Chapter 9
Observations on Experience and Flow in Movement-Based Interaction

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Abstract Movement-based interfaces assume that their users move. Users have to perform exercises, they have to dance, they have to golf or football, or they want to train particular bodily skills. Many examples of those interfaces exist, sometimes asking for subtle interaction between user and interface and sometimes asking for 'brute force' interaction between user and interface. Often these interfaces mediate between players of a game. Obviously, one of the players may be a virtual human. We embed this interface research in ambient intelligence and entertainment computing research, and the interfaces we consider are not only mediating, but they also 'add' intelligence to the interaction. Intelligent movement-based interfaces, being able to know and learn about their users, should also be able to provide means to keep their users engaged in the interaction. Issues that will be discussed in this chapter are 'flow' and 'immersion' for movement-based interfaces and we look at the possible role of interaction synchrony to measure and support engagement.

Introduction

Nowadays, when we talk about human-computer interaction, it is not about the mouse and the keyboard anymore. Clearly, mouse and keyboard are useful and needed for many useful and mundane tasks, but they do not provide natural and non-intrusive interaction between humans and the environments in which they live and work. The environments in which humans live are now becoming equipped with sensors that collect data about what is going on in the environments and are

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backed up by computers that integrate and interpret this data. Hence, we have environments that can observe their human inhabitants, can interpret what they know, want and do, and re-actively and pro-actively support them in their activities. In these ambient intelligence environments there is an inhabitant (often called a user), but more importantly, this 'user' is one of the many 'agents' that are modeled in such environments. Human inhabitants, (semi-) autonomous human-like agents (virtual humans, robots), and 'intelligent devices' such as furniture and other natural and obvious devices (pets, TV, pda's …) with embedded artificial intelligence will be considered part of these environments.

User interfaces have been introduced that offer, elicit and stimulate bodily activity for recreational and health purposes. Obviously, there are other applications that can be informed and guided by bodily activity information and that can be controlled by such information. For example, in a smart, sensor-equipped, home environment bodily activity can be employed to control devices, or the smart home environment might anticipate our activities and behave in a pro-active and anticipatory supporting way. Although in home environments there exists freedom concerning when and how to perform tasks, there are regular patterns of bodily activity and therefore activities can be predicted and anomalies can be detected.

Whole Body Movement Interfaces

In game or entertainment environments the 'user' may take part in events that require bodily interaction with sensor-equipped environments. This can be a home environment, but it can be a city environment as well. For example, in a home environment we can have a user use an exercise bicycle or a treadmill to navigate or play a game in a 'Second Life'-like environment. Clearly, we can inform the user about performance in the past (allowing him or her to compete with him- or herself) and we can inform the user about the performance of other users. In an urban game, mobile devices may be used to inform the users about activities they have to perform or about activities of their partners or opponents in the game. The game can require the gamer to walk, run, or perform other activities, in order to compete or cooperate with others involved in the game. Other types of these so-called exertion interfaces have been designed. Some characteristic examples will be discussed later in this paper.

In this chapter we assume that these entertainment and exertion interfaces will be anywhere: in home, office, sports, fitness, and medical environments, and also in public spaces. The motivation to use them can differ. For example, we can look at exertion exercises to improve health conditions, sports performance, or (therapeutic) physical rehabilitation. Often these interfaces are promoted from the point of view of fighting obesity. But, we want to look at exertion interfaces that are designed to provide fun and that engage a user in a game and entertainment experience, and in which considerations about health, physical performance, and rehabilitation are by-products.

Whether such interfaces are designed for fun or for health and well-being purposes, they need to engage the user in the interaction in order to be successful. This view has led to new interesting research in which rather than the efficiency of interaction the quality of interaction is investigated. Can we make an interface affective or persuasive, can we make the interaction intuitive and rewarding, and can we define and measure interaction experience and involvement? Two concepts that seem to be particularly interesting from the point of view of whole body interaction and exertion interfaces are 'flow' and 'immersion'. The concept of flow was introduced by Mihaly Csikszentmihalyi [12] to describe a mental state of 'optimal experience', a state induced by focused and successful activity. These concepts have been studied in the context of work, sports, education, art and music, and games.

In game design measuring experiences and mental states in order to improve the design of an interaction or to real-time adapt the interface and the application to the user has become a flourishing research area. Questionnaires have been developed to measure the emotional experiences of users. Rather than having self-reports that can help in improving the design it would be useful to have ways and sensors to automatically measure these experiences. And, preferably, be able to do so in an unobtrusive way. These topics will be discussed in this chapter.

About This Chapter

The main aim of this chapter is to provide a review of the issues that need to be considered for entertainment and exertion interface design. We want to embed this interface design in the frameworks that have been suggested for game design, where, as mentioned, we look in particular at flow and engagement issues.

