1-2023

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INTERNATIONAL JOURNAL OF HUMAN–COMPUTER INTERACTION
https://doi.org/10.1080/10447318.2023.2269004

Motivating Physical Activity with Fitness Tracking and the Interpersonal Context

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ABSTRACT

Many societies have aging populations. Getting older people to exercise can help them achieve a higher quality of life. Fitness tracking and social support can buttress that goal. This study tested the effects of fitness tracking and spousal influence on the physical activity of older adults. In a 2 (blinded vs. feedback) × 2 (individual vs. dyad) between-group experiment, 240 participants received a fitness tracker with a visible or blinded display. They participated in the three-month experiment either individually or with their spouses. Participants who received feedback met daily step counts of 7500 and 10,000 more frequently than those without feedback. Interestingly, those who participated with their spouses had lower mean and median step counts and met daily step counts of 10,000 and 15,000 less frequently than those who participated by themselves. The results show that real-time personalized feedback can motivate physical activity among older adults, while engrained routines among older couples may impede behavior change. Whereas individuals can adjust their personal routines to achieve a physical activity goal, such adjustment is more complex when it involves the quotidian routines of dyadic partners.

KEYWORDS

Mobile health; wearables; behavior change; personalized feedback; strong-tie dyads; spousal influence; social context

The global population is getting older and the old-age dependency ratio is on the rise (United Nations Department of Economic and Social Affairs, 2019). As that ratio increases, so does the importance of promoting healthy aging. Physical activity is a seemingly straightforward means to that end and has been the topic of many recent studies on healthy aging (Greco et al., 2023).

Wearable technologies hold the promise of promoting physical activity among older adults. They have been the focus of numerous mobile health (mHealth) studies. Despite evidence of positive outcomes of mHealth interventions, a minority of those studies involved older participants (Cajamarca et al., 2019). Further, there is a lack of clarity about which mechanisms motivate physical activity (Conn et al., 2003; Sullivan & Lachman, 2016).

This study explores individual and interpersonal influences on the physical activity of older adults, drawing generally on social cognitive theory (Bandura, 1991). According to that theory, the interplay of personal and environmental factors influences self-regulation in behavior, including self-monitoring and reacting to personal and social norms. Whereas several studies have shown the benefits of fitness tracking (Jin et al., 2022), there is a relative paucity of research on older couples engaging in mHealth interventions together. To fill that gap, we conducted a field experiment involving married couples in Singapore. We used data from fitness trackers to test the effects of personalized feedback and spousal influence on physical activity. Such research contributes to the literature on healthy aging by clarifying some of the mechanisms supporting (or hindering) the physical activity of older adults.

Our approach addresses a limitation of prior physical activity interventions, namely, that they tended to focus on individual factors and seldom accounted also for the influence of social ties. To address that limitation, the current study focuses on both types of influence. Additionally, many prior studies measured self-reported behavior rather than using more objective measures, limiting their validity (Falck et al., 2016). The current use of an experimental design and fitness trackers allows us to draw causal inferences about intrapersonal and interpersonal factors affecting physical activity.

1. Feedback for motivating behavior change in the individual

Personalized feedback can motivate behavioral change (DiClemente et al., 2001). It provides information and raises awareness about current behavior. In the context of physical activity, individuals who are unaware of their current activity levels may erroneously believe they are sufficiently active. This can hinder their engagement in physical activity (van Sluijs et al., 2007). Feedback provides a basis for more accurate self-estimations (Watkinson et al., 2010) that can highlight shortcomings in individuals' physical activity and help them to set and approach behavioral goals (Barone et al., 1997).

Fitness trackers provide real-time continuous ipsative feedback (Kamišalić et al., 2018), which can be synchronized

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This article was originally published with errors, which have now been corrected in the online version. Please see Correction (http://dx.doi.org/10.1080/10447318.2023.2274647).

with a smartphone app for ease of monitoring (Hoy, 2016). This is an example of automated *ipsative* feedback. After the initial setup, data collection and display happen automatically with minimal user input. The feedback is ipsative because it is self-referent, providing users with information comparing their current and past activity levels. Meta-analyses have shown that receiving this kind of feedback from fitness trackers results in increased physical activity (Brickwood et al., 2019) and improved health indicators (Yen & Chiu, 2019). Our first hypothesis replicates this prior research:

H1: Receiving feedback from a fitness tracker will result in more physical activity than not receiving feedback.

2. Influence of the interpersonal context on physical activity

The others with whom one interacts also influence behavior (McLeod & Chaffee, 1973). Research on self-regulation had traditionally focused on intrapersonal processes, and interpersonal influences started to receive scholarly attention only in the recent one to two decades (Fitzsimons & Finkel, 2010). Individuals' social spheres can trigger new goals and affect their self-regulation (Fitzsimons & Finkel, 2010). The involvement of others provides an avenue for *normative* feedback, which helps to motivate physical activity (Wally & Cameron, 2017). This article focuses on what is often perhaps the most central strong-tie dyadic partner of all – the spouse (P. L. Berger & Kellner, 1993).

One line of research points to an indirect influence of strong ties on couples' physical activity, regardless of whether they engage in physical activity together or not. The contagion effect in social networks (Aral & Nicolaides, 2017) has appeared in studies demonstrating how the proportion of family members exercising (Lian et al., 1999) and the number of friends exercising (Thøgersen-Ntoumani, 2009) is correlated with older adults' physical activity. Other research found that strong-tie partners who engage in coactivity have a strong and direct effect on one another's level of physical activity (Böhm et al., 2016).

