Developing Compelling Repetitive-Motion Exergames by Balancing Player Agency with the Constraints of Exercise

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ABSTRACT
Participation rates in repetitive-motion exercise programs, such as programs for muscle-strengthening and physical rehabilitation, are low. Exergames show promise in encouraging people to exercise, but it is challenging to build compelling games around repetitive exercises. Games involve players making meaningful choices, but repetitive-motion workout programs are rigidly structured, making it difficult to find opportunities for such choices. As such, there is a struggle between providing players with meaningful choices and meeting the constraints of the exercise program. We discuss methods for enhancing agency in repetitive-motion exergames while still meeting these rigid constraints. We illustrate these methods through *Brains & Brawn*, a novel strategy card game for muscle-strengthening. Playtesting with eight participants demonstrated that players experienced agency during gameplay, were incented to exercise with correct form, and showed favorable attitude toward the game.

Author Keywords
Game design; agency; repetitive exercises; exergames; physical rehabilitation; muscle-strengthening; strength training; resistance training; exercise prescription.

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INTRODUCTION
Repetitive-motion exercise programs are characterized by many repetitions of the same movement, typically following a workout plan [9] or exercise prescription [34]. Examples include strength training, where participants perform a planned workout involving exercises such as deadlifts, shoulder presses, and squats [49], and rehabilitation exercises where people repeat movements to improve balance [73] or range of motion [28, 73]. Despite important benefits to health and daily living [13, 25, 66, 73], participation rates in strength training and compliance to rehabilitation programs are woefully low [11, 29, 55, 68]. For instance, Carlson et al. found that only 21.9% of U.S. adults met the muscle-strengthening requirements of the 2008 Physical Activity Guidelines for Americans [11].

Exergames have been proposed as a way of motivating people to perform physical exercise. There has been considerable success in the design of exergames for meeting cardiorespiratory guidelines and for promoting anti-sedentary behavior [9, 27, 37, 38, 41, 57]. Developing exergames for repetitive-motion exercises has proven more challenging. Repetitive-motion exercises offer little choice in how or at what pace they are performed – a workout plan might specify that a person perform three sets of 8-12 squat exercises at a slow and controlled pace. Because the exercises must be performed in a specific manner, there is little opportunity to introduce agency in gameplay, allowing players to choose between different meaningful courses of action. Consequently, designers of repetitive-motion exergames have had to choose between providing players with opportunities to make meaningful choices and providing players with high quality exercise.

In this paper, we show how it is possible to address this lack of agency in repetitive-motion exergames. In order for players to be able to make meaningful choices in these games, we propose three game design techniques that balance agency with the constraints of repetitive-motion exercises. Specifically, agency can be enhanced by providing rich gameplay during rest breaks, by using player form as a game mechanic, and by judiciously providing *illusion of agency* when real agency is not possible.

We illustrate these methods through *Brains & Brawn*, a novel card game in the style of *Hearthstone: Heroes of Warcraft* [8] and *Pokémon* [45] developed for people with little or no experience with muscle-strengthening exercises. Results of playtesting with eight participants lend confidence that these methods provide an engaging game while meeting the constraints of repetitive-motion exercise programs. Participants used a variety of strategies, demonstrating the agency provided in the game. Players' exercise form improved over the game, indicating the success of using exercise form as a game mechanic. All participants reported

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having enjoyed the game, and the majority stated that they would participate in a muscle-strengthening program using *Brains & Brawn*.

The remainder of the paper is structured as follows. We first review the importance of agency in games, highlighting challenges of introducing agency into both traditional games and repetitive-motion exergames. We further show how *illusion of agency* can be leveraged to hide a lack of agency. We then discuss how *Brains & Brawn* balances agency with the constraints of repetitive-motion exercises. Finally, we detail the results of our exploratory user study and conclude with takeaways for designers and a summary of our findings.

AGENCY

Repetitive-motion exercises, such as for muscle-strengthening and physical rehabilitation, require the same movements to be performed over and over again in a precise manner. Workouts involving repetitive exercises are typically prescribed by a specialist, such as a personal trainer or physical rehabilitation therapist [9, 34]. These include physical rehabilitation programs for calf rehabilitation [50], for shoulder rehabilitation [22, 28], and for post-stroke rehabilitation [3, 4, 10]. These also include workouts for strength training programs [9, 32]. Unfortunately, adherence to these exercise programs is low [11, 29, 55, 68]. Preliminary evidence has shown that games can help with enjoyment of programs involving repetitive exercises [1, 3, 4, 6, 10, 20, 21, 22, 28, 33, 53, 63]. Participants perform these exercises at a specific pace, with a specific exercise form, and following a rigid prescription consisting of x sets of y repetitions of z exercises. This limits players' physical actions, making it difficult to provide players with agency in games developed for these exercises.

Agency and Its Importance to Games

Agency is the ability to act in a given environment; in its simplest form, agency comprises the choices players can make in a game world. However, in games we expect more of agency than simply providing players with choices. For instance, Janet Murray, author of *Hamlet on the Holodeck*, believes that "agency is the satisfying power to take meaningful action and see the results of our decisions and choices" [42]. Similarly, Sid Meier, creator of the *Civilization* [40] game franchise, has stated that a "game is a series of interesting decisions" [52].

