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Go for a Walk! Monitoring Walking for Depressed Mood

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GO FOR A WALK! MONITORING WALKING FOR DEPRESSED MOOD

By

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GO FOR A WALK! MONITORING WALKING FOR DEPRESSED MOOD

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ABSTRACT

GO FOR A WALK! MONITORING WALKING FOR DEPRESSED MOOD

By

Michael Edwin Shrake

Literature suggests that exercise has benefits for health and mood. For people suffering from depression however, even summoning motivation to go for a walk can seem impossible, no matter the alleged benefits. My study builds on current articles suggesting that wearable technology like activity-tracking bracelets can have significant effects on motivation and physical health goals. The current study followed 11 individuals who met the minimum threshold for depression as measured by the Patient Health Questionnaire-9 (PHQ-9) for a period of 28 days and tracked their walking using a Jawbone UP activity bracelet. The results showed that daily activity differed significantly across participants and did not have an effect on daily scores on PHQ-9 questions except for the Question 5 related to appetite. These scores increased significantly at the end of the period (day 27 specifically) but also decrease significantly the following day (day 28) suggesting that appetite concerns fluctuate day to day and do not necessarily correlate with the number of steps. Concerns about sleep were less intense on average during the first week but fluctuated across the remaining three weeks. Scores indicating whether participants felt bad about themselves varied between high and low scores over the period and had no correlation with the number of steps.

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INTRODUCTION

This study is concerned with how monitoring physical activity affects mood on a day-to-day basis. Literature on depression suggests that exercise may reduce symptom severity for depression (Aurelio et al. 2005, Dixon et al. 2003, Luppino et al. 2010, Lepine & Briley 2011) and that activity trackers can improve motivation. First, the daily relationship between specific depression symptoms and physical activity such as walking is non-existent. Second, to my knowledge no study has tried to monitor daily walking activity with same-day specific symptom severity for depressed people. My thesis explores, to some extent, the relationship between daily walking and depression symptoms using the Patient Health Questionnaire for depression, also known as the PHQ-9 and an activity tracker bracelet (UP™ by Jawbone).

In this work, daily walking was defined as the number of steps the participant takes per day and was recorded using the bracelet for a duration of 28 days; while over the same period the participants were asked to complete a modified PHQ-9 on a daily basis.

The original PHQ-9 was designed to be taken every two-weeks but it can also be adapted for shorter periods such as in a study by Torous et al (2015), where participants'

daily mood was collected every day through texting. Another study showed that daily ratings can be used to illustrate a more detailed picture of the depression profile of an individual compared to the traditional instructions of the PHQ-9, where the daily high and low intensity of symptoms are averaged into a single score across the previous two weeks (Aguilera et al, 2015). Aguilera et al (2015) suggested that asking an individual to recall symptom frequency over the previous two weeks may be subject to a recency bias. In our case, we slightly modify the questionnaire by asking the participants to report their symptoms on a daily basis rather than over a two week period.

Chapter 1 is an overview of modern depression and the effect of walking on depression. This chapter starts with a discussion of differences in the defining features of depression between the earliest diagnostic manuals and the most current. It also discusses the development and the use of depression screening inventories along with differences in the frequency of diagnosis between genders. The following section focuses on walking as a treatment for mild depression. It begins with a discussion of common depression interventions such as cognitive behavioral therapy and psychiatric medication. Walking is proposed as an intervention for mild depression, which does not require the higher level of care provided by a therapist or psychiatrist. Literature examining the effect of exercise on mood is discussed, followed by a handful of studies that utilized pedometers and health surveys to track changes in physical and emotional wellness, as well as the tracking devices' effect on motivation.

Chapter 2 goes over the study itself and our results. We selected a depression screening inventory (the PHQ-9) and utilized it to screen potential participants for a minimum threshold of depression. Participants in our sample received an activity

tracking bracelet and then completed a PHQ-9 modified for daily use for 28 days. Data were analyzed using a Linear Mixed Model in SPSS. We found that the number of days wearing the tracker bracelet had a significant effect on the variance of PHQ-9 questions across participants but no significant effect on the scores of PHQ-9 over time except for question 5 which is related to eating too much or too little. Finally, while our study did not find an effect for Day of participation on the number of steps, correlating the number of daily steps to the day's PHQ-9 sum score produced a negative correlation for eight of eleven participants.

