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Original article

Group dynamics motivation to increase exercise intensity with a virtual partner

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Abstract

Background: The effect of the Köhler group dynamics paradigm (i.e., working together with a more capable partner where one's performance is indispensable to the team outcome) has been shown to increase motivation to exercise longer at a strength task in partnered exercise video games (exergames) using a software-generated partner (SGP). However, the effect on exercise intensity with an SGP has not been investigated. The purpose of this study was to examine the motivation to maintain or increase exercise intensity among healthy, physically active middle-aged adults using an SGP in an aerobic exergame.
Methods: Participants ($n = 85$, mean age = 44.9 years) exercised with an SGP in a 6-day cycle ergometer protocol, randomly assigned to either (a) no partner control, (b) superior SGP who was not a teammate, or (c) superior SGP as a teammate (team score was dependent on the inferior member). The protocol alternated between 30-min continuous and 4-min interval high-intensity session days, during which participants could change cycle power output (watts) from target intensity to alter distance and speed.
Results: Mean change in watts from a targeted intensity (75% and 90% maximum heart rate) was the primary dependent variable reflecting motivational effort. Increases in performance over baseline were demonstrated without significant differences between conditions. Self-efficacy and enjoyment were significantly related to effort in the more intense interval sessions.
Conclusion: Under these conditions, no Köhler effect was observed. Exercise performance during the higher-intensity interval format is more closely related to enjoyment and self-efficacy beliefs compared to the continuous sessions.

Keywords: Exercise intensity; Köhler effect; Motivation; Software-generated partner

1. Introduction

The majority of Americans fail to exercise at levels shown to increase fitness and reduce health risk,[1,2] falling short of the 150 min/week of moderate-intensity physical activity (PA) required to meet the Physical Activity Guidelines for Americans (PAG).[3] Among the various approaches being explored to motivate adults to increase PA, there is evidence that exercising in a group setting or with exercise companions can increase time engaged in regular PA.[4,5] Simply performing in the presence of another group member may have a positive (or negative) effect on one's performance.[6] However, considerable laboratory research on motivation in task groups has suggested that certain types of interdependence among group members can lead to a significantly increased level of effort and motivation *gains* (i.e., versus working individually). These motivation gains stand in contrast to work focused on preventing the adverse group effects of social loafing, in which a group member exerts less effort than would be expected by his or her individual performance.[7,8] A well-studied and particularly robust motivation group dynamic, the Köhler effect,[9,10] capitalizes on group member interdependence to motivate greater effort in taxing physical performance of lower-ability

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group members. Köhler[11] noted that weaker members of dyads could perform a taxing physical task (viz., yoked biceps curls) longer than one would expect from their individual performances. The dyads in Köhler's experiments were functionally linked during the task (i.e., yoked) so that once the weaker member was exhausted and quit, the stronger member was forced to quit as well. This interdependent arrangement, in which the weaker member determines the potential group productivity, is referred to as a conjunctive task demand.[12] The conjunctive task condition stresses the indispensability of a weaker member's efforts for his or her team; motivation is likely to be enhanced when the person sees his or her efforts as being highly instrumental in achieving team success.[13] The Köhler effect also occurs when low-ability group members increase their motivation as a result of upward social comparison[14] with their more capable group members.[13] Furthermore, prior research has shown the motivation to increase effort is most pronounced when the weaker member perceives a moderate difference in ability, so that the partner is not too similar or too superior.[15]

It should be noted that motivation cannot be observed directly and must be inferred. Researchers measure motivation in numerous ways, including the use of behavioral representations and self-reports. These behaviors represent one's conscious or nonconscious self-regulation and decision making related to attaining a desired goal. Researchers studying the Köhler effect use behavior, in terms of performance effort at simple tasks, to infer motivation. As Touré-Tillery and Fishbach[16] note, "Measures such as choice, speed, performance, or persistence exerted in the course of goal pursuit capture the goal congruence of behavior and can thus assess the strength of one's motivation to pursue the goal".

A 2007 meta-analysis reported a large effect size for the Köhler motivation gain across many studies.[17] More recent research has explored the Köhler motivation gain effect in exercise settings.[18–20] This series of studies used simple muscular persistence tasks (e.g., abdominal plank exercises) and aerobic cycle ergometer protocols while participants interacted with a human partner presented to them through an Internet connection. Depending on the protocol, a video screen served to project images of the participant exercising, clips of a trainer demonstrating the exercises, and the partner exercising. Whether the protocols were single- or multiple-session exercise regimens, participants demonstrated significant motivation gains in exercise persistence in support of the Köhler effect group dynamic.