The organization of this chapter is as follows. In section "Exertion and entertainment interfaces" we discuss some existing exertion interfaces. A short state-of-the-art survey is presented, where we look at entertainment and exertion interfaces that allow direct and mediated interaction. Section "Intelligent exertion interfaces" of this chapter is on 'intelligence' in exertion interfaces. That is, how does the interface perceive and interpret the exertion activities of the user? Obviously, in general this requires interpretation of multi-modal input signals; in particular we look at audio-visual signals and the interpretation of these signals in order to provide the user with relevant (and stimulating) feedback. We discuss flow and immersion in general and in particular in interfaces that aim at whole-body interaction. In section "Joint and coordinated activities in exertion interaction" we discuss interactional synchrony and its role in measuring the quality of whole body interaction. It is argued that this interactional synchrony has a role in measuring and maintaining flow and immersion in whole body interaction. This chapter ends with section "Conclusions" in which we have some notes on future research and conclusions.

Exertion and Entertainment Interfaces

Interfaces that require body movement as input also require some physical effort from the user. In particular exertion interfaces are designed in order to elicit exertion. Exertion can be fun, social and rewarding. As an example, marathons are organized all over the world. In 2009 more than 40,000 people finished the New York City marathon. Similar events take place in almost any capital of the world. 'Fun', 'social', 'rewarding' are keywords for designing exertion interfaces. Improvement of well-being, health conditions, and useful or entertaining physical skills are other effects of exertion interfaces.

The notion of exertion interfaces was introduced by Florian (Floyd) Müller in his 'sports over a distance' research [30]. he introduced many examples of 'exergames' where people had to play a physical game such as football, tennis or hockey against a remote player and both players' actions are detected and displayed on some kind of shared video wall. But clearly, exertion interfaces do not necessarily require a remote player whose actions are mediated and visualized by the exertion interface. The interface can challenge the user to jump, to move his arms, his legs and use all kinds of body movements to earn points or have another satisfying experience. Rather than having a human opponent it is also possible to design an exergame that requires one or more human opponents, but where the human opponents are played by virtual humans or characters that have the required skills to play these roles.

Looking back, accepting these points of view, we can say that already in the early 1980s we can recognize examples of exergaming, e.g., the Atari Puffer exercise bike or games with foot operated pads, that resemble the now popular Nintendo balance board. Pressure sensors and accelerometers have been used to detect activities and embed them in playful interactions with visual challenges and feedback on a computer screen.

We distinguish three ways of looking at exertion interfaces:

1. adding game elements to computer mediated physical exercises for health, well-being, and rehabilitation,
2. adding exertion elements to existing games or variants of existing games, and, nowadays more obvious,
3. have an integrated approach where game and exertion experience are designed in an interface that has sensors and sensor intelligence to detect and interpret the activities of the exergamer in a game aware, context aware and person aware way.

It is important that in these cases exertion activities and game elements are coupled. Game elements seduce and motivate users to engage in physical activity [54]. In the past only the first two viewpoints became visible in exergaming research. Currently, as will be discussed in more detail in section "Intelligent exertion interfaces" of this chapter, because of the availability of all kinds of sensor hardware and software the third viewpoint has entered the domain of game, entertainment, and exergaming interface research.

However, starting with the past and the first mentioned viewpoint, an obvious way to obtain an exertion interface is to connect existing exercise devices (treadmills, rowing machines, exercise bikes) to an activity in a 3D virtual environment or in a game environment. The exercise device can be used to control a game, or to navigate in an interesting virtual environment (e.g., a beautiful landscape, or a Second Life city-like environment). In the virtual environment we can introduce challenges, competition and social interaction with other users. A well-known early example is the Virku (Virtual Fitness Centre) research project [28], where a traditional exercise bike is used to explore interesting surroundings and where environmental sounds are added to these surroundings to increase the presence of the user. And, not too difficult to realize, when a user cycles uphill it will take more effort and when going downhill less effort. In a similar project [17] but more recent project it was investigated whether an increase in presence (by making the environment more realistic) led to an increase in motivation. It turned out that the users not only reported more interest and enjoyment, but they also pedaled faster, without realizing they put more effort in.

Looking at the second mentioned viewpoint, we can mention that existing popular video games are sometimes exported to the physical world. Probably the first computer game that was exported from a 3D virtual world to the physical world was the classic arcade Pacman game. Researchers of the Mixed Reality Lab in Singapore introduced this game at the campus of their university. Students were equipped with wearable computers, head sets and sensing mechanisms and then could play the role of one of the Ghosts or Pacman while running around on the campus [9].

