Video Games and Rehabilitation: Using Design Principles to Enhance Engagement in Physical Therapy

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Patient nonadherence with therapy is a major barrier to rehabilitation. Recovery is often limited and requires prolonged, intensive rehabilitation that is time-consuming, expensive, and difficult. We review evidence for the potential use of video games in rehabilitation with respect to the behavioral, physiological, and motivational effects of gameplay. In this Special Interest article, we offer a method to evaluate effects of video game play on motor learning and their potential to increase patient engagement with therapy, particularly commercial games that can be interfaced with adapted control systems. We take the novel approach of integrating research across game design, motor learning, neurophysiology changes, and rehabilitation science to provide criteria by which therapists can assist patients in choosing games appropriate for rehabilitation. Research suggests that video games are beneficial for cognitive and motor skill learning in both rehabilitation science and experimental studies with healthy subjects. Physiological data suggest that gameplay can induce neuroplastic reorganization that leads to long-term retention and transfer of skill; however, more clinical research in this area is needed. There is interdisciplinary evidence suggesting that key factors in game design, including choice, reward, and goals, lead to increased motivation and engagement. We maintain that video game play could be an effective supplement to traditional therapy. Motion controllers can be used to practice rehabilitation-relevant movements, and well-designed game mechanics can augment patient engagement and motivation in rehabilitation. We recommend future research and development exploring rehabilitation-relevant motions to control games and increase time in therapy through gameplay.

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INTRODUCTION

There is a major concern in rehabilitation that patients are not meeting the sufficient "dosage" of movements required to induce neuroplastic adaptations underlying behavioral improvement.[1] We argue that motion-controlled video games are an appealing avenue of research to augment therapy, because using rehabilitation-relevant movements in the context of an engaging and motivational game can potentially augment the dosage of therapy. In this article, we review experimental studies of video game training in basic science and rehabilitation. These data suggest that gameplay can induce desirable behavioral and physiological changes. We also review interdisciplinary evidence to suggest that specific game mechanics/design principles increase motivation and engagement, increasing the amount of time players (patients) are willing to spend in the game (as a therapy supplement). On this evidence, we present a framework for motivational properties of games to justify games as a therapeutic tool.

This Special Interest article will focus on motor rehabilitation of persons with hemiparesis; however, the principles discussed in this article could apply to rehabilitation more generally. Hemiparesis is a common outcome following stroke and of children diagnosed with cerebral palsy. Function of the paretic upper extremity (UE) is impaired for up to 6 months after stroke in about 50% of survivors of stroke, and only 5% to 20% of this population regains complete functionality of UE.[2] While up to 50% of functional recovery following stroke is spontaneous, additional recovery can only be acquired through prolonged, intensive therapy.

In interviews with survivors of stroke with UE functional loss, nearly 1.1 million participants reported difficulties performing activities of daily life.[3] Health care systems cannot provide sufficient financial coverage to keep patients in therapist-supported programs for a sufficient duration to produce and maintain maximal gains.[1] The dose of movements required to induce significant change is measured in the thousands of repetitions,[4,5] but on average, only 30 movements are practiced for a given movement in a traditional daily rehabilitation session.[1]

To complicate the effects of the functional loss, patients can suffer from depression, decreasing motivation for sustained rehabilitation.[6] Patients also report that traditional exercises are uninteresting, reducing motivation for sustaining treatment.[7,8] In contrast, the video game industry produces accessible and affordable activities that engage users for long periods of time. In the United States, 183 million people spend at least 13 hours per week playing video games.[9] Gaming is more common even in "nontraditional" demographics: 37% of gamers are older than 35 years, and 47% of gamers identify as female.[10] Thus, integrating video games into therapy following hemiparesis may provide a viable solution to the lack of engagement and accessibility in current therapies. In contrast to other approaches that recommend rehabilitation-specific games,[7] we propose using adapted accessibility solutions that allow patients to play commercially available video games during rehabilitation. Emphasis is placed on commercial solutions because of the overwhelming market-derived evidence that these games are effective at motivating individuals to use them.

CURRENT TECHNOLOGIES IN REHABILITATION: WHERE DO VIDEO GAMES FIT IN?