Agency is a crucial component to games. Domsch argues, "The appeal of games lies in their promise of agency, in the promise of an openness that is dependent on the player and her choices" [15]. It is also what separates games from other forms of entertainment media, such as movies and novels [15], in which people can only passively experience the world. In movies and novels, people cannot step inside the story and alter it, but in games players are active participants of the world around them, able to interact with it and make meaningful choices that alter the state of that world [42].

But what makes a choice meaningful? Mateas argues that agency is experienced when actions that *cry out* to be taken in a game (formal affordances) are balanced with the raw materials to perform these actions (material affordances), and a decrease in agency occurs when these properties are imbalanced [39, 70]. Thompson et al. describe four elements of perceived agency: foreseeability, ability, desirability, and connection [19, 60, 61]. Then, meaningful choices are compelled by the design of the game and enabled by actions made possible for the player. They are choices with an outcome that is desirable, foreseeable, and perceived to be connected to the choice the player made.

Different game genres provide agency in different ways. Agency exists as the choices and consequences of the player's tactics in strategy games. It is what allows the player to choose which enemy to target with what weapon in shooter games. It provides the option to choose which character abilities to enhance in role-playing games.

Agency Challenges in Games

Providing agency can compete with other game design goals. For instance, game designers often face a struggle between giving players agency and providing a cohesive story. A linear story provides a singular view of events, but "[t]he desire for agency in digital environments makes us impatient when our options are so limited" [43]. On the other hand, the high cost of development means that branching games must at some point constrict players to one of only a few paths, perhaps rendering the choices that the player has made up to that point meaningless.

This is exemplified in *Deus Ex: Human Revolution* [18]. The game provides many options for completing quests, such as choosing between violent and non-violent solutions, but eventually forces players to face enemies using only one, violent, option. This is "highly jarring with the freedom that the rest of the game allows and that has been a constant focus of criticism in the initial reviews" [15].

Game designers can also face a struggle to provide agency while adhering to the game's planned narrative. For example, Diane Carr notes that in *Baldur's Gate* [7], the player character's mentor must be killed as part of the game's narrative. However, the game does not allow the player to kill the mentor any earlier than that point, even if the character has been developed to be evil [35].

Solving this issue takes careful consideration of the game design and the cost of implementation. The authors advocate considering what happens when tasks are completed in unexpected orders, that not all players develop the same character, and that when possible, the story should be able to advance without limiting agency [15, 35, 43].

Agency Challenges in Repetitive-Motion Exergames

Designers of exergames face the particular struggle of providing agency while meeting the constraints of the exercise. For instance, games for cardiorespiratory exercise must find ways to provide players with agency while

incenting proper exertion levels [30] and preventing overexertion [56]. Repetitive-motion exercises also have constraints that limit opportunities for agency. These include maintaining a slow and controlled pace, ensuring players exercise with correct form, and meeting an exercise prescription.

Slow and Controlled Pace

The success of cardiorespiratory exergames has been due, at least in part, to a straightforward mapping of activities such as cycling, running, or jumping to avatar movement in the game, such as in the Liberi exergame, where pedaling a stationary bicycle powers the movement of an avatar [26]. Mapping real-world movement to in-game actions can be dangerous for muscle-strengthening exercises and is inappropriate for some physical rehabilitation exercises. For example, performing load-bearing exercises at a high speed in order to make an avatar go faster could lead to injury. Game designers must ensure that repetitive-motion exercises are performed at a slow and controlled pace [12].

Correct Exercise Form

Repetitive-motion exercises should also be performed in a precise manner. When performing a bicep curl, for instance, only the biceps should be used to curl the weight. Modifications of many exercises exist, such as varying a bicep curl by alternating which arm is lifted each repetition. But, the exercise must still be performed with precise form for safety. In this case, knees should be slightly bent, wrists should remain stationary, and the hips and back should not assist in lifting the weights [14]. However, like in a gym environment, players have real-world agency in how they perform the exercise. During the game, players may choose to exercise poorly, simply to get the exercise out of the way and return to the more game-like elements. Game designers are tasked with finding ways to incent players to perform exercises with correct form.

Following an Exercise Prescription

In general, repetitive-motion exercise programs require that a specific number of exercises be performed. Novices generally follow the prescription rigidly. Experts may know how to swap out exercises while receiving the same benefit. Ultimately, though, even experts still have to perform a rigid set of exercises to meet their workout goals. Following a rigid prescription provides people with little or no opportunity for agency around choice of exercise. Agency in games relies on people having choices around what actions to perform next, and is therefore difficult to provide when the next action is dictated by the exercise prescription. Thus, game designers must consider how play of the game will guarantee that players perform exactly those exercises required of the prescription. Otherwise, players might not complete the prescription (game ends early), or might perform more exercises than prescribed (game ends late).

Agency in Existing Repetitive-Motion Exergames

Existing repetitive-motion exergames follow three basic designs: favoring high quality exercise over gameplay, favoring gameplay over quality of exercise, and aiming to blend high quality exercise with compelling gameplay. Little attention, however, has been given to granting players agency while meeting exercise requirements.

High-Quality Exercise Approach

Commercial repetitive-motion exergames have generally favored exercise quality over game quality. These games have been primarily developed for muscle-strengthening exercise programs and include *EA Sports Active: Personal Trainer* [17], *Nike+ Kinect Training* [58], *Your Shape: Fitness Evolved* [64], *UFC Personal Trainer* [26], and *Wii Fit U* [44]. Although they use game mechanics, such as providing scores, these are not games in the traditional sense. Instead, they are interactive fitness products that provide digital support for traditional workouts, for instance, using sensors to track exercise form.

