13]. Regarding the use of DM in PE, there are several studies, the findings of which have been summarized in recent literature reviews (e.g., systematic reviews by Jastrow et al. [14] and Modra et al. [15], scoping review by Mackenbrock and Kleinert [16]). With regard to the motivational effects of DM in PE, the scoping review by Mackenbrock and Kleinert [16] includes studies in which DM, such as smartphones, tablets, consoles, computers, or other visual display media and applications [17], were used to support motivation in PE. Of the 14 included studies, 11 showed positive effects of DM on students' motivation. The motivational effects refer to improved BPNS, reduced amotivation, and controlled behavioral regulation, as well as increased self-determined behavioral regulation. These findings on the motivational potential of DM in PE are supported by reviews on online, blended, and flipped learning in PE [18, 19] and original studies on the correlation between DM and PA motivation in different contexts and target groups [20, 21].

One problem of previous research on the motivational effects of DM in PE is that the provided information on whether or how a theoretical background was used in the intervention conception is often not sufficient [16]. This represents a research gap because theory-based interventions are seen to be more promising in motivational effects than non-theory-based interventions [1]. Due to the lack of theory-based DM interventions, it is often only marginally possible to theoretically explain and discuss why and how students' motivation changes in PE with the use of DM [16]. However, this information is important for targeted DM use in PE.

In summary, the field of research on DM and its impact on motivation in PE is still very young and not yet sufficiently researched. In particular, it is needed to design theory-based DM interventions for PE and evaluate their efficacy in an experimental intervention study design. Such a design makes it possible to explain empirical effects causally and on a theoretical basis. Therefore, the aim of the present study is to investigate whether an SDT-based DM intervention can improve students' motivation in PE. Specifically, we aim to investigate changes in BPNS and internalization of behavior in the course of a DM intervention. Three research questions and hypotheses can be derived from the study aim:

1. Does the DM intervention enhance students' BPNS in PE?

We assumed (H1) that participation in the DM intervention will enhance students' BPNS in PE compared to a control group (CG) without a specific DM intervention.

2. Does the DM intervention enhance students' internalization of behavior regarding their participation in PE?

We assumed (H2) that participation in the DM intervention will enhance students' internalization of behavior regarding their participation in PE compared to the CG without a specific DM intervention.

3. Does the change in BPNS in PE moderate students' internalization of behavior regarding their participation in PE?

We assumed (H3) that an increase in BPNS in PE moderates students' internalization of behavior regarding their participation in PE.

2 MATERIAL AND METHODS

2.1 Study design

The study employed a quasi-experimental intervention design in which PE classes were assigned to an intervention group (IG) and a CG. The IG underwent a five-week intervention aimed at enhancing motivation in PE through the implementation of smartphones/tablets in PE. The CG did not receive any intervention and engaged in regular PE without the use of smartphones/tablets. Data were collected with two measurements, one at the beginning and the other at the end of the five weeks.

2.2 Participants

A sample size calculation was conducted a priori using G*Power [22] with an alpha level of .05, a statistical power of 95%, and a moderate effect size of .25 (Cohen's f) due to current research findings in meta-analyses [1] and original studies on motivation in PE [e.g., 23]. The sample size analysis determined a total sample size of 210 for the test conditions. Students of 8th and 9th grade of North-Rhine Westphalian (Germany) grammar schools were eligible to participate. The students themselves and their parents or legal guardians gave their consent. A total of 505 students agreed to join the study. In total, 309 (male = 142; female = 163; diverse = 4) participated in the pre- and post-measure and made up the final sample. The IG consisted of 161 students (male = 78; female = 82; diverse = 1) aged between 12 and 16 years ($M = 13.68$; $SD = 0.59$). The CG consisted of 148 students (male = 64; female = 81; diverse = 3) aged between 12 and 15 years ($M = 13.73$; $SD = 0.66$). More information on descriptive statistics describing the sample is given in Table 1.

Table 1. Descriptive statistics describing the sample characteristics

	Total ($n = 309$)	IG ($n = 161$)	CG ($n = 148$)
Grade 8 (n)	140 (45.3%)	67 (41.6%)	73 (49.3%)
Grade 9 (n)	168 (54.4%)	93 (57.8%)	75 (50.7%)
Gender m (n)	142 (46.0%)	78 (48.4%)	64 (43.2%)
Gender f (n)	163 (52.8%)	82 (50.9%)	81 (54.7%)
Gender d (n)	4 (1.3%)	1 (0.6%)	3 (2.0%)
Age M	13.70	13.68	13.73
Age SD	0.62	0.59	0.66
Age Min	12	12	12
Age Max	16	16	15

Notes: d = diverse; f = female; m = male; M = Mean; Max = Maximum; Min = Minimum; n = sample size; SD = standard deviation.

2.3 Intervention

Intervention content and structure. Regarding the content of the intervention, physical fitness training has been identified as both an important area of sport for the target

group [24] and anchored in the curriculum of German grammar schools in North-Rhine Westphalia within the movement field “Perceiving the body and developing movement skills.” The core of this movement field consists of motor abilities and elements of physical fitness, which are reflected in the structure of the intervention. The structure of the intervention is such that in every week, the intervention unit dealt with a different motor ability: 1. strength, 2. endurance, 3. speed, 4. coordination, and 5. flexibility. Each of the five intervention units followed the same structure of a warm-up, cool-down, and home workout. The warm-ups, cool-downs, and home workouts were carried out using DM in the form of smartphones/tablets and lasted an average of 15 minutes. The warm-ups were mainly for activating and preparing for the PE unit (e.g., endurance unit: Tabata warm-up with music). In the cool-downs, the focus was mainly on regulation/relaxation after the activity (e.g., strength unit: stretching). In the home workouts, the content of the warm-ups and cool-downs of the intervention unit were drawn on so that the children could try out ways to be physically active at home. The main parts of the PE lessons were not part of the intervention (e.g., no use of smartphones/tablets) and were led by the PE teachers. Within the intervention parts (warm-ups, cool-downs, home workouts), the students completed different tasks related to the respective topic of the intervention unit. In the different parts of the PE lesson, the smartphone/tablet was used in different ways (e.g., instruction with videos and images of exercises, feedback by taking photos of the exercise execution, entertainment by playing music with the smartphone/tablet) derived from the scoping review of Mackenbrock and Kleinert [16]. Table 2 provides an overview of the intervention content.