CHAPTER ONE: MODERN DEPRESSION

1. DEPRESSION

Depression is a common mood disorder found worldwide across age, gender, and demographic (Robertson et al, 2012). It effects professional, social, and emotional interaction including work productivity, intimate relationships, and daily moods. Symptoms typically include sadness, apathy, and a feeling of emotional isolation or detachment (Bostwick & Pankratz, 2000). Though an average depressive episode lasts between three and six months, depression can be recurrent and a lifetime struggle (Lepine & Briley 2011).

Diagnostic criteria for depression have evolved over time and are regularly revised with new editions of diagnostic manuals such as the Diagnostic and Statistical Manual of Mental Disorders (DSM) and the International Statistical Classification of Diseases and Related Health Problems (ICD). With progressive editions of the DSM, the lifetime prevalence of depression had increased from 3% of the population in 1970 (with the DSM-II) to 10-20% in 1994 (with the DSM-IV) (Bostwick & Pankratz, 2000). It is important to note that different definitions of depression, particularly between editions of diagnostic manuals, which emphasized or omitted different symptoms, contributed to the ballooned rates of prevalence. The DSM-II defined "Manic-depressive illness, depressed type" as a disorder characterized by severely depressed mood and mental and motor retardation (American Psychiatric Association, 1975). Additional symptoms could include uneasiness, apprehension, perplexity, and agitation. Manic-depressive illness, depressed type differed from manic or circular types in that it consisted exclusively of

depressed episodes (American Psychiatric Association, 1975). By contrast, the DSM-IV-TR features seven mood disorder diagnoses where depression can be the primary symptom, including two diagnoses that classify the depression diagnosis either as an episode or a disorder (major depressive episode/disorder and bipolar episode/disorder) (American Psychiatric Association, 2000). The DSM 5 elaborates further, distinguishing eight distinct diagnoses in the section "Depressive Disorders", spanning 33 pages; a significant elaboration from the page and a half of the DSM-II (American Psychiatric Association, 1975, 2013)!

The DSM 5 includes: Disruptive Mood Disregulation Disorder; Major Depressive Disorder; Persistent Depressive Disorder (Dysthymia); Premenstrual Dysphoric Disorder; Substance/Medication-Induced Depressive Disorder; Depressive Disorder Due to Another Medical Condition; Other Specified Depressive Disorder; and Unspecified Depressive Disorder. Each of these diagnoses is characterized by a sad, empty or irritable mood along with significant somatic and cognitive changes, which impair the individual's capacity to function. They differ in duration, timing, and presumed etiology (See Appendix B for more detailed definition of each disorder).

1.1. ASSESSING DEPRESSION

To assess depression several tests and scales have been developed following DSM criteria. These include the Beck Depression Inventory – II (BDI-II) (Beck, Steer, & Brown, 1996) and the PHQ-9 (Kroenke et al., 2001). The BDI-II is a revision of the widely used Beck Depression Inventory (BDI), introduced in 1961 as a 21-question survey designed to measure the behavioral manifestations of depression (Beck et al, 1996, Beck et al, 1961). A new edition of the BDI-II was released 35 years later in 1996

in response to incremental changes in symptoms defining depression, including revisions in the DSM. It is used to identify specific depression symptoms and their frequency for psychiatrically diagnosed adults and adolescents, but it is not used as a lone diagnostic tool, as symptoms of depression may be part of a separate primary disorder (Beck et al, 1996). The Patient Health Questionnaire (PHQ-9) is a nine-item survey used to screen for depression and symptom severity (Lowe et al. 2003). It was developed by Pfizer in the early 1990's as part of PRIME-MD, an instrument used to assist clinicians in making criteria-based diagnosis of five DSM-IV disorders commonly encountered in medical patients (Kroenke & Spitzer, 2002). Kroenke et al. (2001) found it was well-validated in fifteen studies including over 6,000 patients. Because it is entirely self-administered and brief, the PHQ-9 is now the most commonly used depression screening tool in clinical and research settings (Malpas et al. 2010; Lowe et al. 2003; Kroenke & Spitzer 2002).

