Effects of Playful Audio Augmentation on Teenagers' Motivations in Cooperative Physical Play

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ABSTRACT
Physical Education (PE) is beneficial for students' mental and physical health, however, teenagers are increasingly becoming less motivated to actively participate in the current form of PE. Motivational studies show that collective physical activity augmented by playful interactions could encourage more participation and social engagement in physical activities (PA). In this paper, we present a within-subject field study with 20 teenagers formed into five groups sized equally. The study is conducted using *Shuttlezap*, a prototype that provides real-time playful audio augmentation to the process of the activity. Results show that the teenagers enjoyed playful audio augmentation and were socially engaged with an enhancement of their perception of competence. By further comparing the conditions between with and without the audio augmentation, we found that the playful audio augmentation positively contributed to the playfulness in terms of perceived relaxation and expression. We conclude with design implications for social play in the context of PE for teenagers.

Author Keywords
Physical Education; teenagers; audio augmentation; playful experiences; social engagement.

ACM Classification Keywords
• Human-centered computing ~ Empirical studies in HCI

INTRODUCTION
School-age teenagers are suggested to participate in daily physical activities (PA) more often to yield beneficial health and behavioural outcomes [33]. Physical Education (PE) contributes to students' physical, social, emotional and intellectual development [13]. It is also a promising context for students to develop interests towards a more physically active behaviour [9]. However, extensive research has showed that teenagers (12-15 years) have a significant decline in actively participating the current form of PE in the secondary school [32], partly due to a lack of motivation to be active.

Previous studies have investigated approaches to promote students' motivation in the PE context. Ryan et al. believed enjoyable experiences relate to the pervasive motivation for social and physical development [28]. Roberts indicated collective activities contributes to more social interactions and maintains a regular exercise routine [29]. Playfulness and social interaction are also regarded as meaningful experiences [5] and central educational goals in PE [6]. Hence, in this study we examine playful experiences with interactive interventions, for motivating teenagers' participation in PE.

In the field of human-computer interaction (HCI), various studies have examined different means of interactions in PA to enhance playful experiences and social engagement. For example, solutions with visual [16,19], auditory [8,17,20,21] and tactile augmentations [24] have shown effects on stimulating multisensory experiences and improving the performance of players. It would be interesting to investigate whether applying similar techniques would have similar effects in the PE context.

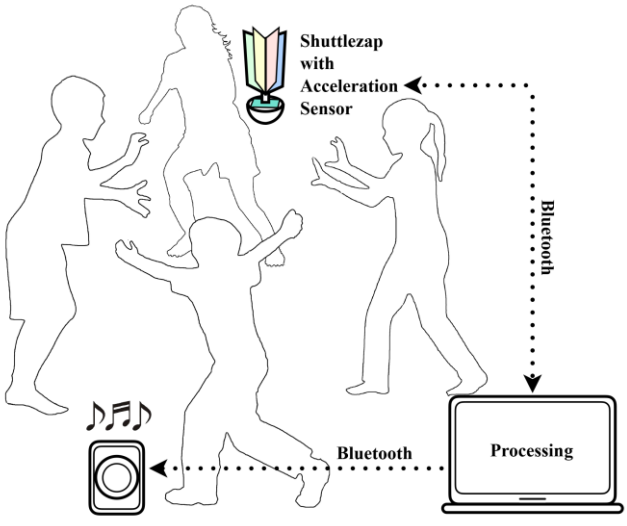

Figure 1. System structure of *Shuttlezap*

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To motivate teenagers' active participation in PE by means of interactive intervention, we have designed *Shuttlezap*. This prototype consists of eight feathers embedded into a hemispherical sponge base. Players aim to keep the *Shuttlezap* in the air using their body parts. It provides real-time audio augmentation (see Figure 1) to the process of the activity. Audio effects are extracted from computer games and designed to switch among several patterns related to users' performance. This research explores how real-time playful audio augmentation could influence teenagers' motivations towards PE, specifically *playfulness, social relationship*, and *competence* in cooperative physical play.

In this paper, we first review studies related to motivation, playfulness, and audio augmentation in PA. We then describe the audio-augmented *Shuttlezap* and the experiment setup, after which the within-subject field study (n=20) is presented, followed by a discussion of the results and their implications. The contribution of the work is twofold: it shows how to use auditory augmentation to enhance the playfulness in the context of PE for teenagers and it uncovers positive and negative influences on motivational properties of audio augmentation in the PE context.

RELATED WORK

Teenage Motivations in PE

Most of the studies conducted on assessing different motivations in PE were keen on examining teenage competence [36]. Weiss reviewed research results spanning 25 years and categorized teenage motivation in PA participation in three aspects: 1) positive affect such as enjoyment is the main motivation on teenage long-term participation 2) social relationships with coaches, peers and parents influence teenage engagement 3) perception of competence which relates to teenage motor skill level predicts their intrinsic motivation [37].

Other research has focused on teenage learning experience in PE. Dismore et al. found fun and enjoyment were students' central attitudes toward PE experience. Enjoyment was utilised to evaluate the effectiveness of PE, as both motivation and achievement [10]. Beni et al. concluded five meaningful activity experiences-social interaction, fun, challenge, motor competence and personal relevant learning, by reviewing the research in PE and youth sports [5].

In conclusion, these studies suggest a strong connection between motivation and experience in PE. Motivation such as *playfulness, social relationship*, and *competence* interact with each other and contribute to active participation, engagement and sustainability. Hence, in this paper, we scope our investigation on how interaction design intervention could influence *playfulness, social relationship*, and *competence* of the teenagers in PE.

Designing for Playful Experiences

Forlizzi et al. highlighted the importance of co-experiences which occurred in social contexts could be created or shared in a collective way [11]. This inspired us to design playful feedback for groups instead of individuals.

Many studies are related to users' playful experiences. Costello et al. elicited 13 pleasures of play for evaluating experience of users and artists in interactive artworks [7]. Korhonen et al. developed an initial framework of 22 playful user experiences supplied by studies in video games, to guide the design of experience in interactive products [18]. Boberg et al. constructed a Playful Experience Questionnaire that measures 17 aspects of playful experiences in the use of both game and non-game products and services [4]. This research provides valuable references for the design, evaluation, and measurement of the playful experiences.