Table 2. Overview of the intervention content (type of digital implementation in parentheses)

Strength	Endurance	Speed	Coordination	Flexibility
Digital Part with Smartphones or Tablets: Welcome and Introduction				
Digital Part with Smartphones or Tablets: Warm-Up				
Strengthening exercises (images, text and quiz)	Tabata-HIIT-Workout (images and music)	Running-ABC (images and quiz)	Life-kinetics exercises (text and images)	Mobilization exercises (text and images)
Main part (not part of the intervention content – no use of smartphones or tablets)				
Digital Part with Smartphones or Tablets: Cool-Down				
Stretching exercises (images, text and quiz)	Time estimation run + pulse measurement (images and quiz)	Body scan (text and video)	Slow-paced Breathing (text, video and quiz)	Yoga-Challenge (text, images and quiz)
Digital Part with Smartphones or Tablets: Home Workout Teaser and Closing of PE Lesson				
Digital Part with smartphones or Tablets: Home Workout				
Individual strengthening Tabata-Workout (text and images)	Tracking of running routes (text and images)	Shuttle run with music (text and music)	Auditive reaction training (text and audio)	Yoga/Pilates on YouTube (text and video)

Theoretical framework of the intervention. The intervention is based on the SDT and especially the mini-theories BPNT and OIT [7, 11] and aims to improve BPNS and internalization of behavior in PE. Different intervention techniques were chosen to satisfy the three different BPNs. Firstly, autonomy was addressed with possibilities to choose or (further) develop exercises (e.g., creating one’s own warm-ups to music). Secondly, competence was addressed with the instruction of different exercise levels,

from which the students could choose (e.g., personal challenges). Thirdly, relatedness was addressed by the instruction of pair or group tasks (e.g., partner yoga tasks). In addition to BPNS, which mainly focused on the improvement of intrinsic motivation, identified and integrated regulation were also aimed to be enhanced. Identified regulation should be promoted by highlighting the purpose and value of fitness training through knowledge transfer (e.g., integrating fun facts and quizzes). For the improvement of integrated regulation, tasks that fit the students' values and interests were chosen (e.g., music and video formats as on common social media platforms like Instagram, TikTok, or YouTube). Figure 1 shows screenshots of the Biparcours app divided into the three BPNs to promote intrinsic motivation, as well as the rather self-determined types of behavioral regulation, identified and integrated regulation.



Fig. 1. Screenshots of the intervention content in Biparcours

Technical realization. Smartphones and tablets were chosen as the hardware. This decision was based on the high prevalence and popularity of smartphones and tablets among children and adolescents in terms of their own possession [25], the availability and increasing use of these hardware in schools [26, 27] as well as the positive evaluation compared to conventional analogue teaching media such as textbooks [28]. As software, the application Biparcours (<https://biparcours.de/>) was used to realize the intervention content with the smartphones and tablets. Biparcours is a free-of-charge app for educational institutions in North-Rhine Westphalia (Germany) and is available on both iOS and Android. Furthermore, Biparcours is compliant with the data protection law of the European Union and well-known in the German educational system. The app offers opportunities to design interactive and multimedia educational programs with a web-based editor. For example, different media formats such as images, audios, and videos can be integrated. Moreover, Biparcours enables the creation of interactive quizzes and tasks that can be solved with different

answer formats (e.g., multiple choice, surveys, challenges). The intervention content was provided to the teachers and students via QR codes. The students scanned the QR codes and downloaded the intervention content before the PE lesson so that the content could be used offline in the sports hall. In consultation with the teachers and parents, students' own devices (mainly smartphones) and school devices (mainly tablets) were used. The students were allowed to use the school devices at home so that they could complete the home workout as part of the intervention.

2.4 Measures

Sociodemographic variables (age, gender, class level) were assessed to describe the study population. BPNS in PE was measured with a modified version of the Contextual Basic Need Satisfaction Scale (CBANS) [29]. The CBANS consists of eleven items, representing the satisfaction of autonomy, competence, and relatedness. At the first measurement, the students were instructed to answer the CBANS items with consideration to their usual experiences in PE. At the second measurement, they were asked to refer to the last five weeks (i.e., the period after the first measurement). All 11 items followed the stem "In my PE lessons...". Autonomy was presented by five items (e.g., "... I do what I want"; t1: $\alpha = .83$; t2: $\alpha = .89$). The factors competence and relatedness were each built by three items: competence (e.g., "... I experience my abilities"; t1: $\alpha = .71$; t2: $\alpha = .79$) and relatedness (e.g., "... I belong to something or someone"; t1: $\alpha = .69$; t2: $\alpha = .73$). The answer scale of the CBANS ranged from 0 "not at all" to 3 "very strongly." Behavioral regulation in PE was measured with the German version of the Perceived Locus of Causality Questionnaire (PLOCQ-G) [German version 30; original version 31]. At the first measurement, the students were instructed to answer why they usually participated in PE. At the second measurement, they were asked why they had participated in the last five weeks in PE (i.e., the period after the first measurement). Twenty-four items followed the stem "I take part in PE classes...". The 24 items were separated into six factors (types of behavioral regulation) with four items each: amotivation (e.g., "...but I really don't know why"; t1: $\alpha = .85$; t2: $\alpha = .90$), external regulation (e.g., "...because I'll get into trouble if I don't"; t1: $\alpha = .86$; t2: $\alpha = .89$), introjected regulation (e.g., "...because I want the teacher to think I'm a good student"; t1: $\alpha = .79$; t2: $\alpha = .79$), identified regulation (e.g., "...because I want to learn sport skills"; t1: $\alpha = .87$; t2: $\alpha = .91$), integrated regulation (e.g., "...because PE is a part of me"; t1: $\alpha = .93$; t2: $\alpha = .94$), and intrinsic motivation (e.g., "...because PE is fun"; t1: $\alpha = .93$; t2: $\alpha = .92$). The answers were given on a seven-point Likert scale ranging from 1 "strongly disagree" to 7 "strongly agree".

