# Exertion in the Small: Improving Differentiation and Expressiveness in Sports Games with Physical Controls

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## ABSTRACT
Many sports video games contain elements such as running or throwing that are based on real-world physical activities, but the translation of these activities to game controllers means that the original physicality is lost. This results in games where players have limited opportunity to improve their physical skills, where there is little differentiation in people's physical abilities, and where skills do not change over the course of a game. To explore ways of adding these elements back into sports games, we developed two games with small-scale physical controls for running and throwing – one game was a simple running race, and one was a team-based handball-style game called Jelly Polo. In two studies (three track-and-field tournaments for the running game, and a four-week league for Jelly Polo), we observed the effects of physical controls on gameplay. Our studies showed that the physical controls enabled substantial individual differences in running and passing skill, allowed people to increase their expertise over time, and led to fatigue-based changes in performance during a game. Physical controls increased the games' challenge, complexity, and unpredictability, and dramatically improved player interest, expressiveness, and enjoyment. Our work shows that game designers should consider the idea of 'exertion in the small' as a way to improve play experience in games based on physical activities.

### Author Keywords
Sports video games, physical controls, exertion games

### ACM Classification Keywords
H.5.2. Information interfaces (HCI): Interaction techniques

## INTRODUCTION
Many video games contain elements that are based on physical activities (e.g., running, throwing, jumping, or kicking), and sports games in particular are strongly based on physicality. Sports games have many complexities, and players can build up considerable amounts of expertise in them – but the nature of this expertise is usually very *un*like that of the original sport. This is because games must translate a real-world physical activity to an action that can be carried out with an Xbox-style game controller, and in the translation, the physicality of the original activity is lost.

For example, one main element of many real-world games is bodily movement such as running. Running in many sports video games is translated to a rate-controlled joystick action (i.e., press the stick to move the on-screen character) or a fixed-rate keyboard action (i.e., press and hold the WASD keys to move). This changes the activity of running from a repeated large-muscle action with substantial physical demands, to small fixed movements of the fingers and hand on a controller. In addition, this translation changes a complex multi-degree-of-freedom action to a simpler rate-controlled action where velocity is a function of the system rather than a function of player effort.

A second example involves throwing skill. In the real world, passing is a precision skill that requires substantial practice, but in many sports games, passing is translated into an action that is at least partially controlled by the computer (e.g., direction and distance are automatically set or adjusted so that a pass will go to a teammate).

These kinds of translations between physical activities and controller actions are present in almost all sports games (and many other avatar-based games as well). However, this approach presents three drawbacks for sports games:

- There is limited opportunity for expertise development. Although there are many ways for a player to increase their skill in a sports game, there is little opportunity for improvement of basic actions like running or throwing. In contrast, improvement in basic physical skills is a foundation for expertise in real-world sports.
- There is little differentiation between players in terms of basic actions like running and passing, and thus little opportunity to use these differences in the game. In contrast, success in real-world sports often revolves around individual differences (e.g., taking advantage of a mismatch with an opponent's physical capabilities, or setting up a team to capitalize on individual strengths and minimize individual weaknesses).
- Third, the artificial simplicity of controller actions means that there is no change in a player's physical capabilities over the course of a game. In real-world sports, effort-based factors such as fatigue clearly set apart better players and teams from weaker ones – e.g., many games are won and lost when the team with more endurance takes advantage of the other team's fatigue.


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Overall, these drawbacks reduce the richness and realism of sports video games. Although some games can add other types of richness (e.g., difficulty levels for computer players, minigames such as fighting in a hockey game, or 'manager modes'), the core play experience of a sports game is often limited by these problems.

In this paper we investigate the idea of adding physicality back into controller-based movement in order to add expressiveness and player differentiation back into sports video games. We maintained the basic play environment, with standard controllers and settings, but added two kinds of physical control: *impulse-based movement*, where each physical action on the controller only moves the character a small amount (similar to taking a single step); and *high-precision throwing*, where control input has a detailed relationship to the direction and distance of a throw.

To test the idea of physical controls in sports video games, we developed two games and ran two studies. The first game was a track-and-field running game called Track and Field Racing (TaFR), where two players race each other in a simulated 100m, 200m, or 400m race. Players controlled the running movement by alternately pressing two keys on the keyboard, as fast as possible, with their first and second fingers. We ran three track meets with TaFR to see whether the physical controls led to individual differences and to performance changes over time. Our study clearly showed both of these effects – physical controls appeared to greatly increase the complexity and unpredictability of the game.

Our second game – called Jelly Polo – was a three-on-three top-down ball game loosely based on European Handball. Discrete movement in Jelly Polo involves repeatedly tapping the left joystick of a game controller in the desired direction; precise throwing involves pushing the right joystick in a particular direction and by a particular amount. To explore the effects of these controls on gameplay, we ran a four-week 'Jelly Polo league' with four persistent teams of three people. We found substantial evidence that the physical controls changed all three of the issues identified above: first, people's basic skills in discrete running and precise throwing increased over the four weeks; second, there was considerable individual skill difference across the twelve players, and both people and teams had to adjust to accommodate these differences; and third, fatigue played a major role in the gameplay – it directly affected player speed, and led to novel team strategies and exploitation of fatigue-based mismatches.

Our work builds on existing foundations of exertion-based interfaces (e.g., [12, 14, 17]), but looks specifically at 'exertion in the small,' with physical actions of hands and fingers. We make four novel contributions:

- we show that small-scale effort-based control can add considerable complexity and unpredictability to simple actions such as running and movement;
- we show that providing more expressive input provides increased opportunities for expertise (and differentiation in expertise) for both movement and throwing actions;
- we show that physical controls can add interest, challenge, and enjoyment to simple team games;
- we show that fatigue can be a valuable design principle that can dramatically change the way that gameplay evolves, and the ways that teams develop strategy.