While researchers continue to test the boundaries of the Köhler effect on exercise persistence, none have sought to apply the successful motivation paradigm to study increasing the intensity of exercise under high-intensity aerobic conditions (>80% of maximum heart rate (HR_{max})).[21] Those engaging in PA must attain at least a moderate-to-vigorous level of intensity to benefit fitness and health.[3] Among active adults, shorter-duration, higher-intensity exercise is often used (i.e., at least 75 min/week of vigorous-intensity aerobic PA, or an equivalent combination of moderate- and vigorous-intensity aerobic activity) as an accepted alternative to meet the PAG.[3] In fact, high-intensity interval training (HIIT) has become an increasingly popular method of satisfying recommended levels of PA.[21] HIIT usually involves brief, intense bursts of activity, alternating with periods of recovery or active recovery (movement at a low intensity or 40%−50% of HR_{max}[21]). Evidence that HIIT is effective in improving health for nondiseased adults and adults suffering from cardiometabolic disease[22,23] has helped fuel the trend for shorter, but more intense, exercise protocols. As the intensity of exercise increases, inherent difficulties and discomfort may result in motivation challenges to continue the exercise or challenges to achieve the intended workout levels. Although there is evidence to suggest that high-intensity interval and vigorous aerobic exercise may not be intimidating for most active adults,[24] researchers have demonstrated that higher intensities may have a negative impact on adherence, reported exertion, and affect in less-active adults.[25,26] Therefore, it is worth exploring whether the Köhler motivation gain effect may help adults reach the necessary intensity levels to ensure that the health-related goals of exercise are met.

Unfortunately, despite recognized motivation gains in group settings, exercising with a partner or group poses significant challenges. Locating and coordinating time to exercise with one or more partners, even with sessions of shorter duration, is not always easy to do and adds a hurdle in achieving consistent workouts. More importantly, ability discrepancies between desired partners may not be optimal or fluctuate session to session. Exercising with a software-generated partner (SGP) may provide a practical way to control for such problems inherent with traditional human workout partners. Using SGPs in a Köhler motivation paradigm affords the opportunity to adapt the necessary experimental design as this research line moves forward toward practical applications. Of course, to benefit from an SGP during exercise, one would be required to accept, to some extent, the non-human partner as if he or she was real.

According to the *Media Equation* concept, people often interact with media similarly to human interpersonal interactions.[27] Nass and colleagues[28] found that computers are often recognized as "social actors". In other words, people respond socially to human-like characteristics of computers and apply social rules to their interactions when doing so.[29,30] Recent studies have successfully used SGPs in exercise-persistence tasks.[31−33] Not only did the participants rate the exercise SGPs positively in terms of likability and anthropomorphic features, but the motivation gain across these sequential studies also demonstrated moderate effect sizes (Feltz et al.,[31] $d = 0.57$; Samendinger et al.,[33] $d = 0.76$). These effects were similar in magnitude to those previously reported to be observed with human partners during conjunctive task groups ($g = 0.72$).[17] Such findings suggest adult exercisers can be motivated by an SGP to exercise longer in their sessions.

Self-efficacy is another key variable to consider in the study of exercise performance because one's beliefs about successfully completing a task have been shown to be a significant predictor.[34,35] Depending on feedback from sources of one's self-efficacy (e.g., mastery experiences, vicarious experiences), people with higher levels of self-efficacy will often set more challenging performance goals and persist in challenging situations longer than individuals with lower-efficacy beliefs. These challenging goals create a performance discrepancy that can motivate behavior. Bandura[36] recognized that not only does one's self-efficacy help to determine new performance goals, but mastery experiences may also alter one's self-efficacy in a reciprocal relationship. Increasing PA, in general, can be the focus of this goal-directed process, but it can also be specific to the persistence or intensity of such behavior.

The purpose of this study was to examine the Köhler group dynamics paradigm on the motivation to maintain or increase exercise intensity with middle-aged active adults, as well as to explore the association of self-efficacy and enjoyment with performance. An SGP embedded in a simple exergame video display was used to manipulate the psychological mechanisms of social comparison and team indispensability that have consistently produced the Köhler effect. This study is significant because if an SGP within the Köhler group dynamics paradigm can enhance high-intensity exercise training, while also being self-efficacious and enjoyable, it can open up a powerful set of new tools in exercise video-game design for fitness, especially for those with social physique anxiety, those who lack the time or resources to join an exercise group, and those in exercise rehabilitation therapies. The first hypothesis was that exercise effort would be greater with a more capable coacting SGP (i.e., exercising alongside an SGP but not linked in a team) than when exercising alone because of the effects of a social comparison mechanism. The second hypothesis was that exercising with a moderately more capable SGP teammate under conjunctive task would lead to the highest gains in performance (because of the additional effect of the indispensability of one's efforts).