In the first 6 months poststroke, there is a significant amount of spontaneous recovery, and a physical therapist takes advantage of this increased neuroplasticity immediately following stroke.[11] Following this period, lengthy and rigorous physical therapy using various techniques can continue to improve motor function, with increased time in therapy the primary predictor for increased functional recovery.[2,12-14]

Constraint-induced movement therapy, in which the less-affected limb is encumbered with the intent of encouraging the use of the hemiparetic limb, has been shown to increase the use of the more-affected limb in activities of daily living in addition to improvements on clinical tests.[15-18] Constraint-induced movement therapy also balances cortical excitability of both hemispheres,[19-21] suggesting that neuroplastic changes in the motor cortex partially explain recovery of function. Bilateral training requires the participant to move both limbs together to perform mirrored motions. Multiple studies have revealed greater improvements in the affected limb as a result of bilateral training than for both unimanual and linked-hands training techniques.[21-23] Improvements are retained even when participants transferred to bimanual and unimanual tasks of daily living, suggesting that partial reorganization of activation pathways was long-lasting.[22]

Virtual reality (VR) training can be used to augment bilateral training and constraint-induced movement therapy techniques. Participants who are taught motor skills in a VR environment have better retention and are more efficient in transferring skills than participants who received similar training in the real world.[24] These learning advantages are attributable to increased experimenter control and feedback augmentation in VR.[24-28] To maximize effectiveness, therapy needs to have high repetition, supervision, clear rewards, and long duration over time.[29,30] These are elements that can be individually produced and monitored in a VR environment. For example, the Kinect system (Microsoft Inc, Redmond, Washington) has been used as a sensor to monitor the kinematics of participants' upper limb movements in VR-based rehabilitation exercise studies. This approach has been implemented in a game akin to baseball.[31] By moving their shoulders and elbows, study participants control the arm motions of an avatar to receive VR-batted balls. This VR task led to improved performance and improved patient affect.

In spite of the many techniques available to facilitate therapy, motivation and access are major obstacles to patients in achieving the necessary dosage of movements needed for recovery. Motivation, accessibility, and cost all contribute to attrition/abatement in the amount of time spent in therapy following an injury/illness,[32,33] and current data suggest that the dosage of therapy, in terms of the number of repetitions of an exercise, is already far less than optimal for recovery.[1] Thus, by adding a gaming supplement to therapy, patient adherence can be improved (shown abstractly in Figure 1). Motion controllers in games allow therapy-relevant movements to be practiced in the context of a game, and many of the benefits of virtual environments and augmented feedback can be realized in video game play. Borrowing on a model of usability from human computer interaction,[34] we posit that the reinforcing factors of gameplay could increase the likelihood of (1) initiating a gameplay session (the point of engagement), (2) augmenting engagement, (3) delaying disengagement, and (4) increasing the likelihood of reengagement (see Figure 1). Increasing patient engagement through gameplay has the potential to increase the dosage of therapy-relevant movements by integrating these movements into an interactive environment.

In the following sections, we present evidence for the use of commercial video games as a supplement to physical therapy, on the basis of behavioral, physiological, and

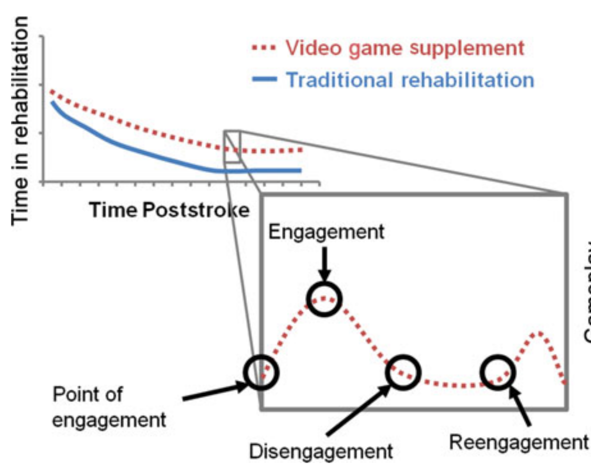

Figure 1. Integrating gameplay into therapy can increase time spent in therapy by increasing the likelihood of starting a therapy session (point of engagement), amount of time engaged in therapy (engagement and disengagement), and chances of going back to therapy for another exercise (reengagement).

(limited) rehabilitative studies of gaming interventions. We first review experimental studies of game-based training in both basic science and rehabilitation to demonstrate that gameplay is effective for inducing desirable behavioral and physiological changes. Second, we review the motivational properties of video games and present a framework for motivation and engagement in gaming based on interdisciplinary research, to justify games as a therapeutic tool. Evident in this review is the need for more basic and clinical research on gaming as a supplement to rehabilitation, and further technological development of adapted accessibility solutions that allow patients to play commercially available video games.

