Designing for strength training

Design recommendations for adding technology and sensors to strength training platforms

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ABSTRACT

This paper offers recommendations on design elements that should be considered when implementing and utilizing sensor technology and gamification in strength training platforms. The recommendations are based on reviewed articles addressing concepts, experiments and theories on the effects of gamification and feedback elements. The latter are further discussed in relation to sport psychology and motivation theories. The conclusion highlights that elements that 1) show progression; 2) makes self-monitoring possible; 3) help setting long-term and short-term goals; 4) induce flow; and 4) motivate for further use; should be considered. Elements that facilitate the user to achieve his or her Ideal Performance State, and trigger the user's intrinsic motivation, should also be taken into consideration. Common game design elements such as rewards, levels, points, and other elements triggering a person's competitiveness and self-comparison with others, must be carefully used to not hinder the potential of long-term effects. These elements could also make the platform unsuitable for some users because of individual differences.

KEYWORDS: Feedback, Gamification, Motivation, Strength Training, Biofeedback, Design

1. INTRODUCTION

There has been a huge increase in the market of new health applications and training products the last decade. Technology and software are getting implemented in new fields and areas from wristwatches to stationary bicycles with the aim to improve the user's training performance and increase the final benefits.

As the world is growing more innovative sensor technology are getting vastly better, the improvement of training and exercising platforms and equipment could be developed coherently. Design considerations should be developed so that sensors can be used in the best way possible and yield all its potential. Motivation for training can easily vanish if the training is conducted wrong, or the results are minimal. To design and facilitate for correct and effective training, that substantiate results and enhances performance are therefore highly important

Data gathered by different sensors could facilitate for training in several ways. It could be visualised as graphs, stored as data or given as direct feedback that prompt the user in certain ways. Also, the use of elements from game design to utilize the data is possible and widely used. Examples of game design elements are scoreboards, digital rewards and levels. This way of utilizing the data is referred to as gamification of the activity (Cugelman, 2013).

The purpose of feedback and gamification are often to motivate the user so that he or she will reach his or her goal, or simply to give complete control over the training output. Products utilizing these elements usually have a connection with endurance sports or exercises and is less exploited in strength training equipment and programs.

The effect of feedback and gamification on strength training and its effect on execution performance is to some extent unclear (Alsawaier, 2018). Hence, the aim herein is to give an overview of how direct visual feedback and gamification elements could affect strength training performance through motivation and psychology theories. This will then be used to discuss what elements should and could be included in a sensor-based platform for strength training and help designers to develop a good designed and well functional product or experience.

The following research question is defined:

- Can incoming technology, gamification and (bio)feedback improve the performance on strength training, and how should it be utilized?

2. METHOD

An extensive literature search related to motivation, gamification, sport psychology, strength training and biofeedback was conducted. The aim of the screening was to find papers with research and experiments containing answers regarding the effect on motivation and strength training performance from gamification and (bio)feedback.
The literature was found using the search engines Oria and Google Scholar. The key words used are as follow:

Gamification
- "motivation" AND "Gamification"

Feedback
- "Performance" AND "Feedback"

Wearable technology
- "Effect" AND "wearable technology"

Sport psychology
- "Flow"
- "Ideal Performance State"
- "Goal setting"

Motivation
- "Self Determination Theory"
- "Motivation" AND "Performance"

The literature was sorted by relevance based on their title, abstract and conclusion. The most relevant articles were then screened full text, and citations therein were checked to gain deeper insight on specific fields.

Most of the articles reviewed are released from within the last 8 years, except those regarding theories on motivation and psychology where Deci E.L. and Ryan R.M have been pioneers and their work is considered as classics.

Outcome of research:

Gamification is still quite a new field, and there is a lot of research that could be done to create empirical supported theories. Research on motivation is on the other hand extensive and theories are established. Biofeedback has some older research conducted, and has been a topic for some years, but the research is still not conclusive on the effects and uses in strength training.