Design interventions and guidelines were developed for creating playful experiences specifically for motivating teenagers' PA. Sturm et al. derived a playful persuasion principle which argued that game-based playful persuasion could more effectively trigger teenagers' intrinsic motivation [34]. Høiseth et al. suggested a useful approach in which pervasive technology merges into game-like solutions to stimulate pleasurable social experience in children's PA [15]. Landrey et al. developed an exergame named Fish Game to stimulate a variety of children's full-body movement in a playful way [22]. Macvean et al. developed iFitQuest, a mobile location-aware exergame to facilitate adolescents' exercise in PE class [23]. These examples showed the feasibility of designing and evaluating playful experiences in PA through gamified playful persuasion.

Audio augmentation as a Motivator for PA

Audio augmentation refers to an approach which uses auditory feedback to augment users' experiences during the interaction with intelligent systems. Several studies have evaluated the specific effects of audio augmentation in PA. Chittaro et al. developed a mobile exergame with an audio storytelling soundscape and that effectively stimulates the player's perception of enjoyment experience in a running activity [8]. Research by Tajadura-Jiménez et al. evaluated the altering sounds based on the frequency of participants' footsteps, which could influence their emotion, perception, and physical performance [35]. Newbold et al. showed that different harmonic stability of musical feedback could both encourage making progress and prevent overdoing in physical rehabilitate stretch activities [26]. These studies demonstrated that audio augmentation could contribute to player's emotional experience and actual performance.

Audio augmentation designs mostly focused on providing instruction and guidance. For instance, Kim et al. developed a Sonic-Badminton with localised audio augmentation to facilitate blind people and sighted people enjoy PA together [20]. Nylander et al. developed SwingSound system which mimics the sound of golf swing to help players reflect on

their swing movements when playing golf [25]. These cases showed the effectiveness of audio augmentation in motor skill practice and training.

Researchers have also explored the recreational property of playful audio augmentation in PA. Ishii et al. developed a physical ping-pang game augmented with virtual dynamic images and audio [16]. Hartnett et al. designed a playful audio player to motivate children in being physically active. Music tempo of the audio player responds to children's number of steps counted by a pedometer [14]. Izuta et al. created an augmented sports system named Bouncing Star, which provides exciting soundscape and 4 types of audio augmentation related to the movement state of the Bouncing Star [17]. Another example is an interactive exergame Dungeons & Swimmers, designed by Lee et al. which provides four-stroke types with gamified audio augmentation in swimming [21].

DESIGN OF SHUTTLEZAP

Enhancing Interaction with Shuttlecock in PE

The original shuttlecock play is a popular playful PA with a long history in Asia. It requires motor skills in coordinating feet, knees, hips and torso to keep the shuttlecock (see A in Figure 3) in the air. It is a moderate to vigorous aerobic exercise which benefits the health and helps to build hand-eye coordination [3]. Shuttlecock has versatile traits, for example, it can be played indoor and outdoor, alone or with one or several other players. We embedded playful audio augmentation into the shuttlecock play for three reasons: 1) motor skills of the teenagers meet the requirements of shuttlecock play 2) the versatile traits of shuttlecock meet the needs of PE context 3) teenagers in the Netherlands are not familiar with this activity and hence the effect of preconceptions about the activity on experimental results was excluded.

Bian et al. introduced the traditional shuttlecock play into PE class in the United States [3]. Ren et al. created an intelligent shuttlecock with game interface and ambient soundscape for Chinese office workers [30]. Results of these two studies indicated the effectiveness of the shuttlecock play in different cultural contexts, and the potential of audio augmentation in enhancing player's experience and performance.

To start with the design process, we collected five players who were familiar with the traditional shuttlecock game and video recorded them playing together in freestyle for half an hour. We analysed the players' behaviours and summarised the behaviours into six patterns, which are picking up, weighing in hand, kicking solitary, kicking collectively, catching in hands, and failing to catching. Afterwards, we made a one-minute video-based mock-up (see Figure 2) to show the concept of playing audio-augmented shuttlecock. We amplified the six patterns of behaviour by matching them with remixed audio effects which were extracted from computer games and cartoons.

Figure 2. Video-based mock-up and six patterns of players' behaviour in a traditional shuttlecock play.

Expert Interview

With the video-based mock-up, we conducted an expert interview with five people: one of them was a PE-teacher at Fontys School of Sport Studies and the other four were senior students with three-year intern experience in secondary school PE classes. The procedure started with five interviewees playing five-minute traditional shuttlecock activity together and with giving their opinion about whether this activity fits teenagers and PE context. Then, we presented the one-minute video-based mock-up and collected feedback about design opportunities with augmenting audio. The entire interview took half an hour.

Figure 3. Design iterations of *Shuttlezap*: (A) traditional Shuttlecock; (B) small size interactive *Shuttlezap*; (C) larger size interactive *Shuttlezap* in a rubber base; (D) larger size interactive *Shuttlezap* in a sponge base.

Students' motor skill ability

The experts suggested that teenage students should be able to play shuttlecock as it acquires similar skills such as kicking, passing, and catching from football training. The challenge could be that not every teenager is good at inward and outward kicking. Moreover, the small size of the shuttlecock increases the difficulty in responding agilely.

Hence, we designed *Shuttlezap*, with a larger size and softer material for the base (see C and D in Figure 3), to guarantee that the teenagers will be able to play using more body parts, and with reduced difficulties in catching and kicking.

Requirements in the PE context

The experts believed the shuttlecock play has traits similar to those of badminton and volleyball, but it is more flexible in duration, rules, and group size. The shuttlecock play is suitable for group warming up activities in PE classes. Moreover, the portability of the shuttlecock opens up the possibilities of switching between playing inside a gym and outside in playgrounds.

User experience of the playful audio feedback

The interview confirmed that playful audio feedback is more suitable for playing the shuttlecock in a group. The experts experienced how the augmenting audio could create laughter and make group activity more enjoyable. In contrast, they assumed that if students wanted to practice shuttlecock alone, they might feel awkward or be annoyed by the playful sounds. The experts also believed the audio feedback would help the students become more aware of what they are doing. Moreover, they mentioned that positive sounds might help students feel better about their performance, forget the difficulty of the activity, and become motivated to try again. Based on the expert feedback, we implemented game mechanics with real-time playful audio augmentation (see Table 1) to trigger player's performance. For instance, the specified positive/negative audio were programmed to map the certain level of victory/failure. Six patterns of players' interactive behaviour were transformed into three key states of *Shuttlezap,* such as hits, passes and misses.