WHAT CAN GAMES DO?

Playing video games has been shown to have many positive behavioral and physiological effects. In rehabilitation settings, video games have been shown to have positive impacts on cognitive performance, motor performance, and affect. In quasi-experimental studies comparing video game experts with video game novices, experts show improved attentional capacity, expanded useful field of vision, and improved temporal resolution of attention relative to novices.[35] Surgeons who played video games made 37% fewer errors, were 27% faster with laparoscopic drills, and were 33% better at suturing tasks than nongamer surgeons.[36] Although supportive of video game–training benefits, the quasi-experimental nature of these studies prevents any causal judgments. Thus, in this Special Interest article, we focus exclusively on experimental studies of video game training (by searching electronic databases and the bibliographies of relevant research). This Special Interest article is inclusive in the types of games used, duration of the intervention, and sample population studied. Positive results and null findings found in published studies are presented hereafter. While we have attempted to be comprehensive in our review of the evidence, the interpretations are qualitative rather than quantitative. Considerable research still remains to be done in this area before the effectiveness and efficacy of video games in rehabilitation can be conclusively determined.

Behavioral Consequences of Video Game Play

Behavioral effects of video game–training studies are summarized in Table 1. Training can lead to meaningful improvement across cognitive, motor, and affective measures (although null results have also been reported[38]). With respect to cognitive aspects, training with action-based video games has been shown to improve attentional capacity and attentional deployment, and these gains transfer beyond the game environment.[35,45,46] Improvements in visual-motor and cognitive-motor performance have been shown in visuospatial rotations,[41,51] faster reaction times,[39,50] and execution of

Table 1. Summary of Video Game Training Studies Using Behavioral Measures[a]

Study	Measures Improved	Experimental Group	Control Group
Basak et al[37]	Working-memory capacity, task-switching ability, visual short-term memory, verbal reasoning	23.5 hours of training in a real-time strategy game	Similarly aged controls, no training
Boot et al[38]	Visuospatial reasoning. *Null results on attention, memory, and executive control*	20 hours of training in an action game	Identical time in a strategy game or a puzzle game
Clark et al[39]	Response selection in 2-choice reaction time	Minimum of 2 hour per week for 7 weeks of game training, elderly participants	Similarly aged controls, no training
Drew and Waters[40]	Visual attention, manual dexterity (pegboard), rotary pursuit, WAIS-R	2 months of training twice per week (∼11.5 hours total), elderly participants	Aged matched controls
Dorval and Peppin[41]	Visuospatial reasoning	8 sessions of gameplay over 2 weeks	Similarly aged controls, no training
Dustman et al[42]	Simple reaction time	11 weeks of video game play	Comparable time watching movies and a no-intervention group
Dye et al[43]	Response speed and accuracy in choice reaction time	50 hours of training in an action game	Identical time in social game
Goldstein et al[44]	Choice reaction time, self-reported well-being	25 hours of training over 5 weeks	Similarly aged controls, no training
Green and Bavelier[35,45,46]	Attentional capacity, deployment of visual attention	10 hours of video game training over 15 days in an action game	Identical time in a puzzle game
Green and Bavelier[47]	Spatial acuity of vision	30 hours of training in an action game	Identical time in a puzzle game
Hollander and Plummer[48]	Affect, feelings of success, achievement	3 weeks of play with cognitively challenging games (eg, trivia)	Pre-/posttherapy self-reports
McGuire[49]	Self-esteem, affect	8 weeks of elective video game play	Similarly aged controls, no games available
Orosy-Fildes and Allan[50]	Simple reaction time	15 minutes of gameplay	Similarly aged controls, no training
Subrahmanyam and Greenfield[51]	Visuospatial reasoning	3 × 45-minute sessions of gameplay on spatially challenging game	Identical training on a verbally challenging game
Weisman[52]	Self-esteem, engagement, attention	Games available to moderately impaired patients in nursing homes for 5 months	Self-reports, staff observations

Abbreviation: WAIS-R, Wechsler Adult Intelligence Scale Revised.
[a]"Action games" in these studies were generally first-person shooter games.

fine motor tasks.[40] These training effects suggest that differences between gamers and nongamers in quasi-experimental studies are attributable to training.[35,43,53] However, the amount of training across various studies has not been consistent, making it difficult to determine requirements needed for significant improvements (see Table 1). Moreover, there have been no systematic attempts to assess motivation and self-selected time spent in gaming. Although there are good reasons to infer that the motivational properties of video games would increase the time individuals spend playing games (eg, improved affect[48,49,52]), there are currently little empirical data that address this issue directly. There are, however, reports from clinical studies that suggest some patients desire to continue using games at the end of a gaming intervention.