2.5 Study procedure

Pre-study organization. Firstly, the study design was approved by the ethics committee of the university. For the acquisition, contact lists of PE teachers and school secretaries were used. The first contact was made via e-mail with an information flyer. Interested teachers were informed about the requirements, organizational issues, and the intervention content in a personal meeting or telephone call. The teachers who agreed to participate with their classes were assigned to the IG or the CG. Then, the teachers received information letters including consent forms for the parents or legal guardians of the students. The signed consent forms were sent back to the study administration.

Measurement organization. The study was conducted longitudinally with two measurements (each 10–12 minutes). The first questionnaire was answered before the first PE lesson (week one), and the second questionnaire after the fifth PE lesson (week five). The PE teachers ensured that the students had sufficient time to complete the questionnaires on their own. The participants were informed that they could contact the study management if they had any questions or uncertainties.

Organization of the intervention. In order to prepare the IG teachers for the use of DM in PE [32], they were briefed on technical aspects, organizational aspects, and the intervention content. Regarding technical aspects, teachers obtained information on the use of Biparcours (e.g., pre-downloading of the intervention content). Concerning organizational aspects, the teachers received, for example, information on necessary materials and how to behave during the intervention (i.e., instruct the students in the use of Biparcours and monitor whether the students were carrying out the intervention content). So that the teachers could manage the PE lessons, they were instructed to familiarize themselves with the intervention content, which was sent to them as a QR code about a week before the PE lesson. In the PE lesson, the students started the downloaded Biparcours on their devices and followed the intervention content in the given order. All instructions were given via the smartphone/tablet. During the exercise, the devices were put to the side and used again after the exercise was completed to move on with the following content.

2.6 Data analysis

Data were processed using IBM SPSS Statistics 29. Before data analysis, data were screened, including checking for full datasets (i.e., removing participants with only data at one measurement), checking for duplicates (i.e., removing participants with the same self-generated ID), and implausible responses (e.g., removing participants who marked the same value for each item of a questionnaire). An analysis of missing data regarding single items showed that less than 5% of the data were missing, which is why the missing data were not replaced [33]. The final data set consisted of 309 participants.

After data screening, the factors of BPNS and behavioral regulation were formed. The three BPNs were calculated based on the mean scores of the respective items of the CBANS data. The six types of behavioral regulation were summarized in mean scores based on the PLOCQ-G data. Multivariate outlier analysis was carried out using the Mahalanobis distance [34]. As the factors were used for the hypotheses testing, multivariate outlier analysis was carried out at the factor level and not at the item level. A total of five multivariate outliers (two regarding CBANS and three regarding PLOCQ-G) were identified and excluded from further calculations for testing the hypotheses. Upon data set preparation, descriptive statistics (M , SD , Min , Max) and bivariate Pearson correlational analysis were calculated to obtain an overview of the data. Subsequently, the hypotheses were tested using inferential statistics. All related inferential statistical tests were performed with a significance level set at $p < .05$. Mixed ANOVAs (2×2) were run to test the first and second hypotheses. The two measurements (t1 vs. t2) made up the within-subject factor time. The study group membership (i.e., IG vs. CG) formed the between-subject factor study group. The aim was to investigate whether the study groups developed differently over time (i.e., interaction effect) with concern to the dependent variables of the BPNS (first hypothesis) and the six types of behavioral regulation (second hypothesis). To test the third hypothesis, ANCOVAs (2×2) were calculated. As in the mixed ANOVAs, the within-subject factor was defined by the two measurements (i.e., t1

vs. t2), and the between-subject factor was based on the two study groups (i.e., IG vs. CG). The change of BPNS between the two measurements was integrated in the ANCOVAs as a covariate to investigate whether the study groups developed differently with regard to behavioral regulation over time under consideration of BPNS change (i.e., interaction effects time \times study group \times BPNS change). Therefore, a total score of BPNS (sum of three need mean scores divided by three) was computed for both measurements. Subsequently, the change in BPNS was calculated using the difference between t2 and t1. In cases where significant interactions involving BPNS change had occurred in the ANCOVAs, subsequent mixed ANOVAs (2x2) were conducted to identify the interaction pattern in a graphical way. In these subsequent mixed ANOVAs, the BPNS change was split into two groups (i.e., one group with BPNS change decrease or stagnation and one group with BPNS change increase) and added as a between-subject variable of two groups of BPNS changes together with the already existing within-subject variable of time (t1 and t2).

3 RESULTS

3.1 Descriptive statistics

The descriptive statistics for BPNS and behavioral regulation are presented in Table 3 (in total) and Table 4 (divided into the study groups). At both measurements, the data in total, but also when considering the IG and CG separately, scatter widely across the entire scale range (with the exception of CG competence t1 and t2 and CG amotivation t2). The strong scatter is also reflected in high standard deviations between 0.62 and 1.91 for a scale range of 0–3 concerning BPNS and 1.52 and 1.87 for a scale range of 1–7 concerning behavioral regulation. Table 5 shows the descriptive statistics on BPNS and behavioral regulation divided into the two groups of BPNS change (decrease/stagnation vs. increase) at both measurements.

Table 3. Descriptive statistics of BPNS and behavioral regulation in total

	Total					
	t1 BPNS: <i>n</i> = 309 BR: <i>n</i> = 309			t2 BPNS: <i>n</i> = 307 BR: <i>n</i> = 309		
	<i>M</i>	<i>SD</i>	<i>Min–Max</i>	<i>M</i>	<i>SD</i>	<i>Min–Max</i>
Competence ¹	1.80	0.62	0–3	1.71	0.74	0–3
Autonomy ¹	1.32	0.70	0–3	1.28	0.77	0–3
Relatedness ¹	1.82	0.68	0–3	1.77	0.73	0–3
Amotivation ²	2.54	1.54	1–7	2.70	1.64	1–7
External regulation ²	3.65	1.82	1–7	3.70	1.87	1–7
Introjected regulation ²	3.40	1.52	1–7	3.40	1.57	1–7
Identified regulation ²	4.38	1.66	1–7	4.25	1.75	1–7
Integrated regulation ²	2.77	1.71	1–7	3.04	1.80	1–7
Intrinsic motivation ²	4.54	1.77	1–7	4.44	1.76	1–7

Notes: ¹ = based on a Likert scale from 0 to 3; ² = based on a Likert scale from 1 to 7; BPNS = Basic psychological need satisfaction; BR = Behavioral regulation; *M* = mean; *Max* = Maximum; *Min* = Minimum; *n* = sample size; *SD* = standard deviation; t1 = first measurement point; t2 = second measurement point.