A more recent floor-sensor controlled game, where an existing game is provided with an exertion interface is a ‘space invaders’ game, again developed by the Mixed Reality Lab in Singapore [22]. In this game the elderly and children play together and have to follow patterns that light up on the game floor, but they are also able to trigger bombs and rockets that force other players to jump out of the way and use other sub panels on the floor. The game has been designed in such a way that the elderly have more time to evade bombs and rockets than the children.

There are more examples where popular video games are translated into games that have to be played in real-life situations and where rather than PC game engines games are controlled by ‘performance’ engines that control, using scripts, the physical environment and activities that can take place in these environments.

In contrast to the idea of connecting exercise devices to a game or entertainment environment, or introducing game elements into an environment for performing physical exercises, we can also look at interfaces where ideas about exertion, games, and entertainment, and the use of (intelligent) sensors are there from the beginning of the design. One early example, the Nautilus game [47], can illustrate this. In this game a group of players have to work together and control the game (displayed on a big screen, sound effects and light effects) with the group’s center of mass, speed and direction of movements that are detected by floor sensors.

One of the best known exertion interfaces is ‘sports over a distance’, where players from different sites have to hit a wall with a ball [30]. The position on the wall and the force with which the ball hits the wall are mediated and made visible for opponents. A player can earn points by 'breaking' tiles on the wall and can profit from weak but not yet broken tiles that are left by his or her opponent. 'Sports over a distance' can be called a networked exertion interface. The same authors have introduced other networked exertion interfaces. For example, air hockey, table tennis, and, more recently, 'shadow boxing over a distance' [29]. In the latter application computer vision is used to extract the players' silhouettes that are displayed on a screen. Players can hit their opponents in the game, that is, they can hit the silhouettes of their opponents. Pressure sensors behind the textile 'screen' measure the position and the impact of the hits and keep track of the score.

In these latter applications entertainment, including entertaining social interaction, has been the main reason to build these interfaces. Improving a particular skill in sports (e.g. baseball [23] or Tai Chi [49]) or improving fitness (aerobics [13] or physiotherapy [1]) have also been main reasons to introduce exertion interfaces. With the growing interest in exertion interfaces designing for social and physical play has become a flourishing research area [2, 7, 11, 24, 32, 45]. Obviously, as will be discussed in the next sections, we need to know how users experience the systems we design and implement. We will return to this (and some of these papers) in section "Intelligent exertion interfaces".

Finally, we need to mention the commercially available exertion interfaces. From the success of Dance Dance Revolution, Sony's EyeToy [46] applications and the Wii Sports (tennis, golf, baseball, boxing and bowling), that allow the player to control the game through natural movements, we now may expect to see more advanced exertion interfaces in the future that do not require a controller like the Wii remote control. These advanced systems will use more sensors that allow, among other things, audio-visual processing and interpretation of the user's activities and affective state. Recently Microsoft also launched an Xbox 360 add-on Kinect (earlier called project NATAL) [16] that uses a sensor device to track whole body gestures, facial recognition and to record spoken comments. Clearly, these commercially available systems still lack many capabilities that are required when we want systems to understand, to anticipate and to provide (adaptive) feedback to gaming or exercising activities of the user.

Intelligent Exertion Interfaces

Intelligent exertion interfaces detect a user's activity and the (possibly continuously) changing environment in which the user operates. That allows them to provide real-time feedback that displays understanding of what the user is doing and experiencing. This makes the difference between many of the current exertion interfaces and the advanced and intelligent interfaces that we see appear in research prototypes of exertion interfaces. In addition, dependent on the application, in intelligent exertion interfaces user feedback should be persuasive, motivating, and rewarding.

Game design requires designing game experience. We need to be aware which issues play a role in experience, how we can adapt them to a particular user during the game, and, in particular for our kind of research, what role does the physical activity have in the game experience.

The relationship between body movement and engagement experience in computer games is studied in [3], where experimental results showed that an increase in body movements resulted in an increase in the player's engagement level. Here it is suggested to use the experience of the player itself as an input to the game. One point in particular is what the user can tell us or the interface about his or her experiences. In this study the gamer's engagement level was assessed with a questionnaire. According to Mueller and Bianchi-Berthouze [31] questionnaires and interviews that are conducted after the gaming action should take into account that the exertion activity demanded physical effort of the participants. This will affect the evaluation task, since players might be out of breath and they are probably in an altered emotional state. Moreover questionnaires and interviews for evaluating user experience are inadequate in capturing a user state during the game. Videotaping playing sessions and coding verbal and non-verbal behaviors that can be analyzed statistically can give valuable information about the player's experience to game designers. But for the automatic adaptation of the game or exertion environment during interaction, to improve the experience, we need automatic detection of the user's experience.