Overall, our work suggests that designers of games based on physical actions (and sports games in particular), should consider 'exertion in the small' as an idea that can improve player experience and player satisfaction.

## RELATED WORK

### Exertion Interfaces and Exergames

A large body of work studies exertion interfaces and their use in games (e.g., [9, 11, 13, 15]). An exertion interface is one that requires some form of physical effort [11], and an exertion game (or exergame) is one in which the player purposely expends physical effort through an exertion interface [16]. These systems have two main goals: first, to create healthier lifestyles and reduce health problems associated with lack of exercise [15]; and second, to use the experience of exertion as a factor in game design – for example, bringing the idea of contact sports into distributed video games [13]. It is important to note, however, that health benefits or exercise (although common in many exergames) are not requirements for the genre.

The majority of previous work looks at full-body interfaces and substantial amounts of exercise and fatigue [11, 12, 14]. Full-body exergames can often be very tiring, and players can get fatigued after a short amount of time. Previous researchers have often accommodated player fatigue by adding elements to their systems that are outside the games themselves – for example, providing rest breaks, or reducing the length of game sessions [11]. One example of this is Mueller's Remote Impact [12] where players have to punch, kick and slam into a mattress on which is projected the silhouette of a remote player. The harder the impact the player can create, the more points they receive [13]. This design requires substantial exertion, and players need breaks in order to play for extended periods of time.

Mueller's taxonomy of exergames (Figure 1) divides the design space into exertion or non-exertion games, competitive or non-competitive exergames, parallel or non-parallel competitive exergames, and finally combat or object-based, non-parallel competitive exergames [16].

There is little work in this area that focuses on fatigue in non-full-body interaction, although a few projects have considered exertion that uses only a specific part of the body. For example, Mueller's MouseGrip system [17] is a low cost input device which fits in the hand and affords a squeezing action to produce exertion. This exertion interface is meant to be small and discreet so users can use it without taking up any extra space. The MouseGrip is intended to make mundane tasks more enjoyable and can even be used for simple games.

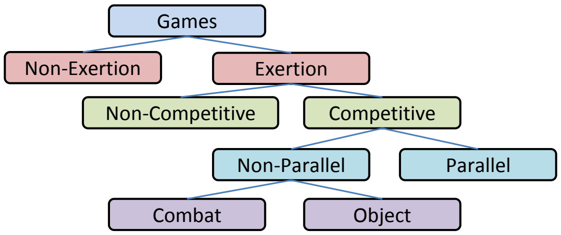


**Figure 1. Exergame Taxonomy (adapted from [16]).**

### Commercial Exergames

Physical activity in commercial video games is now becoming common through the use of new input devices like the Nintendo WiiMote, the Xbox Kinect, and the Playstation Move. Several games make use of the capabilities of these devices for game mechanics such as swinging rackets or swords (e.g., "Wii Sports"), or jumping (e.g., "Kinect Adventures"). The "Mario & Sonic at the Olympic Games" title for the Wii uses physical control almost exclusively – for example, running events involve the player swinging both arms in a running motion as fast as possible. Other events like swimming are controlled in a similar fashion.

Some sports video games also have an option to use physical controls (e.g., Madden football for the Wii). However, this mode of interaction has not been very successful for the sports genre: for example, Madden'08 sold triple the number of units for Xbox as it did for Wii [4]. Nintendo also introduced their "All-Play" series of sports games in 2008 where all controls were physical. This series was not a market success, suggesting that sports gamers prefer traditional platforms and devices.

These commercial games are similar to previous exergame research in two ways. First, the physical activity involves large movements of the arms or legs – players must clear the space around them to play the game. Second, the activities generally involve short bursts of exertion rather than sustained effort – that is, quick-as-possible movements for a short amount of time that do not involve longer-term fatigue when done in isolation.

In contrast, our research focuses on *small-scale exertion*, which we define as exertion that uses small movements and small muscle groups – for example, fingers, hands, and feet. Small-scale exertion has the advantage that it does not require a large space, and can be integrated into traditional game settings where people use standard controllers and sit in groups in front of a display.

There are very few examples of this type of exertion interface in commercial games – but one game of interest is the "Olympic Games" series for the Xbox or Playstation platforms. Unlike the Wii version, here players can control the game with a standard controller. Running a race in "Beijing 2008" involves pressing two controller buttons back and forth as fast as possible (much like our TaFR game discussed below). Interestingly, a newer game in the series ("London 2012") changed the control style so that races are not as fatiguing: instead of pressing as fast as possible, the player must maintain a rhythm in their presses.

### Sports Video Games and Electronic Sports

Sports video games – including titles like Madden Football, EA NHL and NBA, and FIFA Soccer – are the third-largest game genre by units sold (15.3% of all video games), with revenue of $US 1.8bn in 2012 [3, 8]. Despite this popularity, there is little research into sports games.

One large study was performed recently (2012) to find out who plays sports games. An online survey asked 1718 participants what kind of players play sports video games and their habits concerning sports in general. The survey found that 98.4% of sports video game players are males, mostly in their mid-20s. The study also supported a widespread belief that sports gamers are also sports fans with 93.3% self-identifying with this statement [19].

Research has also shown that playing sports video games can improve performance in the real-world sport counterpart [2]. In addition, previous knowledge of a sport can affect success in playing sports video games [10]. This research also states that not much work has been performed concerning individual differences, and this is an area that should be further explored.

