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Designing Serious Game Interventions for Individuals with Autism

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Abstract The design of "Serious games" that use game components (e.g., storyline, long-term goals, rewards) to create engaging learning experiences has increased in recent years. We examine of the core principles of serious game design and examine the current use of these principles in computer-based interventions for individuals with autism. Participants who undergo these computer-based interventions often show little evidence of the ability to generalize such learning to novel, everyday social communicative interactions. This lack of generalized learning may result, in part, from the limited use of fundamental elements of serious game design that are known to maximize learning. We suggest that future computer-based interventions should consider the full range of serious game design principles that promote generalization of learning.

Keywords Autism · Serious game · Virtual reality · Technology · Computer-based intervention · Cognitive training

Introduction

There is an emerging field of intervention research that is designed to enhance cognitive and social skills, with the ultimate goal of improving psychosocial outcomes in both mental health and developmental disorders (e.g., Saperstein and Kurtz 2013). Some of the best examples of this research include interventions that remediate cognitive deficits in schizophrenia, which ultimately improves daily functioning for these patients (e.g., Medalia and Choi 2009). Increasingly, researchers are turning to computerized versions of these interventions because of the ability to scale them up and transport them easily, but also because of the ability to employ strategies for increasing players' motivation and personalizing training, which greatly enhances learning (Saperstein and Kurtz 2013).

In the field of autism research, computer-based interventions are being used to improve emotion and face identity recognition abilities (e.g., Tanaka et al. 2010; Wainer and Ingersol 2011) as well as language and social skills (e.g., Grynszpan et al. 2014). This approach has been inspired, in part, by findings that children with autism (like their typically developing peers) often enjoy playing computer games in their discretionary time (Orsmond and Kuo 2011; Kuo et al. 2013). In addition, the privacy of the game environment provides a safe and non-threatening context for practicing and acquiring new and difficult skills (Kapp 2012). Unfortunately, many of these existing computer-based interventions for autism have shown little evidence of learning generalization or improvement in psychosocial outcomes.

Here, we argue that computerized interventions for individuals with autism may be much more successful if motivation can be improved and learning can be personalized by leveraging principles from another emerging field of "serious game design" in educational research (De Freitas 2006; Dickey 2006; Habgood and Ainsworth 2011). To make this argument, we first explain what serious games are and how they are fundamentally different from entertainment games. Second, we show how the principles

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of serious game design have been used to promote skill acquisition or modify behavior in other health and educational domains. Third, we evaluate the extent to which any of the principles of serious game design have been employed in the existing computer-based interventions designed for individuals with autism. Finally, we provide recommendations for future intervention research regarding the use of serious game design principles to enhance intrinsic motivation and promote generalization of learning. Importantly, these principles can be applied to the design of interventions aimed to improve a broad range of targeted behaviors and/or neurodevelopmental systems.

What are Serious Games?

Serious games are designed to foster learning of targeted skills that are particularly difficult and not rewarding for participants (e.g., encouraging a child to take medicine that makes him feel nauseous in the short term but will likely cure his illness in the long run). A central goal of serious games is that the learning in the game generalizes to improve real life outcomes. They are very different from games designed for the purpose of entertainment, which are not designed for the purpose of skill acquisition and not expected to lead to generalized skills or knowledge beyond the game. Serious games are focused on the integration of educational objectives with specific evidence-based game mechanics known to support learning and generalization of learning. In contrast, entertainment games are designed to be engaging for the sheer purpose of game playing. For example, while extrinsic point-based reward systems are common motivational tools in entertainment games, reward systems that foster intrinsic motivation for more sustainable learning is a principle of serious game design.

Serious games accomplish these goals, in part, by employing principles of video game design to create enjoyable and immersive environments but, importantly, they are also are grounded in theories of learning and development (De Freitas 2006). Serious game design draws from a large body of empirical research suggesting that learning is maximized when it is occurs in relevant contexts that engage learners (see Catalano et al. 2014). For example, the emphasis on promoting behavioral change comes from the social cognitive theory (Bandura 1986; Baranowski et al. 2008), and the emphasis on intrinsic motivation is informed by self-determination theory (Ryan and Deci 2000; Ryan et al. 2006). The role of play in learning is informed by Vygotsky's social constructivist theory and the notion of a zone of proximal development (Barab et al. 2005; Vygotsky 1933/1978). In addition, empirical research indicates that active cognitive processing of material is necessary for effective learning (Wouters et al. 2008) and that learning is enhanced when participants discover and use information rather than memorize it (Garris et al. 2002). In sum, serious game design merges learning theory and empirical findings about maximizing skill learning and generalization of learning together with principles of game design to create a *unique intervention tool* that can target any set of cognitive, social, affective, and/or health-related skills with the goal of improving outcomes *beyond the context of the game*.

Important Design Elements of Serious Games

In this section, we define the core principles of serious game design and show how they have been successfully employed in health and education domains. While there are a wide variety of elements relevant to the design of games, we focus on those that are likely to be particularly relevant to enhancing motivation to play, given that the targeted skills are difficult to learn, not inherently rewarding, and often require weeks or months of training to see any effects, as well as those that are likely to support generalization of learning. These elements include: immersive storylines, goals directed around targeted skills, rewards and feedback about goal progress, increasing levels of difficulty, individualized training, and the provision of choice (Baranowski et al. 2008; Kapp 2012).

Storylines Enhance Motivation and Contextualize Learning

One of the most effective elements for enhancing the motivation to learn in serious game design is the creation of a storyline or narrative that contextualizes the to-be-learned skills and goals. Narratives that integrate the storyline with goal learning increase enjoyment, immersion in the learning context, and learner motivation. In general, storylines enable individuals to experience content in meaningful contexts. In a serious game, the story narrative is built to support learning of the specific educational content targeted by the intervention (Lu et al. 2012). When learning opportunities are directly integrated with the story content, they enhance intrinsic motivation for learning (Baranowski et al. 2008; Garris et al. 2002; Gee 2003; Reiber 1996). For example, one of the most successful serious games, Re-mission, targets patients' willingness to adhere to their chemotherapy treatments as they play a game in which they travel through a body as a "nano-bot" and shoot virtual cancer cells with chemotherapy treatments as ammunition (Kato et al. 2008).

Storylines that develop specific characters provide potential tools for enhancing social skills, like empathy, and also foster intrinsic motivation to learn skills (Dickey 2006). Participants can develop emotional connections with characters (e.g., identifying with the characters and having empathy for them). The development of characters and the dialogue between characters can be important for creating an immersive environment (Dickey 2005, 2006). The characters in educational games can include mentors who facilitate learning by providing guidance in the game (Marchiori et al. 2012). For example, in the game "Escape from DIAB", mentor characters help the player beat the evil king by teaching the player information about healthy lifestyles and eating behaviors (Thompson et al. 2010; Lu et al. 2012). Lu et al. (2012) found that self-reported feelings of immersion positively correlated with health outcomes among individuals who played the "Escape from DIAB" game. Thus, well designed characters and storylines immerse players in the learning context, which contextualizes learning goals. As mentioned previously, this strategy is critical for maximizing learning (Catalano et al. 2014).