3. THEORETICAL BACKGROUND

Strength training

Correct systematic exercising results to improvement of one's physical fitness. This follows that the body adapts to the new physical load. Positive Training adaption only takes form if there is an overload with magnitude greater than the habitual level. This means that if an exercise is conducted with the same load every time, the positive training adaption cease to increase. There are two ways of inducing positive adaption. One way is to increase the load, which is intensity (weight, speed, resistance) or volume (number of sets, time used). Another, is to change the exercise to an activity the body has not yet accustomed to (Zatsiorsky & Kraemer, 2006).

There are several ways of performing a strength training session. These different ways can be categorised into maximal strength training, explosive strength training, hypertrophy strength training, and strength endurance training. The different training categories can involve similar exercises and equipment, but load, intensity, volume and rest length, vary (Haff & Triplett, 2015).

Motivation theories

If you are motivated for a task you are encouraged to do that task, but If you on the other hand feel no inspiration or stimulus to act, you are classified as unmotivated (Edward L Deci & Ryan, 2000). A person's motivation can vary a lot, both in what degree and the orientation. The orientation is dependent on the underlying "why" of the action, which can be a great deal of different things. An example on differences in underlying goal and attitudes that governs different orientations of motivation, could be the motivation for exercising strength. One person might be highly motivated to exercise strength because the muscles becomes bigger and that could be viewed as popular, or alternatively the person is motivated because the training itself is fun and exciting. Different orientation on motivation is the roots of the empirically based theory of motivation called Self Determination Theory (SDT) (Edward L Deci & Ryan, 2008).

Edward L Deci and Ryan (2000) SDT give a distinction between types of motivations, and the outcome of them. It mainly divides motivation in to intrinsic and extrinsic motivation:

- Intrinsic motivation is described as "the doing of an activity for its inherent satisfactions rather than for some separable outcome" (Edward L Deci & Ryan, 2000). This type of motivation more often results in high quality learning and creativity.

- Extrinsic motivation is defined as "a construct that pertains whenever an activity is done in order to attain a separable outcome" (Edward L Deci & Ryan, 2000) this motivation is on the other hand easier to facilitate, but might not give the same high quality learning and performance.

STD is an empirical theory based around that all humans have the same psychological needs. The first need is "competence", which is to perform something while experience mastery and doing the task efficient and successfully. Second is "relatedness" which means connection with others and a sense of social belonging. Last, is the feeling of control over one's own actions and is called "autonomy". If these innate needs are satisfied, it facilitates for one's intrinsic motivation. The action done is then with a sense of full endorsement, which has consistently shown to be associated with good psychological health and effective performance. Extrinsic motivation is on the other hand considered to be associated with a feeling of pressure to behave a certain way (Edward L. Deci & Ryan, 2012).

A sub theory of STD is Cognitive evaluation Theory (CET), which argues that interpersonal events that refers towards the feelings of competence during an action can enhance intrinsic motivation for that action. Interpersonal events could be rewards, communications or positive feedbacks. This means that optimal challenges, promoting feedback and freedom from demanding evaluations are all predicted to facilitate an increase in intrinsic motivation (Edward L Deci & Ryan, 2000).

Ideal Performance State and Flow

The Ideal Performance State (IPS) is a mind/bodily state that consists of several feelings and bodily elements that all work together such that a task at hand most likely will be performed with high and accurate performance (Haff & Triplett, 2015). Some of these elements are high self-confidence, feeling in control, positive attitudes towards performance, being strongly determined and have an expectation of success (Haff & Triplett, 2015). IPS is how a person's mental state should be before an activity that demands good performance. A requirement to achieve this mental state is to know one self's potentials and limits. IPS can be trained to be achieved at will, but It's individual for what has to be done to achieve this state of mind (Harmison, 2011).