Another line of research regards the influence of assigned "exercise buddies" (Neil Thomas et al., 2012) who are not necessarily strong-tie partners. Those interventions led to increased and sustained physical activity albeit using an "artificial" social tie. The current study examined this kind of social influence using marital partners whose connection was not a research contrivance but arose more naturally (Aral & Nicolaides, 2017). This is an important social context in the study of physical activity among older adults because, as research has shown, when one spouse is sedentary, the other also tends to be sedentary (Harada et al., 2018). Other research has found that joint participation by older couples in physical activity increased their activity level (Victor et al., 2016) when compared to those who participated alone (Gellert et al., 2011). This suggests that efforts to promote physical activity targeted at couples may be more effective than those targeted at individuals (Martire et al., 2013), but this potential remains underexplored since most intervention studies have targeted individuals (Cobb et al., 2016). The following hypothesis addresses this gap.

H2: Participating in a physical activity intervention with a strong-tie dyadic partner will result in more physical activity than participating in the intervention without a partner.

The prediction of H2 is contingent on other factors that exist within the dyad. As shown in previous research, the influence of dyadic partners is largely dependent on a supportive dyadic relationship. Whether individuals are supportive or unsupportive of their partners can positively or negatively influence their partners' behavior. Mutually collaborative relationships will likely continue in further collaboration and vice versa (Sytch & Tatarynowicz, 2014). While coactivity between older couples can result in positive outcomes, many individuals have developed independent exercise habits (Barnett et al., 2013). In cases where spouses rarely exercise together, spousal support may be especially important (Barnett et al., 2013). It can help promote long-term engagement (Floegel et al., 2015) and motivation (Deforche & de Bourdeaudhuij, 2000). So, spousal support ought to enhance the effect of being in a dyad, which the following hypothesis predicts.

H3: The effect of a strong-tie partner on physical activity is stronger when there is more support from the partner.

Figure 1 summarizes the current theoretical model, which we tested with a 2 (blinded vs. feedback) × 2 (individual vs. dyad) between-group field experiment.

3. Methods

We conducted a 2 (blinded vs. feedback) × 2 (individual vs. dyad) between-subject factorial experiment, including pre- and post-experimental questionnaires. This study was approved by the Institutional Review Board at Nanyang Technological University.

3.1. Sampling

We recruited a community-dwelling volunteer sample by circulating recruitment posters to 14 organizations in Singapore for older adults, to students and staff at Nanyang Technological University, and on social media (e.g., Facebook and LinkedIn). Interested participants were directed to an online registration form to sign up for the study.

To be included in the study, participants had to be between 54 and 72 years old, be capable of physical activity without assistance, be able to read and understand basic English, and own an iPhone or Android smartphone. In addition, they needed to commit themselves to use only the issued fitness tracker during the three-month experiment period to prevent confounds, such as receiving feedback from other trackers or apps. Lastly, they had to have a spouse with whom they had been living for at least 15 years and who also met the aforementioned requirements. The

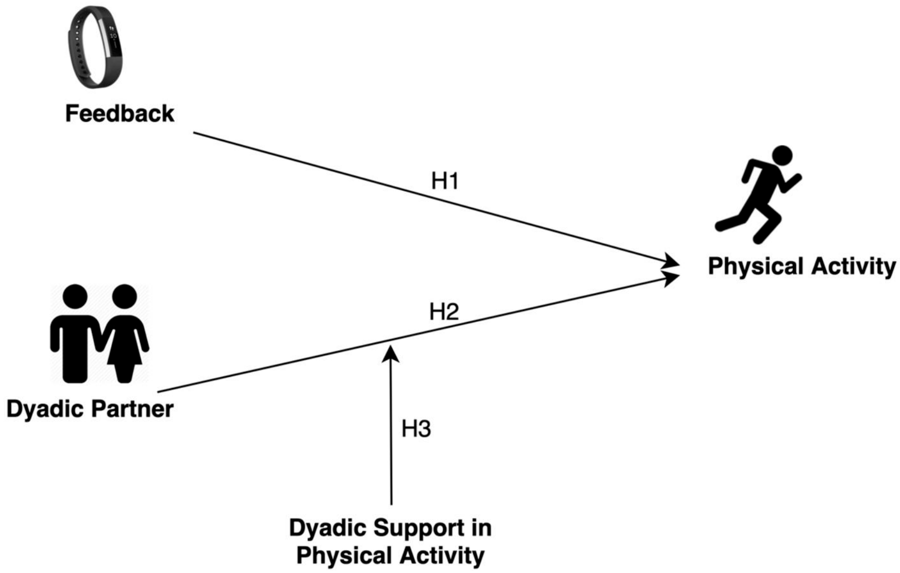

Figure 1. Theoretical model.

spouse had to be willing to eventually participate in the dyadic condition were it their random assignment.

The age range defined in the inclusion criteria is aligned with the baby boom age range in Singapore. It constitutes a sizeable proportion of the local population and creates an impact on aging demographics locally (Sharmistha Roy, 2014). This age range also includes people moving up in age to where they face the risk of increased health issues.

3.2. Procedure

The G*Power 3.1 (Faul et al., 2009) software estimated that 179 was an appropriate sample size for this experiment. We recruited 240 participants to buffer for potential dropouts and removal of participants who violated their group conditions. We then randomly assigned participants ($N = 240$) into four experimental groups ($n = 60$ each). Dyads who received feedback (group DF+) included 30 participants and their spouses. This group received fitness trackers with a real-time display of health and fitness data.

