Empowering the Exercise: a Body-Controlled Trampoline Training Game

Raine Kajastila, Leo Holsti & Perttu Hämäläinen

Aalto University School of Science, Department of Media Technology

Abstract

Video games can empower their players beyond reality, giving them extraordinary abilities. We investigate a novel class of games that provide empowerment in both the real and the virtual world, in this case using a trampoline as part of the human-computer interface. We studied whether novice trampoline jumpers can learn trampolining skills while playing a platform jumping game implemented using computer vision and a screen placed near the trampoline. 29 participants were divided into three groups: self-training, a game with a normal jump height, and a game with an exaggerated jump height. Performance was tested in pre, post and follow-up tests. All groups improved their performance significantly. The game was considered more engaging and the mean flow questionnaire (SFSS) result with games was significantly higher than with self-training. The study shows that trampoline games can be fun, intuitive to play and basic trampolining skills can be improved while playing the game. A game is more engaging than self-training and extra empowerment, such as jump height exaggeration, enhances the experience. The exaggeration did not adversely affect jumping performance, and half of the participants did not even consciously notice it, which suggests that there is considerable design freedom for manipulating the player's movements in trampoline games.

KEYWORDS: MACHINE VISION, GAMES, USER INTERFACES, SPORTS EQUIPMENT, EDUCATIONAL TECHNOLOGY

Video games can empower their players beyond reality, giving them extraordinary abilities and letting them use the abilities for exploring fantasy worlds. Curiosity and fantasy have also been identified among the intrinsic motivations of computer games (Malone & Lepper, 1987; Malone, 1981). From this point of view, it is easy to understand how physical exercise and sports might have trouble competing with digital games.

Fortunately, the last decade has brought about interesting developments in combining video games, sports, and exercise. So called motion games (exergames, active video games) have become mainstream thanks to technologies like Microsoft Kinect, PlayStation Move and Nintendo Wii. At the same time, indoor activity parks and fitness centers appear to utilize more and more motion-enhancing equipments such as trampolines, inflatable bouncy surfaces, crash mats or even wind tunnels for indoor skydiving. The equipment can be considered to serve a dual purpose of 1) scaffolding motor skill learning by reducing the impacts of landings on one's joints and giving more time to perform aerial techniques and 2) implementing the power fantasies of action video games in an embodied fashion.

This paper studies the effect of *mixed reality empowerment* on exercise motivation and motor skill learning using a trampoline platform jumping game. Here, mixed reality empowerment is defined as giving extended abilities and empowering the player both on the screen and in the real world. The game is implemented using a depth camera, real-time computer vision software and a screen near the trampoline. The trampoline boosts the players' jumping abilities in the real world, and the game further exaggerates the movement on-screen. Previously, the combination of real-life and in-game motion enhancing has been studied relatively little, although many virtual reality experiments and arcade games have manipulated the user's physical movement to some degree via, e.g., actuated seats or suspending the user in some form of harness (McKenzie, 1994).

We have previously presented the preliminary trampoline game prototypes shown in Figure 1 (Holsti, Takala, Martikainen, Kajastila, & Hämäläinen, 2013). In the previous study, we found the platform jumping game more interesting for novice trampoline jumpers, whereas more advanced practicers preferred less playful augmented feedback (e.g., video delay) that can be used to aid skill acquisition.

The contribution of the present paper is a comprehensive user study of a mixed reality trampoline game with novice users, using a battery of tests: the self-assessment manikin (SAM), flow and perceived competence questionnaires, as well as quantitative computer vision data and semi-structured interviews. We show that at least the basic skill of jumping high with precision can be improved while playing a fun and exhausting game. Furthermore, the combination of on-screen and real world empowerment can be used to enhance a game. We also provide some design guidelines and lessons learned, as mixed reality trampoline games have not been previously studied to this extent. Next, the previous research relevant to this paper is reviewed in more detail.

Figure 1 Previous trampoline game prototypes by the authors. Left: Player jumping on a trampoline in front of a Kinect camera. Middle: screenshot of a platform jumping game with the player embedded in the 3d graphics. Right: screenshot of a virtual training space with graphical obstacles.

Full-body human-computer interaction and designing for thrill

Our work is related to Myron Krueger's Artificial Reality, where the video image of the user was embedded inside interactive computer graphics (Krueger, Gionfriddo, & Hinrichsen, 1985). Later on, various research projects as well as commercial motion games have used avatars controlled using body tracking (Ishigaki, White, Zordan, & Liu, 2009; *Kinect Sports*, 2010), but in our opinion, using background-removed video or a 3d mesh obtained from a depth camera, as shown in Figure 1, is often better suited for sports training, since it minimizes the visual glitches caused by tracking failures. In general, various authors have researched physically intensive full-body interaction (Bianchi-Berthouze, 2013; Mueller, Agamanolis, & Picard, 2003).

Although commercial motion games are widely available, they are not always ideal for motor skill learning and exercising. One reason for this is probably the need to optimize the games for an average customer in an average living room with very little space, which limits the movements that can be used. While motion game equipment can be suitable even for the elderly in therapeutic use (Sparrer, Duong Dinh, Ilgner, & Westhofen, 2013) and some games do offer intensive exercise, the health benefits of commercial motion games in general are debatable (Baranowski et al., 2012; Owens, Garner, Loftin, van Blerk, & Ermin, 2011).

Skill transfer from a game to real practice does not always require realistic movements. Fery and Ponserre (2001) found that the skill of golf putting can be improved using a game controlled with a computer mouse. However, games are not always more entertaining than real practice, and a skill learned with commercial exergames might not transfer to real world, e.g., a virtually learned basketball throwing skill does not transfer to real performance (Wiemeyer & Schneider, 2012).

Quantifying the game user experience

In a broader view, our work belongs to the tradition of using computer games as experimental stimulus (Järvelä, Ekman, Kivikangas, & Ravaja, 2012; Washburn, 2003), and measuring game user experience (Brockmyer et al., 2009; Nacke, 2009; Takatalo, Häkkinen, Kaistinen, & Nyman, 2007).

Game user experience can be analyzed from various angles. In this paper, we are interested in the following three aspects:

1) Flow, a state of optimal experience characterized by, e.g., becoming completely absorbed in what one is doing, losing track of time, and finding the activity intrinsically rewarding (Nakamura & Csikszentmihalyi, 2002). Facilitating flow experiences is often considered relevant for good game design (Salen & Zimmerman, 2003; Schell, 2008; Sweetser & Wyeth, 2005). As we have also a no-game group of participants in our study, we use a flow questionnaire instead of a game-specific engagement measure such as the widely used Game Engagement Questionnaire (Brockmyer et al., 2009). Questions related to flow also constitute a part of the GEQ.