Physiological Consequences of Video Game Play

Compared with knowledge concerning the behavioral consequences of playing video games, much less is known about the neurophysiological changes that are associated with this type of training. Significant increases in striatal dopamine have been identified during action video game play compared with resting levels, using positron emission tomography.[54] Not only did gameplay increase striatal dopamine release but dopamine release positively correlated with in-game performance. Levels of dopamine release in the ventral striatum (approximately a 13% increase over resting baseline levels) were similar to dopamine release observed in other studies following intravenous injections of amphetamine (16% increase[55]) and methamphetamine (23% increase[56]).

Neuroplastic adaptations as a result of gameplay have been shown in some studies, but none have dealt with motor learning or rehabilitation directly. Li et al[57] found that playing action video games significantly improved the contrast sensitivity function of the eye, and Green et al.[58] showed that video game training improved the spatial resolution of vision. Playing action video games has also been linked to modulation of early sensory processing by increasing sensitivity to changes in the visual environment[59] as well as long-term improvements in spatial cognition.[60] Robust retention and transfer tests in these studies are important because they suggest that video game play, when applied to therapy, could lead to durable improvements that may transfer beyond rehabilitation into the activities of daily life.

Previous research in this area has been conducted using video game controls that are handheld and require only finger movements to play. The introduction of motion controllers (eg, the Nintendo Wii, Playstation Move, and Microsoft Kinect) has increased the type and range of movements possible in control of a video game. The increased interactivity of motion controllers requires complex, coordinated motion within a limb, between two limbs, or even using full-body motion. Increasing a player's range, speed, and amount of movement clearly has the potential to help rehabilitate motor impairments. An ancillary benefit, however, is increased aerobic activity that accompanies motion-based control. This brings up an important distinction between learning, referring to durable neurophysiological adaptations, and training, referring to musculoskeletal or cardiovascular adaptations. Gaming interventions could be focused on learning, training, or both processes, and more research is needed to understand how design characteristics of the game might differentially affect these processes.

Data in this area suggest that "Wii Fit" games are an alternative to light-intensity aerobic exercise in middle-aged and older adults with respect to cardiovascular and metabolic measures of intensity.[61,62] Enjoyment scores (across age groups) for Wii balance and aerobic games (not including yoga) were higher than treadmill walking or hand-held gaming.[61] Also, the Wii Fit system involves whole body motions, but most Wii games are played primarily with the upper extremities. Wii Fit games (full body) were compared with "Wii Sports" games (primarily UE) in men and women (aged 25-44 years); metabolic equivalents in Wii Sports (3.0 ± 0.9) were greater than that in Wii Fit balance (2.1 ± 0.6) or yoga games (2.0 ± 0.6).[63] Of the games investigated across Wii Fit and Wii Sports, 33% qualified as moderate intensity (3-6 metabolic equivalents) and 67% classified as light intensity (<3 metabolic equivalents), suggesting the utility of motion-controlled games as an aerobic-training tool.[63]

Video Games in Rehabilitation

In one study, the use of the Nintendo Wii led to significantly improved motor function in participants within 6 months of stroke when they were compared to a recreational therapy group (tabletop games) 4 weeks postintervention.[64] Similarly, positive results associated with playing Wii (upper limb exercises) were seen in poststroke participants after six 30-minute sessions.[65] There was also a significant increase in Fugl-Meyer and Motricity Index scores, and participants had a desire to continue the therapy as a part of their rehabilitation and to recommend it to others, reporting that they felt it was at least as useful as conventional therapy.[65] Reports of increased enjoyment and desire to continue using the gaming system are congruent with other video game interventions[7] and basic psychological studies of affect,[48,49,52] but there are currently no clinical data showing that integrating games actually augments time in therapy. It is promising that in all 3 case studies,[7] all with participants older than 65 years, the participants were interested in obtaining an "at home" copy of the game for personal use.

The Wii controller has also been used in a biofeedback platform to reduce unwanted compensatory movements during exercise in participants poststroke (eg, twisting at the trunk to move the hand to the midline rather than transverse adduction at the shoulder).[66] A punishment/reward system discouraged compensation and encouraged "good" motions. This biofeedback motivated participants to reduce their compensatory movements and improved the quality of movement in the more-affected limb.