Goals Direct Learning Around Targeted Skills

Serious games direct players to accomplish goals around targeted skills. This includes both primary end-goals (signaling completion of the game) as well as intermediate incremental goals that provide challenges and reflect progress (Garris et al. 2002). Medium-term goals might include completing story-driven narrative objectives or earning sufficient points across trials (over the course of several minutes or hours) to complete a level. For example, in the serious game InsuOnline, which was designed to teach physicians about diabetes treatments, the long-term goal is for the player to learn the skills to take over a medical practice so that the mentor character can go on vacation. The medium-term goals involve treating multiple virtual patients (Diehl et al. 2013). Together, the combination of medium-term and long-term goals tied to narrative storylines (e.g., overcoming obstacles or resolving mysteries) provide multiple skill-learning opportunities and this increases intrinsic motivation to continue playing the game as difficulty increases (Habgood and Ainsworth 2011; Baranowski et al. 2008). Thus, in the design of serious games, when both medium-term and long-term goals are implemented and integrated with the storyline, players exhibit more intrinsic motivation to continue playing, which may be crucial for long-term behavior change.

Feedback and Rewards Shape Learning

Continuous feedback and rewards for progress are critical for shaping behavior in serious games as learners work towards achieving challenging goals. In designing rewards and feedback, both intrinsic and extrinsic motivation needs to be considered (Habgood and Ainsworth 2011). Entertainment games focus almost exclusively on providing immediate extrinsic rewards in the form of visual and auditory feedback, cumulative point systems, and leaderboards that display competitive rankings of players' point totals. Traditional learning theory has demonstrated that behaviors shaped using this kind of contingent, immediate reinforcement extinguish very quickly when the reward is withdrawn. In contrast, serious games focus on providing feedback related to achieving long-term goals and enhancing intrinsic motivation for learning by providing players with information about their progress toward incremental and primary learning goals (Kapp 2012).

Recall that the goal of serious games is to train up targeted skills that are particularly difficult for particular individuals. As a result, serious games are designed to optimally engage, but not frustrate, users (Mishra and Gazzaley 2014). Furthermore, negative feedback, particularly in response to failure, can actually diminish a player's motivation to continue in a game (Lepper and Chabay 1985) and reduce learning potential. This is why continuous feedback and rewards for progress towards achieving long-term goals are so essential in serious games, as is gauging and individualizing the level of difficulty of game play.

Increasing Levels of Difficulty and Individuation

Increasing competence for particular skills during serious games involves providing challenging, yet *achievable*, goals in a safe and supportive environment (Przybylski et al. 2010). Serious games cannot be so difficult that they frustrate and/or discourage individuals from attempting to complete the game (i.e., floor level performance), nor so easy that the player never learns new skills (i.e., ceiling level performance). Theoretical models related to providing achievable challenges in learning include Vygotsky's Zone of Proximal Development (Barab et al. 2005; Vygotsky 1933/1978) and the concept of "flow" theory in task engagement (Shernoff et al. 2003). For example, flow theory suggests that engagement in learning (i.e., concentration, interest, and enjoyment) is highest when perceived challenges and skills are well matched (Shernoff et al. 2003). Critically, both theories suggest that a mismatch between skill level and game difficulty reduces engagement, motivation, and learning. However, individual learners will vary greatly with regards to the game content they find challenging. As a result, there is a critical need to have individualized starting points and to increase difficulty in an individualized way. Serious games build in the capacity to evaluate and calibrate these individual differences in the nature of the game starting point and rate with which difficulty increases. Thus, serious games scaffold behavior by slowly increasing difficulty in ways that are consistent with individual player ability/capacity.

One strategy for personalizing training/game play is to use *adaptive progressions*. In other words, on a trial-by-trial basis, the level of difficulty of the training is specifically adapted to the player's *in–the-moment game performance*. This strategy has been used in previous perceptual training studies (Fisher et al. 2009) in which researchers employ a psychophysical staircase function that enhanced the training challenge in response to accurate performance and reduce it in response to inaccurate performance so as to maintain overall performance level for each participant between 75 and 85 %, the point at which the user was optimally engaged but not frustrated (Mishra and Gazzaley 2014). In this way, the training is uniquely personalized to the cognitive capacity of each participant, but also allows abilities to change over time. Alternative strategies for personalizing game-based training may involve a combination of individualized starting points and appropriately increasing difficulty across levels (rather than at the level of individual trials) within the game as new skills are mastered.

Provision of Choice

Self-determination theory suggests that provision of choice is one of the important tools of fostering intrinsic motivation and enjoyment in serious games (Ryan et al. 2006). In addition to providing individualized levels of difficulty, provisions of choice within a serious game can allow learners to maintain a sense of autonomy and control over their learning experience (Przybylski et al. 2010). Thus, letting the player have choice over some aspects of the game environment is an important element of serious game design, particularly when designed to specifically enhance learning opportunities. Importantly, a recent meta-analysis suggests that provision of choice is most effective in enhancing motivation and learning when the choices are relevant to the instruction and limited in the number to avoid fatigue (Patall et al. 2008). Thus, choices related to achieving the learning goals should be carefully planned in ways that allow for autonomy in deciding how to complete relevant educational content.

These central elements of serious game design have been shown empirically to improve learning and motivation in a wide range of learning domains. The following section will review the current progress in the field of autism computer-based intervention research, with specific focus on the extent to which the studies have employed these principles of serious game design.

Computer-Based Interventions in Autism Research

The use of computer-based interventions in the field of autism research began nearly 15 years ago. However, there is limited use of serious game elements in these existing computerized interventions. Only a handful of existing interventions have attempted to integrate serious game design features into these programs. Thus, in the existing literature, the term "computer-based intervention" includes both serious games (comprised of purposeful utilization of game-based elements) and other interventions delivered through the use of computers that do not utilize serious game design elements (such as virtual reality and cognitive training methodologies).

The existing computer-based interventions have been designed from theoretical models about the science of autism and the choices of targets for intervention have been informed by both deficit-based and neurodevelopmental models of autism. These studies have been reviewed recently in several papers (see Grynszpan et al. 2014; Ramdoss et al. 2012; Wainer and Ingersol 2011). Unfortunately, the general consensus is that these studies report minimal, if any, generalization of learning, as defined by far-transfer to real-world social interactions (Grynszpan et al. 2014).