2) Perceived competence, which is linked to motivation and adherence of sport and exercise (Cairney et al., 2012; Carroll & Loumidis, 2001; Feltz & Lirgg, 2001; Ferrer-Caja & Weiss, 2000). We hypothesize that the virtually exaggerated abilities of the player may affect perceived competence.

3) The affective dimensions of valence, arousal and dominance, which can be measured using the Self-Assessment Manikin (SAM) (Bradley & Lang, 1994). We consider high positive valence, high arousal, and high dominance as descriptive of the “super hero” experiences that we wish to create using the mixed-reality empowerment approach.

Augmented feedback for motor skill learning

The role of feedback in motor skill learning and performance has been studied extensively (Bilodeau & Bilodeau, 1961; Magill & Anderson, 2012; Newell, 1991; Schmidt & Wrisberg, 2008; Sigrist, Rauter, Riener, & Wolf, 2013). Feedback provides athletes information for regulating action in various forms, e.g., intrinsic proprioceptive feedback, visual feedback, and extrinsic verbal feedback from a coach. The essential type of feedback for this study is concurrent augmented visual feedback, i.e., visual information that is given in real-time during the movement and would not be available otherwise, in this case provided by a computer system.

Compared to training with a video camera or receiving feedback from an instructor, computer generated feedback can be faster and more accurate, letting the student do more repetitions and evaluations of a skill in a short time. Considering the experiential learning cycle of concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE) (Kolb, 1983), the feedback design defines the transition speed from CE to RO and what data is available for RO, and can also provide cues and suggestions for AC and AE. However, while optimizing the experiential learning cycle (a closed loop control cycle) with augmented feedback, one must be aware of the guidance hypothesis that states that the learner may develop a dependency on augmented feedback, especially if it’s provided concurrently or too frequently (Magill & Anderson, 2012; Schmidt & Wrisberg, 2008; Sigrist et al., 2013). Feedback design is also important considering that clear goals and feedback are central prerequisities for flow experiences (Csikszentmihalyi, 1990).

There are several previous studies of computer-generated visual feedback. However, concurrent feedback does not always speed up the learning of a skill, and finding feedback that suits a particular skill can be hard (Chua et al., 2003). Using VR to improve motor control skills especially in ball sports is possible (Miles, Pop, Watt, Lawrence, & John, 2012). Yet, there is no single viable solution, and technical limitations such as latency in high-speed sports and inappropriate haptic feedback can deliver negative efficacy in the training task (Miles et al., 2012). There are also numerous non-VR training systems using computers and screens. Game-inspired elements can be used in dance training, but game environments can be more useful when combined with traditional instruction videos (Charbonneau, Miller, & LaViola, 2011). Also, ballet poses can be learned with concurrent feedback utilizing motion capture, but subtle style differences in movement are harder to detect and display (Marquardt, Beira, Em, Paiva, & Kox, 2012). For a more detailed overview of feedback technologies, see reviews by Lieberman et al. (2002), Magill and Anderson (2012), and Sigrist et al. (2013). According to Sigrist et al. (2013), concurrent visual feedback can especially benefit the initial learning of complex skills. For best results in retention tests without the feedback, no-feedback training or some other form of reduced feedback is usually needed in learning simple skills and refining complex skills. In our game, the player’s movements are exaggerated on the screen. Related to this, Buekers, Magill and Hall (1992) found that verbal knowledge of results (KR) can influence learning and retention even if it is erroneous or conflicting with one’s sensory feedback.

Combining motion-enhancing equipment and digital technologies

One of the disciplines that have traditionally experimented with both digital technology and motion-enhancing equipment is contemporary circus. For example, the show Kà by Cirque du Soleil utilizes wire-flying in conjunction with movement tracking, interactive projections, lighting and set elements (*Kà*, 2004). Circus equipment and arts have also inspired new forms of exercising, e.g., in the case of Jukari Fit to Fly, a trapeze-based exercise program designed in collaboration between Cirque du Soleil and Reebok (Murphy, 2009). Flying has also been simulated in a virtual reality system by suspending the user horizontally in the air using a harness (McKenzie, 1994).

Considering previous experiments with trampolines, computer vision has been used to analyze sport videos, including trampolining (Xian-jie, Zhao-qi, & Shi-hong, 2004), and Mori, Fujieda, Shiratori, & Hoshino (2008) have mapped the motion of the trampoline bed to movement in a virtual world. However, to our knowledge, we are the first to study trampoline games with full body tracking or the player's image embedded in the computer graphics.

It should be noted that trampolines can be dangerous, especially in recreational, unsupervised use (AAP Committee on Injury and Poison Prevention and Committee on Sports Medicine and Fitness, 1999; "Trampolines and Trampoline Safety Position Statement of the American Academy of Orthopaedic Surgeons", 2010). Attempting somersaults is not recommended and only one person should be jumping at a time. We believe that technology can be used to increase training safety, e.g., by using computer vision to monitor that there is only one player in the camera view. In addition to simple monitoring of safety guidelines, we are also trying to design goals and feedback to keep players interested longer in preliminary training before attempting high risk skills.

Materials and Methods

Participants

Thirty-four adult participants participated in the user study, of which 29 completed the experiment successfully. All 29 participants were novice trampoline jumpers, with only little or no experience in trampolining and without physical disabilities affecting trampoline jumping. Participants included 21 males, 6 females and 2 who did not define their gender. All participants had an academic background and were recruited through the university's email-lists. The ages of the participants varied from 21 to 59 (M = 31.9, SD = 7.2) and body mass index (BMI) varied from 19.3 to 34.6 (M = 23.9 kg/m2, SD = 3.1). The participants' mean estimation of their physical condition was a bit above average (M = 4.75, SD = 1.0) on a scale from 1 (very poor) to 7 (very good).

The five participants who were excluded from the study included 3 participants who reported back pain and did not successfully finish the test. One participant quit the experiment during warm-up due to a previous knee injury. Follow-up questions after a week affirmed that permanent injuries did not occur. Furthermore, the data from one participant was excluded because of a malfunction in the motion tracker. All participants volunteered and consented to the study. Two experimenters were always present during the experiment, one of which had professional trampoline experience and first-aid training. The university's ethics committee approved the study.

Apparatus

An Acon Air Sport 16 trampoline with a safety net was used, as shown in Figure 2. The trampoline was located in a large indoor research facility. A 40 inch HD TV was positioned 3.5 m from the center of the trampoline and the lower edge of the screen was 0.33 m above trampoline bed.

Figure 2. Test setup when participants were training with a game with exaggerated jumps (EJ). A screen shot from the TV is shown in the upper right corner.

An Asus Xtion Pro Live depth camera was positioned near the screen, 3.35 m from the center of the trampoline and 0.33 m above the trampoline. The camera and the TV were connected to a laptop running Windows 7. The game prototype including the tracking software were developed using the Unity 3D game engine and a custom plugin that gives Unity access to the RGB and depth images of the camera (containing each pixel's distance from the sensor) as well as skeletal tracking data from OpenNI/NITE middleware. Furthermore, video and audio were recorded from all test sessions.