An additional 30 participants and their spouses received fitness trackers with the health and fitness data display disabled. They could see only the watch function, while the fitness tracker kept a record of their health and fitness data in the background. This group comprised dyads without feedback (DF–).

The third and fourth groups each comprised 60 individuals who participated in the study without their spouses. Individuals in one group received health and fitness feedback (IF+), while individuals in the other group did not receive that feedback (IF–). Since the dyadic groups had equal numbers of males and females, we used quotas to ensure an even gender split into the individual groups. Table 1 summarizes the group characteristics.

In Singapore, where this study took place, only heterosexual couples may marry, so all the individuals and spouses under study were part of heterosexual marriages. We note this only because it created an even distribution of males and females in our dyadic groups. After randomly assigning dyads and individuals (with gender quotas) to experimental groups, we checked the random assignment by conducting a one-way analysis of variance (ANOVA) and confirming that the number of years participants had been married did not significantly differ among the groups. This was the only data point available to us at this point as it was part of the inclusion criteria.

We collected data over a 12-week period from May to July 2019. There was a briefing session at the start and a debriefing session at the end of this period. At the briefing, each participant watched an introductory video and completed the pre-experimental questionnaire that, among other things, measured the covariates in the current model. At the debriefing session, they completed a post-experimental questionnaire. At both briefing sessions, we measured the participants' height and weight to calculate their body mass index (BMI).

Each participant received the same fitness tracker, the Fitbit Alta HR, and was instructed to use it through the study. The Fitbit Alta HR (Fitbit Inc., 2020) is a wrist worn fitness tracker with an OLED tap display and consists of a three-axis accelerometer for tracking motion patterns, a vibration motor for alerting the user to notifications and signals, and an optical heart-rate tracker. It records a variety of information from the user, such as steps taken, heart rate, distance covered, calories burned, active minutes, and sleep data.

Data syncing between the fitness tracker and the app took place in person every three weeks. This was necessary for the DF– and IF– participants because they were unable to synchronize their data to the cloud. To ensure similar interactions with participants in all four groups, we also conducted in-person exporting with the DF + and IF + participants. All participants were told that the visits were for ensuring they had no problems with their fitness trackers and for data collection. The data on steps walked, active minutes, and heart rate were recorded for all

Table 1. Groups in experimental design.

	Dyad (D)	Individual (I)
Fitness tracker (feedback, F+)	Group DF+ Strong-tie dyadic partners who each received a fitness tracker displaying health and fitness data (30 individuals and their spouses)	Group IF+ Individuals who received a fitness tracker displaying health and fitness data (60 individuals)
Blinded fitness tracker (no feedback, F–)	Group DF– Strong-tie dyadic partners who each received a fitness tracker that did not display health and fitness data (30 individuals and their spouses)	Group IF– Individuals who received a blinded fitness tracker that did not display health and fitness data (60 individuals)

Each cell contains the details of the experimental treatment participants received.

participants over 12 weeks by remotely exporting fitness data from users' Fitbit dashboards to a data organization platform, Fitabase (Small Steps Labs LLC, 2018).

We incentivized participation by providing grocery vouchers of SGD20 at the start and SGD50 at the end of the experiment. Participants also received a personalized Fitabase report at the debriefing session if they had at least 45 days of data recorded. Finally, participants could retain their fitness tracker (Fitbit Alta HR, worth SGD248) if they had at least 60 days of data recorded.

3.3. Measures

3.3.1. Dependent variables

This study used six primary measures derived from objectively measured data collected through the fitness trackers. Before analysis, we cleaned the data by removing outlying daily step counts below 100 steps (Bassett et al., 2010) or more than three standard deviations above the mean (Arrogi et al., 2017). On the lower end, we noticed 45 occurrences of daily step counts that ranged between 4 and 76, before a large jump to counts of $\geq$100. The former counts were likely to arise from days when participants forgot to wear the fitness tracker. On the higher end, there were 174 data points that were above a daily step count of 26,706 ($M + 3SD$). Using these cutoffs, we removed 219 out of 18,312 data points, or approximately 1% of the data.

We measured the consistency of activity by calculating the percentage of days participants met the daily step thresholds of 5000, 7500, 10,000, and 15,000 steps. We focused on these four thresholds as 10,000 steps per day is generally accepted as a normative step goal for adults (Tudor-Locke et al., 2011) and 7500 steps per day has been identified as a plateau point for lowering all-cause mortality (Lee et al., 2019). Further, the 5000 and 15,000 step thresholds could typify relatively less or more active lifestyles, with the former threshold recommended for reducing fall risks among older adults (Aranyavalai et al., 2020), and the latter threshold being associated with zero metabolic syndrome risks (Tigbe et al., 2017). In addition to measuring the consistency of physical activity, we included the mean and median number of steps per day as additional outcome variables.

We included five secondary outcomes measured in the post-experiment questionnaire: self-reported health status, sedentary hours per week, moderate and vigorous activity hours per week, and objectively measured post-experiment BMI. Self-reported sedentary and active time were useful for identifying how participants felt about their physical activity levels, and self-reported health status helped with understanding how participants felt about their health. Lastly, BMI was included as it signaled actual health outcomes beyond behavior change. Before data analysis, we removed outlying observations more than three standard deviations above the mean (Dunn et al., 2021) on the measures of moderate- and vigorous-intensity physical activity.