In clinical populations other than that with stroke, video game interventions have resulted in functional improvements as well. The Wii Balance Board was a successful training intervention in hemiparetic individuals with acquired brain injury.[67] In one study, participants with early Parkinson disease underwent baseline testing, played Wii Fit games over 8 sessions, and were then evaluated 2 months later. At the 2-month posttest, participants showed no deficit in acquiring or retaining skills compared with healthy controls on 7/10 games, although the overall level of performance was lower for 5/7 of those games. Participants were able to transfer learning from video game play to a functional reach test,[68] as indicated by change in performance from pretest to posttest. Finally, geriatric participants using therapist-guided video game therapy improved more on some measures of balance and mobility than participants receiving traditional therapy in the ward gym matched for treatment time.[69] Although promising, there is clearly need for more research in this area. There appear to be only 3 randomized controlled pilot studies on video games in therapy,[64,67,69] and these were single-blind studies. Also, current data have matched experimental groups to controls for time in therapy but not for the number of movements, which would be an important control in future research. Thus, the clinical utility of video game supplements in therapy needs to be experimentally explored.

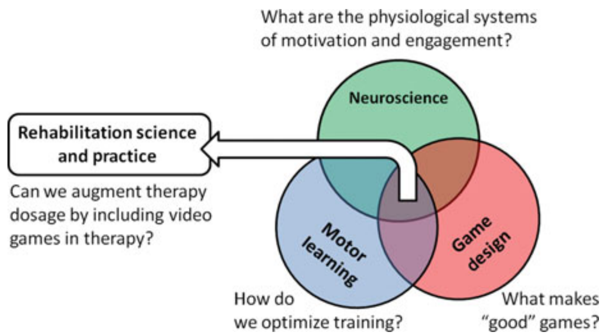

Figure 2. A schematic representation of the process of developing gaming principles for rehabilitation.

APPLYING GAMES TO REHABILITATION: AN INTERDISCIPLINARY APPROACH

The combined results of these studies are promising, and with detailed research and development, video game play might be a safe, cost-efficient, and effective supplement to conventional physical therapy. As research in this area grows, however, there is still a lack of criteria by which therapists can judge how games could be integrated into rehabilitation or assist patients in choosing games appropriate for in-home use. One option is designing therapy-specific games. This might be an option for the future as this niche develops, but it is costly and time-consuming at present. Thus, we advocate the use of readily available, commercial video games designed in the highly competitive gaming industry. We argue that these commercial games are effective, motivating, and engaging for patients because these are based on key factors of game design. We next explore game design factors that are most salient for rehabilitation and use empirical research from psychology, neuroscience, and motor learning to show that there is a scientific basis for what makes a successful video game (ie, one that is motivating and engaging).

Game designers try to maximize the likelihood that their product will be commercially successful. This success is largely defined by the number of hours that gamers are willing to invest in a single title. By extracting factors of good game design, we can gain insight into factors that should increase patient engagement with rehabilitation and hence suggest criteria by which games might be well-suited for rehabilitation. These criteria are not solely based on game design principles from industry. We took an interdisciplinary approach (illustrated in Figure 2) to find areas of overlap between what we know about game design, the neuroscience of motivation, and principles of motor learning that have been shown to improve long-term retention and transfer in the general population.

A list of general game design principles was constructed on the basis of readings from game design and human-computer interaction. Areas of overlap were identified in neuroscientific and motor learning research. Those principles that were empirically supported were evaluated with respect to their use in physical and occupational rehabilitation. From this interdisciplinary perspective, we extracted 6 key principles of effective game design that have an empirical basis for increasing player engagement and motivation: reward, optimal challenge, feedback, choice/interactivity, clear instructions, and socialization. These are not exhaustive or mutually exclusive factors. For example, changes in feedback could affect the difficulty of the game, which in turn affects a player's sense of reward and the motivation to continue playing. These 6 principles should instead be thought of as a framework for conceptualizing engagement and motivation in gameplay.

Motivation is a difficult concept to describe, but for purposes of this Special Interest article, we operationally define *motivation* as a psychological property that encourages a person's action toward a goal by eliciting and/or sustaining goal-directed behavior.[70,71] From research on game design and human-computer interaction, a number of factors increase players' motivation to begin a gaming session and increase their motivation to continue playing. For instance, there are personally motivating factors (eg, perceived control, curiosity and exploration, and imagination) and socially motivating factors (eg, cooperation, competition, and recognition).[72-74] Listed hereafter are 6 factors that impact motivation via gameplay and are empirically supported by research in motor learning and affective neuroscience.