Here, we provide a conceptual review of the *design principles* of these computer-based interventions for individuals with autism. We suggest that the lack of both near- and far-transfer of learning reported in these previous studies is likely related to limited learning during the intervention, which may be related to many factors (e.g., too few learning trials, not enough difficulty, reaching ceiling performance too quickly, early termination of training, learning that is too context-dependent). As a result, we suggest that the intervention training may need to be much more extensive, which is exactly what serious game principles are designed to do; that is they provide learning contexts that are more immersive and contextualized so that learning of difficult behaviors and skills can be scaffolded as motivation to learn them is intrinsically enhanced. We suggest that interventions utilizing computer technology for individuals with autism could be greatly improved upon and will likely produce better results by including more elements of serious game design.

Table 1 provides a summary of the 16 studies we reviewed. This list includes research articles that (1) were published in peer-reviewed academic journals, (2) utilized computer-based intervention methodologies (cognitive training, serious games, or virtual reality) (3) for individuals with autism, and (4) conducted efficacy and generalization testing of the intervention. Studies in Table 1 include three commonly targeted skill domains related to autistic symptomology: language (including vocabulary, syntax, and reading), face-processing abilities (including emotion recognition and face recognition), and social skills (including all other domains related to social behavior). Exercise games as tools for intervention targeting

Table 1 Game-based elements included in computer-based interventions for individuals with autism

References	Training domain	Format	Storyline	Goals	Rewards	Difficulty Increases	Individualized	Generalization of training?
Heimann et al. (1995)	Language	Cog. training	No	Short	Feedback	Yes	Choice	Near-transfer
Moore and Calvert (2000)	Language	Cog. training	No	Short	Reward	No	Yes	Near-transfer
Bosseler et al. (2003)	Language	Cog. training	No	Short	Feedback	Some	Yes	Near-transfer
Whalen et al. (2010)	Language	Cog. training	No	Short	Reward	Yes	Yes	Near-transfer
Bölte et al. (2002)	Face processing	Cog. training	No	Short	Reward	No	No	Training effect
Golan and Baron-Cohen (2006)	Face processing	Cog. training	No	Short	Reward	Some	Choice	Near-transfer
Tanaka et al. (2010)	Face processing	Cog. training	Themed	Medium	Point system	Yes	Choice	Near-transfer
Hopkins et al. (2011)	Face processing	Cog. training	Themed	Medium	Point system	Some	Choice	Far-transfer
Faja et al. (2012)	Face processing	Cog. training	No	Short	Reward	Yes	No	Near-transfer
Swettenham (1996)	Social skills	Cog. training	Some	Short	Feedback	No	No	Near-transfer
Silver and Oakes (2001)	Social skills	Cog. training	No	Short	Feedback	Some	No	Near-transfer
Beaumont and Sofronoff (2008)	Social skills	Serious game	Yes	Long-term	Point system	Yes	No	Far-transfer
Ke and Im (2013)	Social skills	Virtual reality	No	Short	Reward	No	Facilitator	Near-transfer
Kandalaft et al. (2013)	Social skills	Virtual reality	No	Medium	Feedback	Some	Facilitator	Near-transfer
Bernardini et al. (2014)	Social skills	Virtual reality	Some	Medium	Reward	No	No	Near-transfer
Strickland et al. (2013)	Social skills	Virtual reality	No	Medium	Feedback	No	Facilitator	Far-transfer

sedentariness and repetitive behaviors in individuals with autism are included in the text of the review, but not included in Table 1 because of the use of commercial entertainment games.

Each study in Table 1 was evaluated for multiple elements of serious game design including: a storyline (or some story-based elements), types of goals (short-term, medium-term, or long-term), types of rewards (such as feedback on response accuracy, rewards for correct responses, or cumulative point systems across trials), increasing levels of difficulty over time (or some potential difficulty increases), and individualized learning (including individualized starting points, some provisions of choice, or presence of clinician/teacher facilitators). The generalization of training was also examined with regards to whether the study reported significant training effects (e.g., only significant increases within the training procedures and no generalization), near-transfer (e.g., generalization to similar computer-based tasks or standardized tests), and/or far-transfer (e.g., generalization to social or communicative interactions with others or to untrained skills).

Cognitive Training Interventions for Individuals with Autism

Language

The area of vocabulary development has been targeted for improvement by interventions using interactive computer programs for individuals with autism who have low verbal skills (Bosseler and Massaro 2003; Moore and Calvert 2000; Whalen et al. 2006, 2010). These programs included individualized treatment targets (e.g., teaching vocabulary words that were unknown to the child based on pre-testing), feedback about performance accuracy, and rewards for success. Some evidence suggests that these computer-based games may help children with autism (ages 3–6 years) learn more vocabulary than traditional teacher based instruction (Moore and Calvert 2000). Many of these studies have been successful in teaching children with autism to learn words and have provided evidence of near-transfer of learned words. For example, Bosseler and Massaro (2003) taught vocabulary items to nine children ages 7–12 years using an interactive computer program. The game-based elements used included individualized treatment targets (12 vocabulary words that were unknown to the children), along with feedback and rewards for completion of short-term goals. One month following the intervention, children were able to remember 80 % of the vocabulary items that were taught during the game, and variation of the pictures during training allowed for near-transfer of the labels to novel pictures of the trained vocabulary words.

One particularly innovative intervention blended in-person and computer-based instruction to teach vocabulary to young children with autism (Whalen et al. 2010). The computer-based *TeachTown* software included the game-based elements of: rewards for successful trials (including praise and graphical rewards), individualized target words, and increasing levels of difficulty. This experience was paired with face-to-face generalization activities that were completed individually or in small groups with teachers. Children showed learning for the specific items they were taught through instruction (i.e., a treatment effect). The sub-group of pre-school children (ages 3–4 years) had larger receptive vocabularies than their matched control group after training on standardized tests, suggesting that there was near-transfer of learning.

Reading abilities have also been targeted for intervention in children with autism (Heimann et al. 1995). The *Alpha* program involved teaching word reading in the context of increasingly complex sentences. The game-based elements in this intervention included: short-term goals, increasing levels of difficulty, and some provision of choice related to creating sentences in the program. Reading abilities and phonological awareness improved after completing the training, suggesting there was near-transfer of learned skills (Heimann et al. 1995).

To date, language instruction for children with autism has largely focused on expanding vocabularies of children with poor language abilities and has had some success in demonstrating both a treatment effect as well as near-transfer of the learned information. However, these interventions have limited or no use of narrative storylines, longer-term goals and rewards. Generalization testing does not often include naturalistic language samples or other measures that would allow for examining far-transfer of these language abilities to everyday communicative interactions.