The PHQ-9 assesses an individual's depression symptoms over two weeks, since according to the DSM-IV, "a symptom must be present for at least two weeks to be included in a diagnosis of depression." For research purposes, to evaluate the effect of a specific factor such as walking in our case, it is possible to modify the PHQ-9 for daily ratings as they reflect the mood more closely (Aguilera et al., 2015). Korenke et al. (2001) report that PHQ-9 scores of 5, 10, 15, and 20 represent the lowest thresholds for mild, moderate, moderately severe, and severe depression respectively.

1.2. GENDER DIFFERENCE

Women are approximately 1.7 times more likely than men to report a lifetime history of depression but do not differ in the overall course of depression nor the

likelihood of a recurrence in the subsequent twelve months (Kessler et al., 1993, Nolen-Hoeksema, 1991).

There is also no significant difference in the average age of the depression onset between men and women (24.04 years old and 23.53 years old respectively) (Kessler et al, 1993). Nolen-Hoeksema (1987) found that, with few exceptions, women report more depressive symptoms than men worldwide. The researcher evaluated possible differences in relations between several psychosocial, economic, and biological factors between the two genders but none of them was significant. The researcher suggested that this difference could be related to their responses to stress and engagement in distractive behaviors, as females tend to report ruminative behaviors with lower levels of general activity, while males generally pursue distractions from stress including physical activity (Nolen-Hoeksema, 1987). The physical activity engagement and relationship to mood is explored in depth in the following section.

In a different study, Nolen-Hoeksema & Girgus (1994) suggested that ruminative-style responses were related to higher depression scores for both genders. One proposed explanation by Nolen-Hoeksema (2003) is that rumination on negative emotions, even with the intention of problem solving, can draw the individual into negative cycles of thinking which in turn reduces the quality of proposed solutions. Whether rumination is a self-reflective style focused on solutions or a brooding style focused on negativity is specifically related to variations in levels of depression for women, where rumination with brooding traits correlated with elevated levels of depression. Though females were significantly more likely to demonstrate ruminative responses than males, both genders exhibited higher rates of depression with ruminative responses in general than other types

of response and it is suggested that response style may be more indicative of susceptibility to depression than gender alone (Nolen-Hoeksema & Girgus 1994, Nolen-Hoeksema 2003). However, gender may influence which response styles an individual develops.

Differences in typical response style is proposed to be a product of social reinforcement: men are praised or belittled for emotional responses based on social concepts of masculinity ("act like a man"); while emotional responses in girls receive less attention, whether positive or negative, compared to boys; which could lead to learned helplessness and a greater likelihood of depression (Nolen-Hoeksema, 1991). Children of either gender may develop a ruminative or passive response to negative affect if their parents/caregivers model a ruminative response style at home. This response style may also develop if the child is not exposed to appropriate adaptive responses, which may include benign distraction or appropriate problem solving (Nolen-Hoeksema, 1991). It has been suggested that depressed people with ruminative response styles may recover after learning to control the ruminative response through distraction during the course of CBT (Nolen-Hoeksema, 1991).

2. WALKING AS A TREATMENT FOR DEPRESSION

As mentioned previously, engaging in physical activity is considered a distractive behavior and therefore could be related to less depressive mood (Nolen-Hoeksema, 1987, Nolen-Hoeksema, 1991). Modern treatment of depression typically includes cognitive behavioral therapy (CBT) and/or prescription medication. Vernmark et al (2010) report that several psychological interventions have shown relatively similar outcome effects for depression from CBT, online CBT, and prescription medication. Cognitive behavioral

therapy consists of identifying and modifying faulty thought processes, attitudes, and behaviors, and is often paired with psychopharmacological treatments (Durand 2010, Butler et al., 2006). Robertson et al. (2012) stated that treatment with antidepressants is not recommended for people with mild depression and suggested that physical activity should be evaluated for therapeutic use with depressed patients because it might alleviate depression.

