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ORIGINAL RESEARCH

Social facilitation in virtual reality-enhanced exercise: competitiveness moderates exercise effort of older adults

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Abstract: This study examined the effect of virtual social facilitation and competitiveness on exercise effort in exergaming older adults. Fourteen exergaming older adults participated. Competitiveness was assessed prior to the start of exercise. Participants were trained to ride a "cybercycle;" a virtual reality-enhanced stationary bike with interactive competition. After establishing a cybercycling baseline, competitive avatars were introduced. Pedaling effort (watts) was assessed. Repeated measures ANOVA revealed a significant group (high vs low competitiveness) × time (pre- to post-avatar) interaction ($F[1,12] = 13.1$, $P = 0.003$). Virtual social facilitation increased exercise effort among more competitive exercisers. Exercise programs that match competitiveness may maximize exercise effort.

Keywords: exercise, aging, virtual reality, competitiveness, social facilitation, exercise intensity

Introduction

A growing literature has demonstrated that exercise boosts not only physical, but also cognitive and psychological health in older adults.[1–3] However, participation in exercise among older adults is particularly poor. According to the 2007 National Health Interview Survey from the Centers for Disease Control and Prevention (CDC) Healthy People 2010 Database, only 14% of adults 65–74 years old and 7% over 75 years of age reported regular exercise (www.cdc.gov/nchs/healthy_people.htm). With recent revisions to the American College of Sports Medicine (ACSM) standards which are even more stringent,[4] these figures are likely to be overestimates of current rates of exercise. Research has shown that despite pleasure derived from even simple exercise such as walking,[5] a variety of barriers impede older adult participation;[6,7] ranging from low self-efficacy to inclement weather, to a lack of motivation. Thus, alternative and novel forms of exercise are being explored for their potential to increase physical activity. Virtual reality-enhanced exercise, or "exergames" are on the rise in the marketplace and in academic research.[8–10] Although evidence has begun to show that exergaming can increase exercise participation and mood,[10,11] little is known about the role of specific aspects of the virtual environment in facilitating exercise effort. This study examines the role of social facilitation when avatars are introduced, and the potential moderating effect of participants' competitiveness.

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Theories of social facilitation and social comparison have long since been used to explain changes in exercise behavior when in the presence of others.[12,13] Social facilitation most broadly construed holds that behavior in simple tasks is improved

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in the presence of others. Research suggests that social presence causes individuals to evaluate and adjust their exercise performance in response to the individuals within their social environment, and that this change can result from making personal comparisons between their own abilities and the abilities of those around them.[14] The social presence of another individual when completing an exercise task is believed to sharpen one's competitive instincts.[15] The generalized drive hypothesis provides evidence to suggest that social facilitation increases one's innate internal drive and activation level, which are found to be elevated in competitive environments.[16] Studies have shown that exercise performance improves when in a competitive setting,[17,18] and that these changes may be due to a variety of mechanisms including: increased levels of arousal,[19] adrenocortical activity,[20] and mood.[11,21] However, a meta-analysis of over 200 studies concluded that social presence typically led only to small effects.[22]

We hypothesize that a variety of factors could moderate the effect of social facilitation and, if not taken into consideration, the effect could appear dampened. While competitive environments may generally elicit changes in exercise behavior, the level of a personality trait like competitiveness, could interact with and thus moderate this effect.[23] Indeed, social value orientations, such as prosocial, individualistic, and competitive, are largely predictive of behavioral tendencies on task performance, and influence one's intrinsic and extrinsic motivations related to exercise.[24] Competitive environments can result in decreased levels of intrinsic motivation, suggesting that factors, such as competition, may outweigh enjoyment of exercise tasks for certain individuals.[25] It has recently been reported that exergaming, where competition is a key feature, can affect intrinsic motivation.[26] Changes in behavior may also be influenced by the Kohler effect, which suggests that the presence of a superior (eg, stronger, faster) competitor will cause increased effort.[27] Exergames which integrate competitive avatars, provide an ideal environment for evaluating our hypotheses since the presence of competitors can be manipulated, while keeping other features consistent (eg, virtual esthetic environment, course difficulty).