More Advanced Sensing of User and Activities

As mentioned above, in order to design and implement successful exertion interfaces that know about the experience of the users, we need exertion environments that can detect, measure, and interpret physical activity. In the ball and shadow-boxing games of 'sports over a distance' [29, 30], for example, there is no direct sensing of body movements or physiological information. 'Only' the result of the exertion (force, location) is measured and mediated. In contrast – without necessarily leading to a 'better' interface – there is also an interactive boxing interface, where the 'punch' is recognized using gesture recognition with computer vision [15, 39]. In [42] we introduced a virtual dancer that interacts with a human dancer. Pressure sensors, computer vision and audio analysis are used to detect the gestures and movements of the human dancer and to have real-time analysis of the music that is played. The results of the detection are used to generate the animations of the virtual dancer. The virtual dancer can decide to follow the human dancer but she can also take the initiative, introduce new dance movements and do some unexpected things to surprise the human dancer.

Hence, there exist exertion interfaces with direct sensing of bodily activity (body movements, gestures, bodily and facial expressions, dynamic aspects of expression, etc.) and of speech activity that accompanies bodily activity (effort and pain utterances, laughs, prosodic aspects of speech utterances…). Among the sensors are cameras and microphones that allow visual and audio processing of a user's activity. They can provide information about posture and position changes (tracking bodies and faces of individuals) and, among other things, frequency and expressiveness of movements. Other sensors in exertion interfaces can detect touch, pressure or proximity.

Sensing user's activity in ambient entertainment environments is discussed in [36]. Rather than using questionnaires we discuss how in the near future information obtained with computer vision and other sensors can help a movement-based interface to consider experience related issues such as personality, mood, and also pain, fatigue, frustration, irritation, etc.

One step further is to take into account physiological information obtained from the user. This information can be used both to guide the interaction and to measure the user experience [40, 41]. A continuous evaluation method to model the user's emotional state from physiological data is presented in [26]. It is also suggested to use this modeled emotion to dynamically adapt the play environment to keep users engaged. In the FUGA research project [19], among other things, the goal was to find game experience measures that are based on psychophysiological recordings and brain imaging techniques. In [53] the authors explore the relation between behavioral measures (movement of the upper body measured by an accelerometer, changes in sitting position measured by a pressure sensitive chair, force with which players made each mouse click) and people's self-reported emotional experience, measured by questionnaires: the Self Assessment Manikin (SAM) [4] and an in game version of the Game Experience Questionnaire [20]

Clearly, BCI (Brain-Computer Interfacing) may be an extra source from which an interface can learn about the way the user experiences the interaction (besides using it to control the game as we can expect in the future [38]). In [34] Nacke et al. use psychophysiological measurements (electroencephalography-EEG) in studies of affective player-game interaction to understand emotional and cognitive player experiences. In [35] they present the results of a study that assessed game-play experience with subjective and objective measures. Their research shows that EEG measurements can be used for studying affective responses to player-game interaction.

Flow and Immersion in Games

In the previous section we looked at game experience and sensors and questionnaires to measure game experience. When modeling game experience the two issues that often arise are 'flow' and 'immersion'. We will discuss these two issues in the next sections.

The theory of flow was introduced by Csikszentmihalyi [12]:

> a sense that one's skills are adequate to cope with the challenges at hand, in a goal-directed, rule-bound action system that provides clear rules as to how well one is performing. Concentration is so intense that there is no attention left over to think about anything irrelevant, or to worry about problems. Self-consciousness disappears, and the sense of timing becomes distorted. An activity that produces such experiences is so gratifying that people are willing to do it for its own sake, with little concern for what they will get out of it…

Eight (sometimes nine or ten) elements or features of this definition have been distinguished and generally it is assumed that these elements should be present in a game. They are: challenging activity that can be completed, facilitation of concentration, clear goals, immediate feedback, deep and effortless involvement, sense of control over one's actions, disappearing concern for the self, and finally, altered sense of duration of time. All these features can be found as prescriptions in present-day game design literature [48], sometimes using more refined features (agency, rewards, narrative…) and they play a role in game experience evaluation. Until now, they have hardly been explicitly considered in the design of movement-based interfaces for exertion and entertainment. A similar observation can be made for the concept of 'immersion'. Immersion ([33], p. 98) has been described as:

> The experience of being transported to an elaborately simulated place is pleasurable in itself, regardless of the fantasy content. We refer to this experience as immersion. Immersion is a metaphorical term derived from the physical experience of being submerged in water. We seek the same feeling from a psychologically immersive experience that we do from a plunge in the ocean or swimming pool: the sensation of being surrounded by a completely other reality, as different as water is from air that takes over all of our attention our whole perceptual apparatus…

Despite the rather vague nature of the conception there are several approaches to model immersion in a gaming context. Brown and Cairns [5] interview gamers regarding their experiences during gameplay and find three levels of immersion, labeled engagement, engrossment, and total immersion. For each level there exist barriers that have to be overcome to reach the level. Figure 9.1 clarifies the relation between levels and barriers.