Face-Processing and Social Skills Interventions for Individuals with Autism

Another major area of computer-based intervention involves attempts to improve face-processing abilities and social skills for both children and adolescents autism (Bölte et al. 2002, 2006; Silver and Oakes 2001; Golan and Baron-Cohen 2006; Hopkins et al. 2011; Tanaka et al. 2010). The "Let's Face It" intervention (Tanaka et al. 2010) included computer-based training related to labeling emotional expressions, recognizing faces, and several other face-processing skills. The game-based elements included the use of themes (such as an underwater fish theme in the "splash" game; but no story-based narrative), medium-term goals in the form of a point system (with high scores posted on a website leader board allowing for competition), additional rewards for success related to short-term goals, and some provisional choice over which training games participants wanted to play. Results from 42 children and adolescents with autism, who completed 20 h of training, found that children with autism improved in one of the six face-processing tasks using novel stimuli (i.e., near-transfer) following intervention. This pattern of findings has been observed in several other computer-based emotion recognition training studies for individuals with autism as well, including improved identification of emotional expressions that were similar in nature to those practiced during the training, indicating near-transfer of learning (Bölte et al. 2002; Faja et al. 2012; Golan and Baron-Cohen 2006). However, there is no evidence of far-transfer of these skills in any of these existing interventions.

The "Junior Detective Training Program" was designed specifically as a serious game and included: a detective-themed storyline, long-term goals, rewards (e.g., cumulative point system), and increasing levels of difficulty (Beaumont and Sofronoff 2008). Participants were required to identify and label appropriate emotional responses for computer-based characters in various social situations. This intervention included both the computer game as well as in-person group social skills activities. The 24 children with autism (ages 8–12) in the intervention group (but not the control group) showed an increase from pre-test to post-test for the generation of more appropriate explanations about how to manage emotions (anxiety and anger) from hearing stories. Beaumont and Sofronoff (2008) also reported evidence of far-transfer of these skills from increased scores on parent-report measures of everyday social functioning.

In order to measure potential far-transfer of learned social skills, another computer-based training study employed the *FaceSay* intervention that included some use of increasing levels of difficulty, theme-based content (without a narrative storyline), and a point system to provide rewards (Hopkins et al. 2011). Children and adolescents with autism, ages 6–15, completed 12 sessions over 6 weeks with the *FaceSay* program. Relative to the control group, participants who underwent the intervention showed improved face recognition and emotion recognition skills from computer-based tasks as well as improved social interaction behaviors with their peers in a playground observation.

In sum, as with the language interventions, the evidence has revealed some evidence of training effects and near-transfer of learned skills; however, they often show little evidence of far-transfer (e.g., generalization to real-world social interaction contexts), which may have been due to the limited integration of serious game elements. The games showing greater use of game design principles in targeting social behaviors, however, have shown some initial promise in achieving generalization to real-world social behaviors (e.g., Beaumont and Sofronoff 2008; Hopkins et al. 2011).

Virtual Reality Interventions for Individuals with Autism

In contrast to the cognitive training interventions, virtual reality interventions have recently shown some preliminary evidence of generalization from the computer-based training to improvements in real-world behavior for individuals with autism (Kandalaft et al. 2013; Strickland et al. 2013). These interventions often involve real-time virtual interactions between an individual with autism and a facilitator (e.g., clinician or teacher) using various kinds of electronic technology (Ke and Im 2013; Kandalaft et al. 2013; Strickland et al. 2013). In many cases, these interventions are better described as social interaction simulations, as they lack important game-like elements.

In a virtual reality intervention that was designed to improve social cognition, adults with autism practiced scripted role-play scenarios during virtual interactions with two facilitators (clinicians) in an online multi-player entertainment game (i.e., “Second Life”; Kandalaft et al. 2013). The game-based elements included: some story-driven contexts and medium-term goals (e.g., negotiating with a salesperson or interviewing for a job), feedback and some increases in difficulty (e.g., increasingly difficult social situations). The adults who participated in the intervention showed some improvements in emotion recognition and the ability to infer emotional states in others (e.g., near-transfer tasks), as well as some limited evidence of potential far-transfer in the form of increased conversational skills during an in-person role-play assessment (Kandalaft et al. 2013). Strickland et al. (2013) employed a similar virtual reality methodology, where participants were trained to answer job interview questions via the computer. This virtual interview training showed transfer to face-to-face mock interviews at post-test (Strickland et al. 2013).

The ECHOES intervention uses artificial intelligence, rather than a trained clinician, to control a virtual character during a joint attention and communication skills training program (Bernardini et al. 2014). This intervention included some story-based elements (without a full narrative), medium-term goals, and rewards for success. The initial pilot testing revealed that the children increased the number of initiated interactions with the virtual character and with the adult that was present in the room during the intervention session, though generalization tasks were not conducted to measure far-transfer of skills. While virtual reality interventions generally differ from games in that they simulate social interactions without many of the key characteristics of serious games and often require special facilitators, it could be possible to combine elements from both approaches to improve learning.

Exercise Games for Individuals with Autism

Evidence in favor of the potential success of video game-based interventions also comes from studies involving exercise entertainment games, such as sports or dancing games (Anderson-Handley et al. 2011; Getchell et al. 2012; Hilton et al. 2014; Peng et al. 2011). Although vigorous exercise activities have beneficial effects for individuals with autism (Lang et al. 2010), they are less likely to participate in activities such as group sports (Pan and Frey 2006; Rimmer et al. 2010). Thus, children and adolescents with autism are at higher risk for developing obesity compared to the general population (Pan and Frey 2006; Rimmer et al. 2010; Zuckerman et al. 2014). Individuals with autism may also have sensory-motor symptoms that could be targeted by exercise games (e.g., Whyatt and Craig 2013). A recent meta-analysis of exercise games for individuals with typical development suggests that exercise games can increase energy expenditures (Peng et al. 2011). The use of exercise games also allows for increased opportunities and motivation for individuals with autism to engage in physical activity (Getchell et al. 2012; Hilton et al. 2014).

Exercise games may have secondary benefits for individuals with autism, such as reducing repetitive behaviors, improving motor skills, and improving behavior on executive function tasks (Anderson-Handley et al. 2011; Hilton et al. 2014). For example, adolescents with autism, ages 10–18 years, played an exercise game for 20 min (Anderson-Handley et al. 2011). Immediately after playing the exercise games, the adolescents with autism showed evidence of short-term benefits from the exercise games, including reduced frequency of repetitive behaviors and improved performance on a digit span task compared to individuals in a non-exercise control condition (Anderson-Handley et al. 2011). Thus, there may be far-transfer benefits in terms of impacts on motor and cognitive abilities from participating in exercise games for children with autism.

Although exercise gaming studies have shown increased physical activity while playing the games in the context of research laboratories, there is little research examining their effectiveness when individuals with autism have access to these same exercise games in the home. In addition, as the post-testing only involved short-term effects, little is known about the long-term effects of entertainment exercise games. Thus, there is great potential, but many unanswered questions, in this domain of enquiry.

How Can the Design of Computer-Based Autism Interventions be Improved?