The integration of videogames into exercise equipment produces visually stimulating exercise experiences and has resulted in greater improvements in self-efficacy and mood, as well as promoting adherence to exercise behaviors and improved health.[28–31] Some studies have illustrated the importance of a competitive element in the successful integration of videogames into the exercise experience, which in many cases is represented by a virtual competitor, or avatar, which can be perceived as a social presence.[32,33] The nature of an avatar has been found to elicit varied emotional responses in participants; videogame players experienced greater engagement and threat when an avatar represents a human-operator as contrasted with a computer-operated opponent.[33]

The current study aimed to assess the effects of social presence on exercise behavior, focusing on the role of virtual social facilitation. Competitiveness was examined for its impact on the amount of effort expended while completing an exergaming task in the presence of a virtual competitor. This research aimed to improve upon previous literature that has evaluated the effects of virtual social facilitation and competition on video game behaviors by evaluating the impact during an exergame.

Method

Participants

Fourteen independent living older adults ranging in age from 60 to 99 participated (Table 1); all were Caucasian, consistent with the composition of the regional population. These older adults were from eight retirement communities, and were participating in a larger randomized controlled trial (www.clinicaltrials.govidentifier:NCT01167400) examining

Table 1 Baseline characteristics and change in exercise effort with competition

	Competitiveness				*t*-test
	Low (n = 8)		High (n = 6)		*P*
	Mean	*SD*	Mean	*SD*	
Baseline characteristics					
Age (years)	80.7	(12.3)	75.6	(13.5)	0.48
Education (years)	13.9	(2.5)	12.7	(1.0)	0.29
Women (n)	7		6		
Competitiveness	4.4	(3.2)	11.5	(2.6)	0.001
Weight (kg)	68.9	(8.6)	70.1	(10.7)	0.83
BMI	25.7	(2.3)	27.0	(2.8)	0.36
HR	57.1	(5.4)	60.3	(5.0)	0.29
BP (systolic)	126.3	(24.9)	132.3	(13.8)	0.61
BP (diastolic)	71.0	(15.1)	71.0	(9.4)	1.00
Fat tissue %	40.4	(4.2)	44.5	(4.3)	0.10
Fat mass (kg)	26.8	(3.8)	30.5	(7.2)	0.26
Lean mass (kg)	39.7	(6.1)	37.4	(4.0)	0.44
Abdominal fat %	42.3	(9.1)	47.2	(8.2)	0.33
Exercise effort					
Pre-competition (watts)	16.3	(9.6)	25.5	(11.4)	0.12
With competition (watts)	16.9	(9.2)	30.2	(11.1)	0.03
Change (watts)	0.6	(1.1)	4.7	(2.9)	0.003
Change (% watts)	6.0	(9.0)	20.9	(13.2)	0.03

Abbreviations: BP, blood pressure; BMI, body mass index; HR, heart rate.

the cognitive benefits of exergaming 2–5 times per week for 3 months compared with traditional stationary cycling. Volunteers (unpaid) for the RCT were screened (n = 198), 102 received medical clearance and provided signed informed consent, 79 completed pre-evaluations and started training, 63 completed the study, only participants in the first year of the study (n = 31) were eligible for this pilot analysis due to a change in bike equipment in the second year that precluded these analyses and of these, only those assigned to the cybercycle condition were appropriate (n = 14).[34] Baseline measures included: weight (kg) and height (cm) to compute Body Mass Index (BMI), total and abdominal body composition (fat mass, lean mass) using the iDXA (GE Lunar, Inc), and heart rate and blood presssure data were collected by a registered nurse (Table 1).

Measures

Participants' self-reported tendency toward competitiveness was measured using the Competitiveness Index which has been shown to have good reliability (alpha = 0.90) and validity.[35] Twenty different statements are presented on this scale and participants indicate whether each statement is more or less true or false for them. The total score can range from zero to 20, with higher scores indicating greater competitiveness. The scores in this sample ranged 1–16; using a median split procedure (low < 9 and high ≥ 9), six participants were classified as highly competitive (average = 11.5), while eight were less competitive (average = 4.4). The median split mark was also comparable with normative data (mean for women = 9.5).[35]

Exercise effort (watts) was captured in 10-second intervals by cybercycle sensors and recorded on the internal computer, averaged across sessions, and then averaged across the evaluation period. These data were downloaded and average pedaling intensity (watts) was computed over a 1-month period before and after the introduction of on-screen riding competitors (at the end of the second and third months of the larger trial).