State of *Shuttlezap*	**Hits**	**Passes**	**Misses**
Patterns of Sounds	**Positive**	**Neutral**	**Negative**
Score 0-2		"Swoosh"	Failure level 1 "Miss"
Score 3	Victory level 1 "Success"		
Score 4-5		"Swoosh"	Failure level 2 "Pity"
Score 6	Victory level 2 "Triumph"		
Score 7-8		"Swoosh"	Failure level 3 "Failed"
Score ≥9	Victory level 3 "Celebration"		

Table 1. Combining audio augmentation with game mechanics.

Prototype

Shuttlezap is an audio-augmented prototype that provides real-time playful audio augmentation while players aim to keep it in the air using feet, hands, or other body parts. It is equipped with Lightblue Bean+, a microcontroller board with a 3-axis accelerometer, which helps to detect if the *Shuttlezap* is in motion or is static and triggers corresponding audio augmentation in real-time. Audio effects were extracted from computer games and designed to switch among several patterns of users' performance and their behaviour with *Shuttlezap*. We programmed the game mechanics using 'Processing' on a computer. Each audio augmentation of hit or miss is triggered by the score data received from Lightblue Bean+ wirelessly over Bluetooth Low Energy (see Figure 1). A rechargeable 600 mAh lithium battery guarantees power supply for the circuit board. Lightblue Bean+ is wrapped by a 3D printed synthetic rubber shell, which is also a component to join eight feathers of the upper part with the high-density hemisphere sponge base in the lower part (see Figure 4).

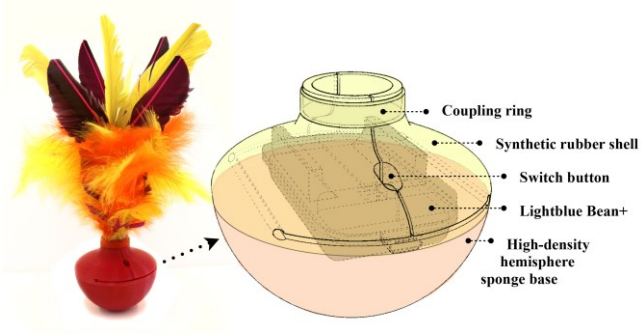

Figure 4. Physical structure of *Shuttlezap*

During prototyping, we also conducted a user test with 12 sedentary office workers on the campus of Eindhoven University of Technology. The early version of *Shuttlezap* was well reviewed on its attractiveness and novelty in user experiences [31].

EVALUATION

In this study, *Shuttlezap* was utilised as a research instrument, for probing how real-time playful audio augmentation could influence teenagers' motivation, specifically *playfulness*, *social relationship*, and *competence*. We conducted a within-subject field study with 20 teenagers (13-14 years) formed into five groups in PE classes. Mixed research methods were implemented with semi-structured interviews and measurement instruments such as an observation scheme and two questionnaires. Quantitative data was collected to validate assumptions.

Participants

Before the experiment, the PE teacher of the secondary school was informed about all the research objectives and procedures. The students from grade one and two in the PE classes were observed, since previous research indicated that this age group has a significant decline in active participation in PE [32]. Later, the students from grade two were included as subjects for the experiment because they showed more serious inactive participation, based on the researcher's observation and the discussion with a PE

teacher. Two weeks before the experiment, the researcher and the PE teacher briefly introduced the traditional shuttlecock play and the upcoming experiment in three PE classes of grade two. The students formed into groups of four and experienced the traditional version of shuttlecock play for five minutes and none of them had experienced this activity before. In the end, 20 students from three different classes in grade two participated in this study.

Before the experiment, participants were asked to complete a prequestionnaire independently. The questions were as follows: 1) Age 2) Gender 3) The level of your fitness? 4) Is PE your favourite subject? Characteristics of our participants were organized in Table 2.

		Numbers
Gender	Male	1
	Female	19
Age	13 years old	7
	14 years old	13
Level of Fitness	Above average	5
	Average	15
Attitude towards PE	Favourite subject	9
	Not favourite subject	11

Table 2. Sample characteristics

We noticed that girls flocked to this study, whereas only one boy eventually participated. As a light sport, *Shuttlezap* appealed more to female teenagers. The girls preferred moderate intensity or less sweating PA, especially when our experiment was conducted at 26 to 30 Celsius. Some of the girls decided to participate after consulting their close friends. As for the boys, some of them complained about having to ask permission from their parents. On the day of the experiment, six boys who were intended to participate changed their mind and joined football or hockey with other classmates.

Experiment Procedure

With the help of PE teacher, we randomly assigned 20 participants into five groups (namely: Group A-E). We used a within-subject design for the study, where each group experienced two different *Shuttlezaps*: one with real-time playful audio augmentation, and the other without audio augmentation. We randomized the sequences of two conditions for each group for reliability. Participants were told that the group goal of each condition was to keep *Shuttlezap* in the air with nine volleys in one round and try to achieve as many rounds as possible. The experiment was divided into two 10-min-long experience sessions of different conditions with a 10-min break in between. To eliminate the potential confounding factor of group difference, we assigned each participant the same group in both two conditions. After each condition, participants completed two questionnaires independently. In the end, participants were interviewed with questions associated with *playfulness*, *social engagement* and *competence*. During the semi-structured interview, participants first wrote down the brief answers on paper individually. They were further asked to explain the answers and discuss the reasons with group members. All the interviews were video-recorded and transcribed for further analysis.

Data Collection

Questionnaires

We gave every participant two questionnaires after each experiment. Motives for PA Measure-Revised (MPAM_R) [27] is a 30-item seven-point Likert scale questionnaire divided into five factors: 1) enjoyment 2) social 3) competence 4) appearance 5) fitness. We aimed to investigate whether real-time playful audio augmentation could influence playfulness, social engagement, and competence. Hence, fitness and appearance factors were excluded because of their irrelevance to our research purpose. As a result, we kept a 19-item questionnaire with enjoyment, social, and competence factors.

Playful Experiences Questionnaire (PLEXQ) [4] is a 51-item five-point Likert scale including a category for "non-applicable", which evaluates 17 aspects of playful experiences and categorizes them in four dimensions of playfulness: 1) stimulation 2) pragmatic 3) momentary 4) negative experience. The experiences addressed in this questionnaire were extracted from game and non-game devices and applications. The goal of using PLEXQ was to gain an understanding of how real-time playful audio augmentation would influence different aspects of playful experiences.