Table 4. Descriptive statistics of BPNS and behavioral regulation divided into the study groups

	IG						CG					
	t1 BPNS: n = 161 BR: n = 161			t2 BPNS: n = 159 BR: n = 161			t1 BPNS: n = 148 BR: n = 148			t2 BPNS: n = 148 BR: n = 148		
	M	SD	Min-Max	M	SD	Min-Max	M	SD	Min-Max	M	SD	Min-Max
Competence ¹	1.76	0.62	0-3	1.62	0.81	0-3	1.85	0.62	0.33-3	1.80	0.66	0.33-3
Autonomy ¹	1.21	0.70	0-3	1.13	0.80	0-3	1.43	0.69	0-3	1.43	0.73	0-3
Relatedness ¹	1.73	0.71	0-3	1.72	0.79	0-3	1.94	0.64	0-3	1.82	0.67	0-3
Amotivation ²	2.67	1.55	1-7	2.93	1.76	1-7	2.42	0.69	1-7	2.45	1.46	1-6.75
External regulation ²	3.91	1.82	1-7	4.02	1.91	1-7	3.36	1.78	1-7	3.35	1.76	1-7
Introjected regulation ²	3.32	1.56	1-7	3.39	1.54	1-7	3.49	1.56	1-7	3.42	1.60	1-7
Identified regulation ²	4.23	1.66	1-7	4.10	1.80	1-7	4.55	1.64	1-7	4.42	1.69	1-7
Integrated regulation ²	2.45	1.52	1-7	2.81	1.78	1-7	3.12	1.85	1-7	3.30	1.77	1-7
Intrinsic motivation ²	4.32	1.80	1-7	4.22	1.81	1-7	4.78	1.73	1-7	4.67	1.68	1-7

Notes: ¹ = based on a Likert scale from 0 to 3; ² = based on a Likert scale from 1 to 7; BPNS = Basic psychological need satisfaction; BR = Behavioral regulation; M = mean; Max = Maximum; Min = Minimum; n = sample size; SD = standard deviation; t1 = first measurement point; t2 = second measurement point.

Table 5. Descriptive statistics of BPNS and BR divided into the groups BPNS decrease/stagnation and BPNS increase

	BPNS Change Decrease/Stagnation						BPNS Change Increase					
	t1 BPNS, BR: n = 180			t2 BPNS, BR: n = 180			t1 BPNS, BR: n = 127			t2 BPNS, BR: n = 127		
	M	SD	Min-Max	M	SD	Min-Max	M	SD	Min-Max	M	SD	Min-Max
Competence ¹	1.81	0.63	0-3	1.43	0.74	0-3	1.81	0.59	0.33-3	2.10	0.81	0-3
Autonomy ¹	1.37	0.71	0-3	1.03	0.71	0-3	1.25	0.68	0-3	1.63	0.80	0.33-3
Relatedness ¹	1.98	0.63	0-3	1.58	0.72	0-3	1.63	0.70	0-3	2.04	0.79	0-3
Amotivation ²	2.70	1.58	1-7	2.84	1.67	1-7	2.28	1.40	1-7	2.44	1.52	1-7
External regulation ²	3.78	1.81	1-7	3.98	1.92	1-7	3.42	1.80	1-7	3.24	1.67	1-7
Introjected regulation ²	3.50	1.55	1-7	3.26	1.51	1-7	3.29	1.58	1-7	3.62	1.62	1-7
Identified regulation ²	4.38	1.60	1-7	3.87	1.70	1-7	4.57	1.70	1-7	4.83	1.63	1-7
Integrated regulation ²	2.58	1.55	1-7	2.57	1.57	1-7	3.07	1.90	1-7	3.74	1.87	1-7
Intrinsic motivation ²	4.34	1.75	1-7	4.02	1.70	1-7	4.88	1.74	1-7	5.09	1.60	1-7

Notes: ¹ = based on a Likert scale from 0 to 3; ² = based on a Likert scale from 1 to 7; BPNS = Basic psychological need satisfaction; BR = Behavioral regulation; M = mean; Max = Maximum; Min = Minimum; n = sample size; SD = standard deviation; t1 = first measurement point; t2 = second measurement point.

3.2 Correlation analyses

Table 6 shows the bivariate correlations between the three BPNs and the six behavioral regulation factors. The results show moderate to high positive correlations between the BPNs at both measurements. In the behavioral regulation factors, the controlled types mainly (introjected regulation being the exception) correlate at both measurements significantly positively to a moderate to strong degree with each other and significantly negatively to a moderate to strong degree with the more self-determined

types of behavioral regulation (identified, integrated, intrinsic). Between the BPNs and behavioral regulation, there are moderate to strong correlations at both measurements. The correlations between the BPNs and the controlled types of behavioral regulation are negatively significant (with the exception of non-significant negative correlations of introjected regulation), whereas the correlations between the BPNs and the self-determined types of behavioral regulation are significantly positive.

Table 6. Intercorrelations of the BPNs and behavioral regulation

	(1)	(2)	(3)	(5)	(6)	(7)	(8)	(9)	(10)
Competence (1)	–	.41**	.37**	–.53**	–.41**	–.01	.61**	.47**	.60**
Autonomy (2)	.61**	–	.38**	–.38**	–.32**	–.07	.34**	.46**	.42**
Relatedness (3)	.49**	.43**	–	–.22**	–.20**	< –.01	.32**	.31**	.30**
Amotivation (5)	–.45**	–.38**	–.27**	–	.61**	.02	–.61**	–.45**	–.64**
External regulation (6)	–.42**	–.47**	–.20**	.57**	–	.31**	–.42**	–.34**	–.48**
Introjected regulation (7)	.07	–.05	.03	.04	.31**	–	.16**	.06	.04
Identified regulation (8)	.54**	.47**	.37**	–.45**	–.32**	.26**	–	.63**	.78**
Integrated regulation (9)	.56**	.49**	.38**	–.32**	–.34**	.14*	.58**	–	.65**
Intrinsic motivation (10)	.59**	.55**	.45**	–.49**	–.41**	.17**	.78**	.63**	–

Notes: * $p < .05$; ** $p < .01$; values above the diagonal represent correlations at t1; values below the diagonal represent correlations at t2.

