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VO_2, Liking, and Relative Reinforcing Value of Cooperative and Competitive Exergame Play in Young Children

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ABSTRACT

International Journal of Exercise Science 13(5): 1501-1511, 2020. The purpose of the current study was to examine physiologic response, liking, and relative reinforcing value (RRV) of children playing an exergame with a friend under two goal structures: competitive and cooperative. A sample of twenty participants (8.7 ± 1.3 years old) and a self-selected friend completed three conditions: rest, competitive, and cooperative play. During the competitive condition, participants played Nintendo Wii Tennis® against their friend. During cooperative play, participants and their friend played together against a computer avatar. During each condition, oxygen consumption (VO_2, ml·kg-1·min-1) and liking (visual analog scale) were recorded. After finishing all conditions, children completed an RRV computer task to assess their motivation to play the competitive versus cooperative goal structures. During this task children performed work (button presses) to participate in additional competitive play, cooperative play, or a combination. The output maximum (Omax), or maximum work for each goal structure, was used as the measure of RRV. It was determined that VO_2 was significantly ($p \leq 0.001$) greater for cooperative and competitive play than rest. Liking was significantly greater for cooperative play than rest ($p \leq 0.001$) and competitive play ($p = 0.03$). There were no significant differences ($p > 0.05$) between cooperative and competitive play for VO_2 or Omax. In conclusion, while liking was greater for the cooperative condition versus competitive, motivation did not differ between goal structures. Further investigation into methods of making physical activity more reinforcing, in addition to well-liked by children, is necessary to optimize this behavior.

KEY WORDS: Physical activity, motivation, physically-active video games, goal structure

INTRODUCTION

The number of American children and adolescents (18.5%) characterized as obese (Body Mass Index [BMI] greater than 95th percentile for age and sex by Centers for Disease Control [CDC] growth charts) in the United States poses a considerable public health risk (22). The associated health risks include hypertension, dyslipidemia, metabolic syndrome, diabetes, and psychological impairments making this a crucial issue (11, 16-18, 22, 29). Thus, the importance of examining behavioral strategies that may combat this childhood health crisis remains a priority.

Two of the primary determinants of pediatric obesity are a sedentary lifestyle (i.e., excessive sitting) and/or a lack of physical activity (8, 26). Examining these lifestyle choices can provide insight into altering such behaviors. One factor that may impact these behaviors is the social context in which children participate in physical activity. Findings suggest that positive peer interaction can have a positive effect on physical activity participation and in some cases reduce sedentary behavior in children, especially if the peer is a friend (3, 4, 5, 9, 14, 15, 31, 35, 36). Therefore, participation with a peer may result in increased physical activity and/or reduced sedentary behavior in children.

Previous research from our group sought to further examine the role of social interaction upon physical activity behavior in a novel context by assessing the impact of the presence of a friend upon children's motivation to participate in a physically-interactive video game (exergame) versus a sedentary alternative (37). However, in that study the presence of a friend did not increase children's motivation to play the exergame versus the sedentary alternative (37). This was contrary to our hypothesis and the unexpected result was postulated to be due to the competitive nature of the game used during the protocol (i.e., Nintendo Wii Sports Boxing®) (37). This finding presents the notion that the competitive goal structure may have negatively impacted children's motivation to play this particular exergame.

Prior research has identified the goal structure of an activity as a potentially salient determinant of children and adolescent's motivation to participate in that activity. For example, working towards a cooperative or competitive goal may have differential effects on behavior (39, 40). Studies in adolescents and young adults have suggested that a cooperative goal structure during exergame play increases intrinsic motivation among participants (23, 27, 39). Furthermore, adolescents achieved increased energy expenditure during cooperative exergame play (i.e., Nintendo Wii®) versus a competitive alternative (39). The tendency to favor a cooperative goal structure may be an even greater determinant of behavior in younger individuals than older counterparts. Scholastically, it has been found that younger children (six years old) respond more favorably to cooperative goals versus older children (eight years old) who favored competitive goals (30). Similar results have been found in athletics (e.g., tennis) as ten to 13-year-olds were found to favor cooperative play whereas 14 to 18-year-olds favored competition (42). While this evidence supports the notion that goal structure may impact participation in that activity, research on this topic is limited. Specifically, there are no studies we are aware of that have experimentally manipulated goal structure and assessed its effect upon pre-adolescent children's motivation, enjoyment, and participation in physical activity in a controlled, laboratory environment.