Observation Scheme

Outdoor Play Observation Scheme (OPOS) [2] was selected for analysing social interaction behaviour. The scheme addresses four types of behaviour in children's outdoor game, namely 1) PA 2) focus 3) social interaction 4) general. In this study, we mainly focused on social interaction to analyse social behaviour which is categorized first between "with another player" and "with a non-player" in OPOS. Among "with another player", there are "functional" and "non-functional" social behaviour. The "non-functional" include "positive", "neutral" and "negative". We defined more detailed sub-behaviours and operational definitions (see Table 3), based on the explanation of social interaction in OPOS. For later analysis, we video-recorded the whole process of experiments. The camera was sheltered and set three meters away from participants to minimise the influence on their participation.

Performance log

The prototype is designed to record all the score data with a time log, which means how many repetitions the *Shuttlezap* is volleyed are recorded for every round. By comparing performance of five groups in two tests, we aim to explore if playful audio augmentation could influence the competence of the participants.

Behaviour			Sub-Behaviour	Explanation	Operational definition
WITH ANOTHER PLAYER	FUNCTIONAL		Functional discussion	Verbal and nonverbal interaction that is functional for playing the game and directed to one or more other players or to no-one. For example, instructions, or expressions such as counting points aloud.	Discussion on how to volley the *Shuttlezap*, order of passing. Counting points aloud when reaching a high score. One player instructed another to move to a different position.
			Functional physical contact	Physical contact that is needed to play the game, such as tagging, holding hand.	One player tugged another to a different position.
	NON-FUNCTIONAL	Positive	Positive expression	Verbal and nonverbal interaction that is not functional for playing the game. Positive expression directed to one or more other players or to no-one, such as cheering, screaming, expressions of enjoyment.	Laughing when someone misses. Laughing due to funny movements of players. Laughing due to the sound made by the *Shuttlezap*. Cheering after reaching the high score.
			Positive physical contact	Physical contact that is not required for playing the game. Positive physical contact such as holding hands, high five.	High fives. Hug.
		Neutral	Neutral expression	Verbal and nonverbal interaction that is not functional for playing the game. Communication about subject that is not related to the game.	Talking about social things like school, friends, holidays etc.
			Unintended physical contact	Physical contact that is not intended and not required for playing the game, such as accidentally bumping into another child.	Two players bump into each other who are trying to hit the *Shuttlezap* at the same time.
		Negative	Negative expression	Verbal and nonverbal interaction that is not functional for playing the game. Negative expression directed to one or more other players or to no-one. For example, negative communication such as swearing and bullying, expressions of pain.	Bullying other players verbally when passing the *Shuttlezap* incorrectly or missing. Expression of disappointment such as sigh, face palm, when missing the ball. Expression of pain.
			Negative physical contact	Negative physical contact that is not required for playing the game, such as kicking or hitting.	Intentionally throwing the *Shuttlezap* with a high speed in order to hit someone. Thrust the other person when he or she does not perform well.
WITH A NON-PLAYER			Verbal and non-verbal interactions	Verbal and non-verbal interactions that are directed to someone who is not a player in the game. This can be a researcher, a teacher, a parent, a peer who is watching the game, etc.	Watch peers who not involved in the game playing in the field. Talking with the teacher about their performance. Asking researcher to confirm the game rule.

Table 3. Social interaction scheme with operational definition.

Interviews

The semi-structured interviews helped us to collect valuable remarks from participants. The questions were as follows: 1) Does the audio augmentation influence your play experience? For example, does the audio augmentation help you enjoy the activity? If so, how and why? 2) Does the audio augmentation influence your relationship with the team members? If so, how and why? 3) Does the audio augmentation influence your performance? For example, does the audio augmentation help you to play better? If so, how and why? To answer each question, participants indicated first whether they experienced positive, negative, or no influence, and then provided further explanation.

Data analysis

Data from Questionnaires

In case the influence from grouping, we conducted Kruskal Wallis Test to check if the influence of grouping variable is significant in each condition (with and without audio augmentation). In MPAM_R, one out of six aspects are significant, which is *enjoyment* (P=0.044) with audio augmentation condition. In PLEXQ, two out of 34 aspects are significant, and they are *sensation* (p=0.015) with no audio augmentation condition and *sensation* (p=0.026) with audio augmentation condition. Hence, we could assume that the grouping variable has a little influence on each

condition and it is applicable to analyse the data at an individual level (N=20).

We first conducted descriptive statistics to identify the general tendency of data from the MPAM_R and PLEXQ questionnaires. To compare data collected from the two tests, we conducted the related-samples nonparametric statistic tests for three reasons: 1) 20 participants are usually regarded as a relatively small sample size 2) the data gathered from two Likert scale questionnaires are not normally distributed but approximately symmetric with skewness between -0.403 and 0.561. 3) the field study we conducted was within-subject tests, which means data from two tests are two related samples. Hence, Wilcoxon signed ranks test is applied.

Video Coding

In total, we collected 10 video recordings of each 10 minutes from five groups. The first author (coder 1) and a design educator (coder 2) evaluated the social behaviours as shown in the videos together. Two coders first went through all videos, discussed and refined operational definitions of social interaction in OPOS (see Table 3). Two coders then coded all participants' social behaviours together based on the agreed version of the observation scheme. The differences in the results were discussed until an agreement was reached between two coders. For video coding, we used BORIS, a behavioural observation research software, to mark each player's social behaviours and the durations.

Data from Interviews

Two independent coders followed the process of thematic analysis [1] to cluster qualitative data gathered from the interviews. The difference in the results was discussed between two coders. The data gathered from the interviews provided us with more specific implications not only to confirm the results from quantitative data, but also to give insights for future design directions.

RESULTS

In this study, the effects of playful audio augmentation were evaluated focusing on three aspects: *playfulness, social relationship,* and *competence.* Detailed findings from the study are presented as follows.

	With No Audio			With Audio		Wilcoxon signed ranks Test	
	N	Mean	SD	Mean	SD	Z	P
Enjoyment	20	5.26	1.29	5.39	1.16	-.415	0.678
Social	20	4.97	1.20	4.85	0.89	-.285	0.776
Competence	20	5.08	1.18	5.13	1.02	-.363	0.717

Table 4. Mean, Standard Deviation, and Wilcoxon signed ranks Test of MPAM_R.

Results from Questionnaire

We conducted two-tailed Wilcoxon signed ranks test to examine the difference between two conditions (with audio augmentation and without). The quantitative data gathered from seven-point Likert scale MPAM_R questionnaire presented a general overview of three motivations (see Table 4).

As shown in Table 5, the results from Wilcoxon signed ranks Test indicated that participants in the condition with audio augmentation experienced more playful experiences related to relaxation (P=0.040) and expression (P=0.046). In the PLEXQ, in addition to the five-point Likert scale, there is also an "non-applicable" category. This category was selected by participants who had not experienced the situation described. For the item chose as "non-applicable" only in one condition, the response in other condition was also removed to guarantee an equal sample size for the analysis aim.