Electronic Sports (eSports) is another area that has recently gained popular attention – eSports are professional sport-like competitions using video games that are broadcast over the Internet [1].These competitions are much like real sports, in that players train, gain expertise, and compete at high levels. Some research in the area of eSports is about new interaction techniques to help with high-level performance [6], and different broadcasting techniques to showcase the competition [1]. The most common genres played professionally are multiplayer online battle arena (MOBA), real-time strategy (RTS), fighting games, and first-person shooters [20]. There is little to no recognition of sports video games being included in the area of eSports; however, professional eSports players have recently been officially granted 'professional athlete' status by the U.S. government in order to obtain visas to play in the U.S. [5].

## A CONTROL SCHEME FOR PHYSICAL ACTIONS

There are many possible ways to map movement control to the available capabilities of a computer input device. Researchers have defined several properties of devices and the input relationship, including the property sensed, state sensed, and number of dimensions sensed [7]. For example, a keyboard key senses only state (up/down) and a single dimension; a joystick on a game controller senses position in two dimensions, but no state.

We designed physical control schemes for two activities - movement and throwing. Movement was designed for both a keyboard (TaFR) and a game controller (Jelly Polo), and our goal was to mimic the physical effort needed to sustain movement in the real world. Real-world movement is based on repeated actions that provide a kinetic impulse to the body - taking one step moves the body by a certain amount. An impulse has both a direction and a magnitude, and the result of the impulse is an increase in velocity that fades over time. If another impulse is received before velocity reaches zero, higher velocities can be attained. Discrete versions of impulse-style controls were common in early handheld games (e.g., Mattel Football), where pressing direction buttons moved an on-screen character by one unit.

Impulse-based control can be implemented in several ways. On the keyboard used in TaFR, we used repeated alternating keypresses as the impulse signal - the magnitude of the impulse was fixed, and no direction was needed as the game involves a straight-line race. In Jelly Polo, we developed a more complex control scheme using the joystick of a game controller: each push of the joystick with the thumb represents a single impulse, with the amount of displacement providing the magnitude value, and the 2D position of the joystick providing the direction. Controller joysticks automatically return to centre, allowing the next impulse to be initiated immediately.

Precision throwing requires that the user control two values: direction and distance. The properties of a joystick can be mapped to these values (2D position to direction, and displacement speed to distance), and so we used the second joystick of the game controller for arm movement and throwing. We used a threshold-based release mechanism so the ball can be thrown without an explicit release switch.

## STUDY 1: TRACK AND FIELD RACING

To explore effort-based repetitive actions as a gameplay mechanic, we created a two-player racing game, TaFR (Figure 2). In a TaFR race, two players run from a start line to a finish line; TaFR is an example of a parallel exergame (Figure 1). We note that this game was designed to explore particular issues in exertion interfaces, and is not intended as a real-world game that people would choose to play.

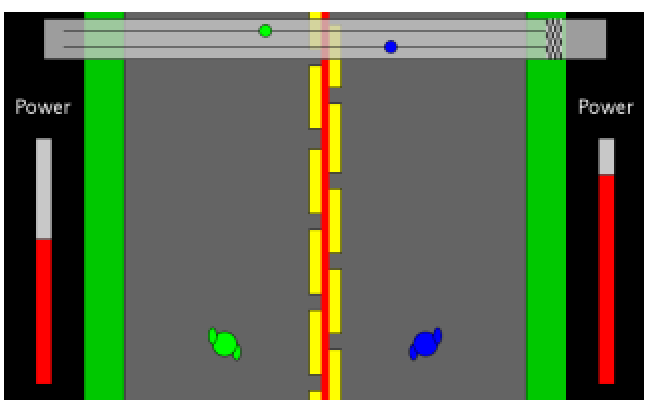


**Figure 2. Track and Field Racing (TaFR).**

To run in TaFR, players press two keys repeatedly (player 1 used the A and D keys; player 2 used left and right arrow keys). The faster the player presses the keys, the higher the player's power bar rises, and the faster the character runs. The power level has an upper limit, and decreases when the keypress rate drops, or when the keys are not pressed in alternating order. To run fast, players must consciously work to alternate fingers at high speed; this repetitive action causes fatigue. There is also a distance chart at the top of the screen, showing how far the players are from each other, and how far from the finish line they are.

### Study Methods

We ran three double-elimination tournaments: one with short races (simulated 100m race), one with medium races (200m) and one with long races (400m). There were two brackets in each tournament. Each player started the tournament in the top bracket. Double elimination means that if a player wins, they move on to the next round. If they lose once, they move down to the bottom bracket. If they lose for a second time, they are eliminated.

Eight participants ran in all three tournaments. Participants were recruited from our research lab (2 female, 6 male), and were between 22 and 32 years old (mean 25.6). We recruited from our lab for convenience, but because we were only looking at low-level effects of exertion, there is little likelihood of any participant bias. Each participant ran between two and seven races. We held races one after another so participants did not have much time to recover; there was a five-minute break between races. For the first tournament (100m) we randomly entered the eight participants into the bracket. Performance in the 100m race determined seeding for the subsequent tournaments.

For each race, we kept track of the time between keypresses, the power level over time, and incorrect keypresses. We also kept track of race times, each player's keypress rate, and each player's average power level.

### Results: TaFR

We used TaFR to investigate two issues: whether physical control over running led to individual differences in ability and to changes in performance over a race.

#### *Movement and ability differences between players*

We recorded players' running power over time – Figure 3 shows four results from the 100m race. As the charts show, people performed very differently in terms of several characteristics: acceleration, top speed, and consistency. For example, player A had faster acceleration and a higher top speed than player B (row 1 of Figure 3). Player C had the fastest top speed of all the players, and was also able to hit the maximum power possible in the game (row 2).