Other studies have demonstrated that there is a relationship between activity level and mood (Aurelio et al. 2005, Dixon et al. 2003, Luppino et al. 2010, Lepine & Briley 2011). Some researchers have found evidence to support the activity of walking as a treatment for depression, though their experiment did not examine which specific symptoms were effected, reporting only whether symptoms in general improved, stayed the same, or got worse over the course of the study (Mobily et al. 1996). Though this study focused on elderly rural adults, it found that even light-intensity exercise such as walking had a positive correlation with the reduction of depressive symptoms. Changes in exercise behavior were predictive of depressive symptoms at a follow-up three years later, while overall the data suggest that this daily level of exercise can reduce depressive symptoms at mild, moderate, and severe levels of depression. Another researcher proposed that physical activity functions as a distraction to negative moods, particularly in depression, by diverting attention to a task and preventing rumination (Nolen-Hoeksema, 1987).

An additional benefit of light exercise (such as walking) while treating depression is that it is a viable option for most people, even those who may be geographically or financially unable to spend time with a therapist. As reduced energy and activity is a

common symptom of depression and could rationally impede light daily exercise, we sought a motivational component to possibly enhance the number of steps a person might take in a day (Salmon, 2001).

3. FITNESS TRACKERS AND THEIR EFFECT ON MOTIVATION

There have been a handful of recent studies examining the effectiveness of fitness trackers on motivating less-active people to become more active. The use of pedometers has helped adults and seniors to improve health by significantly lowering blood pressure, body mass index (BMI), and achieve daily step targets (Klein, 2015). Wearable technology such as activity bracelets are becoming more advanced by the year and their accuracy in monitoring numbers of steps taken, duration and quality of sleep, and other biometrics ought to be regularly applied to new research in a variety of intersectional studies (Paul et al., 2015, Attick, J. et al., 2016). Beyond personal use, wearable technology could help physicians monitor patients remotely between visits, which itself could be helpful for rural or elderly populations (Attick, J. et al. 2016).

A community study in Scotland found that participants who were given a pedometer for twelve weeks and completed daily reports on step counts and health outcomes significantly increased their step count ($p < .001$), time spent in leisure walking, and positive mood compared to a control group (Baker et al. 2008). The researchers cautioned that the health consultation about the benefits of walking in their study has previously been shown to increase daily activity by itself, though no significant effect for the consultation alone increased daily walking in their study. A meta-analysis found a significant effect for motivation on the number of steps with pedometers when participants recorded their activity by hand on a monthly calendar (Tudor-Locke and

Lutes, 2009). Participants who manually recorded their numbers each day reported a mean daily step increase of 2000 steps per day over baseline, while those who wore the pedometer without recording their steps increased daily step count by a mean of 832 steps. Participants in the study explained that a tangible record of their steps worked as a motivator, particularly when comparing their current day steps to previous days. Since activity trackers help with the motivational levels of the person wearing it, we wondered whether their usage could enhance the motivational levels of people suffering from mild depression to engage more often in walking. Measurements for motivation were inferred by an increase in daily number of steps across the month of participation.

4. CONCLUSION

The evaluation of symptom severity and its modulation with various daily walking totals creates a number of opportunities for research and therapeutic applications. Walking is generally a safe, healthy, achievable goal for patients exhibiting a range of psychological maladies including depression. The use of activity tracking devices including pedometers and bracelets has been shown to motivate a variety of populations to increase their daily step rate, resulting in numerous health benefits and often an increase in positive affect. The examination of the relationship between specific depression symptoms and the number of daily steps should provide groundwork for future investigations into the modulatory effects of daily activity upon symptoms of depression.

CHAPTER TWO: WALKING AS A POTENTIAL TREATMENT FOR DEPRESSION

1. INTRODUCTION

The purpose of this study is to explore the relationship between walking and depression scores for individuals who reported mild depression, and to investigate whether fitness trackers that monitor activity such as walking can motivate these individuals to keep up with their activity, demonstrated by an increase in the number of daily steps from the beginning of the study to the end. Previous studies have examined the relationship between mood and various forms of exercise, but to our knowledge, no one correlated the total number of steps by day with daily depression scores for an extended period of time (twenty-eight days). On one hand, we used walking specifically because 1) it does not require any cost, 2) it can be easily tracked (using a fitness bracelet), and 3) it was suggested as an intervention for mild to moderate depression in a study by Robertson et al. (2012). On the other hand, with the emergence of activity trackers on the market that have been shown to enhance motivation, we would like to assess their motivational role when a person's mood is down.