To reach engagement, the first level of immersion, access must be provided. This refers to the gamers' preferences and game controls. The gamer must also be willing to invest time, effort, and attention. Bad game construction is the barrier to engrossment, which in Brown and Cairns' terms refers to visuals, tasks, and plot.

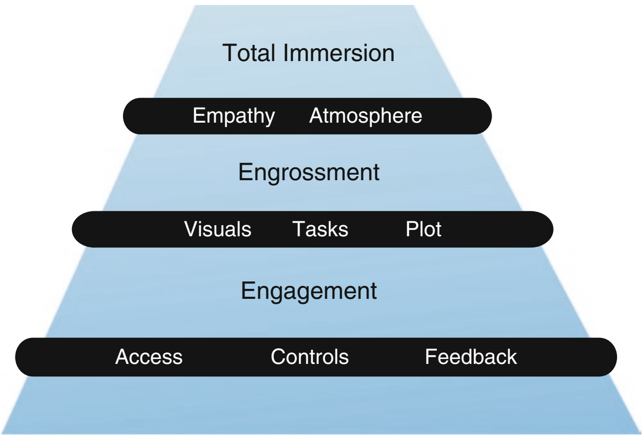

Fig. 9.1 Three levels of immersion from Brown and Cairns [5]; own depiction

Brown and Cairns point out that at this stage the gamers have already invested emotionally into the game and this makes them continue gaming. Total immersion is the final level and it is described as being cut off from the world to an extent where the game is all that matters. Barriers to total immersion are a lack of empathy with game characters or a lack of feeling the atmosphere of the game. In a follow-up study, Cheng and Cairns [8] investigate the stability of immersion. Here, they attempt to deliberately break the immersion of subjects and find that already low levels of immersion make subjects ignore drastic changes in the games' behavior.

A totally different approach to immersion is reported by Ermi and Mäyrä [14]. Looking into different qualities of immersion they interview gaming children and their non-gaming parents. This way they identify three different types of immersion: sensory, challenge-based, and imaginative (SCI), from which they built their SCI-model, which is shown in Fig. 9.2.

Sensory immersion refers to sensory information during gaming. Large screens and powerful sound are given as examples where sensory information of the real world is overpowered and the gamer entirely focuses on the game. Challenge-based immersion is described as most powerful when a balance between the abilities of the player and the challenge of the game is achieved and as such seems to correspond to the flow concept mentioned earlier. Finally, imaginative immersion happens when the player gets absorbed with the story line and identifies with the game characters.

Presence is another term that appears in the literature to describe the gaming experience. The term originates from studies into virtual reality and is often defined as "the feeling of being there" [18]. Cairns and colleagues [6] argue that presence

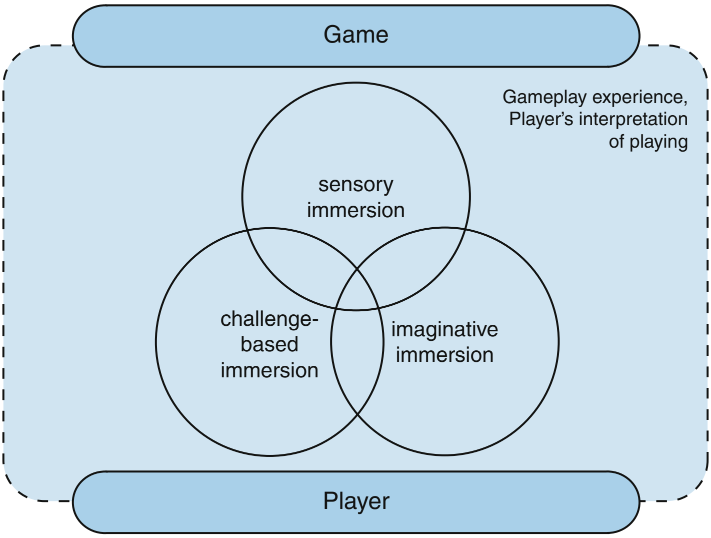

Fig. 9.2 Three types of immersion from Ermi and Mäyrä [14]; simplified

in virtual reality context corresponds to immersion in a gaming context. Similarly, Ermi and Mäyrä prefer the term immersion as "it more clearly connotes the mental processes involved in gameplay" ([14], p. 19). Most scholars seem to agree with this view and see immersion as the appropriate term when speaking of user experience in a gaming context.