Reward

Caillois[75] provides a classification of types of games across cultures. There are games of conflict/competition, chance, imitation/mimicry, and sensation seeking. The unifying theme in these different games is that play is based on reward. Bartle[76] offers a similar classification for individual differences between gamers. Thus, even though the relative strength of rewards or the conditions that trigger rewards may be different across games or gamers, gameplay is motivated by rewarding experiences.

One of the insights from the large body of research on the neuroscience of reward and motivation[77-80] is the discovery that the limbic system, in particular the nucleus accumbens (NA), is critical to learning new behaviors, especially those associated with pursuit of rewards, pleasure, and addiction.[81-83] Activity in the NA has been shown to scale linearly to the probability of receiving a reward, and differences in NA activity correlate with individual differences in sensation seeking.[84] Dopamine in the NA is associated with reward-based learning, feelings of pleasure/enjoyment, and motivation to perform specific behaviors.[73] We hypothesize that a dopaminergic and domain-general reward system underlies gameplay. Although a dopaminergic reward system may underlie rewarding experiences in gameplay, there are several conditions that will elicit dopamine release. The properties of this dopaminergic reward system may change as a function of disease or injury, but human and animal research shows that certain conditions reliably elicit psychological and physiological rewards. Four such conditions are presented in Table 2.

Difficulty/Challenge

At the beginning of a game, players desire a low level of challenge to meet a correspondingly low level of ability and familiarity with the game. Good examples of this are tutorials, in which the player is guided through the game's entry level with specific task-by-task instructions. However, as the player becomes familiar with the controls of the game, accomplishing the tasks gets progressively more difficult.[93] In fact, gamers are failing in their within-game tasks frequently, up to 80% of their in-game time.[94] Lazzaro,[95] has postulated that players are excited and eager to retry a task when they fail positively. Positive failure, unlike passive failure, happens when a player falls just short of success, suggesting that excitement during execution may influence enjoyment more than nominal success.[94] The joy of positive failure is associated also with the state of "flow,"[96] defined in positive psychology literature as the satisfying feeling of heightened functioning. Positive failures also fit with experimental work on dopamine,[81] which suggests that nearly succeeding or narrowly avoiding failure are physiologically rewarding experiences.

Positive failure and flow happen through gradual change in the difficulty of the game. With an increase in experience, greater challenge keeps players on the edge of their ability to accomplish tasks. Adaptive and multilevel games offer the best solution to maintaining the appropriate level of challenge. Physiologically, when the same action is no longer guaranteed to produce the same level of reward, the magnitude of reward prediction error is also increased.[87,88] This desirable increase could be achieved by progressively increasing the level of challenge offered by a game or by changing the game.

From a motor learning perspective, there has been a considerable amount of theorizing on how to maintain an optimal level of challenge[96,97] or to create "desirable difficulties" during practice.[98] To avoid boredom or frustration, players should be kept at the upper limit of their ability by manipulating difficulty in meaningful ways (eg, making things faster is only meaningful if speed is a critical component of real performance). With respect to rehabilitation, it is also important to consider difficulty as an interaction of individual and environmental constraints[99,100] to understand how difficulties might arise directly from injury/disease or from the environmental changes that accompany these individual changes. Furthermore, some data suggest that scaffolding practice from easy to difficult leads to greater skill transfer, whereas beginning at more difficult levels creates specificity.[101] Transfer is particularly important for rehabilitation where game-acquired skills are expected to transfer into activities of daily life.

Feedback

Feedback is any information about how a skill was performed and/or the effectiveness with which the skill was performed. Feedback can be a natural consequence of an action, referred to as *intrinsic feedback*, which includes vision, proprioception, and equilibrioception. Importantly for engagement and learning, additional feedback is often provided from external sources, termed *augmented feedback*, which includes verbal feedback from coaches/therapists, video feedback, points, badges, and other performance-contingent rewards. Interpretable feedback leads to more efficient learning, but feedback should also be *prescriptive* rather than simply *descriptive*. Giving learners prescriptive feedback about what to do following an error reduces the cognitive load,[102,103] which might be helpful early in practice or at a point of impasse.

Feedback serves an informational function for improving motor learning, but it also has a motivational function.