While many existing computer-based interventions for individuals with autism report evidence of learning during the intervention and some report evidence of near-transfer to other computer-based tasks, few show generalization (far-transfer) to real-world social kills. Our review of this literature suggests that the interventions showing the greatest evidence of generalized learning included the greatest number of serious game elements (e.g., Beaumont and Sofronoff 2008; Hopkins et al. 2011). We suggest that future research using computer-based interventions in autism should focus on three key elements of serious game design: (1) use of storyline and goal-directed behaviors, (2) use of cooperative multi-player games that build upon the efficacy of interpersonal interactions in previous virtual reality interventions, and (3) increased use of gaming elements that facilitate the transfer of knowledge and skills from the intervention to more ecologically valid in-person social situations. Finally, we offer several key areas of design considerations researchers should consider when they design serious games for individuals with autism.

Social Storylines and Contexts Providing Long-Term Goals

Computer-based intervention programs designed for individuals with autism often lack a narrative storyline or story-driven goals (See Table 1). These story-driven goals (especially when designed to be meaningful to the individual playing the game) can increase affective engagement and are thus critical for providing a rationale for driving game play (Baranowski et al. 2008; Dickey 2006; Garris et al. 2002; Gee 2003; Reiber 1996). The potential lack of affective engagement could be a limitation in the current design of cognitive training programs, and likely contributes to the poor generalization of learning (i.e., far-transfer). A narrative storyline that elucidates the motivations of *why* characters in the game might be angry (and what behaviors should follow the correct identifying the expression) is essential for linking knowledge of an emotional expression to actionable social and communicative behavior.

As noted, players can be motivated by their own curiosity when the game's storyline provides mysteries that allow for exploration (Garris et al. 2002). We suggest that future serious games for individuals with autism should focus on the inclusion of long-term goals that are tied to a narrative storyline, in addition to the inclusion of other game mechanics. The specific storylines and narratives in serious games need to be directly integrated with the educational objectives to maximize learning potential; disconnected narratives distract from learning goals (Habgood and Ainsworth 2011). For example, characters in a game could reveal their secret clues towards solving a mystery only if players correctly navigate the social conversations (and such navigation may be scaled in difficulty, such as the degree of overt emotional expressiveness by the target; Kato et al. 2008; Thompson et al. 2010). These social interactions with other characters that enable the progression of the game's storyline is an important component of educational gaming that is largely absent from the autism literature.

Advances in "interactive storytelling" technology allow for player's interactions with computer-controlled characters and subsequent decisions within the game to shape the goals and outcome of the storyline (Klimmt et al. 2012). This interactive storytelling would allow for individuals with autism to experience both positive and negative outcomes related to their choices and behaviors in the relative safety of a virtual environment while learning new skills. Consideration of the wide variability in language development for individuals with autism also needs to be considered when creating developmentally appropriate contextual stories for any group of children. Future research should examine the impact of narrative storylines and long-term goals tied to specific learning outcomes on the intrinsic motivation, learning, and generalization of interventions for individuals with autism.

Multi-player: Achieving Goals with Peers

Multi-player games involve two or more players, either collaboratively or competitively. Prior work has demonstrated that multi-player games can meaningfully change user engagement and experience relative to games played individually (e.g., Smyth 2007). Research with typically developing children suggests that encouraging cooperation between individuals during game play may be more likely to increase pro-social behavior than single-player games or games that encourage competition (Bay-Hinitz et al. 1994; Garaigordobil et al. 1996; Greitemeyer and Cox 2013). Typically developing children and adults have also shown increases in learning language skills from cooperative multi-player games (Suh et al. 2010; Young et al. 2012). In addition, playing with (or against) friends may increase engagement, as well as physiological responses measuring arousal (Ravaja et al. 2006).

The majority of computer-based instruction for individuals with autism has been conducted using individual instruction, with the exception of virtual reality interventions containing direct interactions between an individual with autism and a clinician or teacher facilitator within the game setting. For these virtual reality interventions (e.g., Kandalaft et al. 2013; Strickland et al. 2013), the higher rates of generalization (far-transfer) may have been enhanced by the interactions between the facilitator and the individual with autism in the virtual setting. In addition, other advances in virtual reality technology (that allow for greater physiological immersion) may also be used in combination with game-based mechanics to improve learning outcomes (Lange et al. 2012; Wang and Anagnostou 2014).

There may be specific advantages for the use of multi-player games for individuals with autism (with either high or low verbal skills), particularly in terms of increasing opportunities for social interactions. For example, correlational research suggests that playing entertainment video games with friends predicts positive friendship qualities for adolescents with autism (Orsmond and Kuo 2011; Kuo et al. 2013). Promoting communication between multiple individuals in cooperative games may provide unique and safe opportunities for individuals with autism to practice communication and social skills within the game, as well as practice with working collaboratively towards achieving their goals.

Some touch-screen cooperative games have recently been designed for young children with poor verbal abilities, although efficacy testing of these games thus far has been limited (Battocchi et al. 2010). For example, a pilot study by Gal et al. (2009) suggests that children with autism engaged in more positive interactions and play behaviors after playing with a cooperative touch-screen story-building program that enforced cooperation between the children. Research has not been conducted, however, to see what type of collaboration (e.g., clinician, peer, or parent) in the game settings enable transfer of social skills to naturalistic settings. Future research should explore whether or not opportunities for social interaction with peers using multi-player games and other technologies provide greater opportunities for learning beyond what individual instruction can provide.

Blended Models of Training and Instructional Supports

An overarching concern is the lack of generalized learning from many of the computer-based interventions (Wainer and Ingersol 2011). Hybrid, or blended, models of instruction may hold potential in this regard, both for children with high or low verbal abilities. Serious games may be the most effective when they are paired with other activities that supplement the game-based instruction and encourage generalization of the material beyond the game (Ploog et al. 2013; Wouters et al. 2013). This blended computer and traditional in-person instruction model that has shown efficacy in academic learning for typically developing individuals, in areas such as biology and math knowledge (Wouters et al. 2013). Several previous autism interventions have included both computer-based and in-person teaching (Beaumont and Sofronoff 2008; Whalen et al. 2010). For young children with autism who had lower verbal skills, practicing vocabulary trials both on the computer and with the teacher may have aided the efficacy of the Teach Town intervention (Whalen et al. 2010).

The additional in-person activities during blended model interventions may be helpful for providing opportunities for applying the learned knowledge in new settings, or for further reflecting on the learned material (Mayer et al. 2002; Wouters et al. 2013; Wouters and van Oostendorp 2013). This is consistent with Kolb's (1984) model of experiential learning that emphasizes learning as a continuous process that involves both experiencing relevant events and reflection. Given that individuals with autism often show deficits in meta-cognitive abilities (Wilkinson et al. 2010), directly scaffolding and teaching these self-reflection skills (within and in conjunction with serious games) may be a particularly critical element of successful computer-based interventions.