Csikszentmihalyi's views on flow as well as the two models based on immersion allow an assessment of the user experience during gameplay. What lacks in these models is an understanding of how body movements or physical activity during gameplay influences the gaming experience. To get a better understanding of the magnitude of the influence that physical activity can have, the following section looks at the experience of physical activity during sports and games.

Flow and Immersion in Exertion Interfaces

The Experience of Physical Activity. What motivates people to engage in physical activity? This section gives an overview of theories of enjoyment of physical activity. But it appears reasonable to first disentangle different types of activity, i.e. play, game, sport, and exercise, before focusing on motivation and enjoyment and clarify their relationship. Figure 9.3 illustrates that relationship.

Play can be defined as "behaviour for the purpose of fun and enjoyment with no utilitarian or abstract goal in mind" (Shaw et al. [44], p. 2). Shaw and colleagues list four reasons why people play: First, play serves relaxation and recuperative purposes. Second, play can be used to reduce surplus energy. Third, play is an opportunity to practice and rehearse skills. Finally, play can be important to reduce anxiety by confronting one's fears in a safe environment.

Play becomes game when competition is involved in the activity. Hence, they define game as "any form of playful competition whose outcome is determined by

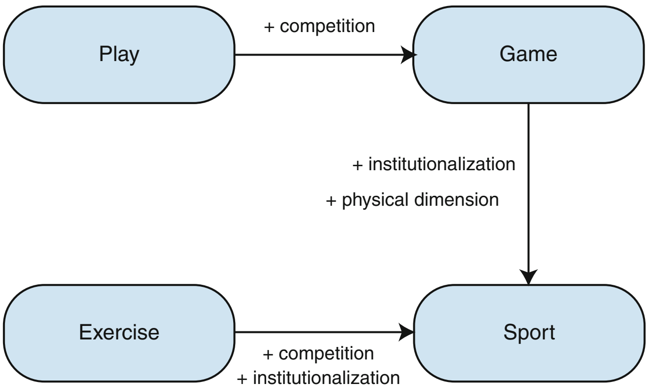

Fig. 9.3 Types of physical activities

physical skill, strategy or chance" and give the following example to illustrate the difference: If one is playing ping pong for fun without keeping score it is play. Once score is kept it is game.

Sport is then defined as "institutionalized competitive play involving physical skill, strategy and chance". The two criteria that distinguish sport from game are institutionalization and physical dimension. Four forms of institutionalization are given: First, sport involves a high degree of organization, in terms of governing bodies, leagues, and sponsors. Another form is technological development, which refers to equipment, clothing, and facilities. Ceremonies and rituals add a symbolic dimension to sport. Finally, sport includes educational aspects that are represented by coaches or written manuals. Apart from institutionalization, a physical dimension is required for sport. This does not necessarily require fitness. For instance, dart can still be seen as sport, while bridge hardly qualifies as sport and suits better into the definition of game. Exercise finally is defined as "any form of physical activity carried out for the purpose of health or fitness" [44].

It should be noted that some activities do not fall into one of the categories and can be rather seen as hybrids in this framework. Still, the framework is helpful to get a clearer view on different types of activities and their specific characteristics.

Jackson and Csikszentmihalyi [21] apply Csikszentmihalyi's theory of flow to the sport domain. They relate the components of flow to aspects an athlete should consider in sport. With the limitation of being intended for a broad audience as a guide to better sport experiences, it still gives some valuable insights into the study of sport experiences.

Figure 9.4 shows how flow can only happen when the challenge at hand is matched by a person's skills. When the challenge is too low boredom occurs, if the skills are insufficient a person might experience anxiety. Both low challenge and low skills result in a state of apathy. Only when both the challenge is demanding and

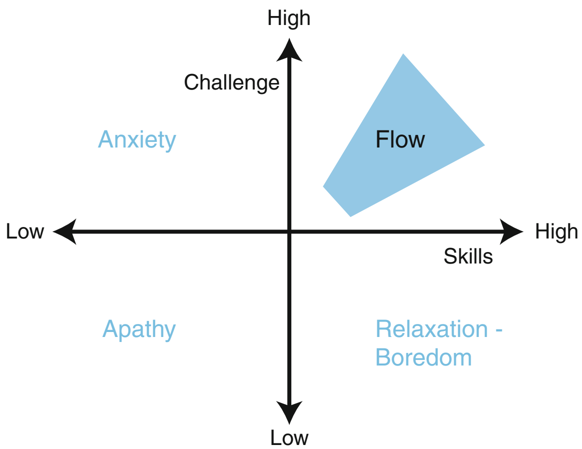

Fig. 9.4 Model of the flow state (Adapted from Jackson and Csikszentmihalyi [21], p. 37)

the skills are high enough to measure to the task the state of flow can be reached. In this context it should be noted that not an objective measurable challenge is decisive for the experience, but rather how a person subjectively estimates the challenge. The same holds for skills: A person might objectively have sufficient skills for a task, but if for some reason the person has only little confidence in his abilities then anxiety or apathy are bound to set in.