Table 2. Proposed Conditions in Gameplay That Induce Dopaminergic Rewards, on the Basis of Research in Behavioral Neuroscience and Neuropsychology[a]

Condition	Mechanism	References
Visceral pleasures	Visceral pleasures have been shown to increase dopamine release. Conditioned stimuli associated with pleasure lead to dopamine release (eg, cultural, social, and personal pleasures)	Hikosaka et al,[85] Rolls,[86] and Wise[71]
Decisions	Decision-making requires resolution of competing options. If a selected behavior is rewarded, the likelihood is increased that the same decision will be made in the future. Dopamine is released not only upon success but also when coming close to success or narrowly avoiding failure, thus increasing motivation to try again	Clark et al[81]
Uncertainty	Uncertainty and chance increase dopamine release. Dopamine release is not driven simply by reward, but by "reward prediction error." Striatal activation in anticipation of uncertain rewards promotes the learning of better predictors of reward	Caplin and Dean,[87] Mirenowicz and Schultz,[88] and Shizgal and Arvanitogannis[89]
Exploration/novelty	Exploratory behaviors are associated with dopamine activity. Exploration is important for acquiring new behaviors in a changing world. Dopamine release in response to novelty might serve an adaptive function by making exploration rewarding	Dulawa et al,[90] Hyland et al,[91] and Legault and Wise [92]

[a]The listed conditions are empirically supported and connect game mechanics to the aesthetic experience of players. However, it is important to note that these conditions are not exhaustive and that dopaminergic activity is not the sole substrate of rewarding experiences.

Data from laboratory studies suggest that providing participants with feedback after good trials leads to better long-term retention of the skill than giving participants equal amounts of feedback following poor trials.[104] This suggests that people like to receive affirmation of competency rather than errors or failure. In support, if participants feel that they are doing well relative to other people, this also increases their motivation to practice, their level of performance, and their retention of a skill.[105-107] In game design, feedback can similarly be used to augment other factors, such as difficulty or socialization.[74] For instance, clear and immediate feedback on differences between players could increase the competitive/adversarial aspects of a game, even if the game is designed to be cooperative. Therapists should be careful in evaluating games for the type of feedback they provide, choosing games that provide positive feedback more frequently.

Choice/Interactivity

Choice and interactivity are integral parts of successful games. Although conceptually distinct, these constructs are intertwined. That is, interactivity requires choice (eg, take path A or path B?) and making a choice in a game is an interaction (ie, players' decisions have an evident effect on the game). Choice and interactivity can be included in game design in many ways: "mini" games or games within games, different paths and outcomes, and multiple ways of completing goals. One possible outcome of having this choice is a feeling of "ownership" of a character, game, or world. Another outcome is that it increases the desire for players to play a game again once they have already beaten it.[75,76] Perhaps the most important for choice/interactivity in rehabilitation is that these constructs separate "active" and "passive" forms of entertainment. Passive entertainment, such as from radio and television, provides many of the same aesthetic experiences that are available in games but do not require the active cognitive or physical participation that games do.[74]

As both a gaming and motor learning principle, the concept of choice and interactivity is critical in increasing engagement; data suggest that simply allowing learners to choose when to receive feedback can increase skill retention and transfer.[108,109] From the perspective of game design, choice and interactivity increase the connection that a player has with the virtual environment, such that interactions can be based on individual psychological needs.[110] These data on interactivity are consistent with surveys that show that players rate game situations with more options as being more enjoyable.[111] Exploration of novel stimuli and new environments are strongly associated with physiological rewards.[90-92] This exploration is akin to interactivity in the game environment, in which a player might literally be exploring a novel virtual environment or exploring more abstract dimensions of the game (eg, story arcs and new characters).

Clear Goals and Mechanics

Gameplay offers achievement-based satisfaction, because goals can be met on very short- to very long-term timescales. Clear goals and instructions for completing a task make task execution efficient. In gameplay, goals are oriented toward self-improvement or survival. Self-improvement goals give rewards that improve the player's avatar and generally satisfy materialistic needs. Survival goals might involve avoiding failure for the length of a level or defeating a powerful opponent. To reach goals, games must include clear instructions, which can be explicit tutorials or implicit cues. Explicit tutorials can either be dynamically included into gameplay or be separate documents. Exploration of the game and its mechanics can serve as implicit cues, which take the form of punishment/reward and can lead to positive failure.[95] That is, a lot of time spent in games involves failing at game objectives before the mechanics are learned.