3.3.2. Independent variables

To assess dyadic support (H3) in the context of physical activity, we adapted questions from Chogahara's (1999) Multidimensional Scale for Assessing Positive and Negative Social Influences on Physical Activity in Older Adults. This variable was measured with five items and was treated as a latent construct. Items measuring dyadic support included spousal compliment, praise, affirmation, respect, and pride over respondents' physical activity. Since dyadic support was proposed as a moderator, pre-experiment responses were used. Response options ranged from 1 (strongly disagree) to 7 (strongly agree). Refer to Table 2 for the list of items.

3.3.3. Control variables

The questionnaire collected sociodemographic data including age, sex, race, employment status, education level, housing type, and the number of children.

People's health statuses and pre-existing conditions can influence their motivation to be physically active, particularly for older adults who are more susceptible to age-related health conditions (Lin, 2021). The measures used to control for this were adapted from nationally representative longitudinal surveys in Singapore, namely, the Panel on Health and Aging of Singaporean Elderly Waves 1 and 2 (Centre for Ageing Research and Education, 2009, 2011) and Transitions in Health, Employment, Social Engagement, and Intergenerational Transfers in Singapore Wave 1 (Centre for Ageing Research and Education, 2016). Items included in the pre-experiment questionnaire to measure pre-existing health conditions and physical activity patterns included daily sedentary hours, weekly moderate activity hours and vigorous activity hours, health status on a rating scale ranging from 1 (poor) to 5 (excellent), BMI, number of diagnosed health conditions, number of hospitalizations in the past six months, and number of falls in the past one year.

In relation to physical activity patterns, we asked participants how many steps they should walk each day and how many steps an average person should walk each day. On a Likert scale ranging from 1 (strongly disagree) to 7 (strongly

Table 2. Summary of the measurement model.

Item	*M* (*SD*)	λ
Dyadic support (pre-experiment)		
$\omega = 0.935$, AVE = 0.745		
Your spouse compliments you on the mastery of a physical activity skill.	4.80 (1.37)	.79
Your spouse praises you that your physical activity level is superior to that of other people your age.	4.51 (1.49)	.89
Your spouse affirms that you have done well in your physical activity.	4.72 (1.37)	.92
Your spouse shows his/her respect for your versatility in physical activity.	5.13 (1.24)	.81
Your spouse tells you that you should be proud of your physical activity skills.	4.91 (1.31)	.89

M: item mean; *SD*: item standard deviation; λ: standardized factor loading.
All items were measured on seven-point Likert scales (1 = strongly disagree, 7 = strongly agree).

agree), participants indicated how much they had worked toward their personal goal and an average person's goal.

Fitness tracker acceptance had to be controlled for in data analysis, as it could affect the experimental outcomes. Questions were adapted from a scale measuring technology acceptance (Davis, 1989). Fitness tracker perceived ease of use was measured with six items, for example, "I would find fitness trackers easy to use." Fitness tracker perceived usefulness was measured with three items, for example, "Using fitness trackers would help me to better manage my physical activity." Response options ranged from 1 (strongly disagree) to 7 (strongly agree). These were treated as latent constructs.

We measured dyadic strength based on the number of years participants were married to their spouses. We also measured dyadic closeness using the Inclusion of Other in the Self (IOS) Scale (Aron et al., 1992). This is a single-item pictorial tool depicting interconnectedness between two persons by the amount of overlap between two circles. Answer options ranged from 1 (no overlap) to 7 (most overlap). Further, we measured dyadic coactivity using questions adapted from Chogahara's (1999) Multidimensional Scale for Assessing Positive and Negative Social Influences on Physical Activity in Older Adults, for example, "Your spouse engages in physical activity together with you." Response options ranged from 1 (strongly disagree) to 7 (strongly agree). This was treated as a latent construct.

3.4. Data analysis

We first checked for baseline differences on control variables by conducting a one-way ANOVA for the single-item control variables and by regressing the latent control variables on the grouping variable.

Thereafter, using the lavaan package (Rosseel, 2012) in R, we conducted a multivariate analysis to test the theoretical model proposed in Figure 1. We applied confirmatory factor analysis and modeled dyadic support in physical activity as a latent construct. After model modifications, factor loadings for all items measuring dyadic support were $\geq$0.79. We then used structural equation modeling (SEM) to analyze the full theoretical model. Missing values were addressed using the full information maximum-likelihood estimator.

We also included two covariates (sedentary hours per day and moderate activity hours per week) to control for their effects on the outcome variable since they were different between groups at baseline. Refer to Figure 2 for the final structural model. Model fit and main effects (H1 and H2) were evaluated simultaneously. Moderation effects (H3) were evaluated separately by adding the moderation term into the model.

4. Results

All 240 participants completed the study. There were no dropouts. However, from the post-experiment questionnaire, we found that 32 participants had violated the conditions of their group assignments. They had either used another fitness tracking device when they were supposed to be in the blinded condition or their spouses used a fitness tracking device when they were supposed to be in the individual condition. The 32 violators (six from group DF–, eight from Group IF+, and 18 from Group IF–) were removed from data analysis, and 208 participants remained. It is notable that most violators were in the IF– condition, but that makes sense since both the participants and their non-participant spouses were not supposed to access fitness tracker data for the duration of the study.

Participants' ages ranged from 54 to 71 ($M = 59.78$, $SD = 4.45$). The sample was 48% male and 52% female and most participants were ethnic Chinese (97%). The most reported working status was being full-time employees (42%) and the median education level was junior college/polytechnic (25%). The most common housing type was a five-room public housing flat (35%). The mean number of children participants had was 2.04 ($SD = 1.07$).