3.3 Research question 1: Effects of the DM intervention on basic psychological need satisfaction

To test the first hypothesis, three mixed ANOVAs (one for every BPN) were calculated (refer to Table 7). The results of the mixed ANOVAs showed no significant interaction effects. With regard to the main effects, a significant time effect was found for the need for competence ($F(1, 303) = 8.37, p = .004, \eta_p^2 = 0.03$). More specifically, there was a decrease from t1 to t2 (t1 $M = 1.80, SD = 0.62$; t2 $M = 1.71, SD = 0.74$). Significant main effects of the groups were found for the needs of autonomy ($F(1, 303) = 11.68, p < .001, \eta_p^2 = 0.04$) and relatedness ($F(1, 303) = 4.60, p = .033, \eta_p^2 = 0.02$). In more detail, the CG ($M = 1.43, SD = 0.65$) showed significantly higher values than the IG ($M = 1.17, SD = 0.66$) regarding autonomy as well as relatedness (IG: $M = 1.72, SD = 0.65$; CG: $M = 1.88, SD = 0.58$).

Table 7. Results of 2 (time: t1, t2) × 2 (study group: IG/CG) mixed ANOVAs for BPNs

Dependent Variable	Effect	df^1	df^2	F	p	η_p^2
Competence	Time	1	303	8.37	.004	0.03
	Study group	1	303	2.99	.085	0.01
	Time × study group	1	303	1.72	.191	0.01
Autonomy	Time	1	303	2.16	.142	0.01
	Study group	1	303	11.68	< .001	0.04
	Time × study group	1	303	1.32	.251	< 0.01
Relatedness	Time	1	303	3.47	.064	0.01
	Study group	1	303	4.60	.033	0.02
	Time × study group	1	303	1.27	.260	< 0.01

Notes: ¹ = degrees of freedom of effect; ² = degrees of freedom of error.

3.4 Research question 2: Effects of the DM intervention on behavioral regulation

For testing the second hypothesis, six mixed ANOVAs (one for every type of behavioral regulation) were calculated (refer to Table 8). The results of the mixed ANOVAs showed no significant interaction effects. Regarding the main effects, the mixed ANOVAs referring to integrated regulation showed a significant time effect: $F(1, 304) = 10.60, p = .001; \eta_p^2 = 0.034$. The time effect was shown by an increase in integrated regulation ($t1 M = 2.77, SD = 1.71; t2 M = 3.04, SD = 1.80$). Moreover, significant group effects for four types of behavioral regulation were found: Amotivation ($F(1, 304) = 4.81, p = .029, \eta_p^2 = 0.016$); external regulation ($F(1, 304) = 10.33, p < 0.001, \eta_p^2 = .033$); integrated regulation ($F(1, 304) = 10.55, p = .001, \eta_p^2 = 0.034$); and intrinsic motivation ($F(1, 304) = 6.09, p = .014, \eta_p^2 = 0.020$). More specifically, the IG reached higher values regarding amotivation (IG: $M = 2.80, SD = 1.43$; CG: $M = 2.44, SD = 1.40$) and external regulation (IG: $M = 3.96, SD = 1.62$; CG: $M = 3.36, SD = 1.61$), whereas the integrated regulation (IG: $M = 2.63, SD = 1.45$; CG: $M = 3.21, SD = 1.71$) and intrinsic motivation (IG: $M = 4.27, SD = 1.62$; CG: $M = 4.73, SD = 1.60$) was higher in CG than in the IG.

Table 8. Results of 2 (time: t1, t2) × 2 (Study group: IG/CG) mixed ANOVAs for behavioral regulation (PLOCQ-G variables)

Dependent Variable	Effect	df ¹	df ²	F	p	η _p ²
Amotivation	Time	1	304	3.77	.053	0.01
	Study group	1	304	4.81	.029	0.02
	Time × study group	1	304	1.89	.170	0.01
External regulation	Time	1	304	0.84	.361	< 0.01
	Study group	1	304	10.33	.001	0.03
	Time × study group	1	304	0.37	.546	< 0.01
Introjected regulation	Time	1	304	0.07	.797	< 0.01
	Study group	1	304	0.46	.501	< 0.01
	Time × study group	1	304	0.41	.525	< 0.01
Identified regulation	Time	1	304	1.63	.202	0.01
	Study group	1	304	3.16	.077	0.01
	Time × study group	1	304	0.08	.774	< 0.01
Integrated regulation	Time	1	304	10.60	.001	0.03
	Study group	1	304	10.55	.001	0.03
	Time × study group	1	304	1.05	.306	< 0.01
Intrinsic motivation	Time	1	304	1.46	.228	0.01
	Study group	1	304	6.09	.014	0.02
	Time × study group	1	304	0.01	.946	< 0.01

Notes: ¹ = degrees of freedom of effect; ² = degrees of freedom of error.

3.5 Research question 3: Moderating role of basic psychological need satisfaction in behavioral regulation change

For testing the third hypothesis, six ANCOVAs (one for every type of behavioral regulation) were calculated with the amount of BPNS change as a metric covariate

(refer to Table 9). The results of the ANCOVAs showed no significant three-way interaction effects between time, study group, and BPNS change. Instead, significant two-way interaction effects between time and BPNS change (i.e., independent of the study group IG/CG) were found for introjected regulation ($F(1, 298) = 8.72, p = .003, \eta_p^2 = 0.03$), identified regulation ($F(1, 298) = 24.78, p < .001, \eta_p^2 = 0.08$), integrated regulation ($F(1, 298) = 23.63, p < .001, \eta_p^2 = .07$), and intrinsic motivation ($F(1, 298) = 13.89, p < .001, \eta_p^2 = 0.05$). Regarding the main effects, significant time effects were found for integrated regulation ($F(1, 298) = 16.40, p < .001, \eta_p^2 = 0.05$). Study group effects were evident in external regulation ($F(1, 298) = 9.45, p = .002, \eta_p^2 = 0.03$), integrated regulation ($F(1, 298) = 8.53, p = .004, \eta_p^2 = 0.03$), and intrinsic motivation ($F(1, 298) = 4.49, p = .035, \eta_p^2 = 0.02$). The identified main effects of time and study group were of the same direction as in the previous ANOVAs (see the previous paragraph).