Goal-directed tasks lead to a higher chance of acceptance of assistive devices.[112,113] A lack of goals and instructions can have a significant negative impact on the motivation of patients.[114,115] Thus, therapeutic goals that are unclear to patients can compromise recovery. Patients with high motivation in a rehabilitation setting reported that they were communicating with their therapist, and that getting clear and consistent instructions built a feeling of reassurance that they were moving toward their therapy goals. Poor/unclear instructions made patients confused and frustrated and ultimately led to low motivation.[114,115]

Socialization

Remote socialization, through being a member of an online community, has been experimentally linked with increasing and stabilizing the amount of time spent playing a game.[116-118] Socialization and social interaction were reported to be the primary reasons for playing online games by 39% of players in an online survey ($n = 1836$).[118]

There are 3 aspects of remote socialization that have emerged in recent literature: competition, feedback, and presence.[75] Social competition is the act of directly comparing the skills of 2 players through either direct competition or scoreboards. Social competition can help maintain self-esteem and create positive experiences.[119,120] Social feedback takes the form of congratulating others on progress and has notably been used to make slot machines more appealing and enjoyable.[121] Social presence is experienced without the need for any direct social interaction; it is the knowledge that players are playing the game with others, sometimes thousands of other people.[117]

Many off-the-shelf video games are designed to be played by multiple players and thus offer opportunities for remote and proximal socialization. Remote socialization for *existing* games is especially beneficial because it places the player in the context of a larger community compared with games designed only for rehabilitation. Proximal socialization in existing games is also beneficial to motivation, engagement, and learning because it allows for cooperation and competition with a partner who is a valuable source of feedback and encouragement.[122,123]

CONCLUSIONS

Therapeutic practices for population with neurological ailments have been developed around the principles of motor learning and neuroplasticity, aiming to optimize the time spent in therapy. Qualitative data, based on interviews with therapists and survivors of stroke in therapy, have helped to identify a lack of motivation as a barrier to adherence to therapy.[7,112,113,124] Thus, dwindling patient motivation and limited accessibility can have negative impacts on time spent in therapy. This suggests that in addition to neuroplasticity and motor learning, positive psychology and motivating principles should be taken into consideration to increase the dosage of physical therapy.

Low motivation and engagement are barriers in physical therapy exercises[112,113] that can lead to nonadherence with therapy.[32,33] Video games have the potential to alleviate nonadherence because of their motivating structure. Games are known for having voluntary participation (ie, players start playing without being required to), extended playtime (ie, players spend on average 12-20 hours per week playing games), and a high probability of being replayed. Furthermore, different genres of video games have been shown to have a positive effect on players' cognitive and motor abilities. By taking an interdisciplinary approach to studying game design, we have distilled 6 key factors to build a framework for understanding the engaging nature of video games: reward, difficulty/challenge, feedback, choice/interactivity, clear goals and mechanics, and socialization. These key factors may be useful also for therapists seeking to evaluate games for use by their patients.

To address the issue of motivation in therapy, we recommend more clinical research integrating existing video games into rehabilitation via modified game control interfaces as a supplement to traditional rehabilitation practice. The advent of motion controllers for home-based video games makes using rehabilitation-relevant motions to control games feasible, and has the practical advantage of reduced cost compared with complex virtual-reality/robotic interfaces. This type of therapy has much promise but still requires significant technological development into control systems that compensate for different degrees/types of limb impairment to make commercial games accessible to patients. The evidence reviewed here suggests that (*a*) video game play can induce the sort of behavioral and physiological changes that are desirable in therapy (Table 1); (*b*) recent, but limited, clinical research suggests that video game usage or video game–based therapies can improve patient performance on clinical measures of motor behavior; and (*c*) with respect to affect, data suggest that participants enjoy gameplay,[7,31,65] and even elderly participants report enjoyment playing video games[7,61] and show interest in acquiring home-based systems for personal use.[7]

Further work remains to be done to demonstrate empirically that patients will use video games to extents that will reap clinical effects; however, we are encouraged by the burgeoning research using existing video games as a therapeutic tool. By integrating game design with principles of neuroscience and psychology, we argue the motivational and engaging properties of games can be used to help patients achieve a higher dosage of movements recommended by neurological theories of rehabilitation. This integration could come in the form of game-based therapies under the supervision of a physical therapist and/or as a gaming supplement more similar to a home-exercise program. In either event, games should be regarded as a therapeutic tool (potentially a powerful tool) that can be intelligently integrated into rehabilitation by qualified therapists. With continued advances in research and technology, games could functionally increase in the amount of time patients spend in physically active rehabilitative tasks at lower cost and with broader reach than other technological supplements.

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