The performance differences arose both from basic differences in the physical capabilities of the players (finger speed and coordination) and from the amount of effort put into the race. The best players (e.g., Player C) could press the two-key sequence faster, could maintain a high press rate without losing coordination, and could continue at that high rate for the entire race. However, performance also depended on effort, in that players had to work hard to win races against opponents who had similar physical abilities.

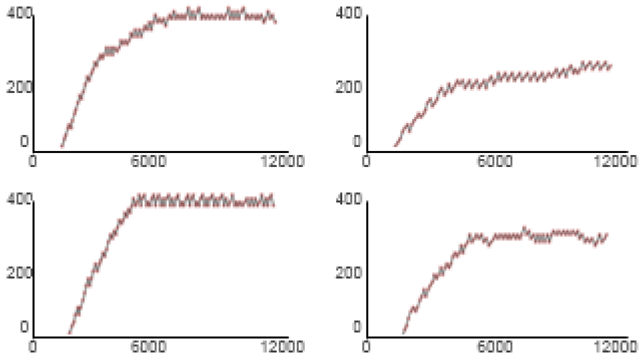


**Figure 3. Power-over-time charts for two 100m races.**

*Changes in performance during the race*

Figure 4 shows power-over-time charts from four additional races: 100m in rows 1 and 2, and 400m in row 3. These charts clearly demonstrate that players' performance changed over the course of a race (sometimes dramatically), due to fatigue or a desire to conserve energy.

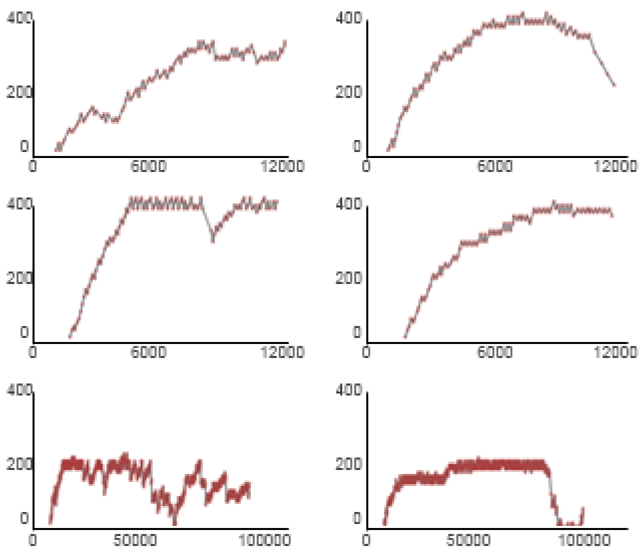


**Figure 4. Power-over-time charts for example races (100m, 100m, 200m, and 400m).**

In the 100m race (Figure 4, row 1), player 1 (left) is well behind the entire race because player 2 (right) can 'run' faster, with better acceleration and a higher top speed. Near the end of the race, player 2 slows down (falling power line) because he is so far ahead that he does not need to expend much effort to win the race.

In the second 100m race (row 2), player 1 (left) moves into an early lead, but partway through the race, becomes tired and has to rest his fingers (sharp dip in the power line). Player 2 (right) has been steadily increasing her speed, and so catches player 1. The approach of player 2 prompts player 1 to expend more effort again to match the increasing speed of the other runner. (Player 1 wins).

The 400m race (row 3) shows an extreme case of an early leader becoming fatigued and losing the race. Player 2 (right) had a substantial lead coming into the final part of the race – but then his fingers 'gave out' from fatigue (power line drops to near zero). Player 1 (left), who had been much less consistent, made a final desperate dash, passing player 2 near the finish line.

These episodes clearly demonstrate that physical controls – even something as simple as two-finger key pressing – can lead to considerable complexity in the way a race plays out. In particular, fatigue becomes an important factor in the race: players must conserve energy, must 'dig deep' to finish the race strongly, and can encounter catastrophic collapses that dramatically change the race's outcome. The TaFR game goes further in terms of fatigue levels than a real-world game would, but showed the effectiveness of the small-scale approach to exertion – and we built upon these lessons in a more realistic game called Jelly Polo.

## STUDY 2: JELLY POLO

The second study explored the use of physical controls for both movement and precise throwing, in an environment more like a sports video game. We created a game called Jelly Polo in which two teams of 3 play a top-down 2D handball-style game for two 10 minute periods. Each player controls one character for the whole game. There are no set positions, players can freely move anywhere, and the team with the most goals at the end of the game wins. Jelly Polo is an object-based, non-parallel exergame (Figure 1).

There are two controls in Jelly Polo: the left and right joysticks on a standard controller. As described above, the left joystick is used for impulse-based movement; unlike most sports games, movement is not rate-based, and players cannot simply hold the joystick to one side to make the player move. In Jelly Polo, players must repeatedly flick the left joystick in the direction they want their character to move; a bigger flick results in a bigger impulse. There is no limit to speed, other than the human limitations on operating the controller.

The right joystick is used to control the character's arm. The arm is used to pass, shoot, steal, fake, and make saves. Unlike many sports games, players must flick the right joystick in the exact direction and speed to throw, requiring precision for passes and effort for hard shots.

