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SYMPOSIUM

Two-Player Partnered Exergame for Obesity Prevention: Using Discrepancy in Players' Abilities as a Strategy to Motivate Physical Activity

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Abstract

Background:

Physical inactivity is associated with obesity and type 2 diabetes. A key obstacle to physical activity is lack of motivation. Although some interactive exercise games (i.e., exergames—video games that require physical exertion in order to play) motivate players to exercise more, few games take advantage of group dynamics to motivate players' duration of exercise. In a test of the Köhler motivation gain effect, this study varied the ability level of a virtually presented partner in an interactive exergame that focused on abdominal strength to identify effects on a subject's (S') persistence with the task.

Method:

Male (n = 63) and female (n = 72) undergraduate students were randomly assigned to one of four conditions (individual control or low-, moderate-, or high- partner discrepancy) in a conditions × gender factorial design and tested on a series of isometric abdominal exercises using PlayStation 2 EyeToy: Kinetic software. They performed the first series of five exercises alone (trial block 1), and after a rest period, those in the partner conditions performed remaining trials (trial block 2) with a same-sex virtually presented partner whom they could observe during their performance, while those in the individual control condition performed the remaining trials alone. In the partner conditions, the partner's performance was manipulated to be always better than the S's, the exact difference depending on the discrepancy condition. The partnered tasks were conjunctive; that is, success in the game depended on the performance of the weaker team member. Persistence, the outcome measure for this study, consisted of the total number of seconds the S held the exercise position.

continued →

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Abbreviations: (HR) heart rate, (RPE) ratings of perceived exertion, (S) subject, (VPA) vigorous physical activity

Keywords: conjunctive task, dyad interactive exercise, exergame, persistence motivation, virtual partner

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Abstract cont.

Results:

Using planned orthogonal contrasts on difference scores between blocks 1 and 2, results showed that persistence was significantly ($p < .001$) greater in all experimental conditions with a virtually presented partner ($M = 33.59$ s) than in the individual control condition ($M = -49.04$ s). Subjects demonstrated more persistence in the moderate-discrepancy condition ($M = 51.36$ s) than in the low-discrepancy condition ($M = 22.52$ s) or the high-discrepancy condition ($M = 26.89$ s). A significant quadratic trend confirmed the expected inverted-U function relating partner discrepancy and persistence ($p = .025$). Although Ss persisted longer and had higher heart rate in partnered conditions, they did not perceive their exertion to be any higher than those in the individual condition.

Conclusions:

Virtually presented partners who are moderately more capable than participants are the most effective at improving persistence in exergame tasks.

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Introduction

Type 2 diabetes is strongly associated with obesity and physical inactivity.[1,2] Although it is more common among older adults, the diagnosis is occurring more frequently in children and adolescents, according to the National Diabetes Information Clearinghouse, (http://diabetes.niddk.nih.gov/.)

Physical inactivity is clearly a part of the problem with this disease and a number of other chronic diseases.[1] Although previous estimates of self-reported physical activity were at 45% of adults meeting recommended levels (at least 30 min of moderate-intensity activities five or more days per week[3]), more recent reports of objectively measured activity (e.g., via an accelerometer) indicate that adherence to the recommendation is less than 5%.[4] Furthermore, other research suggests that respondents achieved 10 min or more of vigorous physical activity (VPA) only on 1.4% of all days and accumulated less than 1 min of VPA on 91.1% of all days.[5]