State of the Art of Physical Activity in Games. While we have no models of the gaming experience including body movements at present, there are several initial investigations into the area, which are presented in the following.

The only attempt for a model of body movements in video games so far is described by Sinclair and colleagues [45]. They focus on physically intense games, such as exergames, that promote the improvement of fitness levels along with extensive use. Their Dual Flow model is based on Csikszentmihalyi's flow theory (Fig. 9.5). It encompasses the two dimensions attractiveness and effectiveness.

Attractiveness here is modeled by the standard model of Csikszentmihalyi's flow theory. This model calls for a balance between a gamer's perceived skills and the perceived challenge he is facing. Thus, it can be seen as the mental side of the dual flow model. Effectiveness is modeled as the physical side, calling for a balance between fitness, which is defined as the body's skill in tolerating exercise and intensity, which is defined as the challenge of the exercise of the body.

The left side of Fig. 9.5 corresponds to the standard flow model and its four quadrants that are presented in Fig. 9.4. To achieve a state of flow, which Sinclair and colleagues translate into the attractiveness of movement-based video game, a balance between the perceived skills of a gamer and the perceived challenge must be established. Four quadrants are also used to illustrate the physical side of their dual flow model. Here, a state of flow sets in if the fitness of the gamer matches the intensity of the exercise that is experienced in the game. This leads to an improvement

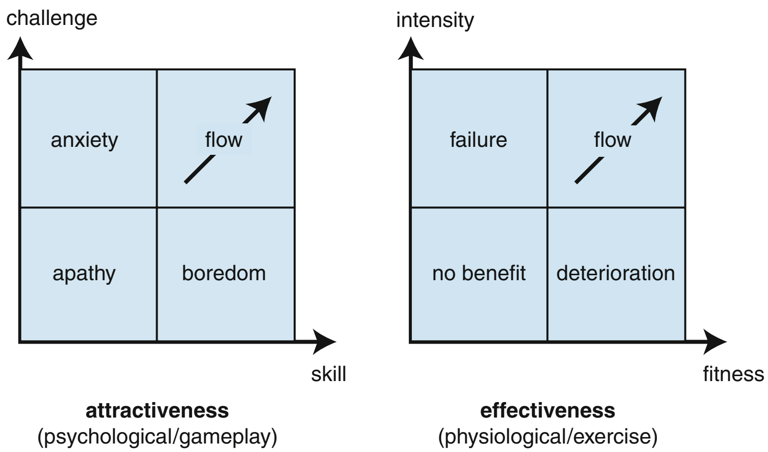

Fig. 9.5 Dual flow model (From Sinclair et al. [45])

in the gamer's fitness. Whereas when the intensity surpasses the fitness level of the gamer, failure occurs and the gamer cannot continue. Deterioration sets in when the fitness level of the gamer greatly outmatches the intensity, where the fitness levels will drop. If both fitness level and intensity are low, there is simply no benefit to the use of the game.

In non movement-based games there only has to be match between skills and challenge. Sinclair and colleagues point out that in commercial development projects this is achieved through extensive testing, which leads to fixed levels of challenge. They claim that in movement-based games this fixed matching is less effective:

> Tuning each successive level of an exergame to achieve a balance of player skill, level of general fitness, and current physical tiredness becomes problematic.

While it is relatively safe to assume that in traditional games the gamer's skills increase parallel to playing time and difficulty level, this is more complicated for movement-based games. Here, the daily form of the gamers can vary significantly. As a solution they envision games that monitor the gamer's current skill level and modify the difficulty level accordingly:

> Rather than just the simple feedback of clearly indicating success or failure to the player, feedback from the player relating to fatigue, exercise level, and boredom should be used to infer the player's current physical state and adjust the level of challenge accordingly. ([45], p. 294)

Joint and Coordinated Activities in Exertion Interaction

Exertion interfaces emphasize the conscious use of bodily activity (jogging, dancing, playing music, sports, physical exercises, fitness, etc.) in coordination and sometimes in competition with other human users (friends, community or team members, accidental passers-by, opponents, etc.). Real-time coordinated interaction between human partners or between humans and virtual or robotic partners makes exertion interfaces exciting. In our research we are particularly interested in interfaces where the exertion interaction takes place with virtual or robotic characters or where the users are able to attribute human-like characteristics to the interface.