2. METHODS

2.1. PARTICIPANTS

Participants were recruited from undergraduate Northern Michigan University courses in general psychology, statistics, and research methods. Recruitment of students took place via email from professors to their respective class lists. Students were informed in the email that there was a brief survey about emotion and that a larger study would be taking

place utilizing an activity tracking bracelet and brief nightly surveys. Eleven students, nine females, participated in the full study after prescreening. Participants ranged in age between 18 and 42 years (mean: 23.08 years, standard deviation: 6.63 years). The mean baseline PHQ-9 score for selected participants was 13.58, with a standard deviation of 5.53 and a range from 6 points to 25 points.

2.2. STIMULI AND APPARATUS

Participants were provided with a "Jawbone UP"™ health tracking bracelet for use through the duration of the study. A study evaluating the accuracy of ten different activity trackers found this bracelet to be reliable when monitoring walking in laboratory and home settings with the mean absolute percentage error (-1.0, 1.4) respectively (Kooiman et al., 2015). Data from the bracelets were collected weekly using iPads with the Jawbone app. Data were processed using Excel and SPSS. Participants were instructed to remove the bracelet only to charge once weekly at night and when bathing or swimming as it is not waterproof. Participants received an email at 9:00 PM each evening with the modified PHQ-9 Survey. They were instructed to complete the survey at the end of each day.

2.3. PROCEDURE

2.3.1. PRE-SCREENING:

Volunteers were directed to a website (Qualtrics, Provo, UT) to complete a modified PHQ-9 survey (Appendix 1). Three hundred and eighty eight volunteers completed the pre-screening survey across the course of the study, with the pre-screening offered at the beginning of each academic semester beginning with summer 2016. Of one hundred and ninety participants who scored at least 5 points (the minimum threshold for mild depression) and higher, eighty indicated an interest in participating in the full study and were emailed an invitation to participate. Participants were selected on a first-response basis. The incentive for completing the screening survey was extra credit in class. The incentive for completing the full 28 day study was a $20 gift card to Target.

A final participation sample of eleven subjects were selected from all invited participants. Screened individuals were instructed on the procedures of the study and provided their consent to participate in the study. Bracelets were to be worn around the clock except when charging or in the shower, and were worn on the participants' arm of choice. Data was not collected concerning the arm of preference for the participant. The study was approved after review by the Institutional Review Board (IRB) of Northern Michigan University in February 2016 (approval code HS 16-761).

2.3.2. EXPERIMENT

Data recorded on the Jawbone bracelet began with the first full day the participant wore the bracelet. Surveys were sent at 9:00 PM each evening to participants' preferred email address beginning on the first full day of data collection. Participants met with the researcher once a week to collect data from the wristbands in most cases. If such a

meeting was missed, data were usually collected within a couple of days. When the participant had completed 28 surveys with activity data for each day, participation was considered fulfilled, the bracelet was returned, and the participant received the promised $20 gift card. Participants with five or more days of missing survey data did not receive the incentive.

The nightly survey for participants featured a PHQ-9 which was altered to inquire only about the previous 24 hours. The survey also included four social questions inquiring as to what extent the participant interacted with close friends, interacted with family, spent time on leisure activities, and time spent idly during the day. In this study the daily number of steps is a predictor variable while specific symptom severity is a criterion variable. When evaluating motivation successive days is a predictor variable while the number of steps is the criterion variable.

2.4. ANALYSIS

Data were analyzed in SPSS using a Linear Mixed Model (LMM) with Days as a factor. The LMM provides a better fit of the data over a repeated measured analysis for the same dataset since our data are considered longitudinal repeated measures. It can also handle missing point times in case participants forgot to fill in the PHQ-9 questions. Repeated measures LMMs were used as each participant's questions were recorded 28 times, with Participant (11) entered as a random effect (intercept), and Days (28) entered as a fixed effect. For each step, the significance of the fixed effect Days was assessed with Type III SS F-tests on the final multivariate model. Changes in model fit for fixed effects were assessed with maximum likelihood (ML) estimation. For all the questions, models were fitted using AR(1) (first-order autoregressive) and ARH(1) (heterogeneous

first-order autoregressive) that are more suited to longitudinal repeated measures (Field, 2013).