A key issue related to the physical inactivity epidemic deals with problems of motivation.[6,7] Even among those who initiate an exercise regimen, research has typically reported that they have an estimated 50% drop-out rate within the first 6 months.[8] Exercise duration also may be harder to maintain as intensity increases.[9] Participants engaging in intense exercise may cut their exercise session short, exercise less intensely than planned, or even discontinue their exercise program altogether.[9] However, higher levels of intensity in exercise are important for several aspects of fitness. When body weight reduction is a goal, increasing the intensity of exercise from low to moderate (~60% of aerobic capacity) is most effective.[10,11] When aerobic fitness and cardioprotective benefits are the goals, VPA (>60% aerobic capacity) is more effective than moderate-intensity exercise, according to a study by Swain and Franklin.[12] Additionally, a study by Babraj and associates[13] found that high-intensity interval training (e.g., four to six bouts of 30 s intervals at maximum exertion 3 days per week) improved insulin action and glucose clearance after just 2 weeks. The authors noted that short but intense bouts of exercise may help with exercise adherence in patients with diabetes. Moreover, weight training, just twice weekly, has been shown to prevent increases in body fat percentage in middle-aged women.[14] However, even if exercise is short in duration or weekly frequency, patients may still become bored with this regimen over time or find it less enjoyable if they do not have other strategies to maintain their motivation.

A number of social and psychological factors have been investigated to try to improve motivation to exercise,[1,15] such as social support from health professionals, family, and friends;[16,17] social modeling of physical activity;[18,19]

the presence of other exercise participants;[20] and group exercise programs.[21] Group exercise programs are associated with higher exercise adherence rates than individual exercise programs.[21] However, for people who are overweight or obese, structured group exercise programs present a problem associated with social physique anxiety.[22] Additionally, merely exercising with other people is not highly effective because it does not typically create groups whose progress and or outcomes are interdependent, which can be a potent source of motivation, as follows.

One group-motivation effect that has been studied in exercise partner groups by Feltz and colleagues[23] is the Köhler effect, named after a German industrial psychologist, Otto Köhler.[24,25] Köhler found that, in certain circumstances, the less capable member of a dyad performed longer at a simple but taxing physical task (namely, standing bicep curls) than when performing alone. This effect occurred in conjunctive task conditions where the pair could persist no longer than its weaker partner—when the weaker partner stopped, the stronger partner was not allowed to continue. This task condition stresses the indispensability of one's efforts for one's team, where motivation is likely to be enhanced when one sees one's efforts as being highly instrumental in achieving team success.[26] Prior laboratory research has found that partners work harder under these conjunctive task demands than under other partner-type conditions (e.g., adding their scores together).[27,28]

Prior laboratory research has also found that this motivation gain was moderated by the discrepancy between dyad partners' abilities—the motivation gain was largest when this discrepancy was moderate.[27,29] When one believes that one's teammate is of nearly the same ability, attempting to keep up with him/her is not particularly challenging. When that teammate is far more capable, attempting to keep up with him/her is likely to seem unachievable.

Feltz and colleagues[23] argued that, although performing a physical task conjunctively with a more capable partner in *ad hoc* laboratory groups has been shown to be motivating, implementing these principles in exercise settings may present some obstacles. Specifically, finding an ideally matched exercise partner (i.e., moderately more capable) could be difficult and would not be particularly helpful for the stronger partner. Thus they proposed the use of a virtually-presented partner that they adapted within an existing exergame (PlayStation 2's EyeToy: Kinetic, Sony, Tokyo, Japan) to examine the Köhler motivation gain effect. Such a partner could be prerecorded and manipulated to be always more capable than the game player. Additionally, they noted that, although many exergames involve competition among players, few take advantage of the potential of group dynamics to motivate physically active play.

To test their idea, they told subjects (Ss) that another S was being run simultaneously at another laboratory and that the two participants would be able to see one another over a Skype-like video connection during the next set of trials. Using the abdominal plank exercises of the game's strength-training module, they compared individual controls, who had no virtual (Skype) partner, with those who had a moderately more capable partner in a conjunctive task condition (where the game ended when the S, who was always weaker, stopped), a coaction condition (S observed but was not dependent on virtual partner), and an additive condition (the scores were added together to assess team performance). The moderate superiority of the virtual partner was manipulated by giving the S feedback that the partner's performance on the first trial block was 40% longer than the S's performance. The images available to the S on the second set of trials suggested that she/he was always the first to quit each exercise game and only knew that his/her partner was able to persist longer but not how much longer. Feltz and colleagues[23] found that persistence was significantly greater in all experimental conditions than in the individual control condition. Thus the results suggested that a virtual partner who is moderately more capable than the exercise participant can improve persistence in exergames.