To provide high quality exercise, these products omit or significantly reduce traditional game elements, such as agency. Their primary goal is to replicate a gym environment by, for example, including a gym backdrop and providing a digital exercise trainer to give instruction and encouragement. Typically, the goal is to match the movements of the trainer, which helps to accommodate a slow and controlled pace. Additional points are awarded for more closely matching the trainer's movements, incenting the player to perform the exercise with correct form. The games also typically provide players with a workout plan to follow. But, there are no interesting decisions for players to make; they simply mimic the trainer's actions.

Compelling Game Approach

Another commercial repetitive-motion game, *Shape Up* [65], takes a game-first approach at the expense of being a useful exercise tool. It embeds workouts into a suite of mini-games, connected by an overarching story. Little attention is given to providing high quality exercise. For instance, one of *Shape Up*'s mini-games, *Squat Me to the Moon*, encourages players to perform squats at an unsafely fast speed. Players compete against one another, performing squats as quickly as possible to reach the moon first. Despite the game-like appearance, *Shape Up* is primarily skill-based; little agency is given to players, who are instead simply following instructions and awarded points based on how well they follow these instructions.

Balanced Approach

Numerous physical rehabilitation games have sought to find a balance between compelling gameplay and quality of exercise [1, 3, 4, 6, 10, 20, 21, 22, 28, 33, 53, 63]. These games include Sayenko et al.'s *Blockade* [23] variant for calf rehabilitation, where the direction of a digital snake is controlled by tilting the foot [53] and Alankus et al.'s series of games for stroke rehabilitation [3, 4]. In one of Alankus et al.'s games, the tilt of the player's torso controls the tilt of a hot-air balloon, which players navigate to reach different on-screen targets [4]. Geurts et al. developed several games for

physical therapy, such as a game in which players move their hand to catch virtual dishes [21].

The authors of these games have noted that repetitive tasks are simultaneously highly important to exercise and highly difficult to motivate people to do [4, 21, 54]. Nevertheless, these projects provide little advice on how to develop a compelling repetitive-motion exergame. Sayenko et al. simply note that the "trade-off between enjoyment of the game and therapeutic benefits must be carefully weighed when designing both hardware and software for rehabilitation" [54] Abeele et al. suggest avoiding time dynamics (e.g., completing tasks within a certain amount of time or hitting targets/pressing correct buttons at the right time) to provide what they describe as "slow fun" [1]. More closely tied to agency, Burke et al. note meaningful play and challenge as two principles of relevance to rehabilitation games [10]. However, they describe meaningful play as providing feedback for choices players make in games; they do not give advice on how to provide players with choices in the first place [10].

Gotsis et al., in their development of *Skyfarer*, provide more concrete game design advice, including weaving the exercises into a coherent narrative in a similar manner to *Shape Up*'s approach [22]. *Skyfarer*, a game designed to address shoulder pain in people suffering from spinal cord injuries, provides engaging gameplay involving a variety of exercises. However, the game achieves this through heavily scripted progression and limited player agency.

Illusion of Agency

Game designers should, and frequently do, attempt to overcome the challenges of incorporating agency in games. However, providing agency is not always possible. This could be due, for instance, to the constraints of narrative discussed earlier or due to the problems with permitting agency in repetitive-motion exergames. An approach that can aid such situations is to provide *illusion of agency*.

Illusion of agency grants players a perception of control in situations where their actions actually have little to no consequences in the game. In general, games use illusion of agency to disguise a lack of agency or to provide emotional experiences via a sense of control in primarily narrative situations. For example, Troika Games' *Vampire: the Masquerade – Bloodlines* [62] uses illusion of agency to disguise their linear storyline [35]. Players can choose from numerous character types and abilities, but these choices have little effect on the game's outcome [35]. Also, dialogue options with non-player characters provide restricted choices that rarely affect the game state, but their immersive presentation lead players to believe their choices matter [35]. Rockstar Games' *L.A. Noire* [51] similarly relies on immersive interaction with non-player characters to hide a linear storyline [15].

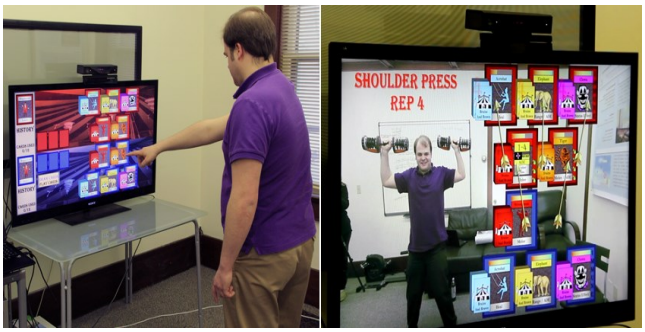

Figure 1a (left). Strategy Mode: Player controls game using gesture controls. Figure 1b (right). Combat mode: Player attacks enemy (arrows flying to enemy) while exercising.

Metal Gear Solid 4 [32] demonstrates how illusion of agency can enhance a narrative while immersing players in the game world. At the end of the game, the protagonist, Snake, must progress through a tunnel filled with deadly radiation. It is implied Snake will die if he does not make it through the tunnel quickly enough [15, 59]. The player controls Snake's progress through the tunnel, but he will never die, regardless of the player's actions. This use of illusion of agency led players to feel that "their actions were meaningful and the game was enjoyable" [59].