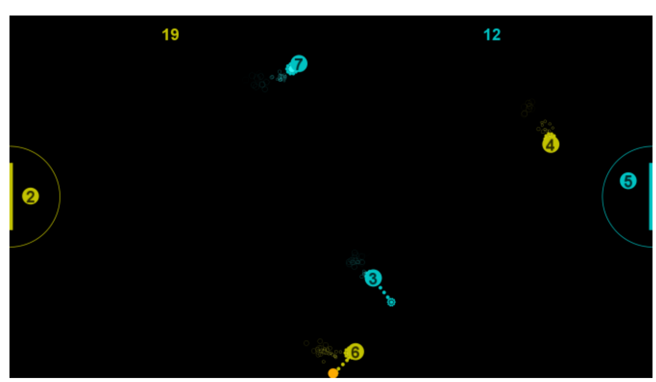


**Figure 5. A game of Jelly Polo in progress.**

Figure 6 shows an annotated action shot of Jelly Polo. Jelly 5 has the ball and is moving toward the other team's net. The bubble trail shows the direction of movement. Jelly 5 is also holding the ball away from the incoming defender (Jelly 6) and the goalie (Jelly 4). The defenders (6 and 4) hold their arms out in an attempt to steal the ball or save a shot. Arm position is independent of player movement.

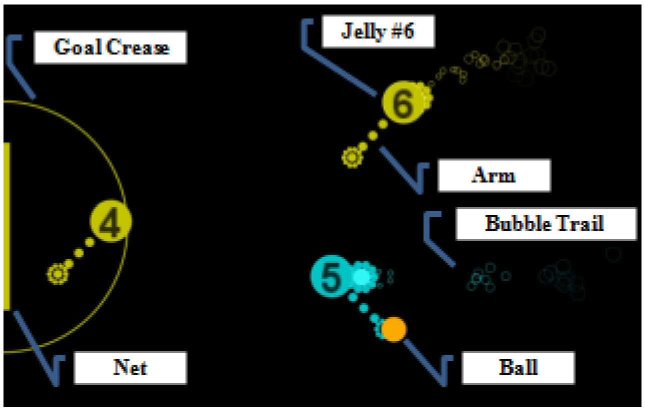


**Figure 6. Jelly Polo close-up.**

### Study Methods

We ran a 4-week Jelly Polo League with 12 participants (4 teams of 3, 10 men and 2 women). Participants ranged in age from 19 to 36 (mean 25.3), and were recruited from within our research lab. Three participants played real-world sports on a regular basis (>3 hrs/wk). All participants had gaming experience (mean 11.7 hrs/wk), although only two participants played sports video games regularly, and only half had played games with physical controls (e.g., Wii Sports). We used participants from our lab because we needed to maintain consistent teams across the month-long study, because we wanted teams to become familiar with each other and discuss strategy between games, and because of the large time commitment (11 play sessions plus several interviews, totaling more than eight hours).

Games were played every Monday, Wednesday and Friday in a round-robin format. After two weeks of play (6 games per team), we had a one-week break, and then held a third week of games. 18 games were played in total (9 for each team). After the three weeks, each team was ranked by wins, and we held a two-round playoff (first vs. fourth, second vs. third, and the two winners played in the finals). The final used a best-of-three format – the first team to win two games was the winner. The finals had two 15-minute periods instead of the standard 10 minute periods.

For each game, we kept track of Goals, Assists, Shots, Saves, Steals, Own Goals, Passes, Face-Off wins, and Turnovers for each player. These stats were kept online. All games were videotaped for later analysis.

### Results (Jelly Polo)

Jelly Polo games were fast, exciting, and extremely active, with high average-per-game numbers of Shots (184), Goals (34), Steals (164), Passes (78), and Saves (87). The teams were highly competitive, and games were rousing and noisy affairs. In addition to the overall success of Jelly Polo as a game, we also observed behavior and events that support our hypotheses about small-scale exertion. The sections below report our observations of expertise development, individual differences, and changes in performance.

#### *Expertise development with physical controls*

Player skills develop over time in all types of games – both in Jelly Polo and in more traditional sports. Here we focus particularly on the development of skill with the physical aspects of the game – impulse-based movement and precision throwing. We observed the development of several types of skills over the four weeks of the Jelly Polo league. Based on questionnaire results, 9 out of the 12 players stated that they had improved over time. In follow-up group interviews with each team, people discussed the ways in which they had seen improvement, and many of these areas were related to our interests in physical-based movement and passing:

- Movement – running speed, mobility (i.e., 'deking' around other players), ball handling (i.e., moving the jelly's arm around to protect the ball), and goalie movement (i.e., how to best block shots);
- Passing and shooting – directional and distance accuracy in throwing the ball, learning to use the walls for bank passes, and mastering trick shots (e.g., fast shots, or shooting in a different direction to movement);
- Strategy – both individual strategies such as choosing the time to make a rush, when to shoot, or when to attempt a steal; and team strategies such as who would play forward or defense, how to set players up for passes, and when to switch goalies.

One person mentioned that their performance did not improve as much as others in one area (they were not as fast as other players), but that they learned other skills that helped to make up for that limitation.

As an example of skill improvement in passing and throwing, Figure 7 shows a well-designed passing play (orange arrows indicate a pass, yellow arrows indicate movement, and the red arrow indicates a shot; red numbers indicate the order of the actions). In this play, Jelly 4 passes to 6 to keep the ball away from opponent 7. Then, Jelly 6 moves up with the ball, and Jelly 2 moves into position to take the pass. Jellies 3 and 5 move to intercept the ball carrier, leaving a lane open for 6 to pass to 2. With the defender and goalie out of place, 2 has an open-net shot.

Another example is diagrammed in Figure 8, in which one team completes a 'bank pass.' In this scene, the goalie (Jelly 7) has the ball. Opponents 4 and 6 rush him to try and steal it. Teammate 5, knowing that his team has clear possession of the ball, moves up field and sees that a bank pass is open. Before 4 and 6 can get to the goalie (7), he passes the ball off the wall and toward his teammate (5), leading to a breakaway.

