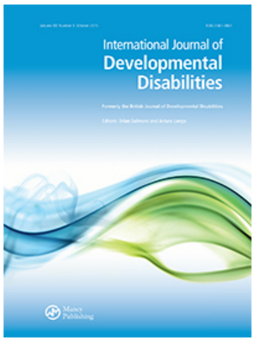

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Moderating effect of social interaction on enjoyment and perception of physical activity in young adults with autism spectrum disorders

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Moderating effect of social interaction on enjoyment and perception of physical activity in young adults with autism spectrum disorders

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Background: Young adults with autism spectrum disorder (ASD) are at increased risk for a sedentary lifestyle and its associated health problems. In neurotypical (NT) individuals, social participation and enjoyment are related to physical activity engagement. Exergaming has been shown to increase energy expenditure compared to traditional video games and is an effective option for community-based recreation.
Methods: We measured physiological and psychological responses of young adults with ASD to exergaming under varying conditions and sought to determine whether playing alone versus with a partner influenced physical activity level and/or experience in NT young adults ($n = 18$) and those with ASD ($n = 18$).
Results: Both ASD and NT groups experienced high enjoyment and perceived exertion while exergaming. Perceived exertion was moderated by enjoyment when young adults with ASD played with a partner, reporting less effort despite actually expending more energy.
Conclusion: Social interaction may lead to increased intensity and duration of physical activity for individuals with ASD. Exergaming is a socially acceptable and age-appropriate exercise modality for this group and likely represents a cost-effective and accessible way to incorporate physical activity and social interaction into their daily lives.

Keywords: Disease prevention, fitness, occupational therapy, participation, motivation, technology, videogames

Introduction

For individuals with Autism Spectrum Disorders (ASD), opportunities for community-based physical activity (PA) may be limited, which could impact overall PA level and lead to decreased fitness and health problems such as obesity, mental health issues, and cardiovascular disease (Tyler *et al*. 2011). Consequently, it is critical to identify enjoyable, feasible methods of incorporating PA into their daily lives. Active videogame play (exergaming) as a leisure activity may be an important strategy to increase PA participation for young adults with ASD.

Background

Exergaming and autism

Exergaming has been shown to increase energy expenditure compared to traditional seated videogames (Daley 2009). Current physical activity (PA) guidelines suggest that for health promotion interventions to be effective, they should focus on activities that individuals have access to on a daily basis (Barkley 2008). Of families surveyed in a previous study of families with at least one member with autism spectrum disorder (ASD), exergames were available in over half the homes of those who responded (Foran and Cermak 2013).

ASD is defined as a neuro-developmental disorder of impaired social interaction, language, and communication, and the presence of repetitive, stereotyped or restrictive behaviors (American Psychiatric Association 2013). In the United States, the prevalence of ASD is increasing and the disorder now affects one in 59 individuals. The gender distribution is approximately 4.2 males to one female (Baio *et al*. 2018).

Emerging interactive technologies such as exergames may be especially important for individuals with ASD, as they often do not have access to organized sports and community programs due to behavioral or social

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issues, financial limitations, and transportation barriers (King *et al.* 2003, Law *et al.* 2007, Rimmer and Rowland 2008). For individuals with ASD, exergame systems are a socially-appropriate, commercially available substitute for a typically sedentary leisure activity, and may also provide a less-threatening medium for social interaction with peers compared to sports and games (Anderson-Hanley *et al.* 2011, Finklestein *et al.* 2010). A few studies using exergaming systems with individuals with ASD and other developmental disabilities have been reported in the literature, although these have been limited to examinations of the effect of exergaming on sensory integration, balance and coordination, attention/executive function, and enjoyment (e.g. Anderson-Hanley *et al.* 2011, Ferguson *et al.* 2012, Hilton *et al.* 2014).

Physical activity and enjoyment

Enjoyment of an activity has been identified as an important factor that is positively associated with PA participation levels (Roemmich *et al.* 2008, Schneider and Cooper 2011). In addition, according to the Person-Environment-Occupation-Performance Model (Baum and Christiansen 2005), when an individual is provided with the appropriate level of task challenge and environmental supports, he or she can achieve optimal performance, which in turn will enhance enjoyment and encourage future participation. Exergaming has been reported to be highly enjoyable for both neurotypical (NT) young adults and those with disabilities. For e.g. Leininger *et al.* (2010) reported that typically developing young adults preferred to play the active video game 'Dance Revolution' to traditional treadmill walking, and Yalon-Chamovitz and Weiss (2008) showed that virtual reality exergames induced high levels of interest and motivation among young adults with physical and intellectual disabilities. Understanding the parameters of PA that are most reinforcing for young adults is important so that exercise guidelines can be developed to promote motivating physical activities.

Previous studies with NT children (serving as their own controls) have demonstrated that PA intensity and motivation to continue playing increase when a peer is present rather than being alone (Strauss 2001, Salvy *et al.* 2008a,b, Efrat 2009). This effect also appears to hold true during exergame play in NT youth (Exner *et al.* 2009, Staiano and Calvert 2010).

While fewer studies have examined this effect in young adults, Arnell *et al.* (2018) reported that for young adults with ASD, social participation can both enhance and inhibit the physical activity experience. For some young adults with ASD, the ability to choose a preferred playing partner increases PA positive perceptions and intensity of PA participation, while for others, solitary play is preferred due to the anxiety created by social demands (Arnell *et al.* 2018). The bulk of research examining the impact of peer influence on the PA patterns of individuals with ASD, however, is limited primarily to studies of classroom or recess behavior. Because of the social challenges inherent to ASD, individuals may become anxious or uncomfortable during direct social interaction and often avoid such situations, resulting in limited traditional PA (O'Neill and Jones 1997).

There have been no studies to date examining differences between computer-generated and real-life partner play in this population. However, a number of studies have highlighted technology as a less stressful medium through which individuals with ASD can interact with others in a socially acceptable manner (Gorini *et al.* 2008). For e.g. individuals with ASD report less anxiety when speaking to someone over an internet video phone service (Skype) than directly to another person (Herskowitz 2009).