2. Methods

2.1. Participants

Participants were male and female physically active community members, 30−62 years of age, who were able to engage in vigorous PA ($n = 85$, 49 females). Participants were recruited through community advertisements and solicitation of community athletic organizations (e.g., running and cycling clubs). Advertisements targeted regular exercisers and athletes (runners, swimmers, triathletes, or others) but excluded individuals who solely compete in competitive cycling events. A physician's consent to participate was required for all men older than 44 years of age, women older than 55 years, and for any others determined to be at risk after screening (using the Physical Activity Readiness Questionnaire). To qualify for participation, potential participants were given an incremental exercise test to exhaustion (cycle ergometer) to estimate their aerobic capacities (VO_{2max}). Participants were required to achieve the 150-W stage of the test (for a steady-state 1.5 min), a general level of fitness considered by the study's exercise physiologists sufficient to participate in an intense aerobic exercise protocol. A total of 6 participants either self-selected out of the study after the incremental exercise test or did not qualify and therefore were not included in the sample. Qualified enrollees were given USD36 (USD6 per visit) for their participation at the end of the study. All participants completed the informed consent process before participation. The study was approved by the Michigan State University's Institutional Review Board.

2.2. Procedures

The protocol consisted of alternating continuous 30-min vigorous aerobic exercise sessions and high-intensity interval sessions over 6 days. To compare the effects of the Köhler group dynamic on participant exercise intensity, participants were randomly assigned to an individual control (IC) condition or to one of two SGP conditions: as a coacting partner (COAP) or as a teammate in a conjunctive group (CONJ) task structure (i.e., working toward a team score dependent on the weaker member). In both partnered conditions, the SGP was programmed to ride moderately faster than the participant and would always appear ahead of him or her on the video monitor.

Participants completed the 6 workout sessions on a cycle ergometer (Monark LC4; Monark Exercise AB, Vansbro, Sweden), alternating between 2 protocols: 30-min continuous cycling with the preset wattage at 75% of his or her estimated HR_{max} and a 4×4-min interval workout at $90\%HR_{max}$ (i.e., 4 intervals lasting 4 min each, with 3 min of active recovery between intervals). Results from the initial qualifying maximal exertion test were used in regression equations to estimate the 75% and 90% of HR_{max} values required for the workout sessions. The workout protocol was taken from the National Aeronautics and Space Administration's (NASA) aerobic training program.[37] In both the 30-min and 4-min interval workouts, participants could increase or decrease the wattage on a keypad. On Days 1 and 2, participants cycled with the game screen turned away as the research assistant adjusted the cycle wattage up or down to ensure that participants were working at the prescribed heartrate. On Days 3 and 4, participants cycled viewing the virtual track without a partner, regardless of experimental condition. On Days 5 and 6, participants cycled with an SGP (except in the IC condition) on the same tracks as Days 3 and 4. The virtual track was flat without surface inclines or declines (Table 1).

CONJ and COAP conditions were visually identical to participants, with instructions and experimental manipulations differing between conditions. From Day 3 onward, participants were provided veridical feedback about their power output (in watts), distance, and revolutions per minute (RPMs). In the experimental conditions, after the workout on Day 4, participants were told they would be working with an SGP. The presence of the workout SGP and experimental manipulations were explained to the participants by a same-sex virtual trainer just before the Day 5 workout. These manipulations included being told that the SGP (coactor or teammate) was programmed to be somewhat more capable than the participant but with finite stamina and the potential to fatigue like any other exerciser. In the COAP condition, participants were

Table 1
Experimental protocol.

Day	Procedure
Pre-study	Screening; consent; fitness test
Day 1	Warm-up: 5 min at 50%HR_{max}; 30-min regimen with experimenter making watts adjustment to verify target heart rate; No video; No SGP
Day 2	Same warm-up as Day 1; 4-min × 4 intervals regimen, with 3-min active recovery (at 50%HR_{max}); experimenter makes watts adjustment; No video; No SGP
Day 3	Same warm-up; Baseline 30-min regimen at 75%HR_{max}; Ss allowed to increase or decrease work intensity; No SGP
Day 4	Same warm-up; Baseline 4-min interval regimen at 90%HR_{max} with 3-min active recovery (at 50%HR_{max}). Ss allowed to increase or decrease their work intensity; No SGP
Day 5	Same warm-up; Experimental 30-min regimen at 75%HR_{max} (same as Day 3); Meet and exercise with SGP (except Control)
Day 6	Same warm-up; Experimental 4-min × 4 intervals regimen at 90%HR_{max}. (same as Day 4) Exercise with SGP (except Control)