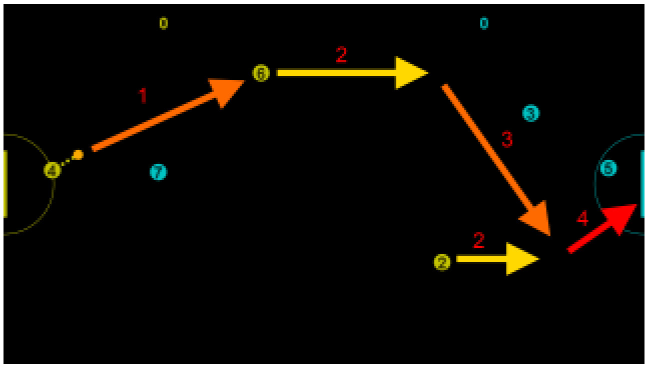

**Figure 7. Jelly Polo 'One-timer' passing play.**

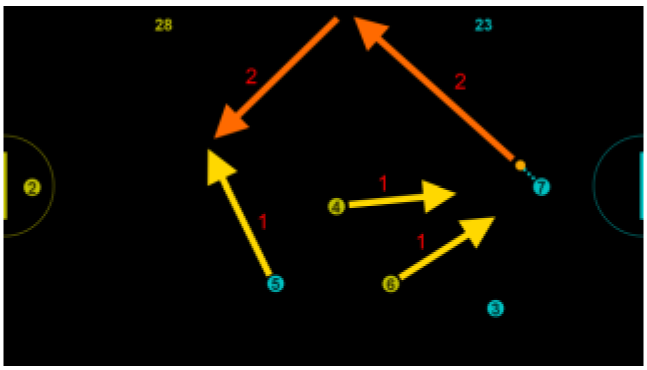

**Figure 8. Jelly Polo bank pass.**

The league had a one-week break in the middle of the season, and players also felt that their skills had degraded somewhat during that rest, suggesting that ‘rust’ from lack of practice occurred during the break.

Player stats, however, did not change dramatically as the league continued – for example, there were similar numbers of Goals, Assists, and Shots in the first half of the league (38, 12, 196) as in the second half (30, 9, 173). Discussions with players suggests that the lack of change to the stats is a result of the global increase in skill across most of the players – that is, players became better at defense as well as offense, and so individual stats did not improve even though the overall level of play was higher.

*Individual Skill Differences Arising from Physicality*

The addition of physicality to the Jelly Polo controls led to a wider range of skill levels in certain aspects of the game – particularly movement speed. It was very clear from observing games and from interviews that different Jelly Polo players had different top speeds. In the interviews, we asked who the fastest player in the league was. Three players received all of the votes (P5: 5 votes; P8: 4 votes; P11: 1 vote), showing that a small set of players had particularly good speed with the impulse-based controller. In the interviews and during the games, people also talked about speed differential in terms of their own abilities: for example, one person stated that for the faster players “even if I could keep up with some people, I still couldn’t catch them;” another stated that “this feels like the opposite problem I have with soccer. I can kind of shoot OK [in Jelly Polo], but I can’t run fast enough.” After being caught on several plays, P3 said: “I can’t move as fast as them!”

Figure 9 shows a situation where a player on a breakaway is caught by a faster opponent. Jelly 3 has an open path to the net, and is as fast as Jelly 4, but is much slower than Jelly 2. Even though he starts far behind, Jelly 2 catches up to Jelly 3 and breaks up the chance. This happened frequently in games – one participant noted “there were plenty of times where it would have been a breakaway if someone didn't charge back and cut you off.”

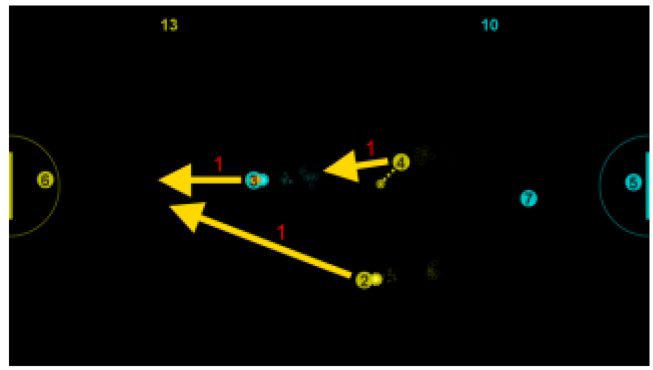

**Figure 9. Jelly Polo caught on a breakaway.**

Player speed also became a part of team strategy – teams had to adjust to accommodate particular players’ abilities. For example, one player discussed having to defend against the speedy P5: “[he] is really fast, so it makes it hard because you can’t catch up to him.” P5’s team sometimes made use of his speed by positioning him in the middle of the field where he could get breakaways. This forced other teams to change their strategy: one player said, “[we] had to keep one guy back to play defense on the cherry picker.”

To check people’s actual speeds with impulse-based control (but outside of a game situation) we carried out an informal race in which players moved as fast as they could across the playing field and back again (using impulse-based control). These races confirmed the wide range of speeds – the fastest player finished in 6.5 seconds, and the slowest in 11.4 seconds, with eight other players distributed between (see Figure 10).