Another mental state like the IPS, is Flow. Flow occurs when a person is fully immersed in the activity at hand, in the degree of where sense of time and space is lost. This mental state is also commonly known as “being in the zone” (Csikszentmihalyi & Bose; Nakamura & Csikszentmihalyi, 2009). This mental state plays out when it is a balance between one’s skills and the difficulty of the challenge ahead. As the skills increases, the task could be perceived as less involving and boring. To maintain the state of flow, the challenge must increase in difficulty together with the skills. Conditions to achieve the flow state are clear proximal goals, immediate feedback and a balance between opportunity and capacity (Nakamura & Csikszentmihalyi, 2014).

When in the Flow state, the activity at hand is worked on to be mastered. The performer must be increasingly challenged to maintain the flow state, and the skills of the performer needs to improve accordingly. Tasks inducing flow state results in personal growth, and increase the feeling of competence, which is one of the physiological needs in STD. It’s documented correlations between high performance, reduction of anxiety, raise of self-esteem, and being in the flow state in different fields. One of these fields are sports (Jackson & Eklund, 2002; Nakamura & Csikszentmihalyi, 2014).

E-health

Health related technology is often described as Digital health or E-health (Thomas & Bond, 2014). New E-health technology has opened for massive collection of data related to health that was earlier only accessible in lab environments (Moller et al., 2017). Most of the data collected is from endurance (cardiovascular) sports such as cycling or running through devices like “FitBit” and “Apple Watch”. Less prevalent is the use of E-health technology for strength workouts, and there is thus smaller amount of collected data and development in the field of strength training. (O'Reilly, Whelan, Ward, Delahunt, & Caulfield, 2017). E-health devices often utilize some sort of biological data gathered from sensors and the most common one is heart rate. The data collected by the sensors is usually displayed like a visual feedback or stored and put in relation with data from other sensors like GPS, accelerometers, Inertia Motion Units and barometers.

Biofeedback

Feedback can be designed to help a person reach his or her goal by showing progression and performance, and ultimately enhancing the feeling of closing in on a goal. Having a goal to strive towards is motivational. The goal can provide the individual with a measure of a wanted “Excellent” performance, which he or she can judge his or her own performance against along the way. This reference of “excellent” performance motivates to alter the behaviour to get closer to the goal (Locke & Latham, 1994).

Biofeedback is a learning process where you improve general health and physical performance by observing signals generated by your own body. The signals monitored could be heart rate, brainwaves, muscle activity, electromyography (EMG), breath, sweat, electroencephalography (EEG), and more. These signals get converted to a sensorial, audible or visual element that is fed back to the user for interpretation. The user can then do the necessary physiological changes to alter the feedback information and learn to control it. Biofeedback is typically implemented in clinical situations for people who struggle to activate the right bodily functions, or to cure migraine and headaches (Association for Applied Psychophysiology and Biofeedback (AAPB), 2008). The recent development in wearable technology have opened many new areas for its use, also in healthy people. New use of biofeedback is believed to have good potential to optimize the training of athletes (Düking, Holmberg, & Sperlich, 2017).

Live feedback

Biofeedback in the form of a live graph showing muscular EMG activity has frequently shown to give a significant increase of maximal muscular strength when used during exercise (Brian, Carl, & Iris, 2000; Croce, 1986; Figoni & Morris, 1984). Experiments done with training programs over several weeks demonstrate that the performance increase on each session from the use of visual biofeedback is distinct and additionally results in greater strength outcome (Croce, 1986). Same results are also found when using torque or force sensors connected to the training apparatus, with a similar type of visual feedback (Figoni & Morris, 1984). The reason for the great increase in maximal strength could be due to the visual feedbacks motivational factor, making the individual exert closer to its true physical limit (Croce, 1986). Studies mentioned have used Isokinetic exercise machines for either concentric or eccentric movements. These machines give a controlled movement affecting few muscles, and the result might not be applicable to every strength exercise.

The Isokinetic exercise machines serve the possibility to set the angle speed of the strength exercise movement. With this setting on the machine, controlled studies on the effect of visual feedback compared with the speed of the movement have been conducted. The research on the field is minimal, but it is an agreement that when the velocity reaches a certain point the positive effect of the visual feedback diminish. Apparently, the human body won't have time to react to the feedback if the velocity of the performed strength exercise is too fast (Figoni & Morris, 1984).