The total collected data consisted of all jumps in all tests, as well as all jumps during the training. Tracker data was gathered at 30fps using the depth camera. Data was stored on each frame, including the xyz-coordinates of the bounding box corners and the approximate coordinates of the center of volume (COV) of the player's mesh. COV was analyzed from the 3D mesh captured using the depth camera. The COV was calculated as the average of the 3D coordinates of all pixels belonging to the player. The jumps' key points were extracted from the data. Jump height was calculated from the Y-value of the COV, extracting the highest value (jump apex) from the lowest point when the jumper's feet are about to touch the trampoline bed. For jumping accuracy, jump start and end positions were calculated from the X and Z coordinates of the COV.

The game used in the experiment was a very simple platform jumping game where the goal was to jump upwards from one platform to another. The player received points by collecting coins and stars, and jumping high jumps over multiple platforms. The score was shown in the upper left corner of the screen. The player was represented by a textured 3d mesh captured using the depth camera (see Figure 2). The player's moves resulted in vertical and horizontal movement on the screen.

Two versions of the game were used in the experiment: exaggerated (EJ) and normal jump height (NJ) relative to the height of the avatar. In NJ the actual jump height measured from the trampoline was mapped closely to the avatar's jump height whereas in EJ the avatar could jump more than 3 times the height of the actual jump. Jump exaggeration was done by scaling the tracked upward velocity and adjusting the simulated gravity.

The game level was designed to become gradually more difficult by making the platforms narrower and increasing the vertical spacing of the platforms. Level design was the same between NJ and EJ. However, as shown in Figure 3, the spacing between the platforms varied between NJ and EJ in order to equalize the effort needed to jump from platform to platform.

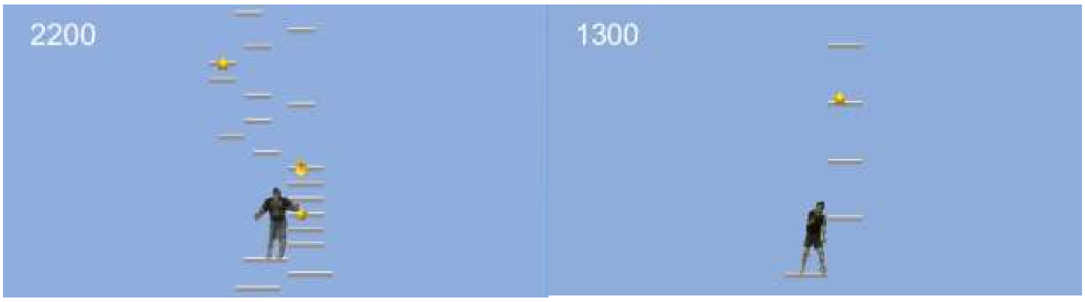

Figure 3. Avatars of two participants on the same platform. Level design was otherwise the same in NJ (left) and EJ (right), but spacing between the platforms was adjusted to the jump height in the game.

Task and Procedure

The whole procedure is shown in condensed form in Table 1.

Each participant performed the task individually. Upon entering the research facility, the procedure was verbally explained to the participants and they signed a release form and filled a questionnaire for background information. The participants were instructed on safe jumping on a trampoline by a professional circus artist/teacher. The participants were free to warm-up and get familiar with the trampoline for about 3 minutes, after which they were asked to try a few high and accurate jumps in middle on the trampoline. After the warm-up, the participants were given a pre-test (PRE) to determine their current maximal jump height and accuracy. The participants were informed that they would have to perform the same test after the training period (POST) and also the next day (NDAY). PRE-test as well as POST-test and NDAY-test consisted of 15 consecutive jumps with the current maximum height 100% (instructed as “the current maximum height that still feels controlled”), and 15 consecutive jumps with a self-assessed 75% and 50% of the maximum height with a short resting period between each jump height. Just before each test the participants filled an adapted perceived competence (PC) questionnaire (Williams & Deci, 1996).

For the training task, the participants were assigned in order of arrival into three groups, who either trained with a game with normal jump height (GN), a game with exaggerated jump height (GE) or self-training with no game at all (ST). An equal number of females were assigned to each group. Note that all the groups can be considered to have used a discovery learning approach, as we gave the participants the goal of learning high and precise jumps, but didn’t instruct them how. In the GN and GE groups, the participants saw their body position and posture in relation to a virtual environment, but did not receive any further instruction. In previous studies, discovery learning has been found to lead to slower skill acquisition but better retention than guided instruction (Singer & Pease, 1976), and explicit instruction has yielded a decrease in performance when compared to discovery learning and guided discovery under anxiety provoking conditions (Smeeton, Hodges, Williams, & Ward, 2005). The training time was 6 minutes in total, which was divided into 3 periods of 2 minutes of training with 1 minute of rest in between (performed standing). The experimenter informed verbally the start and end of the training period. The groups with the game (GN,GE) played the game for 2 minutes. The self training group (ST) were instructed to first jump 1 minute in the center of the trampoline and then 1 minute varying their position sideways, thus experiencing a slightly “guided” discovery learning. The ST group was also instructed to vary their jump height according to their preferences. The amount of jumps during the 6 minutes of training was similar between the groups. The mean number of jumps was 324, 330, 344 for GN, GE, and ST respectively. After the training, the participants filled the Short Flow State Scale (FLOW

SFSS) (Csikszentmihalyi, 1990; Jackson, Eklund, & Martin, 2010), self-assessment manikin (SAM) (Bradley & Lang, 1994), STICK-figure, and an open ended questionnaire asking 3 positive and 3 negative aspects of the training. The main purpose of these questionaires was evaluating differences in the training, but SAM and STICK-figure -questionnaires were also administered in the POST-test and the DAY-test to see if any possible effects of the training methods would persist over time.

The STICK-figure questionnaire consisted of questions illustrated with stick figures (see Figure 4). After filling the questionnaires, the POST-test was done by the participants, after which they filled a STICK-figure questionnaire again.

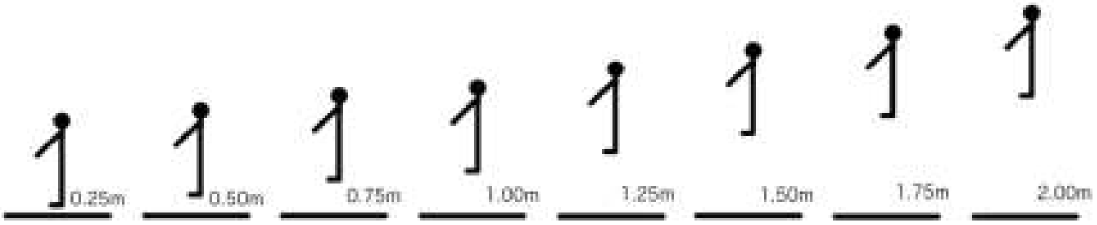

Figure 4 Perceived jump height questionnaire filled after the training and retention tests.