Half-Life 2 [67] also used illusion of agency to provide an emotional experience [15, 59]. In one scene, the player must defend a base against alien enemies. However, the amount and skills of the enemies is biased to ensure that the player will not lose. This gives the player a feeling of heroism without being able to fail [59].

Illusion of agency should be used judiciously because it can lead to negative experiences if players feel they have been deluded into believing their actions have more impact than they actually do [59]. To prevent this, illusion of agency may be combined with real agency. For instance, one way *Vampire: The Masquerade – Bloodlines* hides its linear story is by giving actual agency in quests that players complete along the way [35]. Giving players choices in smaller aspects of the game reduces their concern with being able to make bigger, game branching choices.

BRAINS & BRAWN

We designed *Brains & Brawn*, a novel muscle-strengthening strategy card game in the style of *Hearthstone: Heroes of Warcraft* [8] and *Pokémon* [45], to illustrate how to grant players meaningful choices while incenting high quality exercise. *Brains & Brawn* was developed using an iterative design process, starting as a paper prototype that was playtested for balancing and fun. The game was then converted to a digital version. Three prototype versions were tested using different control schemes: gesture (see Figure 1), voice, and mouse. Ultimately, the prototype using mouse controls was selected for reliability.

Figure 2. Brains & Brawn user interface. The player has just played an area of effect card on the enemy's acrobat.

Figure 3. Example of a melee attack card in Brains & Brawn

Brains & Brawn uses three techniques to enhance agency and meet a prescription: (1) providing strategic agency during rest breaks, (2) using player form as a game mechanic, and (3) applying illusion of agency around choice of exercise. The game provides two modes of play; *strategy mode* provides strategic agency during rest breaks, and *combat mode* provides real-world agency during exercises. The game rewards exercise form by tying exercise quality to damage/healing amounts; this incents players to choose to exercise well. Finally, *Brains & Brawn* judiciously provides illusion of agency around exercise choice.

Brains & Brawn was designed as a turn-based card game in order to accommodate a slow and controlled pace of exercise. The player controls a team of characters with distinct abilities, playing against a similar team of AI-controlled characters. Each turn, the player plays a single card from their hand, allowing them to attack one or more opponents or to heal one or more allies (see Figure 2). In strategy card games, combat is typically resolved automatically when a card is played. In *Brains & Brawn*, play of a card requires the player to perform repetitions of an exercise displayed on the card (e.g., when using the card in Figure 3, the player must perform a set of shoulder presses).

To meet the required number of exercises to fulfill an exercise prescription, *Brains & Brawn* is designed to end exactly and naturally when a prescribed set of exercises has been performed – the player has a fixed number of turns to defeat their opponent by reducing all enemy characters' health to zero. The player has a hand of three face-up cards from which they can choose each turn. At the beginning of the turn, if the player has fewer than three cards in their hand, they select cards from their choice of character decks. Themed around a circus, each of the player's characters specializes in a particular form of combat — e.g., the *strongman* specializes in melee combat, the *clown* specializes in spells, and the *acrobat* in healing.

Providing Strategic Agency during Rest Breaks

Repetitive-motion exercises involve a repeated pattern of exercise, rest, and then more exercise. Rest breaks provide an opportunity for rich gameplay in which players can choose between different tactics. *Brains & Brawn* provides two modes of play, a strategy mode and a combat mode. During rest breaks, players enter strategy mode, where they have full agency in executing an attack against the opposing team. Players choose their next card from one of five

available character decks (see Figure 2), choose which of three cards from their hand to play next, and choose which enemy to target. Drawing from different decks results in different game actions, including spells, melee attacks, ranged attacks, and healing. Giving players a choice of distinct decks to draw from, a choice of cards to play from their hand, and a choice of characters to target allows the player to use a variety of gameplay tactics.

Once a card is played, gameplay enters combat mode, in which the player either fights enemies or heals allies (see Figure 1b). Strategy game elements are hidden and replaced with a mirror image of the player captured from a Kinect camera. This allows the player to track their exercise performance, aiding in adjustment of form. The player carries out the exercise listed on the card they played (e.g., a set of shoulder press exercises with dumbbells.). Once the exercise set is complete, the AI team takes a turn, following which the player returns to strategy mode.

This use of two modes grants players agency throughout the entire game, providing different types of agency during breaks between exercises and while exercising. Providing meaningful strategic choices during rest breaks allows the player to concentrate on the game during a time when they are not also having to focus on exercise form. During combat mode, however, players focus on exercising, and the player's real-world movements determine the outcome.

After each repetition of an exercise performed in combat mode, feedback is provided to maintain immersion. Damage or healing is applied, and visual and audio effects show the result of the action in real time. Sound effects accompany attacks on enemies and healing of allies; visual feedback shows the amount of damage or healing done. This mode provides exciting, real-time combat, while incenting correct exercise form by closely binding a player's movements to game consequences.

Player Form as a Game Mechanic

People can choose how well to perform exercises. Exercising with correct form leads to the best improvement in strength, balance, or range of motion. But, people may choose to perform exercises poorly because it may be less tiring, because they do not know how to correctly perform the exercise, or because they are embarrassed to lift weights that are lighter than those used by people exercising around them.