Abbreviations: HR_{max} = maximum heart rate; SGP = software-generated partner; Ss = subjects.

informed that they could observe the SGP on the screen but would be exercising independently from each other and would receive individual performance feedback. In the CONJ condition, the trainer introduced the SGP as a teammate, yoked together so that neither would be able to cycle too far ahead or too far behind. The trainer also explained that the team outcome depended on the team member who cycled the lesser distance (distance was controlled by the intensity of cycling chosen by each participant by pushing buttons on a keypad). The game software was programmed to always represent distance as a consistent and direct linear representation of the participant-chosen intensity.

When returning on Day 5, participants were introduced to a same-sex SGP, who was created to appear to be comparable in age (Fig. 1), and exchanged a greeting and some basic personal information ("your name, where you're from, something about yourself"). No other interaction occurred during the 2 partnered sessions. In the partnered conditions, the participant and the SGP always began at the same pace, but the SGP soon moved out in front and kept a moderate lead of about 10 feet throughout the entirety of the workout. Despite any acceleration or change in pace by the participant, the SGP's moderate lead was always maintained. This distance was chosen to represent a moderate ability difference without being discouraging to the participant. To maintain the experimental cover story and observe any potential motivation gain effect, the participants were not told until a debriefing that they would never be able to pass the SGP regardless of how high they increased the intensity of the workout.

Fig. 1. Male and female software-generated partners.

2.3. Measures

2.3.1. Effort

Primary measures of performance effort (the inferred measure of motivation) were based on mean power workload (in watts) collected during each session and recorded in the software output. Mean power was calculated from each participant's response to instructions to press a green button to increase intensity (and distance covered) or press a red button to decrease bike intensity (as one might do when selecting a bike gear). Participants were informed that simply pedaling faster or slower would not affect the intensity or distance covered. This experimental feature isolated the inferred motivation measure to whether the participant purposively selected the button. During the 4 × 4-min interval sessions, average power output was calculated without the four 3-min active recovery periods between intervals. The primary measure of performance was the difference in session mean power output in watts from the session pre-programmed beginning watts (i.e., watt difference) throughout the trial (averaged across time). This measure represented the motivation participants acted on to increase watts above the baseline set for them at 75% or 90% of their HR_{max}.

2.3.2. Self-efficacy

Self-efficacy was measured each pre- and post-session following Bandura's guidelines[36] and was based on measures used in previous Köhler effect experiments in exercise settings.[19] The stem of the question on continuous exercise days for each pre-session read, "Rate your confidence that you can cycle for 30 min at the following intensities." The stem of the question for post-sessions was similar except that it referred to "the next time you do this workout". The interval days' presession self-efficacy question stem read, "Rate your confidence that you can cycle for all four 4-min intervals at the following intensities". The stem of the 4-min postsession question was similarly phrased to reflect "the next time" the participant completes this workout. Self-efficacy for each level of intensity increased 5% on the scale items until participants rated their beliefs at 100% intensity, beginning at 75% for the continuous sessions and 90% for the interval sessions. Participants rated their confidence on a scale of 0 (*not confident at all*) to 10 (*completely confident*). The responses for each session type are averaged across the different levels of intensity for a mean value for self-efficacy beliefs.

2.3.3. Enjoyment

To further explore factors that may play a role in participants' performance, enjoyment was measured on each day after exercise using a 5-item modified Physical Activity Enjoyment Scale (PACES).[38] Each item was rated on a 3-point bipolar scale (e.g., 1 = *I enjoy it*; 3 = *I hate it*). The stem of the PACES questionnaire read: "Please rate how you currently feel about the PA you have been doing according to the following scales." The authors of the scale reported adequate factorial validity and invariance over time for the revised measure across two independent samples.