Procedures

All participants were participating in a larger randomized controlled trial, The Cybercycle Study,[36] which was approved by the Institutional Review Boards at Union and Skidmore Colleges. The participants in this study had been randomly assigned to the cybercycle condition and met the minimum ride frequency threshold for inclusion in analyses (average 2–3 rides per week for 3 months or 25 total allowing for brief periods of illness, vacation, equipment malfunction; only two of 79 randomized participants had to be excluded for not meeting this minimum threshold). During the first month of familiarization, these previously sedentary older adult participants were trained to ride the stationary bike in biofeedback mode only (no virtual reality display) and were to attend to their heart rate, aiming for 60% of their computed ideal heart rate reserve range. The cybercycle comprised an easy to use recumbent "step-through" ergometer (Tunturi e60R), interfaced with Netathalon riding software (v 2.0) via a sensor kit, on an Acer laptop. In the second month, participants in the experimental condition were introduced to the virtual reality features (eg, virtual terrain such as a mountain, desert, or small town landscapes). In the third month, on-screen riders were introduced and participants were trained to try to outpace the avatars.

Data analysis

All analyses were conducted in SPSS for Windows (v 16.0.01; SPSS Inc, Chicago, IL). Repeated measures ANOVA was used to test the hypothesis that competitiveness would moderate any effect of social facilitation on exercise effort. Exercise effort (pedaling intensity measured in watts) was the dependent variable and measured over time (1 month pre/post-introduction of competitive avatars). Competitiveness was the independent variable with high and low groups created by median split.

Results

Competitiveness as a moderator of social facilitation effect

The two groups were comparable on demographics and physiological fitness measures taken at pretest (Table 1); there were no significant changes in physiological measures. Assumptions of normality were met for repeated measures ANOVA which revealed a significant group (high vs low competitiveness) × time (pre- to post-competitors) interaction $F(1,12) = 13.1$, $P = 0.003$. Given the imbalance in sex representation, analyses were also conducted after dropping the single male from the sample and the interaction effect was found to be almost identical: $F(1,11) = 13.0$, $P = 0.004$. Results showed that for more competitive older adults, the introduction of on-screen competitors led to an increase in riding intensity more so than for less competitive, older adults (20% and 6% increases, respectively; Table 1).

Discussion

Previous research has shown that older adults have poor compliance with recommended frequency and intensity of exercise in general, but novel, virtual reality-enhanced, exercise has been shown to increase participation.[9] The effect on exercise behaviors of various factors within the virtual environment (such as the presence of a competitive avatar) and within the person (such as competitiveness) is still unclear, however. The aim of this study was to evaluate the effect of virtual social facilitation on exercise behavior in older adults using a virtual reality-enhanced stationary bike or "cybercycle". We were also interested in whether greater competitiveness could moderate the influence of social facilitation on the degree of exercise effort. Results showed that for more competitive compared with less competitive older adults, the presence of competitive avatars significantly increased pedaling intensity exhibited during cybercycling. The observation that social presence in a competitive setting resulted in behavioral change is consistent with previously conducted research.[12,15,17] Additionally, our findings are consistent with research that has suggested that social facilitation interacts with an exerciser's competitive orientation such that it can enhance or detract from exercise goals, depending on the desired outcomes.[24] These findings also fit with results of a recent study which examined the Köhler motivation gain effect resulting from a virtually-presented partner. Using an isometric plank exergame it was found that participants performed significantly better than in a solo control condition in all variants with a superior virtual partner (ie, whether coacting, additive, or conjunctive).[37] This suggests that working out with a superior virtual partner can be effective for enhancing exercise performance. Future research could examine the role of the Köhler effect by manipulating the confederate to be a known superior competitor over repeated trials, perhaps while also manipulating social facilitation by controlling an avatar's presence on the screen or "behind the scenes". To our knowledge, this is the first report to examine the moderating role of competitiveness in virtual social facilitation among older adults.