3. RESULTS:

This study was designed to examine the relationship between monitoring physical activity and depression symptom severity for people experiencing mild depression. The eleven participants (nine female) raged in age from 18-42, with a mean age of 23. Baseline scores on the PHQ-9 from our participants ranged from 6-25 points, with a mean score of about 13.5. Across 308 individual surveys for the 11 participants, 30 were not completed.

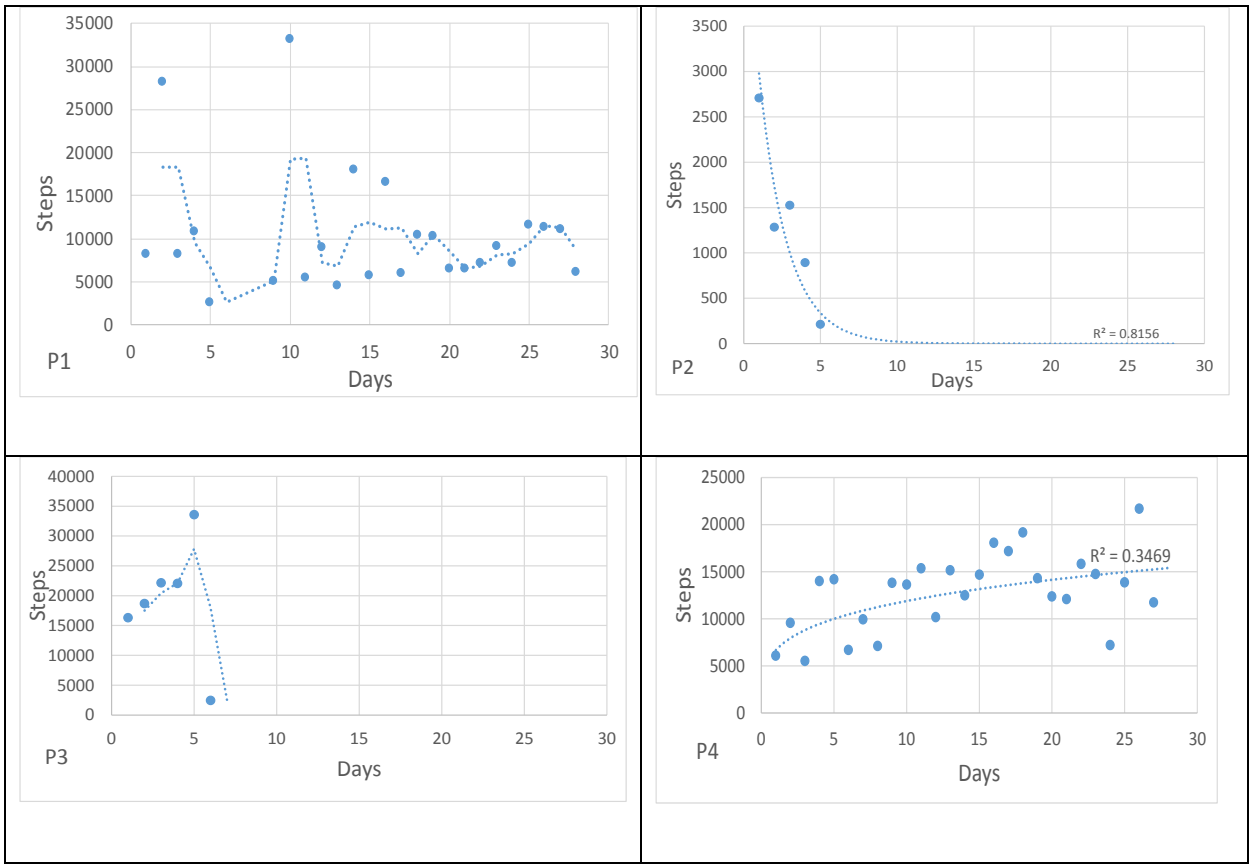
Motivation was monitored by the number of steps taken per day from Day 1 to Day 28. Daily symptom severity was measured using the PHQ-9 and each symptom was analyzed across participants by Day. A daily depression severity sum score was correlated for each participant with the number of steps they took that same day.