Play and ASD

Playing an active videogame with a peer may be another method of social interaction that allows for less threatening engagement in PA play without additional modification to the game. Videogame play is inherently a parallel or associative activity, in which players must remain near one another but requires limited social interaction. For this reason, it may be an ideal naturalistic and non-stigmatizing occupation that accommodates the social limitations of ASD.

Individuals with ASD have been reported to have overall lower motivation for PA compared to their NT peers (Pan *et al.* 2011a,b), so recruiting their interest in a technology-based PA as well as the addition of a playing partner, may enhance motivation for and enjoyment of the activity, leading to longer playing time or playing with greater intensity.

According to Wolfberg (2009), peers perform a distinct role in supporting development through play, which is essentially impossible for adults to duplicate. In studies of social play in individuals with ASD, peer 'buddy' programs have been shown to elicit more appropriate play skills, increase the amount of peer interaction time, and generalize across multiple peers (Bass and Mulick 2007). In this study, we expected that as the young adults learned the new skill of exergaming, the task would be perceived as less challenging and more enjoyable if appropriate supports were put in place to allow for optimal performance and enjoyment.

Objectives

A case series using the same game system with children with autism (Jozkowski *et al*. 2016) suggests that the participants studied enjoyed playing exergames more than traditional seated video games (TSVGs), and that they consistently achieved moderate or moderate-to-vigorous PA levels while exergaming. In the present study, we examined differences in both PA level and enjoyment between exergame playing conditions (playing alone vs. playing with partner) in individuals with ASD. The specific aims for this study were: (1) to compare heart rate (HR), activity counts, perceived exertion, and self-reported enjoyment achieved by young adults with ASD, between videogame types and playing conditions, (2) to compare physical activity and enjoyment responses of individuals with ASD to those achieved by NT young adults while exergaming, and (3) to examine factors associated with physical activity in individuals with ASD, including body coordination, body mass index, previous videogame exposure, and daily activity habits, and to report relationships between these factors and physical activity levels achieved during videogame play.

We hypothesized that HR, physical activity (measured by accelerometer and perceived exertion), and self-reported enjoyment while exergaming would be greater than while playing a TSVG or resting, and also while playing with a partner than while playing alone. We did not expect the magnitude of changes in these factors resulting from exergaming under varying conditions to differ significantly between young adults with and without ASD. We also sought to describe the relationship between individual characteristics and physical activity-related outcomes while exergaming.

Method

Study design

A repeated measures crossover design was employed to determine the relationship between primary study variables and to examine potential relationships between these factors. In this case, the two independent conditions were: exergaming (EG) vs. TSVG game type and solitary vs. social playing condition. Dependent response variables were PA (heart rate, activity counts, and perceived exertion) and enjoyment. Diagnostic group served as the between participants variable and within participants, PA, and enjoyment were analyzed by playing status and game type. All procedures were approved by the Towson University (#13-A007) and University of Southern California Institutional Review (#HS-12-00508) boards.

Procedures

Participants

Participants with ASD at a community-based, university-affiliated center for adults with autism were recruited for the study, in addition to NT partners (students at the university). Autism center participants carry a self-reported diagnosis of ASD, which was confirmed by researcher review of documentation provided by the participant or participant's caregiver. Acceptable documents included an ICD-9 diagnostic code or written diagnosis of 'autism,' 'autistic disorder,' or 'ASD' on a physician-signed form or verified individualized education plan. All potential participants were 18–25 years old. This age range was selected because many individuals in this age group enjoy and participate in videogame play in their everyday routine, and are at a critical transition age for young people with ASD (Eaves and Ho 2008). Outreach for recruitment of ASD-NT partner pairs occurred through the autism center programs and classes at the university in the autism studies, occupational therapy, education, and speech-language pathology departments.

Randomization and assignment

Once the participants with ASD and their respective NT partners were recruited, consented, and enrolled, a randomization sequence generated by the statistical software program was used to assign them to a specific sequence of the six gameplay conditions. The six gameplay conditions (each played for 10 min per session) are as follows: (1) TSVG alone, (2) TSVG with a partner, (3) Tennis EG alone, (4) Tennis EG with a partner, (5) Boxing EG alone, and (6) Boxing EG with a partner. Randomization to the gameplay sequence helped to control for the possible effects of learning or novelty on PA and enjoyment during the different play conditions. Neither the participants nor the researchers were blinded to sequence assignment, because this was not possible given the interactive nature of the study, and unnecessary because knowing the sequence of gameplay conditions was not expected to alter measurement or analysis. During Wave 1 enrollment and assignment of the partner pairs, recruitment of additional pairs continued, with later pairs assigned to a second wave of data collection the following year.

Session protocol

During the first session, eligible participants reported to a private research room at the autism center. Height, weight, and waist circumference measurement was completed, the participant was familiarized with the researchers, HR and activity monitors, and videogame equipment and future sessions were scheduled. A trained occupational therapist administered the Bruininks-Oseretsky test of motor proficiency-II subtest of body coordination (comprised of balance and bilateral integration; Bruininks and Bruininks 2005). This session lasted approximately 90 min per participant.

Upon completion of anthropometric and body coordination testing, a trained occupational therapist and/or occupational therapy student research assistant demonstrated the use of both the TSVG and exergames. Participants were required to demonstrate that they would be able to navigate through the start menu to initiate each of the three games with minimal assistance from the researcher for sequencing. If a participant was unable to do so or requested additional instruction, he or she had the opportunity to participate in up to two additional familiarization sessions prior to testing.

Seven gameplay sessions followed the initial session, during which participants played for 10 min each under two of the six conditions in random order. Each session lasted approximately 30 min. For all sessions, after playing each game, participants were asked to rate their enjoyment and their perceived exertion while playing, using rating scales appropriate to their functional level (described in measures). Amount and intensity of PA were measured via accelerometer and HR monitor during each session.

Throughout the study, the scaffolding approach was used; the researcher, in addition to the NT partner, worked to provide the most appropriate environmental and activity-level conditions for the needs of the individual with ASD, in order to enhance performance and participation in exergaming. These adaptations were achieved through the use of social and environmental cues such as a line placed on the floor for the player to stand behind, the selection of appropriate videogames which were less difficult to navigate, and peer modeling of competitive gameplay.