In *Brains & Brawn*, we translate this real-world agency into a game mechanic. *Brains & Brawn* rewards players for the quality of their exercise. Attack damage, healing amounts, and the chance of casting spells are bound to exercise form, incenting players to perform exercises correctly. In the current implementation of the game, form is evaluated using a Wizard of Oz design. Players are led to believe that a Kinect sensor is evaluating form; however, a trainer is using a separate application that records form and sends the results to the game.

After playing a card, players perform the exercise that is shown on the card (see Figure 3). The quality with which the exercise is performed determines the effectiveness of the card. Each repetition of the exercise does damage or healing based on the player's form; in the card shown in Figure 3, poor form earns 5 points of damage versus the target enemy, while excellent form earns 20 points. By combining this incentive with real-time aural and visual feedback, the game practically, as Mateas describes, *cries out* for the exercise to be performed well [39].

Illusion of Agency around Exercise Choice

Repetitive-motion exercise programs provide little to no agency around what exercises are performed during workouts. *Brains & Brawn* shows how the judicious use of illusion of agency can mask this constraint. As detailed earlier, illusion of agency can be provided to enhance cinematic experiences or to disguise the fact that there is no real agency. Illusion of agency can backfire, however, if players feel that they are being manipulated or tricked. *Brains & Brawn* avoids this problem by combining illusion of agency with real agency around exercise choice.

The cards in *Brains & Brawn* have an exercise component and a game component; for example, the card in Figure 3 pairs a shoulder press exercise with a "Bite" attack. Players perform the exercise displayed on the card, which triggers the game action (e.g., the Bite attack). When players draw a card, they get to choose which deck to take it from, influencing the type of game action that will be provided. For instance, the acrobat deck has healing cards, and the strongman deck has melee attack cards. Thus, drawing a card involves true agency in the form of a strategic choice.

This agency does not extend to the exercise component of the card, however. The order of exercises is determined at the beginning of the game to ensure the exercise prescription is met. For example, if the player is due to receive a *bicep curl* exercise, then no matter which character deck the player draws from, the card will have *bicep curl* as its associated exercise. The order of the exercises drawn is fixed, but players are unaware that no matter what card they draw, that card will contain the same exercise. As described by Harrigan et al. and Thompson et al., this gives players a perception of agency [24, 60], while ensuring that the correct number of sets of each exercise is performed over the course of the game. We consider this to be a judicious use of illusion of agency, since the action of drawing a card combines true agency in the choice of attack type with illusion of agency in the choice of exercise.

In addition, players retain limited agency in which exercise to perform next. When the player draws a card, it is placed in the player's hand. Players choose the next card to be played from one of the three cards in their hand. This grants the player some choice in what exercise to perform next, among those listed on the cards in their hand.

EVALUATION

We conducted a user study to determine whether the design of *Brains & Brawn* resulted in an engaging game that met the constraints of repetitive-motion exercise. We addressed the following research questions:

RQ1: Did our focus on agency lead to players experiencing agency through gameplay?

RQ2: Will making player form a game mechanic influence the players' agency toward exercising with correct form?

RQ3: Would players want to take part in a muscle-strengthening program using *Brains & Brawn*?

To address these questions, we conducted a study in which participants played the game while carrying out a prescribed workout involving four sets of three exercises.

Demographics and Inclusion Criteria

Eight participants were recruited from Queen's University. Inclusion criteria included being 17-25 years old, having little to no experience performing muscle-strengthening exercises, and being experienced with strategy card games such as *Hearthstone* [8], *Magic: The Gathering* [71], or *Pokémon* [45]. Participants were screened for suitability to exercise using the 2014 Physical Activity Readiness Questionnaire (PAR-Q+) [69]. Participants had a median age of 21; two were female, and six were male.

Responding to a demographic questionnaire, a majority of participants reported that they did not feel that they fit in with other people who train with weights at the gym (5/8), were unfamiliar with gym equipment (5/8), found muscle-strengthening exercises boring (6/8), and did not have time to start or adhere to a muscle-strengthening program (5/8). All participants reported living close to a facility where strength training exercises could be performed and having social support for participation in a muscle-strengthening program. No participant reported having bad experiences in the past with strength training exercises. Three of eight participants reported they were worried about potential injury from performing strength training exercises, two of eight reported that they did not find muscle-strengthening exercises important to them, and one participant reported that muscle-strengthening exercises are too intense. As people who are largely unfamiliar and uncomfortable with strength training, these participants represent the group for which *Brains & Brawn* was designed.

Procedure

The participant filled out a demographic questionnaire and completed the 2014 PAR-Q+ [69]. The participant was asked to read a letter of information and sign a consent form. The game was demonstrated and described. The participant was informed that during the game four sets of three exercises would be performed: bicep curl, shoulder press, and squat. A kinesiologist then instructed the participant in how to perform these exercises. These exercises were selected to be representative of a beginner's strength training program and to vary the muscle groups being worked. The participant was informed that they had a goal of 8-12 repetitions per exercise.

The participant was informed that they could ask questions related to the game or exercises at any time. The participant then performed a three-minute warm up by cycling on a recumbent bike as preparation for exercise.