In contrast to our findings, it has also been shown that exercising in the presence of others can have a detrimental impact on the mood or psychological state of individuals who do not have a dominant competitive personality trait, even leading to decreased adherence with exercise.[38,39] However, in this study, participants who were lower on competitiveness maintained their initial level of exercise effort, and thus effort did not appear to be adversely affected by the introduction of on-screen competitors. This may indicate that for less competitive individuals, the virtual reality-enhanced environment may be flexibly perceived, allowing one to choose to cognitively discount or reinterpret the social presence of an avatar since it is not the equal of a real-life competitor. Future research could explore these nuances; perhaps focusing on both the participant's perception of the avatar (eg, by way of manipulating nonverbal cues),[40] as well as their own sense of presence in the virtual world which has been found to be salient in avatar-based exergames.[41]

A strength of this study is the utilization of an exercise bike with engaging virtual features, a comfortable recumbent seat, safe indoor location, and easy access step-through design, all of which overcome many barriers typically asserted by sedentary older adults.[6,7] As such, it may make it easier for participants to reverse negative thinking about exercise.[42] Other important strengths of this study are that it extends prior research on social facilitation to the older adult population, which is often underserved, and applies traditional exercise theory to a novel exergaming modality. The implications of this study are that older adults may benefit from virtual reality-enhanced exercise, and greater exercise effort might be derived by matching the type of exergame experience (eg, competitive or not) to the individual's personality. Given the vast majority of older adults who are not exercising at recommended levels, it would be exciting if exergames could be implemented in senior facilities and carefully prescribed so that more might reap the physical, cognitive, and psychological benefits of engaging exercise in later life.

These results should be interpreted cautiously due to several limitations. First, our data were collected from a small sample of participants who were independent living Caucasian older adults in relatively good health, and of moderately high socioeconomic status; results need replication and generalizability may be limited. Second, our sample was disproportionally women, thus making it difficult to draw accurate conclusions about the moderating effects of social facilitation and competition on exercise performance in men. Additionally, the participants were engaging in a larger clinical trial, and as such had been instructed previously to work toward increasing their exercise behavior; thus it is possible that the confounding of time in the trial and the sequential change in the virtual reality conditions could have obscured results. However, the differential response of the more and less competitiveness subgroups is compelling, since both were given the same instruction at the start of the larger trial.

Future research replicating and extending this study could explore ways to use remote monitoring via the internet, to tailor individual feedback, and increase adherence with either in-home or facility-based applications of this type of exercise modality.[43] Studies could explore the broader physical activity identity of older adults,[44] beyond their sense of competitiveness, and its role in influencing virtual reality-enhanced exercise behavior. Alternatively, physical activity preference (eg, to be alone or with others)[45] may be another way to conceptualize the competitiveness measured herein, and could add to the prediction and enhancement of exercise effort. Similarly, since self-selection (vs assignment) to exergaming has been found to influence mood, it would be useful to clarify the possible moderating role of choice in exergaming.[46] Given that an individual's degree of intrinsic or extrinsic motivation for exercise can significantly influence exercise behavior and also how one responds to social facilitation,[25] it would be interesting to measure motivation in future exergaming research. Since it is possible to influence one's level of competitiveness through priming,[23] a follow-up study could investigate whether such an influence carries through to the behavioral effect found herein. Additional research might explore the possible connection between social facilitation and the known importance of social reinforcement which has been shown to account for much of the variability in exercise behavior.[47,48] Last, future research could compare and contrast the differential impacts of virtual and real social facilitation on exercise behaviors, while taking into account the role that competitive tendency may play.

Conclusion

In summary, over a 1-month period, 14 independent living older adults using a virtual reality-enhanced stationary bike or "cybercycle" were exposed to virtual competitors; more competitive participants were found to significantly increase exercise effort compared with their less competitive counterparts. Thus, the introduction of a competitive avatar did not adversely impact less competitive riders, but it did enhance the exercise effort of more competitive riders. More research is needed to identify alternative motivators that can increase the exercise effort of less competitive older adults. If replicated, this finding suggests that the greatest exercise benefit might be achieved by matching the nature of an exergame experience to a rider's level of competitive tendency, especially for more competitive riders.

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Disclosure

The authors report no conflicts of interest in this work.

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