Figure 2 shows the interaction graphs of the subsequent 2×2 mixed ANOVAs with the split BPNS change as a group factor (increase vs. decrease/stagnation). The identified interactions between time and BPNS change were disordinal in the introjected regulation (see Figure 2, graph a) and semi-disordinal in the identified, integrated, and intrinsic regulation/motivation (see Figure 2, graphs b–d). In the semi-disordinal interactions, the variable BPNS change was shown to be an ordinal factor in which the group with increased BPNS showed an increase in behavioral regulation (identified, integrated, intrinsic), while the group with a decrease/stagnation of BPNS showed a decrease in behavioral regulation over time.

Table 9. Results of 2 (time: t_1, t_2) \times 2 (Study group: IG/CG) ANCOVAs for behavioral regulation with BPNS difference (post-pre) as a covariate

Dependent Variable	Effect	df^1	df^2	F	p	η_p^2
Amotivation	Time	1	298	3.00	.084	0.01
	Study group	1	298	3.46	.064	0.01
	Time \times study group	1	298	0.80	.373	< 0.01
	Time \times BPNS change	1	298	0.22	.639	< 0.01
	Time \times study group \times BPNS change	1	298	0.85	.359	< 0.01
External Regulation	Time	1	298	0.19	.662	< 0.01
	Study group	1	298	9.45	.002	0.03
	Time \times study group	1	298	< 0.01	.984	< 0.01
	Time \times BPNS change	1	298	2.31	.130	0.01
	Time \times study group \times BPNS change	1	298	1.77	.185	0.01
Introjected Regulation	Time	1	298	0.67	.412	< 0.01
	Study group	1	298	0.09	.769	< 0.01
	Time \times study group	1	298	0.63	.427	< 0.01
	Time \times BPNS change	1	298	8.72	.003	0.03
	Time \times study group \times BPNS change	1	298	0.12	.730	< 0.01

(Continued)

Table 9. Results of 2 (time: t1, t2) × 2 (Study group: IG/CG) ANCOVAs for behavioral regulation with BPNS difference (post-pre) as a covariate (*Continued*)

Dependent Variable	Effect	df ¹	df ²	F	p	η _p ²
Identified Regulation	Time	1	298	0.24	.624	< 0.01
	Study group	1	298	1.76	.185	0.01
	Time × study group	1	298	0.38	.537	< 0.01
	Time × BPNS change	1	298	24.78	< .001	0.08
	Time × study group × BPNS change	1	298	0.03	.874	< 0.01
Integrated Regulation	Time	1	298	16.40	< .001	0.05
	Study group	1	298	8.53	.004	0.03
	Time × study group	1	298	1.67	.197	0.01
	Time × BPNS change	1	298	23.63	< .001	0.07
	Time × study group × BPNS change	1	298	0.40	.527	< 0.01
Intrinsic Motivation	Time	1	298	0.56	.454	< 0.01
	Study group	1	298	4.49	.035	0.02
	Time × study group	1	298	0.15	.700	< 0.01
	Time × BPNS change	1	298	13.89	< .001	0.05
	Time × study group × BPNS change	1	298	0.16	.688	< 0.01