The current study takes these findings and asks whether there is an optimal level of ability discrepancy between an exergame player and a virtual partner in order to increase the player's task persistence in conjunctive tasks. Earlier research has found that the Köhler motivation gain effect is smaller when one's more capable teammate is either only slightly more capable or extremely more capable than oneself,[27,30] but this has never been investigated with exergames, which have advantages over face-to-face exercising with a human partner. It is extremely difficult to find a human partner with an optimal match. For example, it is common advice in exercising with a partner to find someone of similar ability,[31] because in face-to-face exercising, the stronger partner may not be challenged enough. With an exergame, the ability level of the virtual exercise partner can be adjusted for each player optimally and consistently, and a game can challenge the pair to engage in highly motivating team

exercise tasks in order to win the game. Given that prior research has found that moderate discrepancy is desirable to maximize the Köhler motivation gain effect, this study hypothesizes that the same should hold in an exergame; a virtual exercise partner should ideally be moderately more capable than the target exerciser. In our current study, we extended the work of Feltz and colleagues[23] and hypothesized the following:

1. Working with a moderately more capable teammate in a conjunctive team exergame will lead to longer duration of exercise than working with a teammate who is either only slightly more capable or extremely more capable, and
2. There will be longer durations of exercising in all three conditions relative to individual controls.

Because perceptions of exertion also may influence one's motivation to persist at an exerting task, we assessed ratings of perceived exertion (RPE) in relation to exercise persistence. Additionally, there have been some suggestive sex differences in the magnitude of the mechanisms contributing to the Köhler effect,[27] but sex differences in the overall effect have been rare. However, it is still informative to include gender in our analyses.

Method

Before conducting this study, approval for use of human Ss was obtained from the institutional review board. All Ss signed an informed consent. Subjects were healthy college students recruited from introductory psychology and kinesiology courses at Michigan State University. Students were given course credit for their participation.

We used a 3 (teammate ability discrepancy: low, moderate, high) + 1 (individual exercise controls) design. Subjects were male (n = 63) and female (n = 72) undergraduate students (19.77 ± 2.86 years old). Within each gender, Ss were randomly assigned (using random number generator in Microsoft Excel) to one of four conditions: individual control (11 males, 15 females), low discrepancy (14 males, 17 females), moderate discrepancy (24 males, 24 females), and high discrepancy (14 males, 16 females) in a 4 (conditions) × 2 (gender) factorial design. Sample size was determined from a power analysis following f index recommendations, which suggested that we should observe a moderate (f = 0.30) Köhler effect with probability >0.80 with this sample size.

The study used the same protocol as Feltz and colleagues.[23] Subjects were tested on a series of five isometric plank exercises presented in an EyeToy: Kinetic exergame. These body-weight resistance exercises require players to hold a position using their abdominal muscles. Each exercise targets different abdominal muscles (e.g., holding a push-up position on one's forearms versus on each side of the body). The activity was not aerobic in nature. EyeToy: Kinetic is a game played on the PlayStation 2 console that offers a variety of fitness activities (e.g., yoga, strengthening exercises, combat exercises). The EyeToy is a camera-based interface that connects to the PlayStation 2 system and displays images of the player on a television screen so that the player can use body movements to interact with virtual game environments displayed on the screen.

Subjects were brought to the exergame laboratory where a researcher taught them how to put on the heart rate (HR) monitor. Then they watched a brief instructional video in which a virtual trainer on the PlayStation 2 EyeToy: Kinetic game demonstrated the five plank exercises. Next they performed the first series of five exercises alone but in the presence of the researcher. There was no need to be connected to the system with the EyeToy camera; Ss just needed to be positioned in front of the screen. After the block of exercises was finished, all participants were given feedback on the average number of seconds they held each exercise. Following a rest period, those in the individual control condition repeated this series again. Those in the partner conditions were told they would do remaining trials with a same-sex virtually present partner whom they could observe during their performance.