On the second day the participants went directly to warm-up on the trampoline. After the warm-up, the NDAY-test was done, after which SAM and STICK-figure questionnaires were filled again. After the NDAY-test, the participants were asked to play both game configurations for about 1 minute each and semi-structured questions were asked in between and after. A semi-stuctured interview was done only after the actual experiment so that it would not affect the results. The questions were defined beforehand, (e.g., "*How did the game with non-exaggerated jumps feel compared to the exaggerated version?”),* but the experimenter could ask the participant to describe the initial answer in more detailed form. GN and GE groups first played the game they used for training the day before. The ST group started with the game with exaggerated jumps, to assess if they perceived the exaggeration or not. The participants were instructed not to discuss the experiment with other participants.

The main experimental interest for administering each questionnaire**:**

- PC: Does the training method have an effect on the perceived competence? Does the change in perceived competence match the possible learning of a skill?
- STICK-figure: Possible interaction between the in-game motion exaggeration and the players’ perceived real-world jump height.
- FLOW: Assess overall participant engagement and flow during the training. Which components differ between groups with different training methods?
- SAM: Participants’ affective experience of the training and the difference between training methods.

Table 1 Procedure of the trampoline jumping experiment during 2 days.

Day 1	**Day 2**
1. Verbal and written introduction, pre-questionnaire	1.Warm-up on the trampoline
2. Warm-up on the trampoline and safety instructions (3 min)	2. NDAY-test (PC questionnaire, SAM, STICK-figure questionnaires)
3. PRE-test (PC questionnaire)	3. Systematic testing of both games and a semi-structured interview
4. Training either with GN, GE or ST. (10 min) (FLOW, SAM, STICK-figure questionnaires)	
5. POST-test (PC questionnaire, STICK-figure questionnaires)	

Results

The jump height data of all tests for GE, GN and ST was evaluated as normally distributed. Skewness values were 0.45, 0.30, 0.50 (SE = 0.075, 0.075, 0.079) for GE, GN and ST, respectively. Kurtosis values were -0.17, -0.21, -0.23 (SE = 0.15, 0.15, 0.16), for GE, GN and ST, respectively. The means of 100% jump heights with change between the tests are shown in the Figure 5.

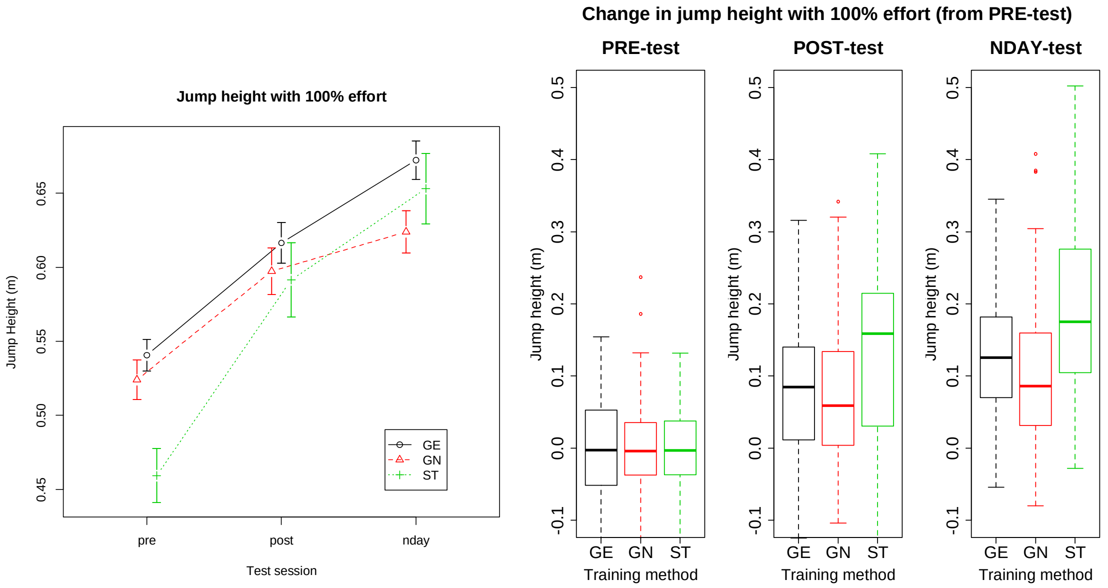

Figure 5. Left: Jump heights with 100% effort. (Error bars represent standard errors) Right: Boxplot of jump heights with 100% effort. Heights are relative to the mean jump height in PRE –test (i.e. change from PRE-test).

A mixed design 3 (training method) × 3 (test session) ANOVA was used with the training method (GN, GE, ST) as the between-subject factor and the three test session time points (PRE, POST, NDAY) as the within-subjects factor. ANOVAs were conducted for gain scores (i.e. change in jump height from PRE-test) in jump height and jump accuracy.

For jump height, analysis revealed a significant main effect of test session (F(2, 52) = 46.19, p < .001, $\eta_p^2 = .28$). There was no main effect of training method (F(2, 26) = 2.59, p = .094). The interaction terms were not significant.

Table 2 The means of 100% jump height and accuracy between groups and PRE, POST and NDAY tests.

Group	**PRE**		**POST**		**NDAY**	
	Height	Accuracy	Height (+change)	Accuracy	Height (+change)	Accuracy
GN	0.52 m SD=0.15	0.19m SD = 0.12	0.60m SD = 0.17 (0.07m)	0.20m SD = 0.16	0.62m SD = 0.16 (0.1m)	0.17m SD = 0.13
GE	0.54 m SD= 0.14	0.19m SD= 0.12	0.60m SD = 0.15 (0.08m)	0.19m SD = 0.12	0.67m SD = 0.14 (0.13m)	0.20m SD = 0.14
ST	0.46 m SD= 0.18	0.17m SD =0.12	0.59m SD = 0.26 (0.13m)	0.16m SD = 0.11	0.65m SD = 0.25 (0.19m)	0.18m SD = 0.13

One-way within-subjects ANOVAs were conducted to determine simple main effects. 1 (training method) x 3(time point: PRE, POST; NDAY) ANOVAs were conducted separately for each training method GN, GE and ST. Analysis revealed a significant effect of test session GN (F(2, 18) = 10.93, p < .001, $\eta_p^2 = .19$), GE (F(2, 18) = 23.10, p < .001, $\eta_p^2 = .29$), ST (F(2, 16) = 16.17, p < .001, $\eta_p^2 = .35$). Post hoc comparisons using the Tukey's test showed that there was a significant increase in jump height from PRE to POST 0.073m, 0.076m, 0.132m (p < .001) and PRE to NDAY 0.100m, 0.132m, 0.194m (p < .001) in GN,GE and ST respectively (see Figure 5). Furthermore, only GE had a significant increase in jump height from POST to NDAY (p < .05).