	With No Audio			With Audio		Wilcoxon signed ranks Test	
	N	Mean	SD	Mean	SD	Z	P
A Stimulation							
Discovery	20	3.54	0.75	3.75	0.69	-1.775	0.076
Exploration	20	3.90	0.92	3.98	0.58	-0.598	0.550
Challenge	20	3.46	0.91	3.48	0.62	-0.223	0.823
Expression	19	2.68	1.01	3.05	1.08	-1.994	0.046*
Fellowship	20	3.34	0.95	3.48	0.90	-0.682	0.495
Nurture	20	3.21	0.68	3.53	0.84	-1.612	0.107
B Pragmatic							
Completion	20	3.53	0.73	3.83	0.59	-1.575	0.115
Control	20	3.28	0.81	3.32	0.65	-0.441	0.659
Competition	20	3.48	1.00	3.48	1.18	-0.057	0.955
Sensation	20	3.87	0.77	4.03	0.66	-1.700	0.089
Thrill	20	3.08	0.91	3.36	1.12	-0.907	0.364
C Momentary							
Relaxation	20	3.58	0.70	3.96	0.49	-2.049	0.040*
Humour	20	4.26	0.85	4.44	0.61	-0.829	0.407
Captivation	17	2.85	1.07	2.88	0.61	-0.182	0.855
D Negative Experiences							
Suffering	18	2.27	0.98	2.14	1.01	-0.914	0.361
Cruelty	18	2.68	1.16	2.72	1.08	-0.757	0.449
Subversion	14	3.01	1.08	2.75	1.35	-0.414	0.679

Table 5. Mean, Standard Deviation, and Wilcoxon signed ranks Test of PLEXQ. (* refer to the significant value).

Results from Video Coding

We coded 20 participants' social behaviour based on OPOS. As shown in Figure 5, the mean of the duration (seconds) of 20 participants in behaviours such as *positive expression, functional discussion*, and *negative expression* increased in the condition with audio augmentation but did not meet a statistical significance. The "non-functional (positive, neutral, negative)" social behaviours occupied approximate three times longer duration of time than "functional" interactions during the activity.

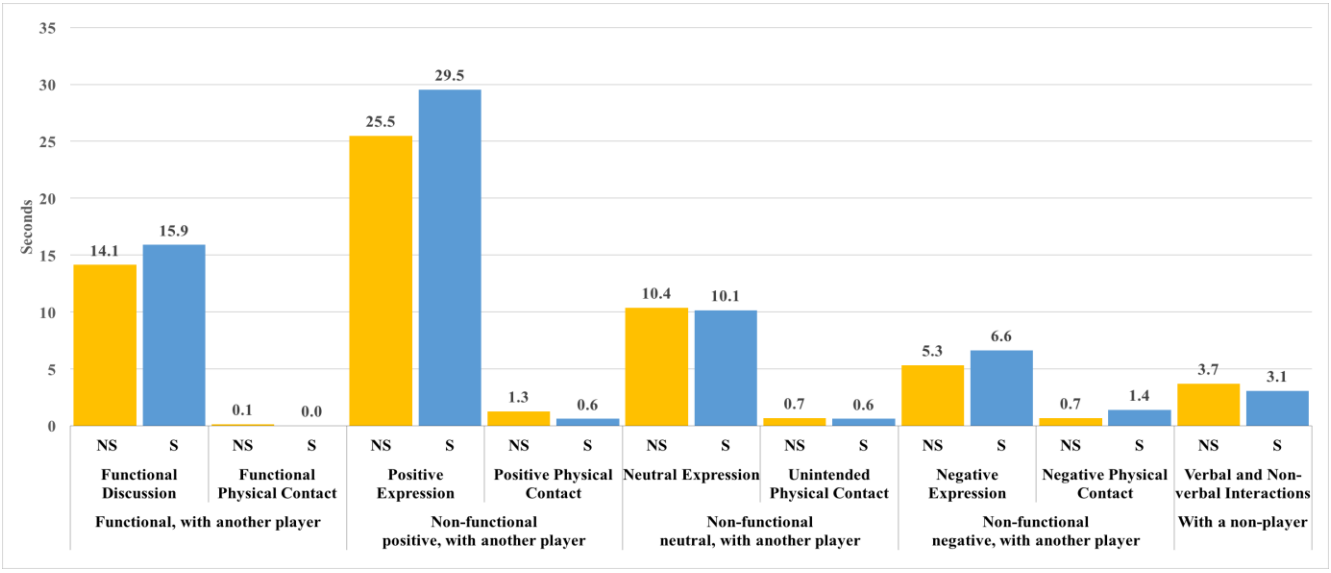

Figure 5. Mean of the duration (seconds) of 20 participants' social interaction behaviour between two conditions (NA: with no audio augmentation; A: with audio augmentation).

Results from Performance Log

The programmed prototype collected five groups' hit score counts among two conditions. The goal of the *Shuttlezap* game was to keep the *Shuttlezap* in the air by nine times volley. Table 6 groups the score counts into four levels: 0-2 beginner, 3-5 elementary, 6-8 intermediate, ≥ 9 advanced. From the clustered data in Table 6, we observed a marginal improvement on the intermediate and advanced level of five groups' score counts.

	Score Counts							
	0 - 2		3 - 5		6 - 8		≥ 9	
	NA	A	NA	A	NA	A	NA	A
Group A	45	56	27	35	1	4	0	1
Group B	30	22	31	32	11	1	0	10
Group C	53	35	24	36	5	7	0	2
Group D	51	57	31	24	3	5	0	0
Group E	42	42	36	40	5	6	2	1
Total	221	212	149	167	25	23	2	14

Table 6. Score counts of five groups in two conditions (NA: with no audio augmentation; A: with audio augmentation).