Another use of Biofeedback that could relate to strength training is the use of EEG, which is a series of sensors monitoring brain activity. It has been shown that there is a difference between an expert athlete's EEG and non-experts, and the potential to use EEG biofeedback and training of one's EEG to provide sporting performance is possible. To fully manage to use EEG, the technology must be easier and more reliable such that it can be used during movement of the head and body. (Thompson, Steffert, Ros, Leach, & Gruzelier, 2008).

Gender

The effect on strength performance from visual feedback could be different between genders. Studies indicate it to be more effective on males. This could be because of the generic differences in competitiveness, perception of effort, and the effect of extrinsic motivators (Brian et al., 2000).

4. GAMIFICATION

Gamification of an activity or task is referred to as using some sort of game design elements in a non-game context (Deterding, Dixon, Khaled, & Nacke, 2011). Game design elements are for instance leader boards, rewards, points, progress visualisation, providing badges and use of avatars. The game design elements are the basic building blocks of gamification, and are designed to be active ingredients that make games addictive (Sailer, Hense, Mayr, & Mandl, 2017). To gamify an activity is to extract the addictive feature from games and put them in to activity platforms, such that the digitalized activity also gets addictive (Cugelman, 2013). The argument for gamification is that it will promote motivation and increase activity and interest for the gamified task (Deterding et al., 2011; Hamari & Koivisto, 2015).

Ingredients of gamification

Cugelman (2013) identifies seven core ingredients in gamification:

- Goal setting
- Capacity to overcome challenges
- Providing feedback on performance
- Reinforcement
- Compare progress
- Social connectivity
- Fun and playfulness

These elements are found to have an established connection with behaviour change strategies and are wide-ranging principles that makes gamification addictive and game design elements effective.

Context and users

Gamification has been verified to work to increase different types of performance, but seemingly only in the right circumstances and fields. The effect on performance is highly dependent on the role of the context being gamified, and the quality of the user (Hamari, Koivisto, & Sarsa, 2014). The goal of gamification is to increase the motivation of the user. If the Underlying motivation of the user is triggered by the gamification, the result might be good. However, If the user is not motivated at all beforehand, the game elements will not have any great effect.

Cugelman (2013) presents a table of criteria a designer should evaluate to determine if gamification of an intervention is preferred or not. Summarized, the criteria consist of evaluating the user's social context, assessing which psychological and behavioural outcomes are being pursued, how the intervention fits with the persuasive architecture of gamification, and the platforms compatibility with game strategies and tactics.

Game design elements

Badges and performance graphs are game design elements with good potential in relation to SDT, it is stressed that they have positive effect on competence need satisfaction, and perceived task meaningfulness (Sailer et al., 2017). This could again have a positive effect on performance due to the possible increase in intrinsic motivation as described by CET (Cerasoli, Nicklin, & Ford, 2014). But as gamification is a new area of expertise, good empirical data has yet to be improved. Evaluation so far show that game design elements of points, levels and leader boards can increase work performance in the sense of quantity done over a given time frame, but with no proven effect on increasing intrinsic motivation. The increase of work performance by gamification could therefore be due only to extrinsic motivation. Gamification does usually not impair the intrinsic motivation and can be seen as effective means for promoting performance quantity (Mekler, Brühlmann, Tuch, & Opwis, 2017). It is also mentioned that such elements does not facilitate for a long term effect, but work only for sparking an immediate interest in the task at hand, and if continuously used it is a good chance that the user will get bored (Nicholson, 2015).