The purpose of the current study was to better understand the importance of goal structure in children's physical activity to potentially aid in the development of more effective physical activity recommendations and/or programming. This was operationalized through the examination of oxygen consumption (VO_2), liking (i.e., enjoyment), and relative reinforcing value (RRV, i.e. motivation) in six to ten-year-old children while playing an exergame with a friend under two goal structure conditions: competitive versus cooperative. To our knowledge, this is the first examination of liking and motivation of these goal structures using exergames in young

children. We hypothesized that children would achieve greater energy expenditure, liking, and motivation in the cooperative setting versus competitive play. This would support prior studies in adolescents who exhibited greater energy expenditure during cooperative versus competitive exergame participation using the Nintendo Wii ® (39). Further supporting this hypothesis are prior findings that in both the classroom and during participation in sports, young children may prefer cooperative activities (30, 42).

METHODS

Participants

A-priori sample size calculations for the present study were based upon research from Staiano et al. (2012), which reported intrinsic motivation during competitive versus cooperative exergame play in adolescents (39). In this prior study, participants reported greater intrinsic motivation in multiple domains (e.g., challenge optimal difficulty, sensory immersion) for cooperative play (mean scores ranged from 19.2 - 28.4, standard deviations ranged from 0.9 - 1.5) versus competitive play (corresponding mean scores ranged from 15.8 to 22.6, standard deviations ranged from 0.8 - 1.4). These differences and standard deviations yielded effect sizes ranging from 3.9 to 4.0. Given these large effect sizes, and an a-priori $\alpha \leq 0.05$, only very small sample sizes (< five participants per group) would be necessary to achieve a power ≥ 0.80. The current study, relative to Staiano et al., used a different assessment of motivation (i.e., RRV versus self-reported intrinsic motivation), a different design (within versus between subjects), and examined younger children (39). Because of these differences we used a sample of 20 participants even though these prior results indicated that differences in motivation between competitive and cooperative exergame play may be detectable with a smaller sample. Additional studies using similar protocols, populations, and statistical analyses have also implemented sample sizes of a similar range (28, 37).

Participants characteristics can be found in Table 1 and participants were free from any known cardiovascular, pulmonary, orthopedic, metabolic, cognitive, neurological, muscular, or behavioral impairments. Each participant was asked to select a same sex friend of the same age (years old) to participate along with them, but was not measured for the dependent variables themselves (N = 20 friends). Prior to participation, written parental informed consent and verbal child assent was obtained from participants and their friends. All procedures were approved by the Institutional Review Board at Kent State University. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (25).

Protocol

Each participant was asked to complete one visit to the laboratory. Anthropometric measurements were taken including height and weight followed by Body Mass Index (BMI) calculation. Demonstration of game play on Wii Sports Tennis® (exergame) was performed in both the competitive and cooperative settings. The cooperative setting involved the participants playing with their friend against a computer avatar. The competitive condition involved the same pair of children playing in direct opposition to each other. This game was chosen due to the cooperative and competitive options and has been previously shown to elicit energy

expenditure above that of a sedentary alternative along with similar intensity as hitting tennis balls during a beginner lesson (39). The children (participants and friends) were allowed to practice for a five-minute period in each game condition prior to the testing period. The experimental procedure involved measurement and data collection during three 10-minute conditions: rest, cooperative, and competitive. The resting condition was completed first followed by the two gaming conditions, the order of which was counterbalanced across participants. The following variables were assessed during each 10-minute period and were only collected from the subject themselves and not their friend: oxygen consumption (VO_2) and liking. After all experimental conditions were completed the subjects performed a computer task to compare the RRV of the two gaming conditions (competitive, cooperative). Descriptions of all study measurements are detailed below.

VO_2: Subjects were measured for VO_2 (mL x kg-1 x min-1) throughout each of the three, 10-minute conditions (rest, competitive, cooperative) to assess energy expenditure during video game play and at rest. This was completed using indirect calorimetry on a metabolic cart (Parvo Medics, Sandy, UT). Hans Rudolph (Shawnee, Kansas) extra small or petite VO_2 masks were used to ensure appropriate fit for our subject population and allowed subjects to still converse while obtaining measurements and therefore experience the social benefit of participating with a friend. Both the subject and their friend wore a mask to make their experience similar, but only the subject was measured for VO_2 using the metabolic cart.