4.1. Baseline differences

There were not any significant between-group differences on the control variables at baseline ($p > .05$) except for sedentary hours per day ($F(3, 204) = 5.360$, $p = .001$) and moderate activity hours per week ($F(3, 199) = 5.770$, $p < .001$). Post hoc comparisons of sedentary hours using the Sidak test indicated that the mean scores for the IF– group ($M = 4.90$, $SD = 2.20$) were significantly different than the DF– group ($M = 7.22$, $SD = 3.98$) and the DF + group ($M = 6.80$, $SD = 3.33$). Post hoc comparisons of moderate activity hours using the Sidak test indicated that the mean scores for the IF + group ($M = 15.73$, $SD = 13.70$) were significantly different than the DF– group ($M = 8.40$, $SD = 7.44$) and the DF + group ($M = 8.86$, $SD = 9.37$).

There were no significant between-group differences on the rest of the control variables at baseline ($p > .05$): age, sex, race, employment status, education level, housing type, number of children, vigorous activity hours per week, health status, BMI, number of diagnosed conditions, number of

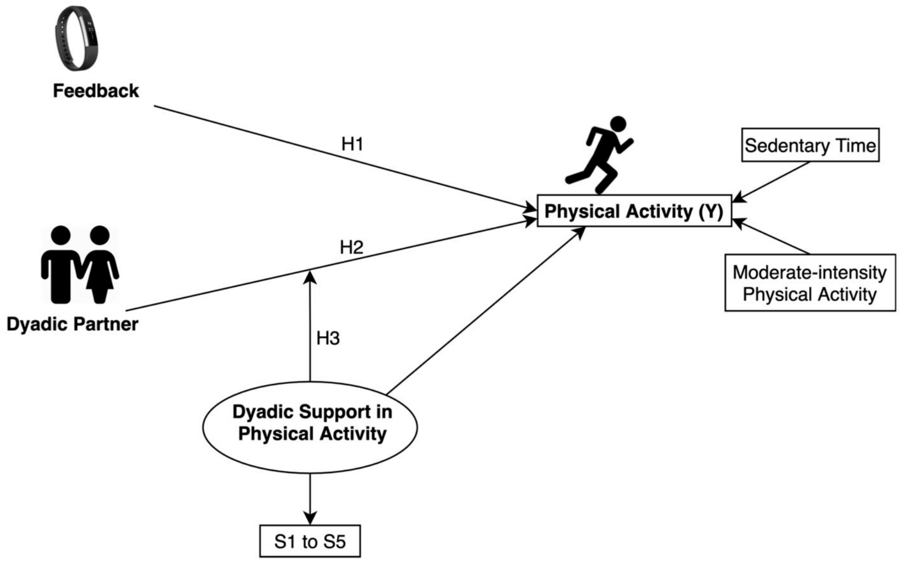

Figure 2. Structural model applied in SEM analysis. S1–5 are measured items.

Table 3. Descriptive statistics of control variables at baseline.

Control variable	IF− (*n* = 42)	DF− (*n* = 54)	IF+ (*n* = 52)	DF+ (*n* = 60)	Total (*N* = 208)	*p*
Sociodemographic data						
Age (years)	60.12 (4.86)	59.20 (3.64)	59.44 (4.43)	60.37 (4.82)	59.78 (4.45)	.479
Sex (% mode: female)	54.8	50.0	53.8	50.0	51.9	.945
Race (% mode: Chinese)	97.6	100.0	96.2	95.0	97.1	.388
Employment status (% mode: full-time employees)	28.6	48.1	46.2	41.7	41.8	.272
Education level (% median: junior college/polytechnic)	26.2	20.4	19.2	31.7	24.5	.078
Housing type (% mode: 5-room public housing flats)	31.0	35.2	50.0	23.3	34.6	.364
No. of children	2.15 (1.15)	2.07 (1.06)	1.98 (0.94)	2.00 (1.15)	2.04 (1.07)	.875
Health						
Sedentary time (hours/day)	4.90 (2.20)	7.22 (3.98)	5.62 (2.86)	6.80 (3.33)	6.23 (3.31)	.001
Moderate activity (hours/week)	12.90 (10.88)	8.40 (7.44)	15.73 (13.70)	8.86 (9.37)	11.28 (10.89)	.000
Vigorous activity (hours/week)	3.23 (4.60)	2.29 (2.12)	3.51 (4.34)	3.41 (4.87)	3.11 (4.11)	.411
Health status[a]	3.45 (0.74)	3.41 (0.84)	3.48 (0.75)	3.25 (0.65)	3.39 (0.75)	.364
BMI	23.95 (3.41)	23.56 (3.17)	23.77 (3.02)	23.60 (3.50)	23.70 (3.26)	.936
No. of diagnosed conditions	1.05 (1.46)	1.09 (1.15)	1.06 (1.00)	1.25 (1.27)	1.12 (1.22)	.804
No. of times hospitalized in past six months	0.07 (0.26)	0.07 (0.26)	0.17 (0.55)	0.15 (0.40)	0.12 (0.39)	.447
No. of times fallen in past one year	0.07 (0.26)	0.11 (0.37)	0.08 (0.33)	0.05 (0.22)	0.08 (0.30)	.758
Presence of goal						
Work toward an average person's goal[b]	6.24 (0.82)	5.98 (0.63)	6.06 (0.96)	5.95 (0.75)	6.04 (0.79)	.297
Work toward a personal goal[b]	6.19 (0.80)	5.98 (0.74)	6.21 (0.70)	5.97 (0.69)	6.08 (0.73)	.168
Dyad strength						
Marriage length (years)	31.00 (5.92)	30.07 (4.35)	30.14 (6.08)	30.37 (5.83)	30.36 (5.53)	.860
Inclusion of other in self	5.10 (2.11)	5.61 (1.54)	4.94 (1.97)	5.07 (1.86)	5.18 (1.87)	.260
Coactivity[b]						.208
Fitness tracker acceptance						
Perceived ease of use[b] [latent variable]						.110
Perceived usefulness[b] [latent variable]						.600