Jump accuracy (measured as the distances between the starting and landing points of jumps) data was skewed to the left and a square-root transform was applied before testing. There was no main effect of test session (F(2, 52) = 0.13, p = .88) or training method (F(2, 26) = 1.11, p = .32). The interaction terms were not significant. Jump accuracy varied only slightly in PRE, POST and NDAY tests, as seen in Table 2.

The amount of jumps during the 6 minutes of training was similar between the groups. The mean number of jumps was 324, 330, 344 for GN, GE, and ST respectively. The distributions of jump heights in each group were also similar.

Questionnaire results:

The nine original Likert-style questions of the Short Flow State Scale (SFSS) (Jackson et al., 2010) were used and mean flow values were calculated (M =3.83, 3.72, 3,11 , SD = 0.36, 0.42, 0.35 , for GE, GN, ST respectively). Cronbach's α was 0.7. A Kruskall–Wallis one-way analysis of variance was used to analyze the results and a significant difference between the rank means of the mean flow scores was found ($\chi^2 = 10.7603$, p < .05). Nemenyi post-hoc analysis (p < .01) of the three conditions shows a significant difference between ST and GE and ST and GN ($p < .01$, $p < .05$). A closer analysis of individual Flow scores with Kurskal-Wallis and Nemenyi post-hoc revealed that the largest differences are seen in action-awareness merging (AM), clear goals (CG), unambiguous feedback (UF) and autotelic experience (AE), where a significant difference to ST is in AM (GE and GN, $p < .05$), CG (GN, $p < .05$), and AE (GN, $p < .05$). This is also seen Figure 6.

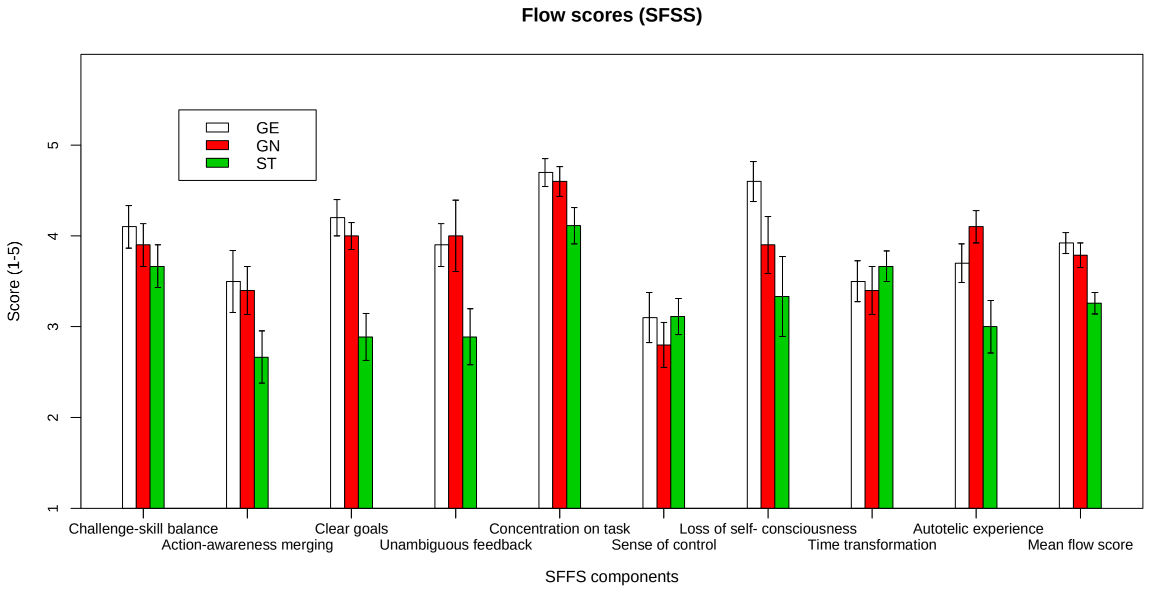

Figure 6. Flow (SFSS) scores for GN, GE and ST after the training show that experience of the ST group differed form GN and GE. (Error bars represent standard errors)

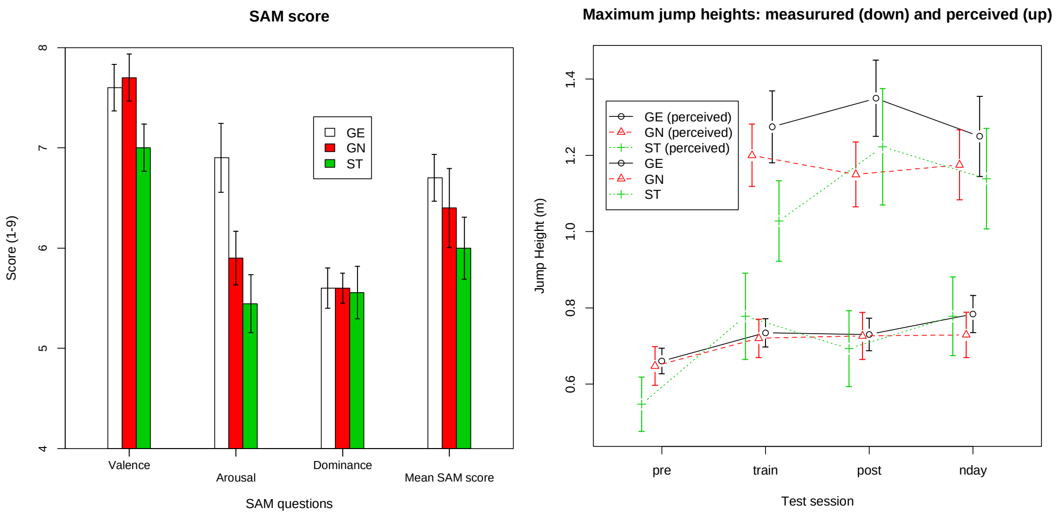

Figure 7 Left: SAM scores for GN, GE and ST after the training. There was a significant difference in arousal between the groups ST and GE ($p < .05$). The bars are shown between scores 4 to 8. Right: Measured and perceived jump heights in the highest point of the highest jump. (Error bars represent standard errors)

The self-assessment manikin (SAM) questionnaire was also filled after training and NDAY-test. A Kruskall–Wallis one-way analysis of variance and post-hoc analysis was used to analyze the results. The only significant difference between the rank means was found in arousal ($\chi^2 = 6.4741$, $p < .05$) and Nemenyi post-hoc analysis showed that difference was significant between GE-ST ($p < .05$). The results are also seen in Figure 7 (left).