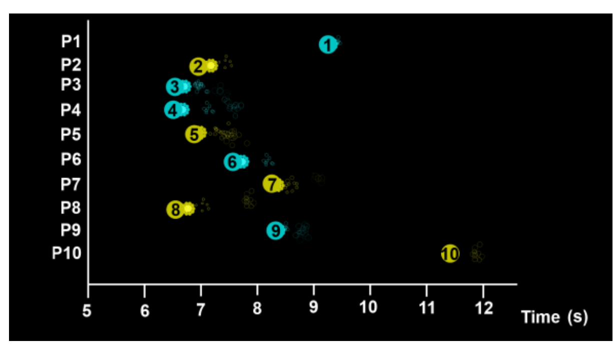


Figure 10. Jelly Polo race results.

We also looked for individual variance in the player stats, and there was clear evidence of differences in this data. For example, the stats showed large differences in Goals, Shots, Saves, and Steals (see Figure 11); this suggests that some players were better in particular roles (e.g., playing in net and making lots of saves, but with few goals).

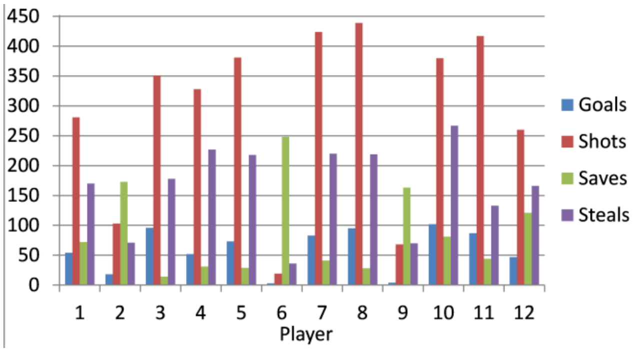


**Figure 11. Individual player stats**

*Changes During Games Arising from Physicality*

The largest difference that we observed between traditional games and Jelly Polo was in the way that the physical controls (i.e., impulse movement) led to changes in people's movement abilities over the course of a game. The main issue was fatigue – people got tired, particularly over the short term. The thumb-based control action required effort, and people could not perform at their maximum speed throughout the whole game. Players were able to 'sprint' with a burst of speed, but then would be unable to move as quickly until they had rested.

The effect of fatigue was clearly evident from game comments and interviews, and had a dramatic effect on both individual and team play. On an individual level, it was clear that people got tired, and that they had to adjust their play based on their fatigue level: one person stated "I got tired a bit if I sprinted back and forth, but I would usually recover before the game ended;" and P1 said "if it didn't have that [thumb-based movement] I would play offence and defense all the time; but I wouldn't go as far forward because I knew I had to go back on defense." Several people also talked about their thumbs getting sore during the game, and one player (P5) even worked so hard that he had his hand cramp up during a game: he yelled out "Cramp!" to tell his teammates that he would be out of the game for a few moments while he massaged his hand.

Several players changed their individual strategy to conserve energy. P1's comment above is one example; two other people stated that they played more in the middle of the field (e.g., "I tried to stay near the middle so I wouldn't have to run so far back and forth;" "I cherry-picked because it would give me time to rest so I could perform when I had to"), and another stated that in general "I tried to minimize movements" to maintain energy for short sprints.

Fatigue also played a major role in the way teams organized themselves. In most cases, the team's forwards had to work harder as they raced toward the other team's net or a loose ball, and so this role was generally much more tiring than playing defense. As a result, most of the teams adopted a strategy where they would switch players between forward and defense (or goalie) in order to give tired people a rest. As one person stated, "we switched off a lot so that made it [game fatigue] better." The switching-roles strategy was useful not only for resting, but also for taking opportunistic advantage of the other team's fatigue. As P10 stated, "if you had a chance to rest, then you could burst out and be faster than everyone. It was like you had the invincibility star. You could be faster than everyone else for a while." Another player found the same strategy, saying "by playing goal for a while I can kind of save up some steam, and then really go on a tear."

The idea that fatigue can be an important factor in the outcome of a game, and can play an important role in minute-to-minute strategy decisions during the game, is something that is taken for granted in real-world sports, but that is almost completely absent from sports video games. In addition, although other exertion games have thought about fatigue [11, 12, 14], there is little work done to use tiredness as a critical factor in the performance of the game itself. Finally, we saw evidence that the effort and physical difficulty of our movement mechanism actually made the game more enjoyable – it increased the complexity of the game play, it increased the degree to which teams had to coordinate their activities, and it added to the unpredictability of the game (e.g. through unexpected events like hand cramps). One player summarized this in the interviews by saying that "the interaction–like the constant clicking [i.e., impulse movement], and the effort you were putting into it, was what made it fun."

*Expressive communication through physicality*

Mueller discusses the idea of 'metagaming' [18] as part of exergames, and suggests that incorporating physicality into digital games can provide opportunities for additional bodily expression and communication. We found many instances of expression through physicality in Jelly Polo. Players would use their onscreen arm for a number of different expressions – spinning their arm around, 'high fiving' each other, or poking other players.

Players could also bounce off another player if they ran into each other. This body checking mechanism was rarely used during gameplay to gain an advantage over the other team, but was often used to taunt other players. This happened especially at half time or before the game began. Players would also chase one another around the screen at these times – either to play a game of keep-away with the ball, or to run away until the other player could make contact with them, like a game of tag.

## FOLLOWUP: RATE-BASED JELLY POLO

We were interested in the degree to which players' enthusiasm for Jelly Polo was related to the physical movement controls, so we created a version of the game with rate-based movement. The game was the same as before (graphics, arm movement, and rules), but in this version players could simply hold the left joystick in any direction and your jelly would move in that direction. Two teams (six people) who played in the Jelly Polo league played one game with the rate-controlled version, and discussed the game, over a period of about an hour.