The types of instructional supports should be chosen at a developmentally appropriate level for the individual learner, as individuals with lower meta-cognitive or language abilities may need differing types of instructional supports than individuals with higher meta-cognitive or language abilities. In-person instructional supports could include: modeling of correct behaviors, corrective feedback from teachers, and providing additional in-person contexts for practicing learned skills (Wouters and van Oostendorp 2013). For individuals with higher language abilities, reflection activities to discuss the newly learned material with a teacher or peers could also be utilized as generalization activities (e.g., Wouters and van Oostendorp 2013). Developmentally appropriate instructional supports provided by teachers, parents, or clinicians outside the game may provide important scaffolding for increasing the generalization of learning from the computer to in-person social and communicative behaviors.

Some instructional support methods may also be included directly into the computer-based game to support generalization for individuals with relatively advanced language skills, rather than requiring teachers to provide this scaffolding (Wouters and van Oostendorp 2013). Self-explanation prompts can include asking individuals to reflect upon why they made a certain decision or otherwise draw attention to important aspects of the learning material (e.g., O'Neil et al. 2014). For example, O'Neil et al. (2014) directly embedded multiple-choice and open-ended question prompts into their educational game. The types of self-reflection prompts built into computer games, however, should be tailored in developmentally sensitive ways that directly aid in learning and don't distract from game-play by being too easy, difficult, or abstract (O'Neil et al. 2014). However, research has not yet been conducted to examine what types of instructional supports are most effective for improving learning for individuals with autism, and what personal characteristics (such as language abilities) predict individual differences in the benefits of these supports.

Conclusions

There is a critical need for cost-effective educational and treatment services for individuals with autism. For example, Knapp et al. (2009) estimated the average annual economic cost in the UK for children at 25,339£ ($42,422) and for adults at 58,877£ ($98,571) for each individual with autism. The use of well-designed serious game interventions for individuals with autism may provide opportunities for cost-effective teaching tools that can be used at home, in classrooms, or other therapy settings to supplement traditional teaching methods. Research in the future should evaluate the cost-effectiveness of serious game and other computer-based intervention applications relative to traditional interventions conducted in-person.

The current research related to serious game design for individuals with autism has been slow to catch on. The majority of computer-based interventions for individuals with autism using cognitive training or virtual reality paradigms do not include many of the key elements of serious game design. Some cognitive training interventions, virtual reality interventions, and exercise games are beginning to show efficacy in targeting the symptoms associated with a diagnosis of autism. Unfortunately, there is limited evidence of generalization from computer-based instruction to real-world social and communicative abilities, especially for cognitive training programs.

A general weakness of the extant work is that it is characterized by small sample sizes, a lack necessary control groups to evaluate whether training is due to practice effects or natural development, and a failure to include tasks designed to measure generalization of behaviors to more natural settings. As a result, there is very limited extant evidence as to whether or not computer-based training can improve autism symptomology. As this field advances, and studies become larger and more carefully controlled, addressing these issues—notably through the careful inclusion of generalization tests based on observational measures of real social interactions—will be essential to continue progress. Observational measures related to communicative and social interactions will be necessary to examine whether the computer-based training programs lead to improved interactions with people in face-to-face settings.

To improve interventions for individuals with autism, future research should focus on key issues related to the design of the computer-based interventions. Our review suggests that interventions can be enhanced by the inclusion of long-term goals embedded in a cohesive narrative in individualized instruction. In addition, the inclusion of specific generalization activities (e.g., instructional supports) and opportunities for self-reflection may be important for encouraging transfer of knowledge from the computer to in-person settings. In conclusion, the development of serious games is an emerging field of research that has important implications for how interventions can be improved for individuals with autism.

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References

Anderson-Handley, C., Tureck, K., & Schneiderman, R. L. (2011). Autism and exergaming: Effects on repetitive behaviors and cognition. *Psychology Research and Behavior Management, 4*, 129–137.

Bandura, A. (1986). *Social foundations for thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice Hall.

Barab, S., Thomas, M., Dodge, T., Cartaeux, R., & Tuzun, H. (2005). Making learning fun: Quest Atlantis, a game without guns. *Educational Technology Research and Development, 53*(1), 86–107.

Baranowski, T., Buday, R., Thompson, D., & Baranowski, J. (2008). Playing for real: Video games and stories for health-related behavior change. *American Journal of Preventative Medicine, 34*(1), 74.e10–82.e10.

Battocchi, A., Ben-Sasson, A., Esposito, G., Gal, E., Pianesi, F., Tomasini, D., et al. (2010). Collaborative puzzle game: A tabletop interface for fostering collaborative skills in children with autism spectrum disorders. *Journal of Assistive Technologies, 4*(1), 4–13.

Bay-Hinitz, A. K., Peterson, R. F., & Quilitch, H. R. (1994). Cooperative games: A way to modify aggressive and cooperative behaviors in young children. *Journal of Applied Behavior Analysis, 27*, 435–446.

Beaumont, R., & Sofronoff, K. (2008). A multi-component social skills intervention for children with Asperger syndrome: The junior detective training program. *Journal of Child Psychology and Psychiatry, 49*(7), 743–753.

Bernardini, S., Porayska-Pomsta, K., & Smith, T. J. (2014). ECHOES: An intelligent serious game for fostering social communication in children with autism. *Information Sciences, 264*, 41–60.

Bölte, S., Feineis-Matthews, S., Leber, S., Dierks, T., Hubl, D., & Poustka, F. (2002). The development and evaluation of a computer-based program to test and to teach the recognition of facial affect. *Journal of Circumpolar Health, 61*, 61–68.

Bölte, S., Hubl, D., Feineis-Matthews, S., Prvulovic, D., Dierks, T., & Poustka, F. (2006). Facial affect recognition training in autism: Can we animate the fusiform gyrus? *Behavioral Neuroscience, 120*(1), 211–216.

Bosseler, A., & Massaro, D. W. (2003). Development and evaluation of a computer-animated tutor for vocabulary and language learning in children with autism. *Journal of Autism and Developmental Disorders, 33*, 653–672.

Catalano, C. E., Luccini, A. M., & Mortara, M. (2014). Best practices for effective design and evaluation of serious games. *International Journal of Serious Games, 1*(1), e1–e13.

De Freitas, S. (2006). Using games and simulations for supporting learning. *Learning, Media, and Technology, 31*(4), 343–358.

Dickey, M. D. (2005). Engaging by design: How engagement strategies in popular computer and video games can inform instructional design. *Educational Technology Research and Development, 53*(2), 67–83.

Dickey, M. D. (2006). Game design narrative for learning: Appropriating adventure game design narrative devices and techniques for the design of interactive learning environments. *Educational Technology Research and Development, 54*(3), 245–263.