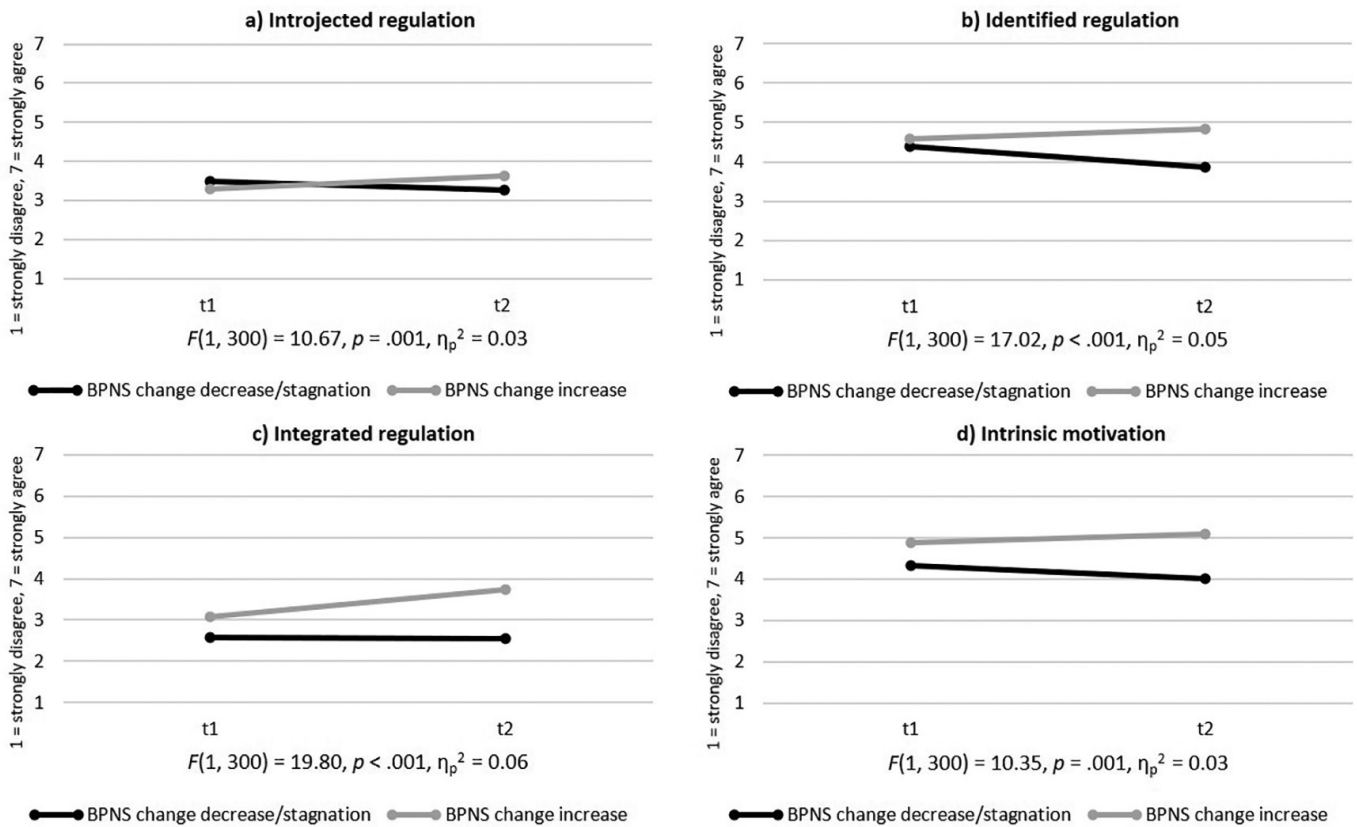


Fig. 2. (a–d) Significant interaction effects of 2 (time: t1, t2) × 2 (group: BPNS change groups) mixed ANOVAs for behavioral regulation

4 DISCUSSION

The purpose of this study was to examine whether a DM intervention based on the theoretical assumptions of Deci and Ryan [7, 11] would improve students' motivation in PE. In particular, we investigated whether a DM intervention led to better basic psychological need satisfaction (BPNS) (research question, RQ 1) and internalization of behavior (RQ 2) in PE compared to regular PE without DM. Moreover, we investigated whether BPNS moderates the internalization of behavior in PE (RQ 3). The results showed, contrary to our expectations, no effects regarding BPNS (RQ 1) or behavioral regulation (RQ 2) that could be attributed to the DM intervention. However, in line with what we assumed, BPNS change was shown to moderate the internalization of behavior (RQ 3)—although this was independent of participation in the DM intervention (see results for RQ 1, RQ 2).

Contrary to our assumption, the DM intervention did not improve BPNS in PE. The lack of effects can be explained by three different aspects. Firstly, although the intervention structure enabled the students in individual tasks to decide by themselves, the overall structure of the intervention and the sequence of tasks were mainly prescribed, limiting the overall autonomy of the students. In particular, students were not able to choose the topic of the intervention unit nor the specific exercises as part of the intervention tasks. However, a structure within an intervention unit seems to be necessary for the implementation of a feasible intervention with regard to the organization and standardization of the intervention. Secondly, the main part of the PE lessons, which was not part of the intervention and was carried out without DM, might have played a role in relation to BPNS. Although the students were instructed in the post-test (measurement of BPNS) to only consider the intervention (warm-up and cool-down, both 15 minutes), it is possible that the students nevertheless not only considered the intervention but also the main part, which took up most of the PE lesson (approx. 40–45 minutes). The main part was planned and carried out independently by the PE teachers, meaning that teacher behavior supportive of autonomy [35] was not considered. Thirdly, the intervention topic and design may not have been attractive enough for the target group. It can be assumed that although the topic of fitness was chosen as a relevant topic anchored in the lives of the children [24], the presentation of the tasks and information was not suitable for them. With concern to suitability, systematic reviews on gamification in PE have shown that gamified elements like badges, points, and challenges, which are commonly used in video games (e.g., Dance Dance Revolution) have a relevant impact, especially on intrinsic motivation fostered by BPNS [36, 37]. Our intervention had gamified aspects, such as quizzes but was not based on video game design or any scoring system and had many explanatory and informative aspects regarding health and PA. The lack of orientation toward video games, as well as the absence of challenges fostered by a scoring system in combination with “boring” explanations, may be reasons for BPNS not being satisfied. This explanation fits other intervention studies on the motivational effects of DM in PE that found no or negative effects regarding motivation. For example, Zhu and Dragon [38] and Lee and Gao [39] also highlight a lack of gamification and interactivity, along with an overdose on information delivery and management, as a possible explanation for their results.

In contrast to our second hypothesis, the DM intervention did not improve the internalization of behavior. In particular, the DM intervention did not enhance the three self-determined types of behavioral regulation (intrinsic motivation, integrated and identified regulation). Firstly, in regard to intrinsic motivation, this could be a consequence of not increasing BPNS. Against the background of SDT, successful

BPNS is a prerequisite for being intrinsically motivated [7, 11]. Thus, the aforementioned reasons why the BPNS could not be improved by the DM intervention are also reasons for the lack of improvement of intrinsic motivation. Secondly, identified regulation was not enhanced because the relevant reasons for adolescents being physically active were probably not completely and sufficiently addressed in our DM intervention. Although we attempted to show students the positive effects of PA (e.g., physical and mental effects) [40], identified regulation did not increase. As a reason, we assume that the content of our DM intervention, such as health, well-being, and stress reduction, is not (yet) so important for the average age group of 14-year-olds that they would become physically active (e.g., to improve their health). This fits with the findings of a qualitative study by James et al. [41], who asked adolescents for recommendations on how to improve their PA. An important result of James et al. [41] is that adolescents do not consider long-term effects of PA, such as health benefits, which played an important role in our DM intervention. Thirdly, integrated regulation was not improved because the intervention was perhaps not similar enough to the way adolescents normally use their DM in everyday life. That is, although we tried to match the intervention content to the values of the target group to address relevant social factors (e.g., use of YouTube videos from popular fitness influencers and current chart music), the students obviously could not identify strongly enough with the intervention content. More specifically, perhaps the intervention was not similar enough to the way adolescents use DM such as TikTok, Snapchat, Instagram, and Fortnite [42]. In particular, we assume that the way the intervention content was communicated (often in text form with the addition of videos and images) was not appropriate and that instructions in the form of postings (e.g., reels on Instagram, short messages with emojis on WhatsApp) would have led to a stronger identification of the students with the intervention (content).