As in the Feltz and colleagues[23] study, the virtually presented partner was viewed over a Skype-like video connection. The partner was presented as a similarly aged college student, clothed in loose-fitting gym shorts and shirt with average build, height, and weight. In reality, the partner was an experimental confederate whose performance was prerecorded. The S could see the partner's image on a video screen before and during the exercise in addition to seeing his/her own image on another video screen that displayed the game. The S believed that his/her partner could likewise see the S's image.

The virtual partner's persistence was manipulated to be always longer than the S's, the exact difference depending on the discrepancy condition. In the high-discrepancy condition, the virtual partner's performance was reported to the S as 100% better than the S's on trial block 1, whereas, in the moderate- and low-discrepancy conditions, it was 40% and 1% better, respectively. In other words,

if the S held his/her position for 60 s, he/she was told that the partner performed for either 120, 84, or 60.6 s, respectively.

To establish the conjunctive nature of the activity, Ss were told that the two of them would be an exercise team and that the team score would be the persistence score of the first teammate to quit an exercise. Thus, when one partner stopped exercising, the other partner would have to stop and could therefore not earn any more points for the team.

Measures

Persistence

Because it is difficult to measure motivation (a cognitive process) directly, motivation gain was inferred from effort at the persistence task as is typical in the Köhler effect paradigm. Persistence was the total number of seconds that the exercise position was held. Block scores were calculated by taking the summed total of the five exercise position times within each trial.

Heart Rate

Heart rate was measured to provide a physiological assessment of exertion. Although the plank exercises were isometric in nature, HR should still increase the longer one persists at the task. Heart rate was measured continuously using a Polar E600 HR monitor (Polar Electro, Kempele, Finland) but was summarized into 5 s epochs. Measures include both HR from time during exercise and time between exercises (~40 s). Overall HR scores for each trial were calculated by averaging HR epochs within the respective trial.

Ratings of Perceived Exertion

Perceived exertion was measured using the Borg[32] RPE scale. The scale ranges from 6–20, where 6 means "no exertion at all" and 20 means "maximal exertion." Participants were asked to rate their exertion at the end of each exercise, with particular reference to their perceived exertion at the moment right before the end of the exercise. The 15-point Borg scale shows acceptable validity with maximal oxygen consumption measures[33] (r = 0.64) and reliability[34] (r = 0.78).

Statistical Methods

We used a set of planned orthogonal contrasts to test our hypotheses. Orthogonal contrasts for analysis of variance are independent linear comparisons between the groups of a factor. Heart rate data were also analyzed with planned contrasts. For RPE data, we used analysis of variance.

Results

Persistence Motivation

First, the time Ss persisted at the five exercises in each trial were added up. Then the difference between trial block 2 and trial block 1 was computed. These difference scores permitted a control for individual differences in strength (estimated by trial block 1 performance). The pattern of results was similar if one used trial block 2 persistence scores as the primary dependent variable and trial block 1 persistence scores as a covariate. The eight conditions defined by the 4 (condition) × 2 (gender) design were analyzed using a set of planned orthogonal contrasts. Specifically, one contrast compared the individual controls with the three partner conditions, a second tested the linear polynomial trend among the three ordered partner conditions (i.e., low, moderate, and high discrepancy, with contrast weights -1 0 1), and the third tested the quadratic polynomial trend among the three partner conditions (with contrast weights -1 2 -1). Our hypotheses predicted that both the first and the third of these contrasts would be significant. The remaining contrasts were a gender main effect test and the interaction of this gender contrast with the first three contrasts (i.e., Did gender moderate any of those contrasts?). A pooled error term (MS_{error} = 3614.5, df = 127) was used in these analyses; the Levene test of homogeneity of variance was not significant.