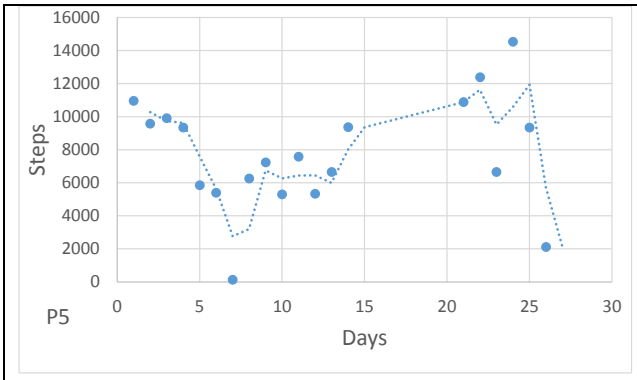
3.1. RESULTS: STEPS

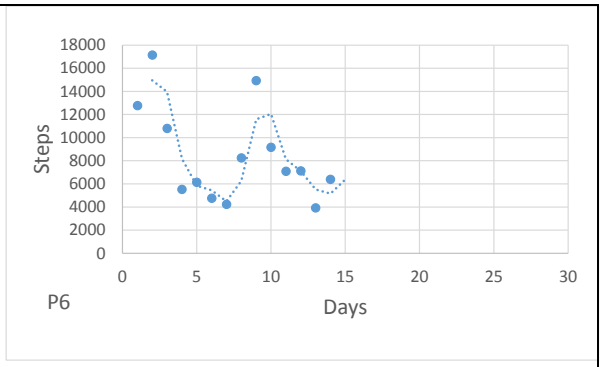
Figure 1 shows the number of steps against days for each participant. Six of the eleven participants (P1, P5, P6, P7, P10, P11) showed a broad range of activity best depicted with a moving average. Two participants (P2, P3) started their participation at or near their highest levels of recorded steps before quickly dropping away to reporting no steps at all. P9 is similar to P2 and P3, but with more variance in the number of steps between days before ceasing to report number of steps.

Participants P4 and P8 demonstrated general upward trends in number of steps taken by day. P4 shows a logarithmic trend line, their rate of increase in steps per day

gradually slowing across days. Participant P8 follows a gradual linear positive slope, increasing steps per day particularly in the final week of their participation. Using the LMM, the relationship between days and steps showed significant variance in intercept across participants $Var(u_{0j}) = 4.98 \times 10^{13}$, $\chi^2(1) = 15.96$, $p < .01$. Each participant recorded significantly different numbers of steps at the beginning of the study, and their pattern of steps across days differed between each participant. No two participants were alike in their daily number of steps. Days did not significantly affect the number of steps.




Steps
Days
P5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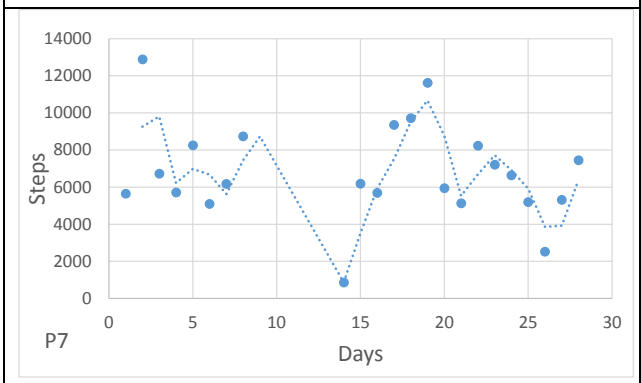
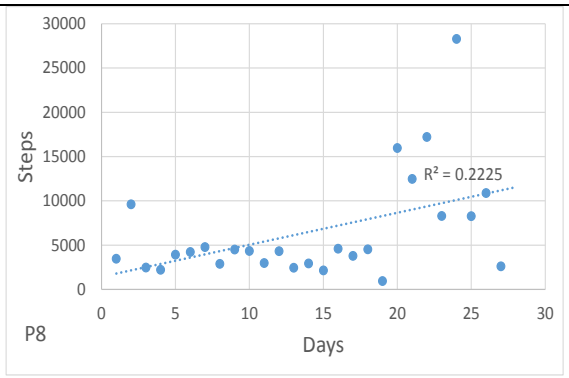
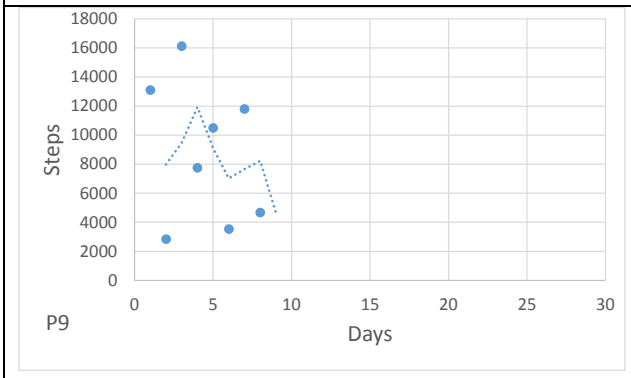
Days
P6