Exergaming system

The Kinect for Xbox360 was selected as the exergaming platform for this study. The Kinect, released in late 2010, is a webcam-like 'video capture' device that plugs into the Xbox 360 videogame console and tracks the user's motions, projecting his or her image onto the television screen, and eliminating the need for a hand-held controller. Because the players body movements are tracked within the game, it can give the players a more physically challenging gaming situation and can create a feeling of presence within the game itself (Sandlund *et al.* 2009).

To control for the possibility that gameplay of a particular exergame varied between alone and partner conditions in a manner that could affect HR or other variables, two games were selected using the criteria described by Jozkowski *et al.* (2016): 'Kinect Sports Tennis™ and Kinect Sports Boxing™.' Other exergames require players to take turns when playing together, but not when playing alone – such games were excluded from consideration for this study. In addition, we chose to test the effects of two exergames, in order to account for the possibility that participants may have preferred one game over another, and thus be more motivated to play or work harder during their preferred game.

The TSVG game used was 'Hydro Thunder Hurricane®' (Microsoft Game Studios, 2010), a simple boat-driving simulation game that requires players to select a racecourse and navigate their boat around obstacles on the course. The game can be played alone or against another player and requires no complicated or multi-button maneuvers of the hand-held controller.

Measures

BMI percentile. Body weight and height were self-reported on the demographic questionnaire and a standard calibrated scale and stadiometer were provided if participants were unaware of their height and weight. Body mass index (BMI) was calculated as weight (kg) divided by height (m) squared, and BMI percentile was determined using SAS code provided by the Centers for Disease Control (CDC), which uses age- and gender-specific growth curves to calculate BMI. Because BMI is a surrogate measure of body fatness and can be affected by differing body proportions (Garn *et al.* 1986), waist circumference was measured at one inch above the umbilicus in order to calculate waist-to-height ratio and body fat percentage.

Rating of perceived exertion. Rating of perceived exertion (RPE) was assessed immediately following each videogame play period. Participants were shown a 10-point visual scale (perceived exertion index, modified from the Children's Effort Rating Table (CERT; Williams *et al.* 1994)), which was explained to participants with a standardized set of instructions. Perceived exertion was described to participants as 'How tired did your body feel while you were playing the game?' The purpose of this scale was to monitor exercise intensity - scores increase in intensity from: 1 ("not tired at all') through 10 ('so tired I can't go anymore'). The CERT was previously used to measure exertion level of children participating in a step test and the results correlated well with measured HR and showed good validity and reliability, especially in individuals over nine years (Yelling *et al.* 2002).

Enjoyment of videogame play. Participants rated their enjoyment of videogame play using a version of the general interest (enjoyment) factor of the 'Pre-Adolescent Attitudes toward Physical Education Questionnaire' (PAAPEQ; Shropshire and Loumidis 1996)), with modified wording for videogame play. The PAAPEQ is a self-report scale containing seven negatively-worded questions regarding participants enjoyment of PA. The modified form consisted of five items measuring enjoyment, interest and value held for videogame play. Participants responded to a four-point Likert scale, ranging from 'always true' (4) to 'not at all true' (1). Items were summed (with item #2 reverse-scored) to provide a single score, with a higher score indicating greater enjoyment of the game in question. The general interest factor of the PAAPEQ has been reported as having high internal reliability, with a Cronbach alpha level of 0.87 (Shropshire and Loumidis 1996). In a study using the PAAPEQ to examine the relationships

Table 1 Demographic and baseline characteristics of participants

	ASD group		NT group	
	Males n = 16	Females n = 2	Males n = 3	Females n = 15
Age (years)	22.3	20.4	18.6	19.9
Ethnicity	14 White 1 Black 1 Latino	2 White	3 White	14 White 1 Latino
Height (in)	69.9	65	69.7	63.9
Weight (lbs)	170.7	200	162	129
Waist circumference	35.7	40.5	30	30.3
BMI (kg/m^2)	24.4	33	23.2	22.3
% overweight/obese	40.0	50.0	33.3	20.0
Waist-to-height ratio (%)	50.9	62.1	43.1	47.4
Body fat percentage	18.0	36.8	10.4	29.1
Resting HR	71.2	83.5	68.3	61.8
	ASD group (n = 18)		**NT group (n = 18)**	
Body coordination standard score	33.4		50.3	
(descriptive category)[a]	(below avgerage)		(average)	
Self-described Gross motor skills[b]				
Well-below average	17%		0%	
Slightly below average	35%		0%	
Average	29%		33%	
Slightly above average	6%		50%	
Above average	6%		17%	
Self-described fine motor skills[b]				
Well-below average	29%		0%	
Slightly below average	18%		6%	
Average	35%		50%	
Slightly above average	18%		39%	
Above average	0%		6%	
Self-described activity Level[b]				
Well-below average	18%		0%	
Slightly below average	24%		0%	
Average	24%		22%	
Slightly above average	21%		39%	
Above average	6%		39%	
Self-described enjoyment of PA[b]			0%	
Well-below average	24%		0%	
Slightly below average	24%		22%	
Average	29%		33%	
Slightly above average	18%		44%	
Above average	6%			
Self-described leisure/recreational preference[b]				
Always sedentary	53%		0%	
Frequently sedentary	6%		11%	
Balance of active/sedentary	29%		22%	
Frequently active	12%		67%	
Always active	0%		0%	
Videogame exposure[c]				
Number of videogame systems owned	5.9		3.3	
Plays videogames	83%		56%	
Hours per day playing TSVGs	2.50		0.75	
Most frequent playing status	Alone		With a friend	

Note. ASD = autism spectrum disorder; NT = neurotypical; BMI = Body mass index; HR = heart rate.
[a]Body coordination descriptive categories are based on age- and gender-specific standard scores on the BOT-2 sub-test (Bruininks and Bruininks 2005).
[b]From the Demographic and Physical Activity Questionnaire (Foran and Cermak 2013).
[c]All measures were significantly different between groups ($p \leq 0.05$).

between perceived competence and enjoyment in PA, children with greater perceived confidence participated in more PA outside of structured school time (Carroll and Loumidis 2007). Three- and four-point Likert scales have been used successfully to measure differences in happiness and enjoyment in youth (Abdel-Khalek 2006, Kazdin 1990), although no studies were identified which have used these scales with individuals with ASD. If individuals were unable to respond to the five questions on the enjoyment measure, they were asked to indicate by pointing to a four-point visual scale (anchored with 'very bad to very happy'). For analysis, visual scale responses were recoded and dichotomized, such that negative responses were equivalent to an enjoyment scale score of 5/20 and positive responses were scored as 15/20.