First, there was a significant gender main effect, $t(127) = -2.45$, $p = .016$; overall, males showed a slight drop in performance from trial block 1 to trial block 2 (mean difference score = -0.23 s), whereas females showed an increase in performance (26.09 s). (Data from this study are not shown in a table.) More importantly, given our objectives, there was a significantly larger gain in persistence in all the partner conditions (difference score mean = 33.59 s) than in the individual controls (difference score mean = -49.04 s), $t(127) = -6.19$, $p < .001$. Dunnett tests showed that each of the partner condition means were significantly larger than the individual control mean ($p < .001$). Finally, the evident inverted-U-shaped function relating discrepancy and motivation gain was statistically verified by the significance of the quadratic trend contrast, $t(127) = 2.27$, $p = .025$ (see **Figure 1**); the gain was significantly larger in the moderate-discrepancy condition (51.36 s) than in the other two conditions (low discrepancy = 22.52 s, high discrepancy = 26.89 s). The linear contrast was not significant, $t(127) < 1$

(i.e., there was no significant difference between the low- and high-discrepancy condition) nor were any of the contrasts testing the moderating role of gender ($p > .10$ for all).

Ancillary Analyses

The (trial block 2–trial block 1) differences in HR were analyzed in the same way as the persistence data. The only significant effect was the contrast of the individual controls (HR difference mean = 0.0) with the partner conditions (overall HR difference mean = 9.99), $t(102) = -2.18$, $p = .031$. The trial block 2 HRs were slightly below the moderate-intensity range (60–80% of age-predicted HR maximum; partner conditions $M = 116.8$, standard deviation = 22.8; individual condition $M = 105.1$, standard deviation = 17.2). However, our HR data include between-exercise rest periods, so they underestimated the HR achieved during the exercise. It also should be noted that there was a fair amount of missing data (and, consequently, reduced power) due to compliance issues (e.g., starting and stopping the monitor when instructed) and/or improper positioning of the HR monitor.

The mean RPE scores for trial block 1 and trial block 2 were analyzed in a 2 (trial) × 4 (condition) × 2 (gender) analysis of variance with repeated measures on the first factor. Participants reported exerting significantly greater effort, $F(1,120) = 30.79$, $p < .001$, on trial block 2 (14.66) than on trial block 1 (13.94), which was hardly surprising given the higher level of fatigue at trial block 2. Thus, although Ss persisted longer and had higher HR in partnered conditions, they did not perceive their exertion to be any higher than those in the individual control condition.

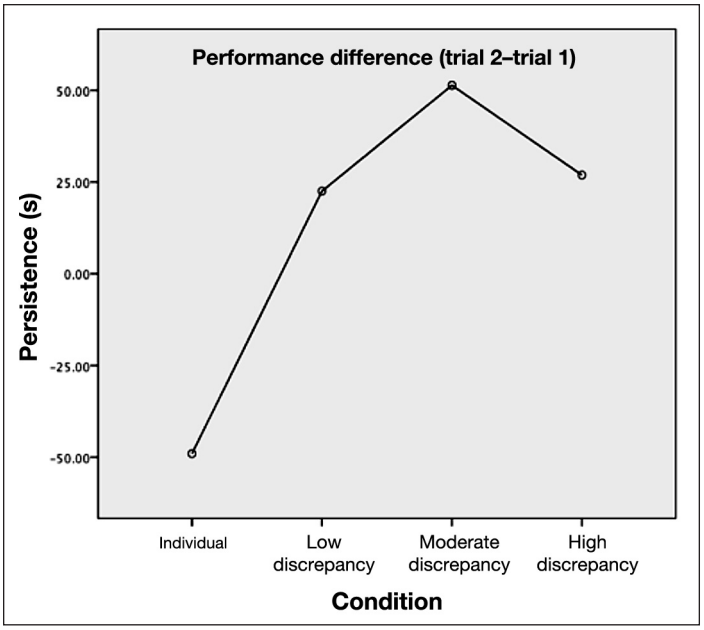

Figure 1. Time 2–time 1 change in persistence (number of seconds spent exercising) in an exergame played under four conditions: individually without a virtual partner or conjunctively with a virtual partner who has low, moderate, or high discrepancy in ability compared with the player.