Liking: Participants were asked to rate how much they liked each 10-minute condition after completion using a visual analog scale (VAS). The scale consisted of a 10-cm line in which the left side was labeled, "do not like it at all" and the right side was labeled, "like it very much". The subjects were then asked to mark along the line with a pen indicating how much they liked that particular condition (i.e., the closer to the right the more they like the task and vice versa). Liking was then assessed by measuring distance from the left most anchor ("do not like it at all") and the point where the participant marked the line. The VAS used has been shown to be a valid measure of liking for physical activity in children (41). Liking, when assessed in this manner, is also a valid predictor of actual participation in physical activity by children (33).

RRV: After completion of the three ten-minute conditions, participants completed an RRV computer task to assess the reinforcing (i.e. motivating) value of playing Wii Tennis® cooperatively versus competitively. The computer task required participants to perform work in the form of manual mouse button pressing to gain additional minutes of "free play" under either the cooperative or competitive conditions for Wii Tennis®. The subjects had two computer screens available to them in which one was for the purpose of earning points for the competitive setting and the other for earning points for cooperative play. During the task, subjects were told they could press the mouse button to change the pattern of three shapes on the computer screen as similar to the arrangement of a slot machine. Once the three shapes matched the subject earned one point, or minute, for the corresponding game condition. The child was able to earn eleven additional minutes for one condition or could divide the minutes between the conditions depending on how they decided to divide their work between the computer screens. The first level was set for a fixed ratio (FR) of one button press to earn one

point. This doubled with each subsequent point earned. For example, the second level required an FR of two or two mouse presses, the third level 4 mouse presses, and so on. Therefore, to earn eleven points, or minutes, for one game type the individual had to complete an FR of 1, 2, 4, 8, 16, 32, 64, 128, 256, 512 and 1024 presses. The output maximum (Omax) is the maximal amount of presses the individual completes to gain one minute of access to each game type (7). This value was utilized as the measure of RRV, or motivation, as applied in prior protocols regarding physical activity (28, 37). This RRV task has been shown in previous studies to be a valid predictor of a child's actual physical activity habits (12).

Statistical Analysis

All statistical analyses were performed utilizing the statistical package for the social sciences (SPSS, Version 26, Chicago, IL). A-priori significance was set at $\alpha \leq 0.05$ for all analyses. A three gaming condition (rest/control, cooperative, competitive) repeated measures analysis of variance (ANOVA) was utilized to assess differences in VO_2 and liking. Because Omax data was not normally distributed in either the cooperative (Shapiro-Wilk = 0.563, $p < 0.001$) or competitive (Shapiro-Wilk = 0.263, $p < 0.001$) condition this value was compared across conditions using the Wilcoxon signed-rank non-parametric test.

RESULTS

Participant physical characteristics are shown in Table 1.

Table 1. Descriptive Statistics (Data are means ± SD)

	N	Age	Height (cm)	Weight (kg)	BMI (kg·m -2)
Subject	20	8.4 ± 1.3	136.5 ± 10.8	33.3 ± 9.3	17.7 ± 3.3

Table 2. VO_2, Liking, and RRV (Data are means ± SD)

	VO_2 (mL x kg-1 x min -1)	Liking (cm)	RRV (Omax)
Rest	5.2 ± 1.3	2.8 ± 2.4	N/A
Competitive	9.6 ± 3.1	8.3 ± 2.3	118.2 ± 310.2
Cooperative	9.0 ± 3.1	9.3 ± 1.6	203.5 ± 361.1

VO_2: A significant ($F = 47.91$, $p < 0.001$) main effect of gaming condition was found for differences in VO_2 (Table 2). Further analysis using pairwise comparisons revealed a significantly ($p < 0.001$) greater VO_2 during both cooperative (9.0 ± 3.1 mL x kg-1 x min -1) and competitive (9.6 ± 3.1 mL x kg-1 x min -1) play versus the resting condition (5.2 ± 1.3 mL x kg-1 x min -1) (Table 2). No significant difference in VO_2 was seen between competitive and cooperative gaming ($p = 0.10$).

Liking: A significant ($F = 88.73$, $p < 0.001$) main effect of game condition was found for liking. Further analysis using pairwise comparisons revealed significantly ($p < 0.001$) greater liking for cooperative (9.3 ± 1.6 cm) and competitive (8.3 ± 2.3 cm) gaming than rest (2.8 ± 2.4 cm). Children

also reported significantly (p = 0.03) greater liking for the cooperative than competitive condition (Figure 1) (Table 2).