Additional measures. Additional measures of: (a) body coordination (from BOT-2); (b) accelerometry; (c) heart rate; (d) demographics and physical activity history; and (e) previous videogame exposure, were used as described in Jozkowski *et al*. (2016).

Safety considerations

All sessions were supervised by at least two researchers, both of whom were certified in cardiopulmonary resuscitation and automatic external defibrillator use from the American Heart Association and American Red Cross to ensure the safety of all participants. In addition, at least one of the researchers was a licensed occupational therapist with a background in working with individuals with ASD, who was consulted in the event that a participant became overwhelmed, anxious, or agitated, and who provided appropriate support and assistance to participants when necessary.

Data analysis

Prior to the testing of aims, preliminary analysis proceeded with examination of standard summary statistics and verification of outliers. Baseline differences in group characteristics were analyzed by t-tests for continuous variables (or the Wilcoxon rank sum test, if appropriate) and chi-square or Fisher's exact tests for categorical data. Demographic characteristics were tabulated using descriptive statistics and frequency distributions. All data measures were tested for normality and variance. Any statistically significant findings were explored further using *post-hoc* testing with corrections as appropriate. Given the small sample sizes, normal distribution of variables was not assumed. Therefore, all results are reported using the adjusted test statistics and p values to correct for violations of homogeneity and sphericity as appropriate.

A repeated measures multivariate analysis of variance (MANOVA) was used to analyze the effect of game type (boxing EG, tennis EG, or TSVG), sequence, and game type by sequence (interaction) effects for all outcome variables. Repeated measures analysis revealed no significant effect of gameplay sequence on main outcomes. Because no significant difference existed due to randomized playing order ($p > 0.05$), data for each playing condition (boxing, tennis, and TSVG; both alone and with a partner) were combined for participants in all random sequence assignments.

The correlation structure of predictors was examined and basic data visualization was performed, in order to determine potential confounders such as age, gender, and body weight status. For continuous variables, normalizing transformations were undertaken, where possible. To make data analogous for comparison purposes, activity counts during each condition were transformed to a 10 min time frame if gameplay deviated from the scheduled time allotted.

We employed a series of two group (ASD/NT) x two condition (alone vs. partner play) x three game (BOX, TEN, and TSVG) factorial three-way analyses of variance tests (ANOVA's). Separate analyses were conducted for each of the five continuous response variables (HR_{avg}, percentage of time in MVPA, activity counts, RPE, and enjoyment). When three-way interactions were present, we then tested two-way interactions at each level of the third variable (generalizing testing of the simple main effects of the two-way interactions).

One-way ANOVA's were performed to examine differences in participant characteristics (age, height, weight, BMI percentile, waist-to-height ratio, and body fat percentage) and the body coordination composite of the BOT-2, between diagnostic groups (ASD vs. NT). Correlation analyses were performed between pre-participation questionnaire scores (anthropometric characteristics, physical activity level, enjoyment of PA, and videogame playing history) and activity level achieved under each condition.

Results

Participants

Eighteen participants with ASD and 18 NT partners completed the study. Additionally, two participants who fully enrolled, and three participants who were recruited and scheduled for enrollment failed to attend any sessions due to scheduling conflicts or ‘personal reasons.’ Table 1 describes the demographic and baseline characteristics of the sample. As expected, there were more males than females in the ASD group, which reflects the population of individuals with ASD (approximately 5:1; U.S. CDC 2014). NT participants heavily skewed female, and may reflect the fact that a majority of the students who participated in autism center activities were studying occupational therapy, speech therapy, and special education, all historically female-dominated fields.

Despite our intent to describe the ASD group with more standardized measures, the autism center requested that no IQ scores or other indicators of diagnostic level (such as the autism diagnostic observation schedule) be collected as part of this study, due to the nature of the community-based (vs. clinically-oriented) center and its relationship with participants. Therefore, participants were divided *post-hoc* by the researcher into three functional descriptive categories, based on clinical observation and video analysis of language and behavior. Analysis of variance revealed no significant differences between functional level groups on any of the PA-related outcomes measures, so the results are presented for all participants combined.

Research hypotheses

In order to determine if HR, PA (measured by accelerometer and perceived exertion), and self-reported enjoyment while exergaming were greater than while playing a TSVG, separate three-way ANOVAs for each dependent variable were performed. Initially, we had planned to collapse data resulting from the two EGs (tennis and boxing) and analyze them together, but because PA response and enjoyment level varied significantly

Table 2 Differences in response to videogame play between ASD and NT groups (paired t-test)

	HR_{avg} (SD) *p Value*	% $time_{MVPA}$ (SD) *p Value*	$Activity_{counts/min}$ (SD) *p Value*	RPE (SD) *p Value*	Enjoyment (SD) *p Value*
BOX2					
ASD	168.2(6.1)	94(1.2)	3812(102)	7.5(1.1)	16.0(2.5)
NT	154.2(3.7)	88(3.1)	1464(40)	4.5(1.0)	14.5(1.5)
	<0.0001	<0.0001	<.0001	<0.0001	<0.05
BOX1					
ASD	160.5(5.7)	91(1.5)	3016(65)	8.0(1.2)	14.5(1.1)
NT	151.3(5.0)	83(2.5)	839(21)	2.5(0.8)	14.0(2.1)
	<0.0001	<0.0001	<0.0001	<0.0001	n.s.
TEN2					
ASD	128.4(4.6)	90(0.9)	1544(40)	2.5(0.8)	15.5(2.6)
NT	122.0(4.5)	69(1.4)	786(16)	3.5(0.4)	12.5(3.0)
	<0.001	<0.0001	<0.0001	<0.0001	<0.01
TEN1					
ASD	118.0(4.8)	70(1.0)	664(17)	4.0(0.2)	15.0(1.6)
NT	120.6(4.1)	69(1.5)	371(7)	1.5(0.1)	13.5(2.1)
	n.s.	<0.05	<0.0001	<0.0001	<0.05
TSVG2					
ASD	90(6.9)	10(0.1)	334(7)	1(0.1)	15.0(1.0)
NT	78(3.4)	0(0.1)	70(5)	1(0.0)	13(2.5)
	<0.0001	<0.0001	<0.0001	n.s.	<0.01
TSVG1					
ASD	84.5(6.1)	0(0.1)	15(5)	1(0.1)	12.5(1.8)
NT	72.6(2.9)	0(0.0)	9(3)	1(0.0)	11.5(1.8)
	<0.0001	n.s.	<0.001	n.s.	n.s.