Discussion

In games that are designed to have virtually presented partners, our results show that, to maximize player effort, the virtual partner should be only moderately better than the player. Those who participated with a moderately better partner persisted 51.36 s longer than in their alone condition, and this represents a more than 100 s difference compared with the individual controls. This may be clinically important to diabetes patients and sedentary individuals when they want to increase short but intense bouts of physical activity, weight training, and/or circuit-type training.[13,14,35] And having a virtually presented partner has practical advantages because it overcomes the difficulty of finding an optimally matched exercise partner who can be available at any given time and location.[23]

These findings extend current knowledge about the Köhler effect to virtual settings because, although we demonstrated previously[23] that a moderately superior virtual partner can improve persistence motivation on exergame tasks, we did not know which discrepancy was most motivating in a virtual game environment. We found that it is precisely when the gap between the virtual partner and the participant is moderate that social comparison is the most engaging and challenging and the goal still seems achievable.

Subjects who worked with a virtual partner produced more physical effort even though they did not experience greater subjective effort than those working individually; they were not consciously aware of their greater exertion. The RPE means represent an effort of moderate intensity ("somewhat hard" to "hard" categories). Given that a sense of high-intensity effort can have negative effects on motivation to exercise, this finding is encouraging, and it predicts continued participation in the task.[34]

The persistence gains in this study occurred within a conjunctive group task, where there was interdependence between exercisers. The participants, as the weaker members of the dyad, were indispensable to its success. A great deal of laboratory research on Köhler motivation gain effects in tasks other than purposeful physical

activity[27,29] indicates that such conjunctive task conditions are more motivating than nonconjunctive tasks in which the participant is not highly indispensable to success (e.g., where the group score is equal to the average of members' performance or where people are working side by side without any interdependence). Feltz and colleagues[23] did not support this conclusion in their initial study in an exergame setting. They suggested that exercising with a virtually presented peer in a game-like setting may be a more inherently competitive context. Further research will be needed to resolve this question by creating a conjunctive condition where there is more opportunity for in-group identification, such as developing a sense of being a team and having a shared commitment to a performance goal.

The current study used a real person as a game partner whose performance was prerecorded and was adjusted in relation to the target exerciser's ability level. However, to have greater practicality in active games and video-embedded exercise equipment, a partner that is software generated would be more ideal. Further research is necessary to determine if participants will react similarly to a nonhuman virtual partner.

No study is without limitations. The current study focused on a single type of isometric strength and a one-time exercise experience. Our findings may not generalize to other exergames that are more dynamic in nature or repeated over several sessions. Future studies should examine other types of exercise (e.g., intermittent, high-intensity exercise or aerobically challenging exercise) over multiple sessions and should include physiological measurements, such as changes in HR, blood pressure, and blood glucose in addition to physical strength and endurance. Additionally, our study employed healthy college-aged Ss, and results may not generalize to those who have or are at risk of having type 2 diabetes. Future studies should focus on these populations, taking into consideration the needs, interests, attitudes, and abilities of this population and its various subgroups.

Conclusions

This study found that exercising with a moderately more capable, virtually present partner under conjunctive task conditions increases persistence in a strength-related exercise game by 58% (273.4 s versus the 173.0s we would have expected had these Ss fatigued at the same rate as the individual controls). The findings warrant further studies investigating effects of virtual partners on motivation to exercise.

The findings are applicable to the design of future physical activity games on a variety of game platforms, including camera-based systems, such as the EyeToy and the Kinect, and dance pad games. With each of these platforms, it is technologically possible to provide a virtually presented partner or teammate that is moderately more capable than the player (based on real-time in-game assessment of the player's physical ability to accomplish the game activity) and to make the game challenge a conjunctive one. We now have a growing body of evidence that this type of partnership can be highly motivating to game players and, as a result, can increase their engagement and perseverance in game-based physical activity.

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