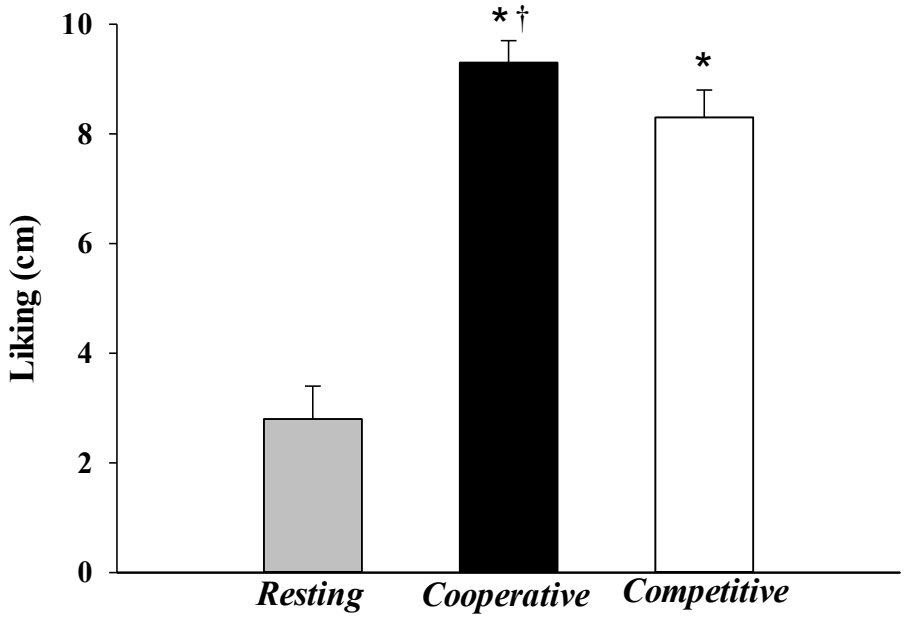

Figure 1. Mean liking for the three activity conditions (Mean ± SEM). *condition was significantly greater than rest at $p \leq 0.001$. † condition was significantly greater than rest and competitive at $p < 0.05$.

RRV: There was no significant (X = 1.56, p = 0.12) difference in Omax between the cooperative and competitive game conditions (Table 2).

DISCUSSION

While previous research has examined competitive versus cooperative play in either older age groups (i.e., adolescents, young adults) or different settings (i.e., education, athletics) this is the first study to our knowledge to examine the effect of goal structure on energy expenditure and psychological variables in young children (30, 39, 42). Both exergame conditions increased energy expenditure in relation to rest, as seen in previous research using Wii Tennis®, but no difference in VO_2 was found between the two gaming conditions (31). The expectation was that cooperative gameplay would promote greater energy expenditure due to an increase in motivation and liking during participation as seen in previous research in adolescents (39). This discrepancy may be due to the fact that no difference in RRV was found between the goal structures in the current study. This was unexpected as we hypothesized that young children would be willing to perform a greater amount of work (i.e., button presses) to participate in cooperative gameplay versus the competitive alternative as seen in previous studies on adolescents where motivation was measured via survey methods (39). A portion of our hypothesis was supported as the young children studied presently reported greater liking for a cooperative versus competitive goal structure which was similar to previous studies examining

goal structure preference in academics and athletics (30, 42). Overall, our results partially support our hypothesis in that young children preferred cooperative play, although they did not further increase VO_2 nor did they find it more reinforcing to participate in cooperative play versus competitive play.

Previous research from our group found that six to ten-year-old children did not report greater liking for an exergame versus a traditional, sedentary video game alternative when playing with a friend versus playing alone. Furthermore, contrary to the hypothesis in this prior study, children found playing a sedentary video game to elicit a greater RRV than an exergame when in the presence of a peer (37). This effect conflicted with other studies that have demonstrated a pro-physical activity effect of playing with a friend in other, non-exergame contexts (e.g., playing in a gymnasium) (4, 35, 36). It was hypothesized that the greater motivation to play the sedentary game in this prior study was due to the competitive nature of the chosen game (Wii Boxing®). This theory was proposed as children commented the game made them feel they were in opposition of their friend (37). Our current study looked to add to this research by examining the effect of cooperative versus competitive exergame play with a friend upon liking and RRV in the same age group. Presently, liking was significantly greater for cooperative gaming than both rest and the competitive goal structure supporting the hypothesis that children may have been averse to the competitive context found in Wii Boxing®. Conversely, there was no significant difference in motivation or VO_2 across the two goal structures in our present study.