Diehl, L. A., Souza, R. M., Alves, J. B., Alejandro, G., Estevez, R. Z., George, M., & Coelho, I. (2013). InsuOnline, a serious game to teach insulin therapy to primary care physicians: Design of the game and a randomized control trial for educational validation. *JIMR Research Protocols, 2*(1), e5.

Faja, S., Webb, S. J., Jones, E., Merkle, K., Kamara, D., Bavaro, J., et al. (2012). The effects of face expertise training on the behavioral performance and brain activity of adults with high functioning autism spectrum disorders. *Journal of Autism and Developmental Disorders, 42*(2), 278–293.

Fisher, M., Holland, C., Merzenich, M., & Vinogradov, S. (2009). Using neuroplasticity-based auditory training to improve verbal memory in schizophrenia. *American Journal of Psychiatry, 166*, 805–811.

Gal, E., Bauminger, N., Goren-Bar, D., Pianesi, F., Stock, O., Zancanaro, M., & Weis, P. L. (2009). Enhancing social communication of children with high-functioning autism through a co-located interface. *AI & SOCIETY, 24*(1), 75–84.

Garaigordobil, M., Maganto, C., & Etxeberria, J. (1996). Effects of a cooperative game program on socio-affective relations and group cooperation capacity. *European Journal of Psychological Assessment, 12*(2), 141–152.

Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, motivation, and learning: A research and practice model. *Simulation Gaming, 33*(4), 441–467.

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. New York: Palgrave Macmillan.

Getchell, N., Miccinello, D., Blom, M., Morris, L., & Szaroleta, M. (2012). Comparing energy expenditure in adolescents with and without autism while playing Nintendo Wii games. *Games for Health Journal, 1*(1), 58–61.

Golan, O., & Baron-Cohen, S. (2006). Systemizing empathy: Teaching adults with Asperger syndrome or high-functioning autism to recognize complex emotions using interactive multimedia. *Development and Psychopathology, 2*, 591–617.

Greitemeyer, T., & Cox, C. (2013). There is no I in team: Effects of cooperative video games on cooperative behavior. *European Journal of Social Psychology, 43*(3), 224–228.

Grynszpan, O., Weiss, P. L., Perez-Diaz, F., & Gal, E. (2014). Innovative technology-based interventions for autism spectrum disorders: A meta-analysis. *Autism, 18*(4), 346–361.

Habgood, M. P. J., & Ainsworth, S. E. (2011). Motivating children to learn effectively: Exploring the value of intrinsic integration in educational games. *Journal of Learning Sciences, 20*(2), 169–206.

Heimann, M., Nelson, K. E., Tjus, T., & Gillberg, C. (1995). Increasing reading and communication skills in children with autism through an interactive multimedia computer program. *Journal of Autism and Developmental Disorders, 25*(5), 459–480.

Hilton, C. L., Cumpata, K., Klohr, C., Gaetke, S., Artner, A., Johnson, H., & Dobbs, S. (2014). Effects of exergaming on executive function and motor skills in children with autism spectrum disorder: A pilot study. *American Journal of Occupational Therapy, 68*(1), 57–65.

Hopkins, I. M., Gower, M. W., Perez, T. A., Smith, D. S., Amthor, F. R., Wimsatt, F. C., & Biasini, F. J. (2011). Avatar Assistant: Improving social skills in students with an ASD through a computer-based intervention. *Journal of Autism and Developmental Disorders, 41*, 1543–1555.

Kandalaft, M. R., Didehbani, N., Krawczyk, D. C., Allen, T. T., & Chapman, S. B. (2013). Virtual reality social cognition training for young adults with high functioning autism. *Journal of Autism and Developmental Disorders, 43*(1), 34–44.

Kapp, K. M. (2012). *The gamification of learning and instruction: Game-based methods and strategies for training and education*. San Francisco, CA: Pfeifer.

Kato, P. M., Cole, S. W., Bradlyn, A. S., & Pollock, B. H. (2008). A video game improves behavioral outcomes in adolescents and young adults with cancer: A randomized trial. *Pediatrics, 112*(2), e305–e317.

Ke, F., & Im, T. (2013). Virtual-reality-based social interaction training for children with high-functioning autism. *Journal of Educational Research, 106*(6), 441–461.

Klimmt, C., Roth, C., Vermeulen, I., Vorderer, P., & Roth, F. S. (2012). Forecasting the experience of future entertainment technology: Interactive storytelling and media enjoyment. *Games and Culture, 7*(3), 187–208.

Knapp, M., Romeo, R., & Beecham, J. (2009). Economic cost of autism in the UK. *Autism, 13*(3), 317–336.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice Hall.

Kuo, M. H., Orsmond, G. I., Cohn, E. S., & Coster, W. J. (2013). Friendship characteristics and activity patterns of adolescents with an autism spectrum disorder. *Autism, 17*(4), 481–500.

Lang, R., Koegel, L. K., Ashbaugh, K., Register, A., Ence, W., & Smith, W. (2010). Physical exercise and individuals with autism spectrum disorders: A systematic review. *Research in Autism Spectrum Disorders, 4*(4), 565–576.

Lange, B., Koenig, S., Chang, C., McConnell, E., Suma, E., Bolas, M., & Rizzo, A. (2012). Designing informed game-based rehabilitation tasks leveraging advances in virtual reality. *Disability and Rehabilitation, 34*(22), 1863–1870.

Lepper, M. R., & Chabay, R. W. (1985). Intrinsic motivation and instruction: Conflicting views on the role of motivational processes in computer-based education. *Educational Psychologist, 20*(4), 217–230.

Lu, A. S., Thompson, D., Baranowski, J., Buday, R., & Baranowski, T. (2012). Story immersion in a health video game for childhood obesity prevention. *Games for Health Journal: Research, Development, and Clinical Applications, 1*(1), 37–44.

Marchiori, E. J., Torrente, J., del Blanco, A., Moreno-Ger, P., Sancho, P., & Fernandez-Manjon, B. (2012). A narrative metaphor to facilitate educational game authoring. *Computers & Education, 58*, 590–599.

Mayer, R. E., Mautone, P., & Prothero, W. (2002). Pictorial aids for learning by doing in a multimedia geology simulation game. *Journal of Educaitonal Psychology, 94*, 171–185.

Medalia, A., & Choi, J. (2009). Cognitive remediation in schizophrenia. *Neuropsychology Review, 19*(3), 353–364.

Mishra, J., & Gazzaley, A. (2014). Harnessing the neuroplastic potential of the human brain & the future of cognitive rehabilitation. *Frontiers in Human Neuroscience, 8*(218), e1–e4. doi:10.3389/fnhum.2014.00218.

Moore, M., & Calvert, S. (2000). Vocabulary acquisition for children with autism: Teacher or computer instruction. *Journal of Autism and Developmental Disorders, 30*(4), 359–362.