2.3.4. Partner and team perceptions

For participants in the partnered conditions (COAP, CONJ), questionnaires were provided to assess their perception of the partner relationship or partner dynamics. On Day 5 (the day participants met the SGP for the first time), they completed the Alternative Godspeed Indices,[39] a 19-item semantic differential survey with 3 subscales: humanness (e.g., artificial *vs.* natural), eeriness (e.g., bland *vs.* uncanny), and attractiveness (e.g., repulsive *vs.* agreeable). This questionnaire attempts to capture the participants' emotional responses to the SGP. Day 6 questionnaires assessed social- and task-related responses to working with an SGP. Participants' feelings toward their partner were surveyed using 4 items on a 5-point rating scale (e.g., "I liked my partner", "I felt comfortable with my partner"). Exercise team perceptions (5 items, e.g., "I felt I was part of a team", "I thought of my partner as a teammate") were collected using a 9-point scale.[30] Group identification was measured using 6 items (e.g., "I considered this exercise group to be important", "I identified with this exercise group") on a response scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

2.4. Statistical analysis

Power analyses (performed using G*Power software[40]) indicated that a total sample size of 66 participants (3 groups, 2 measurement points) would be sufficient to obtain a medium effect size of 0.50 with a power of 0.95 and an α level of 0.05. Data for changes in exercise intensity were evaluated with repeated measures of analysis of variance (RM ANOVA) to examine the effects of treatment (condition type) and day of session for both the 4-min sessions and the continuous sessions. Multiple regression analysis was used to test relationships between pre-exercise self-efficacy, enjoyment, and performance effort. t tests were used to test the social and task-related perceptions of working with an SGP between the experimental conditions (COAP and CONJ). All analyses were conducted using IBM SPSS Statistics Version 22.0 (IBM Corp., Armonk, NY, USA).

3. Results

3.1. Preliminary analyses

Primary attention was given to motivation measures of effort intensity in terms of cycle ergometer watt difference (e.g., mean difference throughout the trial, averaged across time, from initial "programmed" watts versus mean watts during the continuous and interval sessions).

No condition differences were noted for age (44.9 ± 9.5 years, mean ± SD), $F(2, 83) = 0.28$, $p = 0.78$; body mass index (25.3 ± 4.9 kg/m^2), $F(2, 83) = 0.38$, $p = 0.69$ or for self-reports of prior typical moderate or vigorous PA: $F(2, 82) = 0.97$, $p = 0.38$; $F(2, 83) = 0.05$, $p = 0.95$. Furthermore, there were no noted condition differences in fitness (initial qualifying submax test calculated target watts) between the groups for the 75% of HR_{max} and 90% of HR_{max} values: $F(2, 84) = 1.10$, $p = 0.35$; $F(2, 84) = 1.30$, $p = 0.26$.

For experimental conditions (COAP and CONJ), social- and task-related perceptions of working with an SGP during an exercise protocol were assessed with multiple variables, including attitudes toward the partner, perceptions of working in a group and team, and indices of humanness, eeriness, and attractiveness. No significant differences were noted between the CONJ and COAP conditions for any of the relationship variables.

Results indicated that participants in both conditions held favorable attitudes toward the SGP, felt part of a group, and perceived the partner as attractive but not eerie (Table 2). Participant perceptions were neutral in regard to feelings of being part of a team and ratings of the SGP's humanness.

3.2. Primary analyses

For the primary dependent effort variable of watts difference (from programmed watts), two 3 (Condition: IC, COAP, CONJ) × 2 (Day) ANOVAs with repeated measures on the last factor were conducted. These repeated measures ANOVAs examined condition differences for the continuous sessions (Days 3 and 5) and the 4-min sessions (Days 4 and 6), as well as whether there was an interaction between Condition and Day for each type of workout. Continuous-session results showed no significant main effect for Condition: $F(2, 80) = 0.19$, $p = 0.83$. There was a significant effect for Day (i.e., intensity increased from Day 3 to Day 5): $F(1, 80) = 45.48$, $p < 0.001$ (see Table 3 for means). However,

Table 2
Partner relationship variables: perception ratings.

	Mean ± SD	Scale mid-point	Cronbach's α
Partner attitudes	3.39 ± 0.82**	3	0.82
Group identification	3.37 ± 0.96**	3	0.92
Team perceptions	5.09 ± 2.09	5	0.92
Humanness	2.79 ± 0.91	3	0.87
Eeriness	2.49 ± 0.48**	3	0.79
Attractiveness	3.21 ± 0.64*	3	0.87

*$p < 0.05$, **$p < 0.01$, compared with scale mid-point.

Table 3
Watts above target (mean ± SD).