The lack of significant difference in motivation and VO_2 between goal structures may have been complicated in the present study as Wii Tennis® was still competitive in general, although when in the cooperative mode children played directly against a computer avatar and not their selected friend. This was evident as some children made anecdotal comments such as, "It is not nice that the game says 'you lost' when we do not score as many points as the other team". Participating in a game that was not in direct competition with their friend may have improved the child's liking of the activity, but did not alter RRV. This also may have limited any differences in VO_2 as previous research has shown a correlation between motivation and energy expenditure measured via accelerometer counts (31, 39). It has been theorized that children, who are more task oriented, may be more motivated to improve their own skill level as opposed to concentrating on winning a game against an opponent (10). This theory would suggest young children may find greater reinforcement, and in turn exert greater energy, in participating in activities that do not contain a goal structure where winning or losing is the outcome. Similar rationale has been echoed by pediatric professionals in regard to athletic participation as it has been suggested that the goal of participation for young children should be to have fun, learn fundamental skills, and focus on individual achievement within the sport versus external comparison (1, 24). Based on these previous findings and professional recommendations, young children may find activities involving skill development more motivating than competition, which may have led to the discrepancy in outcomes between liking, RRV, and VO_2 in our present study.

It would seem that liking and motivation would be closely linked, but these variables have been found to have a separate and unequal effect on physical activity behavior (26, 31). Factors

relating to neurobiology can potentially explain this difference. Whereas motivational factors, such as RRV, are related to neurotransmitters in the dopamine system, liking is predominately controlled by that of the opioid system (6). Therefore, these variables are operated by two different neurotransmitter systems and may allow a factor to be well liked while not necessarily more reinforcing or vice versa (13, 19, 28, 32). The greater liking of the cooperative goal structure by children in our present study with no difference in RRV may provide further evidence of this phenomenon. Motivation, in this case RRV, has been found to be a stronger predictor of behavior than liking (13). Despite this, liking when assessed using the current method is still predictive of physical activity participation in children (33). Greater liking for cooperative activity thus remains a potentially important finding as prior research has indicated that greater liking of a physical activity predicts greater participation in that behavior in young children (33). Incorporating a cooperative goal structure in physical activity programs and avoiding activities in which winning or losing is the outcome may elicit greater liking which may, in turn, promote greater physical activity participation. Such activities could include free play, skill development in an athletic setting, and/or cooperative obstacle courses or relay races in which improving on a team or individual's own performance is the goal. These methods of physical activity may provide a more cooperative goal structure and in turn maintain liking for the activity and enhance participation through improved motivation. Furthermore, there has been sufficient evidence showing that increased variety of physical activity options enhances liking and in turn physical activity behavior in children (2, 20). While variety was not manipulated in the current study, the potential for increasing enjoyment, and possibly motivation, of exergame play in children may be conceivable through increasing the variety of gaming options.

While this was the first study to compare the effect of competitive versus cooperative goal structures on exergame play in young children, it is not without limitations. Our cooperative and competitive goal structure conditions were established from a single exergame as this allowed for laboratory measurements, such as VO_2, and better control of extraneous variables. The use of a more natural setting (e.g., playgrounds, gymnasiums) in future studies may make the findings more generalizable to physical activities children typically participate in. Additionally, while children worked together in the cooperative condition in the present study they still competed, albeit against a computer avatar. Future research should examine a more truly cooperative physical activity (e.g., an obstacle course or "treasure" hunt) in comparison to a competitive activity in the same subject population. Manipulating the variety of physical activity options in children also provides potential for enhancing enjoyment and physical activity behavior and thus warrants further investigation to assess prospective effects on these variables, as well as motivation, in regards to exergame play (2, 20).

In conclusion, children did not exhibit a difference in RRV or VO_2 between cooperative and competitive exergame play. In contrast, liking was found to be greater for cooperative versus competitive play. As greater liking of an activity is associated with greater participation in that activity, children in the present study may be more likely to participate in exergame play in a cooperative setting versus a competitive one. While more research on the impact of competitive and cooperative goal structure is warranted, the present study adds to the existing literature that suggests there may be pro-behavioral effects of cooperative play in young children.

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