Promotion of physical activity

Zuckerman and Gal-Oz (2014) evaluated the effectiveness of some game design elements for promoting physical activity. In their study "Deconstructing Gamification", they made an accelerometer based mobile application that logged walking and gave real time feedback on performance and updated goals according to goal setting theories. They made several versions of the application where the effect of using game design elements got tested. Elements used were virtual rewards, social comparison, daily goals and real time feedback. The study found significant positive correlation between daily goal and daily walking time, such that higher goals indicated greater walking time. The study emphasised a belief that gamification turns physical activity in to a more enjoyable experience, and therefore motivates for more activity. Interventions which encourage for self-monitoring of the activity were said to be most effective on activity performance.

5. DISCUSSION

There might be several reasons that sensor technology is less prevalent in strength related sports and exercise then in cardiovascular sports to this date. In strength training the sensors will have to recognise more complex movements to give an appropriate analysis of the exercise. The sensor needs to be able to log data from the whole body to give relevant information and valuable feedback of a strength exercise or session.

As the technology is leaping forward the use of biofeedback and sensor technology in strength training might be more and more prevalent. Feedback can now be given through smart watches and sensors could be everyday wearable. Biofeedback and sensor technology could affect the performance of strength training exercises in several ways. They can motivate the user during the exercise, structure training programs, generate goals, log improvements, tell you are fatigue, function as a visualiser of inaccessible bodily information, and even tell when an exercise is harmful for ligaments or is performed wrong. The potential is huge, but the research and technology is still lacking (Düking et al., 2017).

Gamification and feedback could be utilized on training equipment, so the user can easier reach his or her IPS before and during a training session. Every person has their own IPS, and by utilizing the right design elements it might be possible to help users achieve their right mental state and enhancing their overall performance. Gamification can also facilitate for flow and bring people to that state of mind during training (Deterding et al., 2011). To reach flow in a single strength exercise might be difficult, but it will be beneficial to design a product where flow is achieved.

Task motivation

Gamification and visual feedback implemented in a strength exercise system or equipment should also seek to improve one or more of the three core motivational elements from STD so the intrinsic motivation of the task at hand increases, and hopefully positively affect the performance (Mekler et al., 2017). To achieve this is a complex task. Depending on personal preferences can game design elements such as leader boards and badges, both hinder and increase motivation due to competitiveness and pressure from outside, as humans react different to these factors (Reeve & Deci, 1996).

According to Ryan And Desci's CET, there is ways to use extrinsic motivators to boost the intrinsic motivation by affecting the feeling of competence. This theory is supportive for gamifying a strength training system with elements such as optimal challenges, feedback that is positively oriented, and rewards (Edward L Deci & Ryan, 2000). It is also Important to use game elements so that freedom from demanding evaluations is maintained. This could mean that leader boards and comparison with others could hinder the intrinsic motivation.

Performance and motivation

Direct visual feedback through a graph while training is, as mentioned, proven several times to have an immediate effect on strength output performance. One major aspect is the motivational boost visual elements from biofeedback and sensors can give, making the user maintain a higher intensity closer to his or her physiological limit. Thus, further enhance the positive adaption of the strength training. It is stressed that a motivation boost is triggered by the realization of the informative content of the feedback (Croce, 1986), this informative feedback also helps already motivated subjects to define goals and levels of achievement (Figoni & Morris, 1984). This means that the use of (bio)feedback when designing for strength training can be effective on performance. Hence, if used correctly it can be considered as an effective game design element in a gamified strength training platform. Additionally, visual feedback has shown to work differently between genders, and this should be taken into consideration when designing informative feedback.

However, it is uncertain whether the use of feedback from EEG is effective on strength training or not. EEG cannot be used as a single feedback stream such as EMG due to its complexity, but as there is a difference between professionals and non-professionals EEG, it is believed that EEG could be used to learn skills faster and activate the right muscles during an exercise (Thompson et al., 2008). Future research needs to prove this and is also needed to utilize the technology in training systems and equipment.