Protocol	Wattage	
Continuous 75%HR_{max}	**Day 3**	**Day 5**
Control ($n = 21$)	12.17 ± 12.05	17.73 ± 12.42
Coactive ($n = 31$)	9.91 ± 13.43	17.95 ± 16.91
Conjunctive ($n = 31$)	9.13 ± 9.88	16.34 ± 15.31
4-min interval 90%HR_{max}	**Day 4**	**Day 6**
Control ($n = 21$)	2.73 ± 7.37	7.30 ± 11.02
Coactive ($n = 31$)	0.62 ± 6.96	5.44 ± 9.46
Conjunctive ($n = 31$)	1.59 ± 4.55	5.23 ± 8.42

Abbreviation: HR_{max} = maximum heart rate.

the Condition-by-Day interaction was not significant: $F(2, 80) = 0.45$, $p = 0.64$.

Likewise, the results for the 4-min sessions did not demonstrate a significant main effect for Condition: $F(2, 81) = 0.50$, $p = 0.61$ or Condition-by-Day interaction: $F(2, 81) = 0.25$, $p = 0.78$. Again, the effect for Day was significant: $F(1, 81) = 31.74$, $p < 0.001$. The largest condition differences were observed on experimental Day 6 (4-min intervals), with relatively small effect sizes between conditions: CONJ and COAP ($d = 0.02$), IC and COAP ($d = 0.18$), and CONJ and IC ($d = 0.21$); these effects were even smaller at Day 5. Descriptive data for baseline days (Day 3, Day 5) and experimental days (Day 4, Day 6) are listed in Table 3.

Results for the difference between beginning workload watts and the mean workload for each type of session suggest that participants in all conditions maintained or slightly increased the intensity of each workout. This increase in workout intensity was more evident on Days 5 and 6, and the mean differences were higher than baseline Days 3 and 4. Again, there were no significant differences between conditions because all 3 groups demonstrated this general increase of intensity effect in a similar pattern.

Effort was highly variable for the dependent variable of watt difference and non-normally distributed for each day. Parametric analyses were performed because ANOVA is generally robust against violation of normality.[41,42] However, non-parametric analyses were also performed to verify the results. There were no significant differences with a Pearson χ^2 comparison and φ effect size analysis of a Mood's Median Test or χ^2 analysis with a Kruskal-Wallis test.

Overall means, standard deviations, and correlations for performance (watts difference), pre-exercise self-efficacy, and enjoyment are reported in Table 4. Effort during sessions Days 3 and 5 was not significantly correlated with pre-exercise self-efficacy or enjoyment. In contrast, these variables were all significantly correlated on the more intense 90%HR_{max} Days 4 and 6.

In light of the correlation patterns for these variables across all conditions, multiple regression analysis was used to test if the pre-exercise self-efficacy and session enjoyment ratings significantly related to the participants' performance effort (Table 5). As the correlations suggest, the results of the regression indicated that the two-factor model explained 26% of the variance on Day 4: $R^2_{adj} = 0.26$, $F(2, 70) = 13.40$, $p < 0.001$, and 38% of the variance on Day 6: $R^2_{adj} = 0.38$, $F(2, 70) = 22.41$, $p < 0.001$. On Day 4, pre-exercise self-efficacy significantly related to performance: ($\beta = 0.27$, $p < 0.05$), as did enjoyment ($\beta = 0.40$, $p < 0.001$). A similar significant relationship was noted on Day 6 for self-efficacy ($\beta = 0.43$, $p < 0.001$) and enjoyment ($\beta = 0.33$, $p < 0.001$). On Days 3 and 5, the 2 factors did not contribute to the performance variance: $R^2_{adj} = 0.03$, $F(2, 70) = 2.14$, $p = 0.13$; $R^2_{adj} = 0.02$, $F(2, 70) = 0.50$, $p = 0.61$.

4. Discussion

We sought to examine motivation to maintain or increase intensity during an aerobic exercise protocol embedded in a simple exergame using a Köhler group dynamics paradigm with physically active middle-aged adults. The results did not reveal significant differences between participants in a CONJ condition (an interdependent task group) and those in a COAP condition (the coactive independent task group), or when compared to non-partnered ICs. All participants, however, were motivated to increase performance over their baseline target. Furthermore, even while cycling at levels of intensity above 75% and 90% of HR_{max}, participants enjoyed the exercise

Table 4
Means, SD and correlations: effort (WattsDiff), pre-self-efficacy (SE Pre), and enjoyment (PACES).