O'Neil, H. F., Chung, K. W. K., Kerr, D., Vendlinski, T. P., Buschang, R. E., & Mayer, R. E. (2014). Adding self-explanation prompts to an educational computer game. *Computers in Human Behavior, 30*, 23–28.

Orsmond, G. I., & Kuo, M. H. (2011). The daily lives of adolescents with an autism spectrum disorder: Discretionary time use and activity patterns. *Autism, 15*(5), 579–599.

Pan, Y. C., & Frey, G. C. (2006). Physical activity patterns in youth with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 31*, 257–263.

Patall, E. A., Cooper, H., & Robinson, J. C. (2008). The effects of choice on intrinsic motivation and related outcomes: A meta-analysis of research findings. *Psychological Bulletin, 134*(2), 270–300.

Peng, W., Lin, J., & Crouse, J. (2011). Is playing exergames really exercising? A meta-analysis of energy expenditure in active video games. *Cyberpsychology, Behavior, and Social Networking, 14*(11), 681–688.

Ploog, B. O., Scharf, A., Nelson, D., & Brooks, P. J. (2013). Use of computer-assisted technologies (CAT) to enhance social, communicative, and language development in children with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 43*, 301–322.

Przybylski, A. K., Rigby, C. S., & Ryan, R. M. (2010). A motivational model of video game engagement. *Review of General Psychology, 14*(2), 154–166.

Ramdoss, S., Machalicek, W., Rispoli, M., Mulloy, A., Lang, R., & O'Reilly, M. (2012). Computer-based interventions to improve social and emotional skills in individuals with autism spectrum disorders: A systematic review. *Developmental Neurorehabilitation, 15*(2), 119–135.

Ravaja, N., Saari, T., Turpeinen, M., Laarni, J., Salminen, M., & Kivikangas, M. (2006). Spatial presence and emotions during video game playing: Does it matter with whom you play?. *Presence: Teleoperators and Virtual Environments, 15*(4), 381–392.

Reiber, L. P. (1996). Seriously considering play: Designing interactive learning environments based on the blending of microworlds, simulations, and games. *Educational Technology Research and Development, 44*(2), 43–58.

Rimmer, J. H., Chen, M., McCubbin, J., Drum, C., & Peterson, J. (2010). Exercise intervention research in persons with disabilities: What we know and where we need to go. *American Journal of Physical Medicine and Rehabilitation, 89*(3), 249–263.

Ryan, R., & Deci, E. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68–78.

Ryan, R. M., Rigby, C. S., & Przybylski, A. (2006). The motivational pull of video games: A self-determination theory approach. *Motivation and Emotion, 39*(4), 344–360.

Saperstein, A., & Kurtz, M. (2013). Current trends in the empirical study of cognitive remediation for schizophrenia. *The Canadian Journal of Psychiatry, 58*(6), 311–318.

Shernoff, D. J., Csikszentmihalyi, M., Schneider, B., & Shernoff, E. (2003). Student engagement in high school classrooms from the perspective of flow theory. *School Psychology Quarterly, 18*(2), 158–176.

Silver, M., & Oakes, P. (2001). Evaluation of a new computer intervention to teach people with autism or Asperger syndrome to recognize and predict emotions in others. *Autism, 5*(3), 299–316.

Smyth, J. (2007). Massively multiplayer online role-playing games [MMORPGS], reported health, and social behavior. *Cyberpsychology & Behavior, 10*, 717–721.

Strickland, D. C., Coles, C. D., & Southern, L. B. (2013). JobTIPS: A transition to employment program for individuals with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 43*(10), 2472–2483.

Suh, S., Kim, S. W., & Kim, N. J. (2010). Effectiveness of MMORPG-based instruction in elementary English education in Korea. *Journal of Computer Assisted learning, 26*(5), 370–378.

Swettenham, J. (1996). Can children with autism be taught to understand false belief using computers? *Journal of Child Psychology and Psychiatry, 37*(2), 157–165.

Tanaka, J. W., Wolf, J. M., Klaiman, C., Koenig, K., Cockburn, J., Herlihy, L., et al. (2010). Using computerized games to teach face recognition skills to children with ASD: The Let's Face It program. *The Journal of Child Psychology and Psychiatry, 51*(8), 944–952.

Thompson, D., Baranowski, T., & Buday, R. (2010). Conceptual model for the design of a serious video game promoting self-management among youth with Type 1 diabetes. *Journal of Diabetes Science and Technology, 4*(3), 744–749.

Vygotsky, L. (1933/1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Wainer, A. L., & Ingersol, B. R. (2011). The use of innovative computer technology for teaching social communication to individuals with autism spectrum disorders. *Research in Autism Spectrum Disorders, 5*, 96–107.

Wang, M., & Anagnostou, E. (2014). Virtual reality as treatment tool for children with autism. In V. B. Patel, V. R. Preedy, & C. R. Martin (Eds.), *Comprehensive guide to autism* (pp. 2125–2141). New York: Springer.

Whalen, C., Liden, L., Ingersol, B., Dallaire, E., & Liden, S. (2006). Behavioral improvements associated with computer-assisted instruction for children with developmental disabilities. *Journal of Speech-Language Pathology and Applied Behavior Analysis, 1*(1), 11–26.

Whalen, C., Moss, D., Ilan, A. B., Vaupel, M., Fielding, P., Macdonald, K., et al. (2010). Efficacy of TeachTown: Basics in computer-assisted intervention for the intensive comprehensive autism program in Los Angeles unified school district. *Autism, 14*(3), 179–197.

Whyatt, C., & Craig, C. (2013). Sensory-motor problems in autism. *Frontiers in Integrative Neuroscience, 7*, e1–e12. doi:10.3389/fnint.2013.00051.

Wilkinson, D. A., Best, C. A., Minshew, N. J., & Strauss, M. S. (2010). Memory awareness for faces in individuals with autism. *Journal of Autism and Developmental Disorders, 40*, 1371–1377.

Wouters, P., Paas, F., & Van Merrienboer, J. J. G. (2008). How to optimize learning from animated models: A review of guidelines based on cognitive load. *Review of Educational Research, 78*(3), 645–675.

Wouters, P., van Nimwegen, C., van Oostendorp, H., & van der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology, 106*(2), 249–265.

Wouters, P., & van Oostendorp, H. (2013). A meta-analytic review of the role of instructional support in game-based learning. *Computers & Education, 60*(1), 412–425.

Young, M., Slota, S., Cutter, A. B., Jalette, G., Mullin, G., Lai, B., et al. (2012). Our princess is in another castle: A review of trends in serious gaming for education. *Review of Educational Research, 82*, 61–89.

Zuckerman, K. E., Hill, A. P., Guion, K., Voltolina, L., & Fombonne, E. (2014). Overweight and obesity: Prevalence and Correlates in a large clinical sample of children with autism spectrum disorder. *Journal of Autism and Developmental Disorders.*