Note. ASD = autism spectrum disorder; NT = neurotypical; n.s.: non-significant

between tennis and boxing ($p < 0.01_{\text{tennis}}$; $p < 0.05_{\text{boxing}}$) for both groups, they were analyzed separately. Analysis revealed that for both groups, the boxing exergame was the most enjoyable ($p < 0.05$), was perceived to be the most physically demanding ($p < 0.001$), and also required the most energy to play ($p < 0.001$), followed by tennis and the TSVG, respectively (see Table 2 for a summary of PA-related response measures for the two groups group during each gameplay condition). Participant responses were significantly different between conditions, with partner play yielding greater energy expenditure ($p < 0.001$), enjoyment ($p < 0.05$), and perceived exertion ($p < 0.001$), compared to solitary play, across each game type (boxing, tennis, and TSVG).

We hypothesized that the magnitude of changes in enjoyment, HR and activity level resulting from exergaming would not differ significantly between young adults with and without ASD. However, because all five ANOVAs indicated a main effect of diagnostic group on the primary outcomes, paired t-tests between groups were completed for all PA-related response variables (HR, activity counts, percentage of time in MVPA(% $time_{MVPA}$), RPE, and enjoyment). The ANOVA testing also revealed significant group (ASD vs. NT) by game type (boxing, tennis, and TSVG) interactions ($p < 0.001$) and group by playing condition (alone vs. with a partner) interactions for all dependent variables ($p < 0.001$) except enjoyment. Results indicate that although both groups displayed a similar response pattern to playing each type of game (boxing was more strenuous and fun, followed by tennis, and TSVG play), the magnitude of response for individuals with ASD was significantly elevated, compared to the NT group (see Table 2). Similarly, although playing with a partner allowed both groups to achieve greater energy expenditure and enjoyment than while playing alone for all game types, the ASD group had significantly higher enjoyment, HR, and activity level response than the NT young adults. Thus, the original null hypothesis (no differences between group outcomes) was rejected.

However, results of further *post-hoc* ANOVA testing resulted in a deviation from the expected pattern. There were main effects for diagnostic group, gameplay condition, and game type for nearly all outcome variables except gameplay condition and RPE, and significant three-way interactions between the three factors for all outcomes except HR_{avg}. *Post-hoc* analysis of perceived exertion data showed that for participants with ASD, playing with a partner led to an increase in playing intensity (HR_{avg}, % $time_{MVPA}$, and activity counts) and enjoyment, but a decrease in RPE. For NT participants, playing with a partner (regardless of the partner's ASD or NT status) also increased playing intensity and enjoyment, but RPE increased accordingly (opposite the response of the ASD group).

Exploratory questions

To examine factors associated with PA in individuals with ASD, and relationships between these factors and PA levels achieved during videogame play, descriptive statistics were generated and correlations were run between baseline measures, including body coordination, BMI, previous videogame exposure, a daily activity habits, and the main PA-related outcome variables. The group with ASD had lower body coordination scores than their typically developing peers and engaged less frequently in physical activities for leisure/recreation (see Table 1). Participants on the spectrum also owned more videogame systems, played more frequently, and played alone more often than participants in the NT group.

However for both groups combined, correlation analysis revealed no significant relationships between any PA-related outcomes and gender, height, weight, waist circumference, BMI, waist-to-height-ratio, body fat percentage, gross motor skills, or pre-study daily hours playing videogames. The strongest correlations ($r > 0.6$) were between average HR while exergaming and engagement in physically active recreation or leisure pursuits (negative relationship; $p \leq 0.05$). Moderate relationships ($0.4 > r < 0.6$) were found between percentage of exergame playing time spent in MVPA and both engagement in active pursuits and baseline body coordination scores ($p \leq 0.05$). In addition, weak to moderate relationships ($r \leq 0.1$–0.4) were found between perceived exertion and fine motor skills, daily activity level, and pre-study enjoyment of PA ($p \leq 0.05$), with less coordinated participants achieving higher heart rates and more activity counts while playing the exergames. Finally, baseline scores from the BOT-2 (Bruininks and Bruininks 2005) were moderately correlated with enjoyment of exergame play and negatively related to activity counts achieved ($p \leq 0.05$). Moderate negative correlations were found between pre-study enjoyment of physical activity, baseline activity level, frequency of choosing physically active recreation/leisure, and perceived exertion during active gameplay. The opposite was true for these factors and enjoyment of the exergames during the study ($p \leq 0.05$).

When examining the relationships between individual baseline profiles, self-reported daily PA level was strongly correlated with body characteristics – that is, the more fit individuals were the most likely to engage in and enjoy PA. Baseline body coordination (as measured by the BOT-2) was also weakly correlated with self-reported skill level in both fine and gross motor performance for all participants ($0.2 > r < 0.4$; $p < 0.05$).

NT participants, who had significantly better body coordination ($p < 0.01$) and more healthy weight and body fat ranges ($p < 0.05$), achieved less time in MVPA ($p < 0.01$) and fewer activity counts per minute ($p < 0.001$) while playing the active videogames than their peers with ASD. However, NT participants still reached MVPA during 77% of exergame playing time (compared to 86% for participants with ASD). This indicates that for both groups, exergaming for 20 min can contribute at least 15 min of MVPA to recommended daily activity. Although individuals with ASD played all exergames with significantly greater intensity than their NT peers ($p < 0.001$), both ASD and NT groups had higher heart rates and activity counts when playing with a partner versus playing alone ($p < 0.01$).