Results from Interview

Playfulness

Sixteen participants from interviews said that the audio augmentation had a positive influence on their playful experiences while four participants reported a negative influence. There was one aspect of positive influence and two aspects of negative influences on *playfulness* worth noticing from the qualitative data analysis:

Enjoyable and immersive: The Participants claimed that they felt *Shuttlezap* was played more like an enjoyable game with the audio augmentation. As they said "*The audio augmentation made me think of a game experience (A3)".* The playful audio augmentation also triggered them to express more enjoyment. "*We started to laugh more at the audios (E3).*" They were pleased by the audio effects and more immersed in the game experience. *"The audio helps you get more into the game, and it also stimulates the game (B1)*". Most of the participants felt a stronger sense of pleasure and would like to play longer when playing *Shuttlezap* with the audio augmentation. "*The audio makes the game funnier because if you win, you can hear the happy audio (D3)", "The game without the audio got boring very fast. The other game (with audio) was actually kind of fun (A2)*", "*The audio augmentation helped me to play longer because it was very funny and it made me happy (C3)".*

Interactive and explorative: The participants were impressed by the *Shuttlezap's* responsiveness to their performance. "*That was really interactive, it responded with the things you do, and that was special (B4)", "When you heard the happy sound, you felt like 'Oh, yes! We made it!'. Otherwise, our efforts just mean nothing (B3).*" The dynamic sound feedback stimulated the participants' curiosity and exploration. *"You keep trying to do better and discover which sound will come next (B4)", "It makes you play better because you want to hear more kinds of audio (C3).*"

Disappointment and stressful: The negative audio augmentation made two participants feel more disappointed when they failed. "*I heard the negative sound when we almost reached nine times shots after which I felt a little bit disappointed. You knew you failed, you just didn't reach it (C1)*". Two participants reported that the negative audio augmentation increased their stressful attitude toward failure. "*Sometimes I got a bit stressed when I failed, and I had to try to do it better to get the happy audio (D2).*"

Social Relationship

Eleven participants felt positive influence on social engagement, whereas nine participants experienced no influence. However, no participants indicated negative influence. We observed the following reasons for the explanation of positive influence on *social relationship*.

Breaking the silence and providing a joyful atmosphere: The participants felt it was less joyful to play in a quiet atmosphere and the playful audios broke the silence. "*When there is no audio, it is silent and I don't like it (C4)", "I think that the audio augmentation makes sure there is no silence (C3).*" The playful audios changed the atmosphere in a more pleasant and joyful way. "*Since you have fun together, the atmosphere is good (E3)", "I think it does bring more joy, then you enjoy more with the people you play with, and that's why it influenced our relationship (C3).*"

Stimulating interactions and promoting team climate: Although the participants in a team were classmates, they still felt the playful audios stimulated more interaction among them. "*If you play with people you don't know, then you do not really talk to each other. If you do with the audio effects, then you have more interactions with each other (C3)", "I think so because you do interact more with each other if the audios are there (B1)", "The team was laughing more, and was more interactive with others (E1)".* The participants felt closer relations with their team members and became more supportive of each other. *"When it made fun, it was nicer to play. And we felt closer to each other (A3)", "We laugh together to the audios, like 'Oh, that's a funny audio'. It also likes a team bonding cause all of you had fun together (D2)", "You didn't feel as bad as you did when the Shuttlezap falls to the ground. Because of the funny sound, everyone laughed, and we forgot the failure (E4)."*

Competence

Fifteen participants indicated the playful audio augmentation had a positive influence on their competence. Three participants claimed playful audio augmentation had a negative influence while two participants believed it had no influence on their competence. The following two reasons for the explanation of positive influences and one reason for negative influences on *competence* were observed.

Motivating active participation and competitiveness: The playful audios were regarded as rewards, which motivated them to perform better and gain more audios. *"I think it helps because I got more motivated when the audios were there. I want to beat a high score, and the audios helped for it (A1)*", "*The happy audio motivated you to keep playing well (D2)", "Like I said before it triggered you to beat higher than nine times faster (B1).*" The recreational function of playful audio augmentation enhanced participants' performance, motivated their higher sense of competition, and made them feel highly valued. "*The audios make you want to win (A4)*", "*Yeah. I was also more motivated because you want them to hear the winning audios (C4)",* "*Yes, sometimes it helps because you want to hear the good audio that you made it (C3).*"

Providing guidance and feedback: The playful audio augmentation delivered real-time instructional feedback to players' performance. Hence, they could reflect previous actions timely and improve their skills. ***"****I really like that you could hear when you are successful and also when you failed, so you could try harder when you fail (D2)", "Because of the sound, you knew if you won or lost (D3)", "You felt like you reach the goal of the game with a happy audio (E4)."*

Interfere with attention: Three participants felt negative influence of their *competence* mainly because they did not get used to hearing the playful audios while doing physical exercise. *"When you hit the Shuttlezap, there were a lot of audios, which got you distracted (E2)."* They found it challenging to concentrate on the *Shuttlezap* game with the audio augmentation, especially with the negative audio augmentation as a result of poor performance. *"It was more fun but it was a bit annoying sometimes. Because you wanted to hit the Shuttlezap then the audio came, and you missed (E3)" , "Sometimes it is a bit irritating. Only the audio of winning motivates you (C2)."*

DISCUSSION

Playfulness

The playful audio augmentation could enhance the participants' playful experiences in a short time, especially with an influence on *relaxation* (P=0.040) and *expression* (P=0.046). The PLEXQ explained *relaxation* comes from bodily or mental unwinding as result of being engaged in a playful activity [4], which is in line with the *enjoyable and immersive* experiences that was reported from the interviews. Another two noticeable aspects are *discovery* (P=0.076) and *sensation* (P=0.089). *Discovery* involves finding something hidden or uncovering a new property of a product [4], which conform to the *explorative* experience that summarized from interviews.

Previous research on PLEXQ claimed that the *negative experiences* could enhance player's feeling on playful experiences [4]. As mentioned before in Table 1, the game mechanics we developed in *Shuttlezap* augments three levels of failure by providing negative audio augmentation. The results from interviews indicated that the negative audio augmentation could lead to negative experience such as *disappointment and stress*. When designing playful audio augmentation in PE for teenagers, we should consider to use more positive sounds and less negative ones, for instance, by setting more levels of positive sound feedback in game mechanic, increasing duration of positive sound, or trailing off in the volume of negative sounds.

Social Relationship

In the social interaction behaviour, the duration of *positive expression* increased the most compared to the *functional discussion* and *negative expression* in the audio augmented condition. We also noticed most social behaviours observed are "non-functional", in which *positive expression* showed the longest duration. The playful audio augmentation could promote *social relationship* by *break the silence, provide a joyful atmosphere*, *stimulating interactions*, and *promoting team climate*. However, the influences on social behaviour did not significant as shown in Figure 5. It probably due to three reasons: 1) a limited number of subjects 2) the threshold of teenagers' *social relationship* in a classroom setting is high because participants are probably already familiar with each other 3) significant improvement on social interaction may hardly be assessed in the short term. In the future, we could compare if different game mechanism such as cooperation and competition in the physical activity could have different impact to the *social relationship* among friends.