The participant performed a total of twelve exercises over the course of the game (see Figure 1b). Players' combat effectiveness was based on the quality of their form. Participants were led to believe that form was assessed automatically by the game. In fact, a kinesiologist evaluated form and entered it into the game using an interface on a tablet computer connected to the game via a wireless network. Form was rated on a scale of one of four. Exercise statistics, including the form rating, was logged for every repetition of each exercise during the game.

Upon completion of the game, the participant performed a two to three-minute cool-down by either walking or cycling on a recumbent bike. We then conducted a semi-structured interview to obtain participants' impressions of the game. Finally, the participant completed an affective attitude questionnaire [48] to gauge the likelihood of their playing such a game in the future were it available to them.

Measures

The semi-structured interview addressed whether the participant enjoyed the game, whether the game incented the participant to focus on correct exercise form, what tactics they used, and whether they would participate in a strength training program that uses this game. Interviews were approximately three to five minutes in length.

Participants completed Rhodes' affective attitude questionnaire [48], based on Ajzen's theory of planned behavior [2]. This questionnaire has been applied to both general exercise [46, 47] and exergaming [48]. The theory of planned behavior suggests that people's behavior is influenced by their attitudes toward the behavior, their subjective normative beliefs, their perceived behavioral control, and their intention to carry out the behavior [2]. The questionnaire consists of twenty, 7-point Likert-scale questions assessing these influences. Participants played the game once, but using the standard affective attitude questionnaire, questions were phrased in terms of using the game over the next six weeks.

RQ1 was addressed by the semi-structured interview. RQ2 was addressed primarily by the semi-structured interview and also by quantitative analysis of game logs that recorded the form for each repetition of every exercise. RQ3 was addressed primarily by Rhodes' affective attitude questionnaire [48]. The affective attitude component of Ajzen's theory of planned behavior was further addressed by the post-game interview questions, "Did you enjoy the game," and, "Do you feel this game would make strength training more fun or more approachable?" The intention component was further addressed by the semi-structured

interview question, "Do you feel that you would participate in a strength training program that used this game?"

RESULTS

Our results showed that players experienced agency through gameplay (RQ1). Players chose to exercise with correct form (RQ2). Also, players had positive attitude, perceived behavioral control, and intention toward *Brains & Brawn* (RQ3). In the subsections that follow, statements are based on a majority finding of participants, while individual quotes are used to illustrate.

RQ1: Players Experienced Agency during Gameplay

In addressing RQ1, our semi-structured interviews revealed that players experienced agency during gameplay. As we have argued, agency separates passive entertainment, such as reading a book, from active engagement. Thus, to experience agency, players should believe they are active participants in a game. The interviews revealed this to be the case.

For instance, P8 stated, "[I]t actually looks like a game. So, I'm not feeling that I'm doing some exercise; I'm feeling I'm playing some game to beat my opponent." Also, P3 and P4 placed *Brains & Brawn* in the same genre as other strategic card games. P4 noted, "I like the whole setup of the game. It's kind of like Yu-Gi-Oh. It's just really fun." P3 noted that she liked the game because, "I like card games."

Agency was also illustrated through strategic differences between players. The interviews showed that players were actively engaged in game decisions, deployed a variety of strategies during gameplay, and looked forward to deploying other strategies. P6 detailed his gameplay strategy: "My strategy was get rid of their healer first, and then attack the back line, and then worry about the front line." However, he might change that strategy on a second play of the game, indicating that "playing it through a second time I would have a better idea of which characters can do what." Other players were thinking of how they would change their strategy in future play. P3 stated, "[I]f I played again, I'd probably use the clown a lot more." This is in contrast to P4's play style, who said, "I wouldn't use the poison one, the clown, for instance."

Because players have a choice of three cards to play from their hand, each of which had an associated game action and exercise to perform, we were also interested in whether players' choice of what card to play next was driven more by gameplay concerns or by the exercise they would need to perform to play the card. This would give a sense of how immersive they found the game and how important they found strategic decisions to the game's outcome. For instance, favoring game actions over exercise likely indicates immersion in gameplay.

We discovered that while game objectives factored dominantly into players' strategies, the exercise required sometimes played a role. P2, P3, and P5 reported that they based strategy primarily on game objectives. P3 explained that he "wanted to win the game. I wasn't really looking at the exercises until I was doing them." P5 only used the game objectives to form a strategy, and the exercise was seen as a bonus instead of a deterrent. P5 reported, "The in-game stuff was what I was thinking about mostly, and then, whichever exercise on the card that I drew was an added bonus, like, if it was one that I thought I was better at." P4, P6, and P7 used the game objectives to form a strategy, but exercise played a larger role, particularly when deciding between two cards. In this case, P4 reported that, "I would just do the one that was least tiring because maybe I did squats for fifteen reps, and I don't want to do that again". No participant reported basing strategy solely on the required exercise.

RQ2: Players Chose to Exercise with Correct Form

People have real-world agency in how they perform exercises. External factors, including social factors such as being a novice to strength training surrounded by expert bodybuilders in a gym, can influence whether they choose to perform them safely. One of our primary goals with the development of *Brains & Brawn* was to incent players toward correct exercise form, influencing agency in a way that was compelling instead of a deterrent to gameplay. We exploited players' real-world agency by making player form a game mechanic in *Brains & Brawn*. We hypothesized that binding healing/damage amounts to exercise quality would incent players to use correct form. We further conjectured that combining this with real-time aural and visual feedback to the player would, as Mateas describes [39, 70], *cry out* for players to exercise safely.