All figures are presented as *M* (*SD*) (mean and standard deviation) unless otherwise stated.
[a]Measured on a five-point rating scale (1 = poor, 5 = excellent).
[b]Measured on a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree).

times hospitalized in the past six months, number of times fallen down in the past one year, propensity to work toward an average person's goal and a personal goal, marriage length, strength of the dyad by the IOS scale score, coactivity within the dyad, perceived ease of use of fitness trackers, and perceived usefulness of fitness trackers. Table 3 reports the group means and significance levels for between-group comparisons on the measured variables.

4.2. Descriptive statistics

There were six primary measures of physical activity. These included the average daily step count (M = 10,601.42, SD = 3173.98); the median daily step count (M = 10,426.02, SD = 3417.75); and the percentage of days crossing the thresholds of 5000 steps (M = 88.00, SD = 14.83), 7500 steps (M = 71.28, SD = 24.52), 10,000 steps (M = 53.80, SD = 28.85), and 15,000 steps (M = 17.67, SD = 20.84).

There were five secondary measures of physical activity, measured in the post-experiment questionnaire. These included sedentary hours per day (M = 6.01, SD = 2.91), moderate activity hours per week (M = 11.85, SD = 11.02), vigorous activity hours per week (M = 4.03, SD = 6.64), health status on a rating scale ranging from 1 (poor) to 5 (excellent; M = 3.60, SD = 0.74), and BMI (M = 23.60,

Table 4. Descriptive statistics of outcome variables.

Outcome variable	IF– (n = 42)	DF– (n = 54)	IF+ (n = 52)	DF+ (n = 60)	Total (N = 208)
Average steps (steps/day)	11352.66 (3811.07)	9452.57 (2634.08)	11372.69 (3140.14)	10441.09 (2887.11)	10601.42 (3173.98)
Median steps (steps/day)	11304.63 (4177.06)	9185.96 (2806.72)	11249.81 (3252.76)	10213.08 (3167.68)	10426.02 (3417.75)
Days with >5000 steps (%)	87.60 (17.32)	85.17 (14.39)	91.05 (11.29)	88.19 (15.85)	88.00 (14.83)
Days with >7500 steps (%)	73.43 (25.02)	61.73 (25.73)	78.42 (20.76)	72.19 (23.97)	71.28 (24.52)
Days with >10,000 steps (%)	56.79 (30.25)	40.94 (27.09)	62.61 (27.22)	55.64 (27.48)	53.80 (28.85)
Days with >15,000 steps (%)	24.41 (25.36)	11.26 (14.07)	20.94 (23.07)	15.87 (18.87)	17.67 (20.84)
Sedentary time (hours/day)	5.67 (3.08)	6.54 (3.33)	5.56 (2.36)	6.17 (2.79)	6.01 (2.91)
Moderate activity (hours/week)	14.98 (12.69)	11.79 (10.60)	9.82 (10.06)	11.39 (10.69)	11.85 (11.02)
Vigorous activity (hours/week)	4.08 (7.46)	3.02 (3.29)	5.22 (7.99)	3.85 (7.02)	4.03 (6.64)
Health status[a]	3.57 (0.70)	3.61 (0.79)	3.77 (0.68)	3.45 (0.75)	3.60 (0.74)
BMI	23.91 (3.38)	23.41 (3.17)	23.72 (2.97)	23.45 (3.36)	23.60 (3.21)

All figures are presented as *M (SD)* (mean and standard deviation).
[a]Measured on a five-point rating scale (1 = poor, 5 = excellent).

Table 5. Structural model fit indices.

Outcome variable	χ^2	*df*	*p*	CMIN/*df*	CFI	TLI	RMSEA	SRMR	R^2
Mean steps	37.29	28	.113	1.332	.990	0.984	0.040	0.030	.065
Median steps	35.69	28	.151	1.275	.992	0.987	0.036	0.030	.067
Days >5000 steps	35.60	28	.153	1.272	.992	0.987	0.036	0.029	.033
Days >7500 steps	40.24	28	.063	1.437	.987	0.979	0.046	0.032	.068
Days >10,000 steps	42.09	28	.043	1.503	.985	0.976	0.049	0.033	.080
Days >15,000 steps	31.97	28	.276	1.142	.996	0.993	0.026	0.027	.060
Sedentary time	29.01	28	.412	1.036	.999	0.998	0.013	0.025	.352
Moderate activity	29.65	28	.380	1.059	.998	0.997	0.017	0.025	.039
Vigorous activity	32.30	28	.262	1.154	.995	0.992	0.027	0.026	.110
Health status	31.69	28	.287	1.132	.996	0.993	0.025	0.026	.063
BMI	31.42	28	.299	1.122	.996	0.994	0.024	0.025	.013

χ^2: Chi-square value; *df*: degrees of freedom; CMIN/*df*: Chi-square value/degrees of freedom; CFI: comparative fit index; TLI: Tucker–Lewis index; RMSEA: root mean square error of approximation; SRMR: standardized root mean residual; R^2: coefficient of determination.