Competence

Garn et al. believed the perceived *competence* is as essential as the actual skill for teenagers building interests towards PE [12]. This experiment showed that the playful audio augmentation could improve the teenagers' *competence*, specifically more improvement on their perceived *competence* than the observed actual *competence* (see Table 6) in a short period. In the interviews, 15 participants reported the improvement of perceived performance, while the actual scores did not increase significantly.

We explored two motivational properties of audio augmentation. The recreational property could *motivate active participation and competitiveness, which* is in line with studies on users' perceptions [8, 35]. The instructional property could *provide guidance and feedback,* which also has been examined in a rehabilitation study [26]. Recreation and instructional functions together promote teenager's *competence*. In the collective PA, the function of recreation is more necessary.

Limitations and Opportunities

The limited time span of this study may have influenced the reported findings. A longitudinal study is essential to evaluate *Shuttlezap*: 1) how the teenagers' *playful experiences* shift in different stages of participation 2) how effective the teenagers' *social interaction* and *competence* can be enhanced by the duration and frequency of participation.

The results from this study does not represent the views of teenage boys because most of the participants were teenage girls. In further research, we should pay more attention to gender balance when recruiting participants. We could also iterate the design of *Shuttlezap* game by reflecting why it appeals to girls and what design criteria boys care about.

The fact that multiple comparisons were conducted as part of the quantitative analysis may have influenced the chance on a Type I error. We emphasize that it is a mixed method exploratory study to generate an initial understanding of the domain. The outcomes from the qualitative interviews supported the quantitative results from questionnaires.

The results from this study show the potential of augmenting playful audio feedback in a variety of PA, specifically by mapping playful audio with different types of body movements [14,16,17,21]. For a better experience, it is possible to involve teenagers in a group co-creation process and design their own personalised playful audio augmentation. Another possibility is to explore multimodal augmentation with visual and tactile feedback in addition to sound.

CONCLUSION

The scope of this study was to enrich teenage playful experiences in PE using audio augmenting technology. *Shuttlezap* involves real-time playful audio augmentation into a collective physical play. To investigate how playful audio augmentation could influence the motivations, a within-subject field study was conducted with five groups of 20 teenagers from three PE classes in a secondary school. The results show that playful audio augmentation could positively influence two aspects of the playful experiences: *relaxation* and *expression.* Positive effects were also observed on *social interactions* and perceived *competence*. We identified a design opportunity that shows how to use auditory augmentation to enhance the playfulness in the context of PE for teenagers. We also uncovered positive and negative influences on motivational properties of audio augmentation, which can be applied further for HCI and playful interaction in the PE context.

SELECTION AND PARTICIPATION OF CHILDREN

This work took place in three PE classes at Heerbeeck College, Eindhoven, the Netherlands. The study was approved by the school governing body, and all experiments were assisted by a PE teacher. 20 teenagers, aged 13-14, the grade two of the secondary school, volunteered to participate in this study without financial benefit. All participants have received a consent form that informed them of the objectives and procedures of the study. They were informed that the study would be video recorded and all data would be used only for research purpose. All participants had permission from their parents or guardians.

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REFERENCE

1. Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology, Qualitative Research in Psychology, 3:2, 77-101.

2. Saskia Bakker, Panos Markopoulos, and Yvonne de Kort. 2008. OPOS: an observation scheme for evaluating head-up play. In *Proceedings of the 5th Nordic conference on Human-computer interaction: building bridges* (NordiCHI), 33-42.
3. Wei Bian, Jianyu Wang, and Betsy Mckinley. 2009. Integrating Multicultural Education: Activities to Celebrate the Chinese New Year. *Journal of Physical Education*, *Recreation & Dance.* 80, 5: 40-46. http://doi.org/10.1080/07303084.2009.10598324
4. Marion Boberg, Evangelos Karapanos, Jussi Holopainen, and Andrés Lucero. 2015. PLEXQ: Towards a Playful Experiences Questionnaire. *In Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play* (CHI PLAY '15)*,* 381–391. https://doi.org/10.1145/2793107.2793124
5. Stephanie Beni, Tim Fletcher, and Déirdre Ní Chróinín. 2017. Meaningful Experiences in Physical Education and Youth Sport: A Review of the Literature. *Quest*. *69*, 3: 291–312. https://doi.org/10.1080/00336297.2016.1224192
6. Lars B. Borghouts, Menno Slingerland and Leen Haerens. 2017. Assessment quality and practices in secondary PE in the Netherlands. *Physical Education and Sport Pedagogy.* 22, 5: 473-489. DOI:10.1080/17408989.2016.1241226
7. Brigid Costello and Ernest Edmonds. 2007. A Study in Play, Pleasure and Experience Design. In *Proceedings of the 2007 conference on Designing pleasurable products and interfaces* (DPPI'07), 76-91.
8. Luca Chittaro, and Francesco Zuliani. 2013. Exploring audio storytelling in mobile exergames to affect the perception of physical exercise. In *Proceedings of the 7th International Conference on Pervasive Computing Technologies for Healthcare* (PervasiveHealth)*,* 1-8. https://doi.org/10.4108/icst.pervasivehealth.2013.252016
9. Susan Capel, Margaret Whitehead. 2015. *Learning to teach physical education in the secondary school.* Routledge, New York.
10. Harriet Dismore, and Richard Bailey. 2011. Fun and enjoyment in physical education: Young people's attitudes. *Research Papers in Education*. 26, 4: 499–516. doi:10.1080/02671522.2010.484866
11. Jodi Forlizzi, and Katja Battarbee. 2004. Understanding experience in interactive systems. In *Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods, and techniques*, 261–268. doi:10.1145/1013115.1013152
12. Alex C. Garn, Donetta J. Cothran, and Jayne M. Jenkins. 2011. A qualitative analysis of individual interest in middle school physical education: Perspectives of early-adolescents. *Physical Education & Sport Pedagogy* 16, 3: 223-236. doi:10.1080/17408989.2010.532783
13. James H. Humphrey. 2003. *Child development through sports*. The Haworth Press, New York.
14. Jeffrey Hartnett, Pearl Lin, Lillian Ortiz, and Lindsay Tabas. 2006. A responsive and persuasive audio device to stimulate exercise and fitness in children. In *Proceedings of CHI'06 extended abstracts on Human factors in computing systems* (CHI EA 2006), 1837-1842. https://doi.org/10.1145/1125451.1125799
15. Marikken Høiseth, and Maarten Van Mechelen. 2017. Identifying Patterns in IDC Research: Technologies for Improving Children's Well-being Connected to Overweight Issues. In *Proceedings of the 2017 Conference on Interaction Design and Children*, 107-116. doi:10.1145/3078072.3079739
16. Hiroshi Ishii, Craig Wisneski, Julian Orbanes, Ben Chun, and Joe Paradiso. 1999. PingPongPlus: design of an athletic tangible interface for computer-supported cooperative. In *Proceedings of the SIGCHI conference on Human factors in computing systems: the CHI is the limit*, 394–401. http://doi.acm.org/10.1145/302979.303115
17. Osamu Izuta, Toshiki Sato, Sachiko Kodama, and Hideki Koike. 2010. Bouncing Star project: design and development of augmented sports application using a ball including electronic and wireless modules. In *Proceedings of the 1st Augmented Human International Conference on Augmented Human* (AH'10), 22:1-22:7 https://doi.org/10.1145/1785455.1785477
18. Hannu Korhonen, Markus Montola, and Juha Arrasvuori. 2009. Understanding Playful User Experience Through Digital Games. In *Proceedings of International Conference on Designing Pleasurable Products and Interfaces*, 274–285.
19. Raine Kajastila and Perttu Hämäläinen. 2014. Augmented climbing: interacting with projected graphics on a climbing wall. In *Proceedings of the Extended Abstracts on Human Factors in Computing Systems* (CHI EA'14), 1279–1284. http://dx.doi.org/10.1145/2559206.2581139
20. Shin Kim, Kun-pyo Lee, and Tek-Jin Nam. 2016. Sonic-badminton: Audio-augmented badminton game for blind people. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (CHI EA'16), 1922–1929.
21. Haechan Lee, Miri Moon, Taiwoo Park, Inseok Hwang, Uichin Lee, and Junehwa Song. 2013. Dungeons & swimmers: Designing an interactive exergame for swimming. In *Proceedings of the 2013 ACM Conference on Pervasive and Ubiquitous Computing*