Perceived competence (PC) scores show an overall mean increase of 4.67, 4.93, 5,37 (Cronbach's $\alpha = 0.8, 0.9, 0.9$) during PRE, POST and NDAY respectively. There were no significant differences found between GN, GE and ST. The perceived maximum real world jump height was asked after the training, POST-test and NDAY-test. The maximum perceived and measured jump heights are presented in Figure 7 (right). The perceived jump height is consistently higher in training, POST and NDAY (M = 1.20m, SD = 0.33) than the measured one (M = 0.74 m, SD = 0.21).

Interview results:

The game with exaggerated jump height (EJ) was preferred over normal jump height (NJ) by most of the participants in the groups GE and ST. GE and ST were introduced to the exaggerated version of the game first. In the GN group, who used the NJ version first, 5/10 preferred the EJ version.

The game with exaggerated jumps (EJ) received positive comments when *compared* to (NJ):

- *“More rewarding, like driving a racecar instead of a scooter”,*
- *“Because the avatar jumps with ease, it creates a feeling that I’m more competent too”,*
- *“The exaggerated game feels somehow like superpowers in a game. Suddenly you get a boost”,*
- *“The exaggeration has a better correlation to the forces and acceleration that one feels on the trampoline”,*
- *“More rewarding. I’m used to exaggeration in games. It feels more natural, and stimulates me to jump higher",*
- *“The feeling of beeing a superhero”,*
- *“The exaggeration is more interesting, but on the other hand it affects the maneuverability“.*

The normal game (NJ) was described more negatively when *compared* to (EJ):

- *“Like jumping in tar”,*
- *“It felt more boring because of small jumps, a lot of platforms close to each other”,*
- *“Does not encourage to jump higher”.*

However, some participants preferred NJ since it felt more like an exercise or it was easier to control:

- *"It felt somehow more realistic and more demanding, and not too exaggerated"*,
- *"I was more in control"*,
- *"Exaggerated jumps gave a nice feeling, but non-exaggerated jumps gave better control sideways and the pace felt a bit more relaxed"*.

The GN group, who trained with the NJ game, was asked if the jump height was underestimated, normal, or exaggerated. 5/10 said that jump height was normal and 5/10 underestimated. The same question was asked from groups ST and GN, who tried the exaggerated version first. Surprisingly, 4/9 (ST) and 5/10 (GE) participants did not notice any jump exaggeration even though they could jump many times their height on the screen. 2 participants realized the exaggeration only after being asked directly about it: "*I did not notice it… or now when asked about it, yes*", "*not exaggerated, but the avatar feels more able*".

The participants were asked about the positive and negative aspects of training with the game. The real-time feedback of the jumps in the game was appreciated by many participants and increased motivation, fun and efficiency of exercise was mentioned often: *"I get instant feedback when trying something different","Exercising comes with the fun"*.

Discussion and design recommendations

Results show that all groups GE, GN and ST improved their jump heights while maintaining accuracy, as seen in Table 2. This indicates increasing skill, as more effort usually leads to lower accuracy (Schmidt & Wrisberg, 2008). The learning effect is still seen in POST and NDAY tests, when the real-time feedback (game) was removed from the groups GN and GE. The participants were tired after the training, which may partly explain the higher jumps in in the NDAY test compared to the POST-test. A couple of participants also commented on this: *"My muscles were tired in the end test, so I could not jump so high"*

The ST group increased its performance slighty more than GE and GN (see Table 2 and Figure 5 (left)), although no significant difference was found. However, as seen in Figure 5 (left), the ST group had slightly lower average jump height in PRE-test. Individual differences were big in the PRE-test results and we observed that two participants in the ST group were more intimidated by the trampoline training than the other participants. Their maximum jump height remained considerably lower only in the PRE-test. The training style varied between the participants in the ST group. Some jumped maximum jumps for the whole training period, whereas some settled for minimum effort jumps. It should be noted that all groups had some kind of training either with game or without a game. Overall improvement of the skill cannot be evaluated, because a no-treatment group is missing and part of the improvement can be due to a simple repeated-measures effect.

The questionnaire data shows that perceived competence was on the same level in all groups and exhibited a steady increase during PRE, POST and NDAY tests. All participants in all groups had fun in the experiment, which is not surprising because trampoline jumping is regarded as exciting in general. However, small differences between groups can be seen in the questionnaire results. The game with the exaggerated jumps (EJ) was more arousing than no game or NJ as seen in Figure 7.

Also differences in flow scores show that the ST group did not have as positive an experience as the GE and GN groups. This can be seen in the lower score for the question "I found the experience extremely rewarding" (AE). Self-training also received a lower flow score for spontaneous and automatic behavior (AM), knowing what to do (CG) and receiving feedback on one's own performance (UF). The participant's comments also complement this *"I don't pay so much attention to the jumping, it comes automatically when focusing on the game".*

Overall, NJ was reported to be more accurate with sideways jumps, although there was no exaggeration sideways in either of the games. The exaggerated jumps may affect horizontal aiming, because the target platforms are further away on the screen. However, more research is needed to confirm this.

It seems that jump height exaggeration makes the game more engaging and fun without affecting most players' performance. The exaggeration can also feel so natural that the player does not even notice it. A couple of participants asked if the jump height could be relative to the effort: "It would be nice if the jump height would be mapped to my effort and not to my actual jump height".

The game directs the player's attention to the game, which was mostly seen as a positive aspect. The player might use more extrinsic feedback, where as intrinsic feedback might be used more while jumping without the game:

- *"I don't pay so much attention to the jumping, it comes automatically when focusing on the game", "*
- *"I forgot how I was jumping and concentrated on the result".*
- *"More concentration to the body, because I do not have to look at the screen. However, it still lacks the real-time feedback.".*

The screen could be seen well through the safety net. In trampoline jumping, it is common to keep the eyes focused on one spot. It seems that focusing the eyes on a screen while jumping does not cause problems. One participant mentioned that: *"It feels harder to jump accurate jumps without the game. I had to find a focus point for the eyes. With the game it came automatically".*

Although care was taken that the participants had a proper warm-up, there were still people reporting back pain in all groups, although the pain had subsided when we checked back a few days later. Also muscle pain in the calves, thighs, neck and feet was reported. Two subjects even said that their hand muscles got a workout. Although trampoline jumping alone without attempting any tricks is regarded as relatively safe, it also appears to be so engaging that at least adult office workers may use too much effort and get hurt. All our participants reporting back pain were also initially among the most active jumpers. Trampoline training games should clearly include a proper warm-up and safety-instructions. Furthermore, it could also be possible to match the difficulty level of the game to the fatigue level of the player and design breaks as part of the game.

Many participants noted that jumping accurately sideways was difficult before getting used to it. This appears to be an unanticipated result of the trampoline enabling high jumps that travel a long distance. When landing on a platform that is high and to the side in the game world, the player will still continue moving downwards and sideways in reality. This may result in the avatar sliding off the platform if there is a one-to-one mapping between the horizontal positions of the player and the avatar. The design could be changed so that the platforms would slide sideways with the avatar and add an elastic vertical movement to imitate the movement of the trampoline bed.