	Mean	SD	1	2	3	4	5	6	7	8	9	10	11
1. WattsDiff Day 3	10.19	11.70	–										
2. WattsDiff Day 4	1.48	6.24	0.51**	–									
3. WattsDiff Day 5	17.20	15.05	0.80**	0.54**	–								
4. WattsDiff Day 6	5.82	9.44	0.46**	0.69**	0.62**	–							
5. SE Pre Day 3	3.91	2.31	0.15	0.31**	0.16	0.31**	–						
6. SE Pre Day 4	2.03	2.40	0.11	0.29**	0.16	0.28*	0.91**	–					
7. SE Pre Day 5	6.02	2.39	0.10	0.36**	0.13	0.39**	0.72**	0.65**	–				
8. SE Pre Day 6	4.90	3.09	0.18	0.48**	0.27*	0.51**	0.56**	0.53**	0.88**	–			
9. PACES Day 3	2.56	0.39	−0.02	0.30**	0.01	0.25*	0.19	0.26*	0.24*	0.34**	–		
10. PACES Day 4	2.47	0.46	−0.01	0.44**	0.07	0.39**	0.30**	0.26*	0.34**	0.44**	0.80**	–	
11. PACES Day 5	2.55	0.46	0.01	0.36**	0.07	0.40**	0.22	0.22	0.19	0.31*	0.77**	0.75**	–
12. PACES Day 6	2.51	0.53	0.08	0.43**	0.16	0.44**	0.24*	0.22	0.25*	0.37**	0.69**	0.77**	0.86**

*$p < 0.05$, **$p < 0.01$, two-tailed.
Abbreviation: PACES = Physical Activity Enjoyment Scale.

Table 5
Performance regression models for self-efficacy and enjoyment (PACES).

Model	β	*SE*	*B*	*t*	*p*
Day 3 performance model ($R^2_{adj} = 0.03$)					
Enjoyment	−1.03	3.09	–	–	0.74
Pre-exercise self-efficacy	1.15	0.56	0.25	2.07	<0.05
Day 5 performance model ($R^2_{adj} = 0.02$)					
Enjoyment	1.3	3.26	0.05	0.40	0.69
Pre-exercise self-efficacy	0.51	0.62	0.10	0.83	0.41
Day 4 performance model ($R^2_{adj} = 0.26$)					
Enjoyment	4.78	1.25	0.40	3.83	<0.001
Pre-exercise self-efficacy	0.63	0.25	0.27	2.54	<0.05
Day 6 performance model ($R^2_{adj} = 0.38$)					
Enjoyment	6.46	1.98	0.33	3.26	<0.001
Pre-exercise self-efficacy	1.29	0.31	0.43	4.22	<0.001

Abbreviation: PACES = Physical Activity Enjoyment Scale.

task and did so while working out with and without a software-generated character. Both enjoyment and pre-exercise self-efficacy partially explained performance gains on the most intense interval days, Days 4 and 6. Yet, similar positive trends in self-efficacy, as well as positive ratings of enjoyment, did not predict performance increases on the 75%HR_{max} days, Days 3 and 5.

It is quite unusual to fail to obtain a Köhler motivation gain effect. In 2 previous studies in which the Köhler effect was not demonstrated, lack of immediate feedback on the participants' own performance, as well as feedback on their partner's performance, was identified as the cause.[43,44] The lack of informative performance feedback may affect both Köhler mechanisms (i.e., social comparison and team indispensability) if participants are not able to compare their ability with that of their partners and set goals to upwardly match or compete with the performance of their teammates.[43,44] Without sufficient continuous and immediate feedback, participants may also not perceive how and if their performance is instrumental to the team outcome, potentially inhibiting the Köhler motivation gain.

In the present study, feedback (as performance data) was available during the session, but insufficient realism may have served to undermine its role in reinforcing the CONJ manipulation. In theory, participants had the capability to increase the intensity of the workout (i.e., increase watts) to increase the distance cycled and possibly match or surpass the superior SGP. Although increasing intensity would result in longer distance and watt numerical values displayed on the video screen (representing a more intense workout), it did not change how far the SGP appeared to be cycling out in front of the participant. As the superior partner, the SGP appeared to maintain a constant moderate lead throughout the session. This visual invariability of the participant-SGP performance gap, regardless of the participant's own behavior, would both tend to make this feedback incredible and uninformative. If increasing intensity felt different but did not correspond to changes in the partner distance discrepancy, participants may have chosen to ignore it and hence behaved much as those without a partner (which was, essentially, the pattern of the data). Future variations of this Köhler paradigm could test whether this visual invariability moderates the motivation effect using a high-fidelity simulation in which the distance between the participant and the SGP is, or not, sensitive to the participant's momentary level of effort.