Coordination may be required by the rules of the game, the exercise or the tasks that have to be performed ask for it, but most of all people engage in coordinated interaction because it brings satisfaction and enjoyment. We take inspiration from Clark [10]:

> A joint action is one that is carried out by an ensemble of people acting in coordination with each other. As some simple examples, think of two people waltzing, paddling a canoe, playing a piano duet, or making love.

Clearly, these are all joyful and engaging interactions. While Clark uses this observation to explore and develop theories of coordinated language use, we think it can be a useful observation when designing and evaluating exertion interfaces.

For users of exertion interfaces the interaction supporting feedback and the interaction experience are important.

We have studied face to face conversations, multi-party interaction, interactions between a virtual and a human dancer [42], a virtual conductor and a human orchestra [51], and a physiotherapist and her student [43] from the point of view of coordinated interaction [37]. Underlying the joint activities are rules and scripts. To learn these and to put them into practice requires social intelligence, guided by empathy, moods and emotions. Despite many research results from social and behavioral sciences, computational models of joint activities are hardly available. This makes it difficult to design interfaces that aim at providing a similar interactional experience between real humans and virtual humans or robots, as is provided in a real-life human-human exertion activity, as in dancing, paddling, playing quatremains, and making love. Endowing the computer with a human-like appearance strengthens the expectation that the computer will take part in joint activities in human-like ways. Hence, there is a need for computational modeling of human joint activities. We replace one of the human partners in a joint exertion activity by a computer (i.e., a robot or a virtual human). Hence, we need to model joint exertion interaction in order to have the computer behave in a natural and engaging way.

In addition to rules that underlie joint activity there can be a need to align the interaction to external events over which the interaction partners do not necessarily have control. E.g., if we have a human and a virtual dancer then their moves have to be aligned with the music. Similarly, a virtual conductor and his human orchestra follow the score; a virtual aerobics trainer and human student have to align their movements to some kind of rhythm, often supported by upbeat music.

In our present research we investigate ways to measure engagement by looking at the degree of coordination between the activities of a human and a virtual partner in exertion and other entertainment interfaces [37]. In this research, supported by [27, 50, 52], we investigate how to make entertainment interactions more engaging by looking at interaction synchrony. In these and other papers the relation is investigated between synchrony and the quality of the interaction, as it is perceived by the interaction partners. The idea is that on the one hand we aim at disturbing this synchrony in order to introduce new challenges, and on the other hand we aim at convergence towards coordinated anticipatory interaction between humans and artificial partners and their environment. Evidence that this approach will be successful is not yet available. Moreover, there are so many different types of exertion and movement-based entertainment interfaces that a comprehensive hypothesis about the role of interaction synchrony can not be expected to be given.

Design of experience and flow now receives much attention. Most research however is still about ways to characterize complex concepts such as experience, immersion, engagement, and flow. Exceptions are becoming available. For example, when we see the mentioning of 'altered sense of duration of time' in the description of flow, then indeed we can interview gamers about the time they think they have spent during a game and compare their perceived time spent with the actual time that has been measured. Interesting hypotheses related to our point of view on the role of interaction synchrony can be found in [6]. There the authors hypothesize that when players are immersed in a game their eye and body movements are different from those in a non-immersed situation. Obviously, again, there are many types of games and for video games where the gamer controls a game using mouse and keyboard or a joystick we have a quite different situation when the gamer is using a Wii remote control or a Wii Fit or no remote control at all, like in Kinect. The development of controllers designed to allow or impose natural body movements changes the nature of gaming into a more social activity [25] and leads to increased engagement that is moreover qualitatively different from the engagement experienced in games controlled by mouse, keyboard or joystick [3].

In our 'implicit' hypothesis on interactional synchrony we explicitly link this difference to the synchronization that is or is not present between gamer and game events. Notice that the main characteristic of 'flow' is the balance between challenges and skills. We can look at this as being able, as a gamer, to maintain a perfect coordination between eye, finger, and body movements on the one hand, and game/exercise events on the other hand.

Conclusions

We surveyed characteristics of movement-based and exertion interfaces, i.e. interfaces that require and stimulate bodily activity. We discussed recent and future research in this area by zooming in on sensor technology, intelligence and well-known game design and game experience principles. We argued that for future development of interesting exertion (sports and entertainment) interfaces it is useful to embed this research in game design and game experience research. In particular we looked at sensor technology that can not only be used to design interesting exergames, but that can also be used to measure the experience of users. We surveyed the literature on flow and immersion and looked at the modest attempts to model these concepts in movement-based interfaces. In addition we looked at a possible role for coordinated interaction research in the design and the evaluation of exertion interfaces.

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