The players' response to the game was overwhelmingly negative. The first comment heard during the game was "It's terrible when you can't catch up to someone [by moving faster]." Players also complained about not being able to fake as well because the defense could stay on you so much easier now. One participant said "this sucks."

After the much-quieter-than-usual game, players were asked what they thought about the change in movement control. Players agreed that they disliked it: for example, P1 said "I thought it was really annoying." When asked to compare this version of Jelly Polo to the original, players pointed to both the overall excitement of the original, and to the physical basis for that enjoyment: one player said "way less exciting;" another stated "you don't have to put as much effort into it," and a third said "it doesn't force you to get as involved."

This exercise suggests that without the physicality added to the game, players did not have as much fun, and team strategies would not change as much because there was no fatigue factor. Without differentiation and changes over time, the game seemed unrealistic and less competitive.

## DISCUSSION

Our studies provide four main findings:

- Physical controls allowed expertise development over time, particularly for precise passing in Jelly Polo;
- Impulse-based control of movement led to clear individual differences in player abilities, in both TaFR (keyboard input) and Jelly Polo (controller input);
- Physical movement control also clearly led to changes in player capabilities over time, with fatigue becoming a major factor in both in both game outcomes (TaFR) and game strategy (Jelly Polo);
- Physical control appeared to add to the complexity and unpredictability of Jelly Polo, leading to greater player expressiveness, enjoyment, and enthusiasm.

In the following sections, we consider reasons why physical controls had these effects, and discuss issues of generalizability and applicability to other games.

### Explanations for results

There are several ways that physical controls added to the play experience of both TaFR and Jelly Polo. First, the added complexity of the gameplay with physical controls made a major difference in the play experience. In TaFR, physical control over running made an extremely simple system into a fun and challenging contest. The changes in races over time, and the last-minute reversals that occurred, added a level of interest that clearly aided the gameplay.

Second, the element of uncertainty that physical controls (and the resulting fatigue) added to these games was another important improvement. Mueller identified this benefit in terms of exergames more generally:

> *Uncertainty contributes to an element of suspense and facilitates surprise in games through random or chance events, which can play an important part in what makes a game engaging. […] In conventional button-press computer games, any chance encounters need to be artificially introduced through explicitly programmed code […] In exertion games, on the other hand, uncertainty can also arise through the body. The body's response to exertion is hard to predict for player and technology alike ("how long can I keep up?"), and the variety of bodily movements can cause even simple actions to go wrong (e.g. missing a free-throw in basketball or a short putt in golf). [15], p. 2653.*

Although Mueller was discussing larger-scale exertion games, our experience is that even small-scale physicality can provide exactly this kind of uncertainty, leading to enhanced enjoyment and interest in the game.

Third, the added level of commitment that exertion required appeared to enhance the play experience for players of both games. There were many comments heard during the races or during Jelly Polo games that would not have been out of place on a real-world sports field – this is best characterized by P10's exhortations to his teammates in the final Jelly Polo game: "DIG! DIG! DIG!". The physical requirements clearly meant something to the players, and changed the play experience from a casual encounter to a more personal contest. This element was clearly lacking from the rate-based version of Jelly Polo, and players quickly saw and understood the critical difference between these versions.

Fourth, the expressiveness of complex physical controls seemed to be an area that players greatly enjoyed. Players quickly and naturally made use of the full range of communicative capabilities of the Jelly characters. Although this kind of communication also occurs in commercial sports games, it is important to note that the physical control scheme added considerable range to what players were able to express.

### Generalization

Here we consider two potential issues in using the ideas explored here more widely. First, it is important to consider the potential drawbacks of physicality in game controls, and we see two areas for further consideration. Physical controls are intended to be physically difficult (at least to some degree), and they may cause injury if overused. Even in our brief experience, we saw several sore thumbs, and it is not our intention to cause overuse injuries through the employment of small muscle groups like the hands and fingers. This issue may stand in the way of commercial adoption of our movement control schemes – but we note that early handheld games of the 1980s successfully used similar movement mechanisms.

Second, the increased range of expertise and the increased importance of fatigue raise the issues of game balance and inclusiveness. It is clear that as people become better and better at the physical actions of a game like Jelly Polo, the harder it becomes for a weak-thumbed novice to join in the game. Inclusiveness is an important aspect for game design – but our goal in this research was to try and increase the range of experiences that designers would be able to provide for players, rather than simplify controls such that all players become equal. There are other possibilities for balancing in a game such as Jelly Polo (e.g., adjusting impulse speeds), and we plan further studies to see whether these techniques undo the value of individual differences that were created by physical controls.

## CONCLUSIONS AND FUTURE WORK

The physicality and complexity of real-world physical actions are often lost when sports are translated into sports video games. To explore the possibility of returning physicality to controller-based games, we developed two games that provide physical control over movement and precision throwing. Our studies of these games showed that physical controls led to substantial individual differences in running and passing skill, allowing people to increase their expertise over time, and leading to fatigue-based changes in performance during a game. Physical controls increased the games' challenge, complexity, and unpredictability, and improved player interest, expressiveness, and enjoyment. Our results show that the principles of exertion interfaces can also exist 'in the small,' and suggest that game designers should consider exertion as a way to improve play experience in games based on physical activities.

Our future work with these ideas will continue in three directions. First, we will continue to develop small-scale exertion interfaces like Jelly Polo, and evaluate the ideas over a longer time period. Second, we will develop physical controls for other games based on physical activities, such as MMORPGs or fighting games, and explore the ways that the ideas change in other domains. Third, we will further consider the issue of game balance, and explore methods for allowing a wide variety of people to play together, but without losing the complexity and uncertainty that physical controls are able to provide.

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