SD = 3.21). The descriptive statistics of each group's outcome measures are reported in Table 4.

4.3. Model fit

The final measurement model from our confirmatory factor analysis had good fit (Hu & Bentler, 1999): $\chi^2(5) = 8.63$, $p < .001$, CMIN/df = 1.726, CFI = .996, TLI = 0.992, RMSEA = 0.059, and SRMR = 0.011. No residual correlations were required.

We examined construct validity and reliability for the latent variable, dyadic support. It had good reliability, Omega = 0.935 (Omega > 0.7; Bentler, 2009), and the average variance extracted (AVE) was 0.745, greater than 50% (Hair et al., 2014). The square root of the AVE was also larger than the inter-construct correlations, suggesting there was adequate discriminant validity. The item means, standard deviations, and factor loadings and the results of construct validity and reliability tests appear in Table 2.

We estimated the SEM for each of the 11 outcome variables. According to the recommended fit indices (Hu & Bentler, 1999), all 11 models had good fit. Table 5 summarizes the model fit and R^2 for each dependent variable.

4.4. Hypothesis testing

Findings partially supported H1. Participants who received feedback from a fitness tracker met the daily step thresholds of 7500 steps ($\beta = .16$, $p = .016$) and 10,000 steps ($\beta = .19$, $p = .005$) more often than those who did not receive feedback. However, there were no significant effects on the other nine outcome variables.

Contrary to H2, participating in the study with a dyadic partner was negatively associated with the average steps per day ($\beta = -.21$, $p = .004$), the median steps per day ($\beta = -.21$, $p = .003$), and percentages of meeting the daily step thresholds of 7500 steps ($\beta = -.16$, $p = .028$), 10,000 steps ($\beta = -.18$, $p = .012$) and 15,000 steps ($\beta = -.20$, $p = .006$). There were no significant effects on the other six outcome variables.

Consistent with H3, dyadic support moderated the effect of the dyadic partner on sedentary time ($\beta = -.39$, $p = .030$), suggesting that as dyadic support increases, so does the negative association between the dyadic intervention and sedentary time. There were no other significant moderation effects, so the support of H3 is limited. In fact, this relationship was only present for secondary outcome measure of self-reported sedentary time, and not the primary outcome measures of physical activity.

Refer to Table 6 for results from the analysis of the structural model.

5. Discussion

This study examined the effects of personalized feedback from fitness trackers and the social influence of spouses in motivating (or dissuading) physical activity among older Singaporeans. The results provided mixed support for the three hypotheses. In line with the social cognitive theory (Bandura, 1991), we noted that the interplay of personal and environmental factors influenced self-regulation in behavior. Indeed, self-monitoring led to higher activity levels, but social influence, especially when unsupportive, posed a hindrance instead.

5.1. Personalized feedback

We found that personalized feedback from fitness trackers has a positive effect on older adults' physical activity. The feedback serves as an ipsative bridge between people's goals and their behaviors by illuminating discrepancies between a current and desired state of physical activity. Receiving feedback that they had hit these goals also allowed them to feel

Table 6. Structural model results.

	Feedback → Y (H1)				Dyad → Y (H2)				Dyad × Support → Y (H3)			
Outcome variable (Y)	*B*	*SE*	*p*	*β*	*B*	*SE*	*p*	*β*	*B*	*SE*	*p*	*β*
Mean steps[a]	0.57	0.43	.185	.09	−1.32	0.46	.004	−.21	0.17	0.36	.633	.13
Median steps[a]	0.56	0.46	.227	.08	−1.45	0.50	.003	−.21	0.15	0.39	.695	.11
Days >5000 steps[b]	0.32	0.20	.117	.11	−0.26	0.22	.232	−.09	−0.20	0.17	.247	−.32
Days >7500 steps[b]	0.79	0.33	.016	.16	−0.78	0.35	.028	−.16	−0.03	0.28	.908	−.03
Days >10,000 steps[b]	1.08	0.39	.005	.19	−1.04	0.41	.012	−.18	0.19	0.33	.566	.16
Days >15,000 steps[b]	0.12	0.28	.677	.03	−0.84	0.30	.006	−.20	0.28	0.24	.235	.30
Sedentary time	−0.28	0.33	.393	−.05	−0.25	0.35	.482	−.04	−0.60	0.28	.030	−.39
Moderate activity	−2.80	1.53	.067	−.13	0.72	1.65	.664	.03	0.57	1.31	.663	.13
Vigorous activity	0.95	0.91	.293	.07	−0.35	0.98	.718	−.03	0.71	0.77	.358	.26
Health status	0.01	0.10	.913	.01	−0.13	0.11	.236	−.09	0.04	0.09	.602	.15
BMI	−0.11	0.44	.803	−.02	−0.22	0.48	.642	−.03	−0.10	0.38	.796	−.08

B: unstandardized regression coefficient; *SE*: standard error of the unstandardized regression coefficient; *β*: standardized regression coefficient.
[a]Divided by 1000 for scalability.
[b]Divided by 10 for scalability.

self-efficacious (Bandura, 1991), which was crucial for continued motivation toward a physically active lifestyle.

However, the results were inconsistent and seemed to depend on the metric of physical activity. Notably, feedback had a positive effect on moderate levels of physical activity (i.e., daily step counts of 7500 and 10,000) but was unrelated to both low (5000 steps) and high (15,000 steps) physical activity. So, the effect of feedback may depend on the magnitude of physical activity goals.