Our primary source of evidence for RQ2 was the semi-structured interviews, which supported our conjectures. We asked participants if they felt the game helped them focus on their form. All participants reported that the game incented them to exercise correctly. P6 reported that "with the audio and the visuals, seeing live if you need to improve on your form, I think that live feedback was really good." P1 noticed that some exercise forms would earn more damage, "and I tried to fix [exercise form] in the same exercise, in the same attack." P3 "wanted to do more damage so I could win." P7 recognized that "I didn't bend my knees for one of them and as soon as I bent my knees, I did the most [damage]."

While the semi-structured interview is our primary source of evidence that players were incented to exercise with correct form, exercise form was also rated for each repetition by a kinesiologist and recorded in game log files. A simple linear regression was calculated to predict exercise form based on repetitions performed over time. A significant regression equation was found ($F(1,150) = 155.446$, $p < .001$), with an R^2 of .509 (see Figure 4). The results of this regression imply that the players' desire to improve their form did indeed lead to improved form.

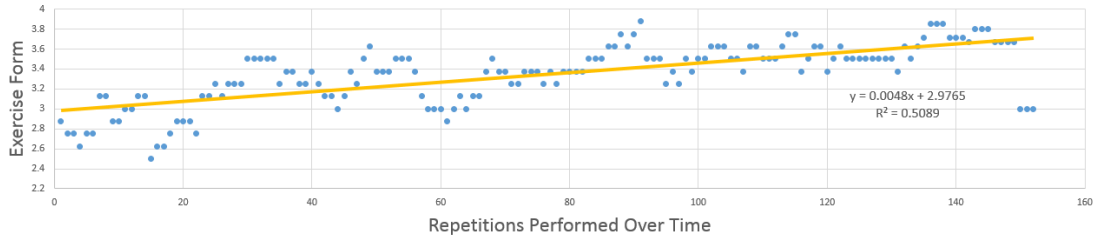

Figure 4. Graph of all participants' form ratings in a single play of the game shows that exercise form improved over time.

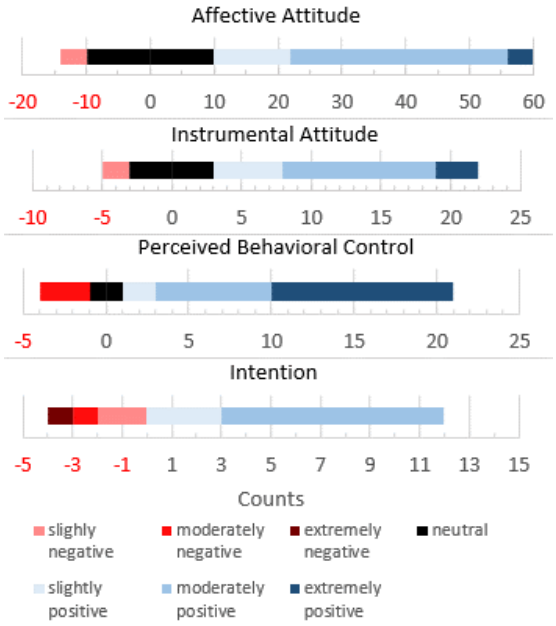

Figure 5. Results of TPB Components.

RQ3: Players Had Positive Beliefs and Intention

Our results lend credence that players experienced agency during gameplay and were incented to exercise with correct form. But, players should also find the game engaging and want to take part in a strength training program using *Brains & Brawn*. Rhodes' affective attitude questionnaire and semi-structured interviews were used to address RQ3, with promising results. The distribution of responses to the questionnaire is shown in Figure 5, using Robbins' diverging stacked bar charts visualization [50].

Participants' mean affective attitude was 5.4 (SD=1.0), moderately positive, indicating that they believed it would be enjoyable to play the game over a six-week period. Instrumental attitude was 5.4 (SD=1.1), indicating that they felt they would benefit from playing the game. Participants also had positive perceived behavioral control (Mean=5.8, SD=1.6, see Figure 5), indicating that they believed they could exercise using *Brains & Brawn* if they wanted to, an important component in starting an exercise program [9]. Finally, participants had slightly to moderately positive intention, the belief that an individual will or will not enact a behavior, with a mean of 4.9 (SD=1.6) [2].

In the post-game interviews, all eight participants reported that they enjoyed the game, and a majority of participants reported they would take part in a strength training program that involved *Brains & Brawn*. Participants highlighted that they enjoyed combining exercise with a game. P2 enjoyed the combination of strategy and exercise, stating that she liked the fact that "I used my brain and have to exercise." P4 said, "It's good because it integrates exercise with a game." Given that the majority of participants reported having time for strength training, the results indicate there is strong potential for using *Brains & Brawn* as an exergaming approach to muscle-strengthening.

KEY TAKEAWAYS FOR DESIGNERS

Our consideration of agency in the development of *Brains & Brawn* has led to four takeaways for designers of repetitive-motion exergames. The timing of agency is important; designers should consider what type of agency is appropriate during and between exercises. Physical movement should be decoupled from avatar movement. Agency can be used as a mechanism to incent good form, reducing the risk of injury. And, illusion of agency can be combined with real agency.

Consider the Timing for the Types of Agency Provided

Repetitive-motion workouts are comprised of periods of exercise, then rest, then exercise. But, it is difficult for people to perform cognitive tasks while actively exercising [31]. Granting players strategic agency would be inappropriate while they are actively exercising because they would have to divide their attention between strategizing and performing the exercise safely. Conversely, a fast-paced game would be inappropriate during rest breaks.