As we expected, the direction and amount of change in BPNS over time moderated the internalization of behavior. In particular, it was shown that the internalization regarding the three self-determined types of behavioral regulation got stronger over time in the group with increased BPNS compared to the group of decreased/stagnated BPNS. These findings can be theoretically explained with Deci and Ryan's [11] description of the degree of BPNS affecting the type and strength of the internalization of behavior (i.e., increase of identified and integrated regulation). These moderation effects of our study are consistent with other empirical findings showing strong positive correlations between BPNS and self-determined types of behavioral regulation [5]. Besides the moderation of BPNS change on the self-determined types of behavioral regulation, one special finding of our study is that introjected regulation also increased stronger over time in the group of BPNS increase compared to the students with stagnated or decreased BPNS. Thus, introjected regulation as a controlled form of behavioral regulation developed in the same way as the self-determined types. On the one hand, this result is surprising given the theoretical assumptions of the SDT [11]. On the other hand, this result fits with meta-analytical findings showing that BPNS correlates moderately positively with introjected regulation and that introjected regulation correlates moderately to strongly positively with self-determined behavioral regulation in PE [5]. The positive correlation between introjected and identified regulation may be related to the two types of introjected regulation (approach and avoidance), whereby approach orientation is more internalized and is associated with aspects similar to identified regulation [43, 44].

Strengths and Limitations. The present study has three major strengths. Firstly, the experimental design, featuring both an IG and a CG, enhances internal validity

and allows for causal inferences. Secondly, the inclusion of the intervention within real-world settings and into existing PE classes bolsters ecological validity, ensuring the findings are applicable to real educational environments. This also includes the point that the DM intervention was implemented for a part of the PE lessons only, which fits the ecological opportunities (e.g., increased planning effort for digital components). Thirdly, despite the lack of effects, the intervention should be seen as a strength, as it was designed based on theory and thus provided a transparent and solid basis for discussing the results of the study and simplified modifications of the interventions and replication studies. Despite these strengths, however, the study has some limitations. Firstly, there are limitations regarding the study design. The study duration was five weeks, with two measurements (before and after the intervention). This means that possible changes in motivation between the two measurements were not recorded. Secondly, the drop-out of participants is also a limitation. Initially, 505 students participated in the first measurement. At the second measurement point, we obtained data from 309 students, meaning that there was a drop-out of almost 39% of the students. The most common reasons for dropping out mentioned by the teachers in our study were usual reasons for not taking part in PE (e.g., illness, forgetting of equipment). It can therefore be assumed that the drop-outs in this case did not represent a systematic bias. Thirdly, there are limitations regarding the intervention design. With the aim of developing a realizable, cost-free, and practicable intervention, we decided to exclude the main part of the PE lesson from the intervention. This means we cannot clearly determine whether the study results are solely related to our DM intervention or if the combination of short DM segments with regular PE without DM (which comprised the main part of the PE) influenced students' motivation assessments, thus complicating the clear attribution of motivational effects specifically to the DM intervention.

Future research and practical implications. Future research should address two aspects. Firstly, our study showed that in regard to DM interventions for children and adolescents, it is particularly important to investigate students' preferences and expectations concerning the use of DM in PE. Therefore, students should be involved in the planning phase of future studies to find out under what circumstances the use of DM is motivating or even demotivating. Research should include aspects such as the type of preferred DM (e.g., which devices do the students want to use?), the kind of DM used (e.g., should DM be used for instruction/video feedback etc?), and the frequency of use (e.g., should DM be used regularly or only exceptionally?). Secondly, enjoyable interventions should be created with consideration to students' preferences regarding DM use in PE and suitable behavior-change techniques [45]. School-based interventions are most successful when students enjoy taking part [41]. Therefore, researchers and intervention developers should focus on BPNS as an important prerequisite for achieving intrinsic motivation for using DM (i.e., interest, pleasure, enjoyment) [10]. For this, gamification and exergame approaches, as well as interactive elements, seem to offer great potential regarding enjoyment in PE [36, 46]. Regarding gamification, a scoring system could be integrated into the DM intervention. Such a scoring system for quizzes and tasks could be used for challenges in the class or with parallel classes. Moreover, the used instructions for exercises could be adapted so that they appear more as postings on common social media platforms (e.g., Instagram, TikTok) [42] than like instructions in school books. Concrete examples could also be used for this, in which the students select sport and fitness influencers, whose content is then implemented and critically reflected in PE lessons. With regard to the practical application of the present study, our main

recommendation is to have a critical eye on the use of DM in PE. Even though the current state of research on the motivational effects of DM in PE suggests that the use of DM in PE can be motivating [16], the results of this study show that this is not always the case. Therefore, we can recommend that teachers should ask themselves whether the use of DM is helpful for the teaching aim, critically reflect on possible influences on students' motivation, and talk to their students about whether or not they would like to use DM in PE.

5 CONCLUSION

In conclusion, this controlled intervention study aimed to enhance students' motivation in PE with a DM intervention grounded on the SDT of Deci and Ryan [7, 11]. Contrary to our expectations, the intervention did not improve students' BPNS or internalization of behavior. This lack of effects could be attributed to several factors, including the limited autonomy provided within the intervention, the main part of the PE lesson not being covered by the DM intervention, and the potentially less attractive or enjoyable design of the intervention content. However, the moderation effects shown in our study highlight the role of BPNS in the process of internalization. Given these explanations of missing effects, the study underscores the need for future research to explore students' preferences for DM use in PE. This information on students' preferences is relevant and necessary to develop enjoyable and motivating DM interventions in PE (e.g., by adding gamified elements such as scoring systems or social media elements as on Instagram and TikTok). Therefore, practical recommendations include a cautious approach to integrating DM in PE, ensuring its alignment with educational goals, and actively engaging students in the design process to enhance their motivation.

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Conflict of interest: No potential conflict of interest was reported by the authors.

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7 AUTHOR CONTRIBUTIONS

JM and JK contributed to the study conception. Intervention design was developed by JM, AG and JK. Data collection was carried out by JM. Data analysis was performed by JM, FP and JK. The first draft of the manuscript was written by JM. All authors commented on and edited parts of the manuscript (JK: all parts; AG: methods; FP: methods (data analysis), results). All authors read and approved the final manuscript.

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