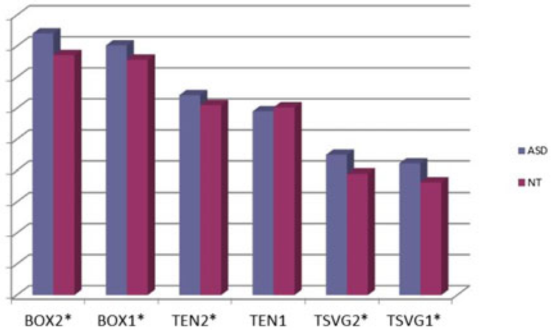

Figure 1 Average heart rate (in bpm) during videogame play by ASD and NT groups. *Significant between-groups difference ($p < 0.05$). BOX2: boxing with a partner; BOX1: boxing alone; TEN2: tennis with a partner; TEN1: tennis alone; TSVG2: traditional seated videogame with a partner; TSVG1: traditional seated videogame alone

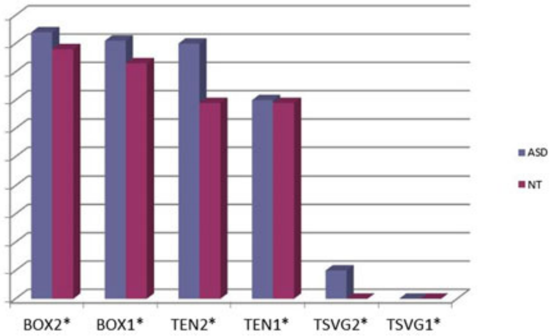

Figure 2 Average percent of time (during 10 min session) spent in MVPA by group.*Significant between-groups difference ($p < 0.05$). HR_{target} (a representation of MVPA) is computed for each individual by calculating 60–80% HR_{max} by age and gender. BOX2: boxing with a partner; BOX1: boxing alone; TEN2: tennis with a partner; TEN1: tennis alone; TSVG2: traditional seated videogame with a partner; TSVG1: traditional seated videogame alone

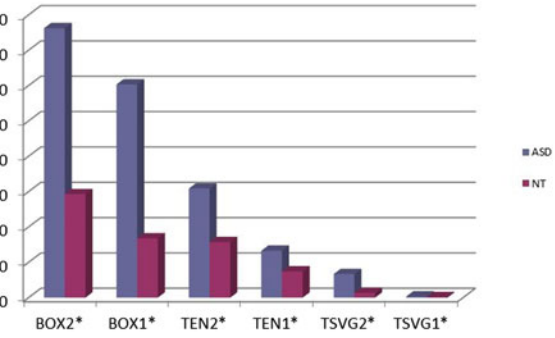

Figure 3 Average activity counts per minute during videogame play by group. *Significant between-groups difference ($p < 0.05$). HR_{target} (a representation of MVPA) is computed for each individual by calculating 60–80% HR_{max} by age and gender. BOX2: boxing with a partner; BOX1: boxing alone; TEN2: tennis with a partner; TEN1: tennis alone; TSVG2: traditional seated videogame with a partner; TSVG1: traditional seated videogame alone

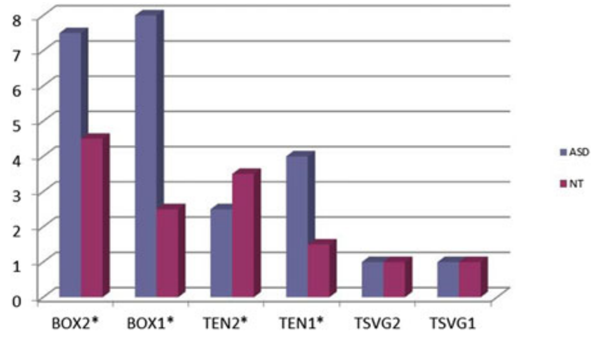

Figure 4 Average Rating of Perceived Exertion (RPE) during videogame play by group. *Significant between-groups difference ($p < 0.05$). HR_{target} (a representation of MVPA) is computed for each individual by calculating 60–80% HR_{max} by age and gender. BOX2: boxing with a partner; BOX1: boxing alone; TEN2: tennis with a partner; TEN1: tennis alone; TSVG2: traditional seated videogame with a partner; TSVG1: traditional seated videogame alone

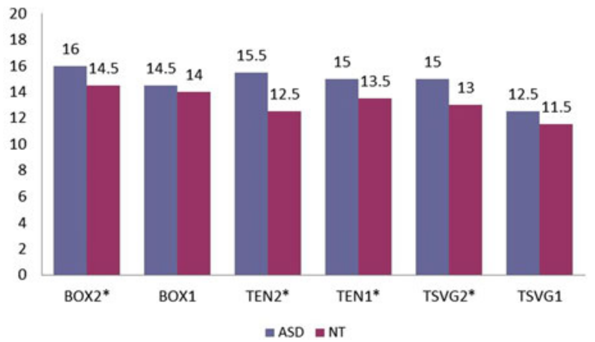

Figure 5 Enjoyment of videogames by group. *Significant between-groups difference ($p < 0.05$). HR_{target} (a representation of MVPA) is computed for each individual by calculating 60–80% HR_{max} by age and gender. BOX2: boxing with a partner; BOX1: boxing alone; TEN2: tennis with a partner; TEN1: tennis alone; TSVG2: traditional seated videogame with a partner; TSVG1: traditional seated videogame alone

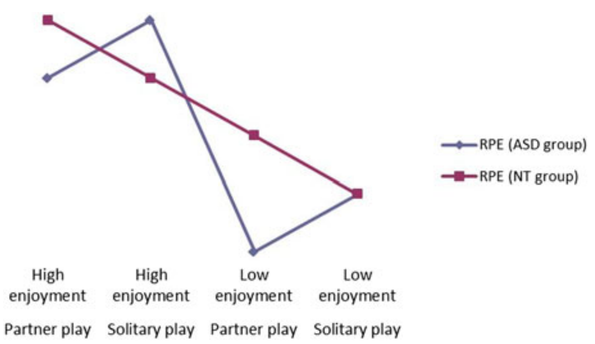

Figure 6 Model of moderating effect (three-way interaction) of enjoyment during partner play on rating of perceived enjoyment

To better visualize the PA-related response patterns during videogame play of ASD and NT groups for each of the game conditions, separate Figures for each measure are presented for $HR_{avg,}$ (Figure 1), percent of time participants spent in MVPA (or 60–80% age- and gender-specific HR_{max}; Figure 2), difference in average activity counts per minute (Figure 3), average RPE (Figure 4), and average enjoyment scores (Figure 5).