Brains & Brawn identifies two types of agency to enable meaningful gameplay both during and between exercises. While the player is exercising, *Brains & Brawn* acts as an action game, where a player's real-world movement is integral to the game's outcome. Between exercises, players are granted agency by allowing strategic decisions to be made. Results addressing RQ1 indicated that players experienced agency during play.

Since the type of agency changes during gameplay, repetitive-motion exercises may be best embedded in games where there are natural changes of activity. For instance, turn-based games include transitions that naturally support downtime after the player's turn; examples include board games, card games, and turn-based role-playing games.

Decouple Physical Movement from Avatar Movement

Each of the rehabilitation games we studied makes use of a mapping between the player's physical movement and

movement of an avatar, some going to great lengths to ensure this mapping works appropriately for each player [3, 4, 21]. While this may have been appropriate for their games, such a mapping can be unsafe or inappropriate for many exercises, such as bicep curls, bent-over rows, and deadlifts.

In exercises involving basic movement patterns (e.g., bend-and-lift, single-leg, pushing, pulling, and rotational), this can also be unnecessarily limiting. Mapping avatar movement to a wide variety of exercises would require many calibrations and customizations to account for varying abilities. It would likely require developing several vastly different games to account for the different ways each body segment moves. Also, in rehabilitation programs, the body segment being mapped is weakened; thus, the mapped movement will be imprecise, making it a design challenge for each game developed using this mapping as a mechanic.

Removing the need to couple physical movement to avatar movement opens the space of possible designs, leading to design where physical movement is linked to game outcomes. Despite the link being less direct, we found in our study that participants clearly understood the consequences of their physical actions and, as our results showed for RQ2, even modified their movements to be awarded with the highest attack/healing amounts.

Exploit Agency to Improve Form, Prevent Injury

People have real-world choice in how well to perform exercise; in gym settings, many people choose to perform them poorly. This real-world agency can be exploited to have in-game consequences, with the dual benefit of increasing players' perception of control and incenting correct form. But, games should go beyond simple extrinsic rewards for correct movements (e.g., simply being awarded points). Several commercial games, such as Ubisoft's *Your Shape: Fitness Evolved* [64], only provide simple extrinsic rewards for correct form, and these do not typically feel like games.

In *Brains & Brawn*, correct exercise form is integral to the game's outcome. *Brains & Brawn* rewards exercise quality with higher damage amounts on opponents, higher healing amounts on teammates, and greater chances of spells taking effect. Our study showed that this incentive worked well; results from semi-structured interview questions answering RQ2 indicated that players wanted to perform the exercise well so that they could win the game.

Similarly, many game genres can reward quality of exercise in a way that is integral to the game's outcome. Fighting games could increase character health between bouts. Racing games could repair more damage to cars in pit stops. Role-playing games could reward players with more experience for completing quests. Resource management games could grant quicker resource collection.

Brains & Brawn provides a mirror image of players' movements, along with real-time feedback of how well players are performing the exercise. Results of answering RQ2 showed this was sufficient to improve form over time. But, it is possible to go further and give feedback on how to improve form. Mueller et al. suggest celebrating the joy of movement and how well players are articulating the correct movement [42]. Lyons advocates displaying visual feedback related to movement accuracy (e.g., placing color-coded lines over the player's limbs) and consistency (e.g., placing a glowing outline around the player's body) [35].

Illusion of Agency Can Be Combined with Real Agency

Illusion of agency may be provided to meet the exercise constraints, but its use should be carefully crafted so that it does not diminish the game experience. Seeing through the illusion can change the way players interact with the game. For example, in the speech-controlled version of Façade, players discovered they could not ask questions to game characters in a natural speaking manner [16]. One player said he consciously used a simpler manner of speaking: "I was training myself to be a little more simple with my speaking… less long sentences… or one or two word responses." [16]. In the worst case, discovering that choices are meaningless can lead to grave disappointment for players, like how all choices led to a single ending in the Mass Effect trilogy [72].

This problem can be mitigated by combining real agency with illusion of agency. This combination allows players to make meaningful decisions regardless of whether the illusion is present. We combined illusion of agency with real agency in *Brains & Brawn*. Illusion of agency solely affects exercise choice and does not limit game options. If, at some point, players discover the illusion, they still maintain agency in formulating and executing a strategy.

CONCLUSION

The constraints of repetitive-motion exercise programs make it difficult to develop a game that allows players to make interesting decisions. These include exercising at a slow and controlled pace, performing exercises with a precise form, and fulfilling an exercise prescription. Existing repetitive-motion exergames exhibit this lack of agency, providing few meaningful choices to players.

We provided four key takeaways for designers to use agency to overcome limitations in these games. First, designers should consider the types of agency that can be provided during and between exercises. Next, physical movement should be decoupled from avatar movement. Designers should exploit agency by making player form a game mechanic to incent exercising with correct form. Finally, designers may provide illusion of agency, but this should be combined with real agency so that players have meaningful options even if they see through the illusion.

We implemented these methods in the development of *Brains & Brawn*. Initial playtesting showed that players experienced agency and were incented to exercise with good form. They enjoyed the game, and the majority of participants reported that they would take part in a muscle-strengthening program using the game.

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