Velocity of movement

If a training platform is solely for fast dynamic movements, it is hard to utilize the benefits of direct visual feedback. The movement is usually so fast in such exercises that the user will not have time to interpret and make use of the feedback. However, saving feedback data for later reference and interpretation will be good for visualising progression and motivate the user to put in an extra effort in the next set. A strength training platform utilizing direct visual feedback should facilitate for a greater span of exercises, and make sure that not all exercises require dynamically fast movements. Studies on verbal encouragement have also shown to be effective on strength training performance (Brian et al., 2000). Audible feedback could be of use in collaboration with visual feedback, or alone if the user won't be able to see the information given during exercise.

Strength training and feedback

When doing MST, the intensity must stay high on few repetitions to give wanted results. To utilize visual biofeedback on such training routines could be very effective (Croce, 1986). The rests should be long, and the volume small. If the training goes over to endurance strength, the effect is more uncertain as it is lover intensity and higher volume, and the motivational effect to exert with greater force diminishes. Interesting to research further is If biofeedback actually could give a positive motivational effect when used during exercises with lower intensity and higher repetitions.

Which optimal form of feedback that could boost motivation and increase performance also remains to future research (Figoni & Morris, 1984). Most of the experiments done on the use of visual feedback in strength training is with data from EEG or torque sensors, which is shown as a simple graph. There might be other more effective ways to give the feedback from sensor values, for example vibration, heat, light or smell could be fed back to the user.

Evaluation of gamification criteria's

If we evaluate Brian Cugelman's gamification criteria's in relation to the research question (Cugelman, 2013), it is indicated that the use of gamification does not imply increase in strength training performance in all situations. It depends a lot on the users doing strength, the context being gamified and their motivation for it. To gamify a strength exercise might be useless if it is a very simple machine with little compatibility to game strategies and tactics, and few uses that won't affect any behaviour outcome. If the strength training platform is a more complex machine that could be used for several exercises and that can be used solely on a single strength session, the compatibility with game design tactics and strategies will be more prevalent, and the effect on the performance might increase.

Brian Cugelman also emphasises that gamification only has its merit when used in the right way, under the right circumstances. It is highly important that designers and developers seeking to utilize gamification, need to understand its limits, and make well evaluated decisions if it will be effective on the given activity (Cugelman, 2013).

Sensor technology could facilitate for self-monitoring and is an argument for the possible effectiveness of gamification on physical activity. An issue is to keep the gamification motivating over a longer term. To do this Zuckerman and Gal Oz advise to design "novel ubiquitous measures, intending to facilitate for reflection on meaningful aspects of physical activity" (Zuckerman & Gal-Oz, 2014). Other ways to keep gamification motivating and effective over a longer term is to design the system as a journey, with long term goals and slow transitions over to the real world (Nicholson, 2015).

6. DESIGN RECOMMENDATIONS

The research done herein highlights some recommendations for the design of a new and sensor-based strength training platform. The use of direct visual or audible feedback could motivate the user and enhance the performance during exercise and is a good element to use. The feedback should be direct and give data that is possible to manipulate during the exercise. Especially for Maximal Strength Training the application of such direct feedback should be considered. For explosive strength and exercises involving fast movements, the direct feedback might not work as a motivator during the action, but rather as an analysis tool for later reference and helper in setting valuable goals.

The use of gamification could also have its merits when designing a new strength training platform. Especially if it is a more complex platform with several uses that can facilitate for a complete strength training session with different exercises. Such a platform should consider elements designed to show progression, makes self-monitoring possible, helps in setting the right goals, induce flow and motivate for further use. All these elements should then help the user to achieve his or her Ideal Performance State, and help triggering the user's intrinsic motivation. Other elements that triggers a person's competitiveness and self-comparison with others should be more carefully used as it is highly dependent on the user if it will give a positive or negative effect.

The use of points, levels and rewards in a gamified system is said to most likely hinder the potential of long-term effect of the gamification, and eventually resulting in the user getting bored by the system. To use those game design elements needs to be carefully considered. If the main goal is to make the user engaged in the platform these game design elements can be considered. If the main goal is to develop a product with positive long-term effects, the elements should be avoided or toned out.

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