Setting goals for physical activity using fitness technology has been a popular approach for motivating exercise and the topic of many studies (Sullivan & Lachman, 2016). Flow theory (Csíkszentmihályi, 1975) is a helpful framework to explain the linkage between feedback and achieving moderate goals. According to flow theory, people experience a feeling of immersion in an activity when there is a balance between task challenge and personal skill. If a task is too easy, people get bored. If a task is too difficult, they get frustrated. It is possible that hitting 5000 steps is too easy for older adults and hitting 15,000 steps is too difficult. But hitting the moderate levels of 7500 and 10,000 steps has enough challenge to be engaging and not so much as to be off-putting. Although we cannot conclude that the fitness trackers led to flow-like experiences of physical activity, we can reasonably say that feedback shines a light on goal achievement. When individuals receive feedback that they have achieved a goal, their satisfaction with that achievement may be related to the amount of effort they put into it. That satisfaction may increase up to the point that achieving a goal becomes frustrating. So, feedback may help people feel satisfied with good-effort achievements, in this case, hitting 7500 and 10,000 daily steps.

5.2. Interpersonal context

The surprising finding from this study relates to the interpersonal dimension, that is the influence of strong-tie partners. Contrary to previous intervention studies that found, for example, positive effects of exercise buddies (e.g., Buman et al., 2011; Neil Thomas et al., 2012), the current study found a negative effect of participating with a strong-tie partner. Specifically, being in the intervention with a spouse resulted in lower physical activity, especially for higher step thresholds (10,000 and 15,000 steps). To understand this finding, it is important to consider the nature of the pre-existing strong ties.

The average participant in this study was 60 years old and had been married to and living with the same spouse for 30 years. High scores on the IOS Scale (Aron et al., 1992) suggest that the participants considered themselves deeply integrated with their spouses. This is unsurprising and suggests that the couples had well-established quotidian routines that did not necessarily include exercise. Leading up to our third hypothesis, we highlighted though that older couples often develop independent exercise habits, spousal support remained likely to influence their activity levels (Barnett et al., 2013). The current findings further suggest that independent exercise habits may become ingrained in spousal dynamics, and for some couples, exercising together disrupts those dynamics. To the extent that exercising together was not the norm for these couples, changing their daily habits could require major nomic reshuffling at the individual and interpersonal levels. Achieving the highest levels of activity was the largest deviation from that norm and, arguably, the most likely to be resisted. Pursuing that level of activity together could require a destabilizing adjustment of a coupled identity from years of marriage (P. Berger & Kellner, 1964). That effect seems to increase when couples are more supportive of each other, perhaps because dyadic support calls to attention spousal dynamics, roles, and norms. Due to the set lifestyles of older couples, effecting change in the couple appears to be more difficult than effecting change in the individual. Perhaps most important and counterintuitive, extant strong social ties may be a determinant to encouraging physical activity in older adults.

5.3. Limitations and future directions

This study has several limitations. First, it used a volunteer sample as opposed to a random sample. Resultantly, participants were likely to have been more health-conscious since they were interested to participate in a study that is about motivating physical activity. Additionally, there is a possibility that the sample was more open to digital health opportunities. We further acknowledge that the results may not be applicable to certain subgroups of older adults, such as those who are too frail to maintain independent mobility. However, we applied an experimental design to primarily manipulate the presence of feedback and the social context and to isolate their influences on older adults' physical activity. Future studies can consider applying similar designs in different contexts, even non-health ones, to see how these independent variables can drive behavior change.

Second, the experiment focused only on the strong-tie dyad as a form of social influence on physical activity. While it explored both the direct and indirect influences from spouses, the experiment did not account for other social contexts beyond that between spouses. We chose to focus only on the spousal context to streamline the operationalization of social ties in the experiment. Nonetheless, it would be good for future studies to account for various aspects of social influence.

Third, the study was a field experiment and lacked the control that a laboratory experiment could have afforded. To maintain external validity, the data had to be collected from their naturally occurring environments. Nonetheless, much care had been put into ensuring the integrity of the group manipulations, and eliminating the extraneous variables using questionnaire responses and controlling for them statistically. At the same time, because this was a field experiment, free rein was given to participants so that the data will accurately reflect how they used their fitness trackers in the most naturalistic conditions. Future interventions can consider enforcing normative feedback by adding partners as friends on participants' apps. Having an interface that feeds normative feedback to participants would be one way to manipulate the presence of normative feedback.

Finally, while this study focuses on the physical activity of older adults, the effects of the two independent variables can be extended to other applications of motivating behavior change in this target group. At the same time, it is not one technology or another that brings about behavior change, but the specific mechanisms working in fitness tracking technology that can lead to behavior change. In this era where wearable technology is increasingly ubiquitous, it is no longer worthwhile splitting hairs about the absence or presence of such technology. To bring about greater behavior change, it is crucial to understand how and why such technology can make a difference and the influences of extant factors around the user.

Ethical approval

The Ethics Committee of Nanyang Technological University approved this study (IRB-2018-12-016). Interviewees signed informed consent forms before participating in the study.

Disclosure statement

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

This research was funded by the Ministry of Education, Singapore (2017-T1-002-014).

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Data availability statement

The data generated during and/or analyzed during the current study are not currently publicly available but are available from the corresponding author on reasonable request. Ethics approval, participant permissions, and all other relevant approvals were granted for this data sharing.

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