It should be noted that in our previous computer vision game experiments, we have found it quite easy to exaggerate the player's jumps by simply boosting the tracked upwards velocity and adjusting gravity. We didn't initially realize that the exaggeration is more difficult in the case of trampolining where the user is jumping constantly. The player should not land on the ground later in the virtual world than in the real world, because otherwise the player starts to move back up before landing in the game, which can cause missed or mid-air jumps, depending on the game mechanics. In the platformer used in this study, gravity is exaggerated so that the player lands early enough even when jumping down from a high platform, but this seems to add a sticky feeling to small jumps, because the player stays on the ground longer than in the real world.

Overall, trampolining was seen as an interesting sport and many participants stated that balance challenges, effective full-body workout, and high jumps make it intriguing. On average, the participants positioned the exhaustion level of the trampoline training in this experiment between jogging and running. The exhaustion level was also compared to aerobic, football, zumba, biking uphill, badminton, interval training, dancing and rope skipping. Safety, velocity and increased abilities were also mentioned by several participants: *"Scary but safe at the same time"*, *"Euphoria from the velocity"*, *"Illusion that I'm stronger than in reality, which is not an everyday feeling"*.

Conclusion

We studied how playing a simple body-controlled game while jumping on a trampoline affects the exercise experience, and whether the game enables the learning of basic trampolining skills. The platform jumping game was implemented using computer vision and a screen placed near the trampoline. The results show that improvement in high and precise jumps on a trampoline is similar between the group playing a game and the group without a game. Although trampoline training was regarded as fun by itself, the game made it more engaging. Focusing on the game did not disturb the participants' jump training and many participants considered the real-time feedback beneficial. Extra empowerment in the game, as jump height exaggeration, did not affect the performance adversely. Most of the participants preffered the exaggerated version of the game. The exageration felt natural and half of the participants did not even notice it. This suggests that extra empowerment may be used to make the training more engaging without affecting the results negatively. In light of these results, we suggest that mixed reality empowerment should be studied more to understand better its impact on exercise motivation and motor learning. We are currently investigating what abilities beyond jump height can be exaggerated, and how it affects motivation, interaction, and the social context of play, e.g., the skill attributed to the player by an audience.

References

AAP Committee on Injury and Poison Prevention and Committee on Sports Medicine and Fitness. (1999). Trampolines at Home, School, and Recreational Centers. *Pediatrics*, *103*(5), 1053–1056.

Baranowski, T., Abdelsamad, D., Baranowski, J., O'Connor, T. M., Thompson, D., Barnett, A., … Chen, T.-A. (2012). Impact of an Active Video Game on Healthy Children's Physical Activity. *Pediatrics*, *129*(3), e636–e642. doi:10.1542/peds.2011-2050

Bianchi-Berthouze, N. (2013). Understanding the Role of Body Movement in Player Engagement. *Human–Computer Interaction*, *28*(1), 40–75. doi:10.1080/07370024.2012.688468

Bilodeau, E. A., & Bilodeau, I. M. (1961). Motor Skills Learning. *Annual Review of Psychology*, *12*, 243–280.

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry*, *25*(1), 49 – 59. doi:http://dx.doi.org/10.1016/0005-7916(94)90063-9

Brockmyer, J. H., Fox, C. M., Curtiss, K. A., McBroom, E., Burkhart, K. M., & Pidruzny, J. N. (2009). The development of the Game Engagement Questionnaire: A measure of engagement in video game-playing. *Journal of Experimental Social Psychology*, *45*(4), 624–634. doi:10.1016/j.jesp.2009.02.016

Buekers, M. J. A., Magill, R. A., & Hall, K. G. (1992). The Effect of Erroneous Knowledge of Results on Skill Acquisition when Augmented Information is Redundant. *The Quarterly Journal of Experimental Psychology Section A*, *44*(1), 105–117. doi:10.1080/14640749208401285

Cairney, J., Kwan, M. Y., Velduizen, S., Hay, J., Bray, S. R., & Faught, B. E. (2012). Gender, perceived competence and the enjoyment of physical education in children: a longitudinal examination. *The international journal of behavioral nutrition and physical activity*, *9*, 26.

Carroll, B., & Loumidis, J. (2001). Children’s perceived competence and enjoyment in physical education and physical activity outside school. *European Physical Education Review*, *7*, 24–43.

Charbonneau, E., Miller, A., & LaViola, J. J. (2011). Teach me to dance: exploring player experience and performance in full body dance games. In *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology, (*Article 43), Lisbon, Portugal.

Chua, P. T., Crivella, R., Daly, B., Hu, N., Schaaf, R., Ventura, D., … Pausch, R. (2003). Training for physical tasks in virtual environments: Tai Chi. In *Proceedings of IEEE Virtual Reality 2003* (pp. 87–94).

Csikszentmihalyi, M. (1990). *Flow: the psychology of optimal experience*. New York: Harper & Row.

Feltz, D. L., & Lirgg, C. D. (2001). Self-efficacy beliefs of athletes, teams, and coaches. *Handbook of sport psychology*, *2*, 340–361.

Ferrer-Caja, E., & Weiss, M. R. (2000). Predictors of Intrinsic Motivation among Adolescent Students in Physical Education. *Research Quarterly for Exercise and Sport*, *71*(3), 267–279. doi:10.1080/02701367.2000.10608907

Fery, Y. A., & Ponserre, S. (2001). Enhancing the control of force in putting by video game training. *Ergonomics*, *44*(12), 1025–1037.

Holsti, L., Takala, T., Martikainen, A., Kajastila, R., & Hämäläinen, P. (2013). Body-controlled trampoline training games based on computer vision. In *CHI ’13 Extended Abstracts on Human Factors in Computing Systems* (pp. 1143–1148). New York, NY, USA: ACM. doi:10.1145/2468356.2468560

Ishigaki, S., White, T., Zordan, V. B., & Liu, C. K. (2009). Performance-based control interface for character animation. In *ACM SIGGRAPH 2009 Papers* (pp. 61:1–61:8). New York, NY, USA: ACM. doi:10.1145/1576246.1531367

Jackson, S. A., Eklund, R., & Martin, A. (2010). *The FLOW manual*. Queensland, Australia: Mind Garden, Inc.

Järvelä, S., Ekman, I., Kivikangas, M. J., & Ravaja, N. (2012). Digital games as experiment stimulus. In *Proceedings of DiGRA Nordic 2012 Conference*. DiGRA. Retrieved from http://www.digra.org/wp-content/uploads/digital-library/12168.58027.pdf

Kà. (2004). Retrieved from http://en.wikipedia.org/w/index.php?title=K%C3%A0&oldid=531564174

Kinect Sports. (2010). Retrieved from http://en.wikipedia.org/w/index.php?title=Kinect_Sports&oldid=516981922

Kolb, D. A. (1983). *Experiential Learning: Experience as the Source of Learning and Development* (1st ed.). Prentice Hall.