adjunct publication (UbiComp 2013), 287–290. https://doi.org/10.1145/2494091.2494180

22. Pascal Landry, Joseph Minsky, Marta Castañer, Oleguer Camerino, Rosa Rodriguez-Arregui, Enric Ormo, and Narcis Pares. 2013. Design strategy to stimulate a diversity of motor skills for an exergame addressed to children. In *Proceedings of the 12th International Conference on Interaction Design and Children* (IDC '13). ACM, New York, NY, USA, 84-91.
23. Andrew Macvean and Judy Robertson. 2012. iFitQuest: a school based study of a mobile location-aware exergame for adolescents. In *Proceedings of the 14th international conference on Human-computer interaction with mobile devices and services* (MobileHCI '12). ACM, New York, NY, USA, 359-368. https://doi.org/10.1145/2371574.2371630
24. Stina Nylander, Jakob Tholander, and Alex Kent. 2013. Peripheral interaction for sports – exploring two modalities for real-time feedback. In *Proceedings of the INTERACT workshop on Peripheral Interaction.*
25. Stina Nylander, Alex Kent, and Jakob Tholander. 2014. Swing sound: experiencing the golf swing through sound. In *Proceedings of CHI'14 Extended Abstracts on Human Factors in Computing Systems* (CHI EA '14), 443-446. https://doi.org/10.1145/2559206.2574789
26. Joseph W. Newbold, Nadia Bianchi-Berthouze, Nicolas E. Gold, Ana Tajadura-Jiménez, and Amanda CdC Williams. 2016. Musically informed sonification for chronic pain rehabilitation: Facilitating progress & avoiding over-doing. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 5698-5703. https://doi.org/10.1145/2858036.2858302
27. Richard M. Ryan, Christina Frederick, Deborah Lepes, Noel Rubio, and Kennon M. Sheldon. 1997. Intrinsic motivation and exercise adherence. *International Journal of Sport Psychology*. 28: 335-354.
28. Richard M. Ryan and Edward L. Deci. 2000. Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. *Contemporary Educational Psychology.* 25: 54–67. https://doi.org/10.1006/ceps.1999.1020
29. Glyn C. Roberts. 2001. *Advances in motivation in sport and exercise.* Human Kinetics Publishers.
30. Xipei Ren, Yuan Lu, Aarnout Brombacher, and Tilde Bekker. 2016. ShuttleKickers: Exploring Social Persuasions to Encourage Physical Activities. In *Proccedings of the 30th BCS-HCI British Human Computer Interaction Conference*, 1–11. http://doi.org/10.14236/ewic/HCI2016.19
31. Xipei Ren, Yudan Ma, Yuan Lu, Aarnout Brombacher. 2017. ShuttleKicker+: Designing Gamified Sonification to Augment the Physical Leisure Activity. In *Proccedings of the Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play.*
32. James F. Sallis, Judith J. Prochaska, and Wendell C. Taylor. 2000. A Review of Correlates of Physical Activity of Children and Adolescents. *Medicine and science in sports and exercise*. 32, 5: 963–75. doi:10.1097/00005768-200005000-00014.
33. William B. Strong, Robert M. Malina, Cameron J. R. Blimkie, Stephen R. Daniels, Rodney K. Dishman, Bernard Gutin, … François Trudeau. 2005. Evidence based physical activity for school-age youth. *The Journal of paediatrics*. 146, 6: 732-737. https://doi.org/10.1016/j.jpeds.2005.01.055
34. Janienke Sturm, Rob Tieben, Menno Deen, Tilde Bekker, and Ben Schouten. 2011. PlayFit: designing playful activity interventions for teenagers. In *Proceedings of DIGRA*, 14–17. https://doi.org/10.1017/CBO9781107415324.004
35. Ana Tajadura-Jiménez, Maria Basia, Ophelia Deroy, Merle Fairhurst, Nicolai Marquardt, and Nadia Bianchi-Berthouze. 2015. As Light as your Footsteps: Altering Walking Sounds to Change Perceived Body Weight, Emotional State and Gait. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15). ACM, New York, NY, USA, 2943-2952. https://doi.org/10.1145/2702123.2702374
36. Victoria Warburton, and Christopher Spray. 2008. Motivation in physical education across the primary--secondary school transition. *European Physical Education Review*. 14, 2: 157–178. https://doi.org/10.1177/1356336X08090704
37. Maureen R. Weiss. 2013. Back to the Future: Research Trends in Youth Motivation and Physical Activity. *Pediatric Exercise Science*. *25*, 4: 561–572.