Although the two diagnostic groups have been depicted separately in the figures, it is important to highlight the similarities in response pattern between the groups. For all participants, boxing with a partner was the most physically challenging game condition, followed by boxing alone, then tennis with a partner, tennis alone, and finally the TSVG games. This same order describes the most enjoyable games, from boxing with a partner to solitary TSVG play. However, RPEs reported by the ASD group were higher when playing alone compared to playing the same game with a partner, while the NT group reported higher RPEs when playing with someone else. This effect was explained by interaction testing, which revealed a moderating effect of enjoyment and the partner play condition (which were found to be strong covariates) on perceived exertion for the ASD group only ($p < 0.001$, see Figure 6). This means that for the individuals on the autism spectrum, 'the increased enjoyment gained through social interaction likely influenced the strength of the relationship between perceived exertion and gameplay.'

Neurotypical contrast group

In order to provide a comparison to gameplay response, the NT participants were paired with another enrolled NT participant in addition to playing alone and with their partners with ASD. For each main outcome (HR_{avg}, % $time_{MVPA}$, activity counts, RPE, and enjoyment), there were no significant differences between participants responses when playing with the NT partner compared to the partner with ASD ($p > 0.05$ for all tests). This finding is noteworthy, because it indicates that the NT participants were likely not 'playing down' to their partners with ASD, and that 'they worked just as hard and reported having just as much fun with both playing partners.' Thus, we can be more confident that the physiological responses were relatively accurate to 'real-world' gameplay and that 'playing with a neurodiverse individual did not limit enjoyment for typically developing young adults.'

Unanticipated outcomes

Review of video recordings and post-study interviews confirms that both participant groups preferred partner to solitary play and that they felt participation in the study helped them to develop relationships with others outside their typical social worlds. A number of unanticipated positive outcomes occurred in addition to the empirical findings. For example, one reserved young NT man, who participated consistently but did not often exhibit clear signs of enjoyment, told the researcher at the conclusion of the study that the experience had been 'life-changing,' and that he now wished to pursue special education as a career instead of business. Another NT participant had enrolled in the study because her education class had assigned each student a semester-long project to ‘challenge themselves by doing something uncomfortable.’ This participant admitted that she had never interacted with individuals with disabilities and was afraid to do so before the study. By the end, this participant was easily chatting and joking with her partner with ASD and even brought him a gift at the end of the study because she knew she would miss him. These and other examples are encouraging, as they again reinforce the idea that engagement in PA can contribute to improved quality of social interaction among people with and without ASD.

Discussion

Although the researchers expected prior videogame experience to be related to PA-related responses, this was not found to be the case. One reason for this may be that for both groups, the majority of previous videogame experience was with TSVGs and the researcher selected EGs for the study that were simple to learn and use, increasing the likelihood that most participants would understand the rules quickly, decreasing the possibility of frustration while playing.

Baseline resting HR was significantly higher in participants with ASD compared to their NT partners, although when this was controlled for, participants on the autism spectrum still achieved a greater percentage of time in MVPA while playing all videogames except the TSVG alone. As the ASD group was slightly older than the NT group, it is possible that age was one factor in the elevated average HR of this group, which is also reflected in the weak positive correlation between HR and age (Nyakas *et al.*1992). Regression analysis indicates that the anthropometric variables (weight, body fat, etc.), in combination with lower coordination scores, also likely contributed to this difference. This result is not surprising, given that from video analysis, individuals with poorer coordination demonstrated larger, less ‘smooth’ movement patterns while playing, which were less efficient and therefore may have increased heart rate and activity level.

Participants with ASD reported higher RPEs and expended more energy (as measured by HR and activity counts) during gameplay than their NT partners for all exergaming conditions, but a critical difference is noted here - participants with ASD reported greater perceived exertion when playing alone ($p<.05$), while NT participants reported greater perceived exertion when playing with a partner ($p<.05$). This finding indicates that although NT participants are more accurate in their self-assessment of exercise intensity (RPE was more strongly correlated with HR and activity counts), the participants with ASD perceived themselves to be working less when playing with their partner. A test of the interaction effect of enjoyment indicates that for participants with ASD, enjoyment (which was greater during partner play than solitary play) does in fact moderate the experience and/or perception of energy expenditure during physical activity ($p < 0.01$; see Figure 6). This finding is important, as it demonstrates through quantitative physiological data that individuals on the autism spectrum can be motivated for exercise by social interaction – which may in turn increase intensity and duration of PA engagement and further enhance enjoyment. In terms of intervention, occupational therapy practitioners, educators, and caregivers should work together with young adults with ASD to provide or create an environment supportive of exergaming. This may include proper space and equipment, technological assistance, and sensory accommodations both at home and in the community. Increased access to exergaming, along with inclusive practices, may increase the likelihood of partnering with NT peers, which was found to enhance the effects of exergame play.

Significant differences were found between diagnostic groups for all demographic and anthropometric measures, although these characteristics were confounded by gender, as there were significantly more males than females in the ASD group and significantly more females than males in the NT group. However for comparison of gender-specific variables (such as BMI percentile and height-to-waist ratio), the ASD group was, on the whole, more likely to be overweight than the NT partners ($p < 0.01$). Despite these group-wise differences, the main outcomes of concern for this study were the responses of the participants with ASD to the various gameplay conditions. It is possible that some of the change in enjoyment and HR in the ASD group during partner play could be explained by the excitement and subsequent physiological response to interaction with an opposite-gendered peer. A larger sample size would be needed to tease out these partial effects using regression analysis. Although the ASD and NT group responses were significantly different, they were similar in overall pattern and direction, which supports the authors assumption that individuals with ASD are likely to work harder and have more fun when playing with a partner, just as NT participants have been shown to do. The opportunity for the individuals with ASD to engage in a naturalistic occupation with same-age peers, who as young adults often desire to interact with the opposite sex, outweighs the possible limitations of confounding on our interpretation of secondary results.