Krueger, M. W., Gionfriddo, T., & Hinrichsen, K. (1985). VIDEOPLACE - an artificial reality. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 35–40). New York, NY, USA: ACM. doi:10.1145/317456.317463

Liebermann, D. G., Katz, L., Hughes, M. D., Bartlett, R. M., McClements, J., & Franks, I. M. (2002). Advances in the application of information technology to sport performance. *Journal of sports sciences*, *20*(10), 755–769.

Magill, R. A., & Anderson, D. I. (2012). The roles and uses of augmented feedback in motor skill acquisition. In N. Hodges & A. M. Williams (Eds.), *Skill Acquisition in Sport: Research, Theory and Practice*. Routledge.

Malone, T. W. (1981). Toward a theory of intrinsically motivating instruction. *Cognitive Science*, *5*(4), 333–369. doi:10.1016/S0364-0213(81)80017-1

Malone, T. W., & Lepper, M. R. (1987). Making learning fun: A taxonomy of intrinsic motivations for learning. *Aptitude, learning, and instruction*, *3*, 223–253.

Marquardt, Z., Beira, J., Em, N., Paiva, I., & Kox, S. (2012). Super Mirror: a kinect interface for ballet dancers. In *Proceedings of the 2012 ACM Annual Conference Extended Abstracts on Human Factors in Computing Systems Extended Abstracts* (pp. 1619–1624). New York, NY, USA: ACM. Retrieved from http://doi.acm.org/10.1145/2223656.2223682

McKenzie, J. (1994). Virtual Reality: Performance, Immersion, and the Thaw. *TDR (1988-)*, *38*(4), 83. doi:10.2307/1146426

Miles, H. C., Pop, S. R., Watt, S. J., Lawrence, G. P., & John, N. W. (2012). A review of virtual environments for training in ball sports. *Computers & Graphics*, *36*, 714–726.

Mori, H., Fujieda, T., Shiratori, K., & Hoshino, J. (2008). Kangaroo: the trampoline entertainment system for aiding exercise. In *Proceedings of the 2008 International Conference on Advances in Computer Entertainment Technology* (pp. 414–414). New York, NY, USA: ACM. Retrieved from http://doi.acm.org/10.1145/1501750.1501864

Mueller, F., Agamanolis, S., & Picard, R. (2003). Exertion interfaces: sports over a distance for social bonding and fun. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 561–568). New York, NY, USA: ACM. doi:10.1145/642611.642709

Murphy, S. (2009, August 3). Jukari Fit to Fly with Cirque du Soleil. *The Guardian*. Retrieved from http://www.guardian.co.uk/lifeandstyle/2009/aug/03/jukari-fit-to-fly

Nacke, L. (2009). *Affective Ludology [Elektronisk resurs] : Scientific Measurement of User Experience in Interactive Entertainment*. Retrieved from http://www.bth.se/fou/forskinfo.nsf/all/ca7dff01c93318fdc1257646004dfce1/$file/Nacke_diss.pdf

Nakamura, J., & Csikszentmihalyi, M. (2002). The concept of flow. In C. R. Snyder & S. J. Lopez (Eds.), *Handbook of Positive Psychology* (pp. 89–105). New York, NY, US: Oxford University Press.

Newell, K. M. (1991). Motor Skill Acquisition. *Annual Review of Psychology*, *42*(1), 213–237. doi:10.1146/annurev.ps.42.020191.001241

Owens, S. G., Garner, J. C., Loftin, J. M., Van Blerk, N., & Ermin, K. (2011). Changes in Physical Activity and Fitness After 3 Months of Home Wii Fit^{TM} Use. *Journal of Strength and Conditioning Research*, *25*(11), 3191–3197. doi:10.1519/JSC.0b013e3182132d55

Salen, K., & Zimmerman, E. (2003). *Rules of Play: Game Design Fundamentals*. The MIT Press.

Schell, J. (2008). *The art of game design a book of lenses*. Amsterdam; Boston: Elsevier/Morgan Kaufmann.

Schmidt, R. A., & Wrisberg, C. A. (2008). *Motor Learning and Performance* (4rd ed.). Human Kinetics.

Sigrist, R., Rauter, G., Riener, R., & Wolf, P. (2013). Augmented visual, auditory, haptic, and multimodal feedback in motor learning: A review. *Psychonomic Bulletin & Review*, *20*(1), 21–53. doi:10.3758/s13423-012-0333-8

Singer, R. N., & Pease, D. (1976). A Comparison of Discovery Learning and Guided Instructional Strategies on Motor Skill Learning, Retention, and Transfer. *Research Quarterly. American Alliance for Health, Physical Education and Recreation*, *47*(4), 788–796. doi:10.1080/10671315.1976.10616742

Smeeton, N. J., Hodges, N. J., Williams, A. M., & Ward, P. (2005). The Relative Effectiveness of Various Instructional Approaches in Developing Anticipation Skill. *Journal of Experimental Psychology. Applied*, *11*(2), 98–110. doi:10.1037/1076-898X.11.2.98

Sparrer, I., Duong Dinh, T. A., Ilgner, J., & Westhofen, M. (2013). Vestibular rehabilitation using the Nintendo® Wii Balance Board -- a user-friendly alternative for central nervous compensation. *Acta oto-laryngologica*, *133*(3), 239–245. doi:10.3109/00016489.2012.732707

Sweetser, P., & Wyeth, P. (2005). GameFlow: a model for evaluating player enjoyment in games. *Comput. Entertain.*, *3*(3), 3–3. doi:10.1145/1077246.1077253

Takatalo, J., Häkkinen, J., Kaistinen, J., & Nyman, G. (2007). Measuring user experience in digital gaming: Theoretical and methodological issues. In Y. M. Luke C. Cui (Ed.), *Proceedings of SPIE - The International Society for Optical Engineering* (Vol. 6494).

Trampolines and Trampoline Safety Position Statement of the American Academy of Orthopaedic Surgeons. (2010). Retrieved from http://www.aaos.org/about/papers/position/1135.asp

Washburn, D. A. (2003). The games psychologists play (and the data they provide). *Behavior Research Methods, Instruments, & Computers*, *35*(2), 185–193. doi:10.3758/BF03202541

Wiemeyer, J., & Schneider, P. (2012). Applying Serious Games to Motor Learning in Sport. *International Journal of Game-Based Learning (IJGBL)*, *2*(4), 61–73.

Williams, G. C., & Deci, E. L. (1996). Internalization of biopsychosocial values by medical students: a test of self-determination theory. *Journal of personality and social psychology*, *70*(4), 767–779.

Xian-jie, Q., Zhao-qi, W., & Shi-hong, X. (2004). A Novel Computer Vision Technique Used on Sport Video. *Journal of WSCG, Vol 12*(1-3).