It is possible that enjoyment and self-efficacy played a role in motivating performance during the final high-intensity session days, Days 5 and 6. Not surprisingly, participants in all conditions increased in self-efficacy beliefs after successfully completing each workout session compared to presession ratings. Likewise, presession self-efficacy was higher when participants returned for the next similar session (i.e., continuous 75%HR_{max} or 4-min interval 90%HR_{max}) than were ratings collected immediately after successfully completing the previous session. Upward trends in self-efficacy, as well as consistent positive enjoyment ratings, were significantly related to performance in our regression models on the higher-intensity 4-min interval days, although not on the continuous-session days. In support of self-efficacy theory, participants may have felt a great sense of accomplishment when first enduring such a challenging task as these 4-min intervals. These feelings of accomplishment may then have led to an increased sense of self-efficacy and enjoyment about that accomplishment, and that provided the motivation to work even harder at the next 4-min interval day. Furthermore, the findings for self-efficacy and enjoyment may partially be explained by the fitness of the sample and the relative challenges of the 2 different session types. For example, for these active adults, the 30-min continuous session may have been perceived as boring and not challenging, which was exacerbated by a relative comparison to successfully mastering the more vigorous interval sessions. It is possible that 30 min of high-intensity vigorous aerobic cycling (even at 75%HR_{max}) was not compelling enough to concern the majority of participants. Another possibility is that there was simply more time for participants to concentrate on potential flaws in SGP feedback and devise alternative goals to those established by the CONJ team manipulation. The more intense sessions provided an opportunity for participants to master the challenges and, as a result, be influenced by their enjoyment and efficacy perceptions.

In terms of SGP relationship variables, participant responses to the video display and SGPs successfully reinforced these adults' willingness to accept and interact with a virtual character. Attitudes toward the SGPs were positive, while participants also viewed them as attractive and not eerie, yet recognizing that the SGPs were not humanlike. Participants in both partnered conditions identified as exercising in a group, but neither clearly believed they were working out as a team—in other words, not with someone to be dependent on. A longer exercise training period may be necessary to build that sense of being in a team structure.

As previously noted, insufficient feedback (invariability of partner distance to participant) may have contributed to the lack of findings. This study did not intend to directly test this aspect of relative performance feedback, but future research could explore the moderating effect of this variable. However, performance variability may have posed the biggest limitation to answering our research question because high variance in participant performance posed challenges to both interpreting data and identifying experimental differences. The variability is not surprising in light of examining responses to high-intensity exercise in a relatively small community of adults (even a physically active one), with an inherent wide range of age, ability, motivation, and personal characteristics.

This experiment does extend the Köhler motivation gain effect literature in that it continued to explore the boundaries and moderators of this group dynamic. Despite the lack of Köhler motivation gains in the CONJ condition, this experiment demonstrated increases in performance over baseline in an intense exercise protocol. Even while cycling at intensity levels above 75% and 90% of HR_{max}, male and female participants enjoyed the exercise task and did so while working out with and without a software-generated character.

Exercising for purely personal concerns (improving health, losing weight) can be powerful motivators, but interpersonal and social concerns (for comparing favorably with others or for not letting a partner down) have the potential to add equally powerful new sources of motivation. These sources of motivation could open up a powerful set of new tools in exercise video-game design for fitness, especially for those with social physique anxiety, those who lack the time or resources to join an exercise group, and those in exercise rehabilitation therapies. This line of exercise group dynamics research has the potential for commercial applications to build more engaging and enjoyable exercise video games for various populations.

5. Conclusion

This experiment did not replicate the Köhler effect in eliciting motivation gains when measured as increases in intensity of aerobic exercise protocol with an SGP. High exercise condition realism and feedback (e.g., continuous SGP distance variability in sync with participant changes in effort) has been identified as a potentially crucial factor for evoking the motivation-enhancing mechanisms of the Köhler effect. Furthermore, findings suggest that perceptions of participants' enjoyment and self-efficacy could predict the degree of motivation gains during the more intense 4-min interval days, although not during the less intense 30-min continuous days. In fact, all participants were motivated to increase performance over their baseline target.

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Authors' contributions

SS was a project manager, carried out the study, performed statistical analysis, and drafted the manuscript; CRH was a project manager, carried out the study, and helped draft the manuscript; NLK was a co-investigator, participated in study design and conception, and contributed to statistical analysis and manuscript revision; BW was a co-investigator, created the study software, and helped with manuscript revision; AE was a project manager, carried out the study, and helped revise the manuscript; JMP was a co-investigator and participated in study design and manuscript revision; LPS was a co-investigator, participated in study design and conception, assisted with exercise protocol design, and helped with manuscript revision; DLF was the principal investigator, participated in study design and conception, oversaw statistical analysis, and assisted with manuscript revision. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors

Competing interests

The authors declare that they have no competing interests.

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