The primary aim was to determine if young adults on the autism spectrum achieved similar patterns in PA-related outcomes as NT individuals in previous studies of exergaming. The hypothesis was that the both the ASD and NT groups would experience significantly higher energy expenditure while playing exergames versus TSVGs and while playing with a partner versus playing alone. We confirmed that both groups spent more time in MVPA during exergames play compared to TSVGs although the ASD group played with greater intensity overall. In addition, we expected that for both groups, playing exergames (as opposed to TSVGs), and playing together (vs. alone) would yield greater enjoyment. Again, we found this to be true. However, the most interesting finding was the unanticipated difference in perceived exertion between groups, with participants with ASD reporting lower perceived exertion while playing with a partner (at higher intensity), than those in the NT group. A test of moderating effects yielded the explanation – the greater enjoyment experienced during partner play moderated the perceived exertion of those in the ASD group while playing exergames – perhaps leading them to report that they were expending less energy than they actually were.

Limitations

This study has several limitations. Participants presented with a wide range of functional abilities (typical of ASD), which, while limiting the true effect size, makes it more likely that conclusions drawn about the effect of exergaming with this population are accurate across functional levels. In addition, it was not possible to control for baseline differences in age, gender, and other variables given that the ASD-NT partner pairs were recruited using convenience sampling from an existing organization with an unbalanced make-up of participants. Therefore, ASD-NT partner pairs did not have comparable age or gender characteristics. A more homogenous and controlled sample would allow for formal reporting of effect size and is suggested in future studies. Participants with ASD were mostly male, less physically fit, and slightly older than their NT partners, most of whom were female. Partnering with a more fit, slightly younger, female player for exergaming may have increased enjoyment for some players with ASD, confounding the results. Future studies should examine the effect of same gender partners or ASD/ASD partners.

Furthermore, participants in this study were a select group who participate in a university-sponsored social program, which could have led to self-selection bias, and thus the results cannot be generalized to all young adults with ASD. Finally, the NT participants, although encouraged not to do so and supervised by the researcher, may have altered their playing intensity when playing with their partner with ASD so as to avoid upset and improve their partner's self-concept. However this could explain their lower energy expenditure compared to the ASD group; because the NT groups physical activity response was also lower while playing alone, it is more likely that the difference in energy expenditure between groups was caused by the ASD participants poorer body coordination, which likely required increased effort.

Conclusion

This is the first study to describe the relationship of exergaming and PA levels in young people with ASD. In particular, the study provides evidence of consistency with prevailing literature that PA is heightened during play with a peer, which could have clinical implications for combating sedentary lifestyle and overweight and obesity.

Results of the study will inform future research using videogame technology as a way to promote PA for individuals with ASD and will enhance our understanding of the role technology can play in enhancing the social worlds of young adults on the autism spectrum. This study reinforces previous research that participants expend more energy while playing active videogames than while playing TSVGs (Daley 2009, Mark *et al.* 2008), although participants in this study achieved MVPA (as determined by change in heart rate) more often than has been previously reported.

Others have cautioned that exergames may not be as demanding as more traditional sports and games, and should not be substituted for higher-intensity activities (Foley and Maddison 2010). The participants in this study experienced MVPA during the majority of exergames playing time, although each session was limited to one or two bouts of 10 min. More research including participants with ASD is needed to determine which games in particular may be more likely to elicit MVPA and under what conditions. Although each game was repeated twice, the effect of novelty and the excitement of partner play may have enhanced participants motivation to play with high intensity. In addition, individuals with ASD and their advocates should request facilities and physical education programs specially adapted to the needs and preferences of those with ASD and other disabilities, as such adapted environments can lead to decreased anxiety and increased participation in PA (Arnell *et al.* 2018).

In this study, perceived exertion during PA was moderated by enjoyment and enjoyment of gameplay was increased, 'when the ASD group played with a partner.' This is consistent with research on PA motivation in typically developing individuals, which posits that people are have more fun and expend more energy when exercising with a partner versus alone (Staiano and Calvert 2010). Although evidence is beginning to show that individuals with ASD do desire social interaction, many people outside the scientific and special needs communities continue to perceive this population as uninterested in social interaction and unable to participate in social activities (Howard *et al.* 2006). Additionally, frequent videogame play could possibly lead to social isolation or stigma for young adults with

ASD. Our findings suggest that not only do young adults with ASD enjoy social interaction, but it may help motivate PA participation and enhance the experience of exercising. With the new release of iPhone interactive games, such as 'Pokemon GO,' it is anticipated that individuals with ASD may engage in this parallel form of PA and social interaction with NT peers.

Individuals with ASD, who are known to have problems with social interaction, found exergaming with a peer to be more enjoyable, they worked harder, and they perceived it as being less effortful in comparison to playing alone. Through the medium of the exergaming system, participants were encouraged to interact with peers in an enjoyable and active way, which could promote healthy lifestyle changes increasing engagement in PA. These findings contribute to the scientific literature on factors associated with PA, enjoyment, social play, and the use of videogames in young people with ASD. This evidence has clinical and health promotion implications for individuals with neurodevelopmental disabilities who are at risk for sedentary lifestyle and overweight/obesity. In addition, the results will inform future research using videogame technology to promote PA for individuals with ASD and increases our understanding of the role technology can play in enhancing the social worlds of young adults with ASD.

We conclude that exergaming is an effective and accessible medium to incorporate PA into daily routines and has the potential to assist in decreasing risk for sedentary lifestyle and overweight/obesity in young adults with ASD and other developmental disabilities. In addition, exergaming with a partner may enhance social skills and increase interaction between individuals with ASD and their NT peers.

Disclosure statement

The authors report no declarations of interest.

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