Steps
Days
P7


Steps
Days
P8
R² = 0.2225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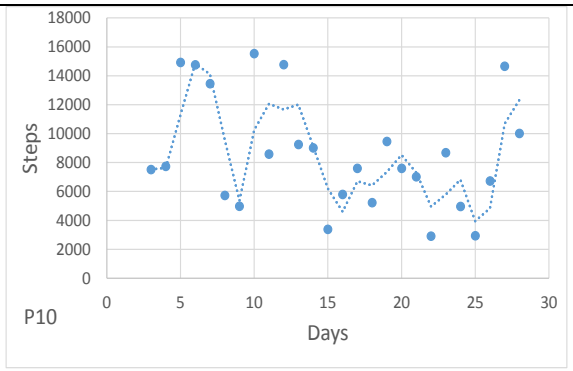
Days
P9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Days
P10

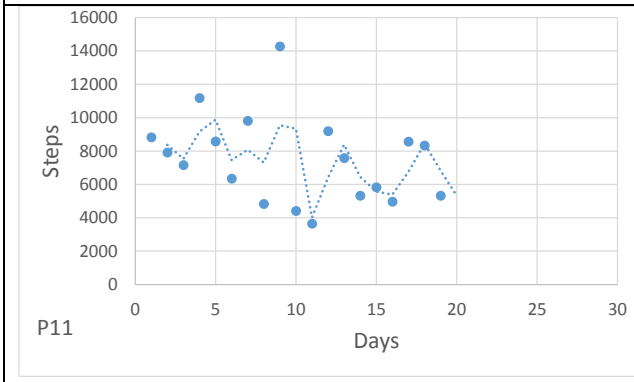

Steps
Days
P11

FIGURE 1. THE NUMBER OF STEPS PER DAY BY PARTICIPANT.

3.2. RESULTS: PHQ-9

3.2.1. PHQ-9: QUESTION1:

Question 1 from the PHQ-9 deals with diminished interest or pleasure in doing things. It asked the participants: "Over the last 24 hours, have you experienced little interest or pleasure in doing things?" The relationship between days and PHQ-9-1 showed significant variance in intercept across participants, $Var(u_{0j}) = .15$, $\chi^2(1) = 24.5$, $p < .01$. However, days did not significantly affect question 1 of the PHQ-9.

3.2.2. PHQ-9: QUESTION2:

Question 2 from the daily PHQ-9 asked participants: "Over the last 24 hours, have you experienced feeling down, depressed, or hopeless?" The relationship between days and PHQ-9-2 showed significant variance in intercept across participants, $Var(u_{0j}) = .016$, $\chi^2(1) = 32.79$, $p < .01$. Question 2 of the PHQ-9 was not significantly affected by Days.

3.2.3. PHQ-9: QUESTION3:

Question 3 from the PHQ-9 enquires about sleep concerns. Participants were asked: "Over the last 24 hours, have you experienced trouble falling or staying asleep, or sleeping too much?" The relationship between days and PHQ9-3 showed significant variance in intercept across participants, $Var(u_{0j}) = .026$, $\chi^2(1) = 46.62$, $p < .01$. Days ~~h~~ significantly affected question 3 scores of the PHQ-9 ($p = 0.08$). Figure 2 shows the mean scores per day for question 3. It seems that participants' sleep was improving during the first 10 days but start fluctuating for the rest of the testing period suggesting that wearing the bracelet did not affect the mood of the participants (see figure 2). More specifically

there was no significant correlation between the PHQ-9 scores for question 3 and the number of steps.

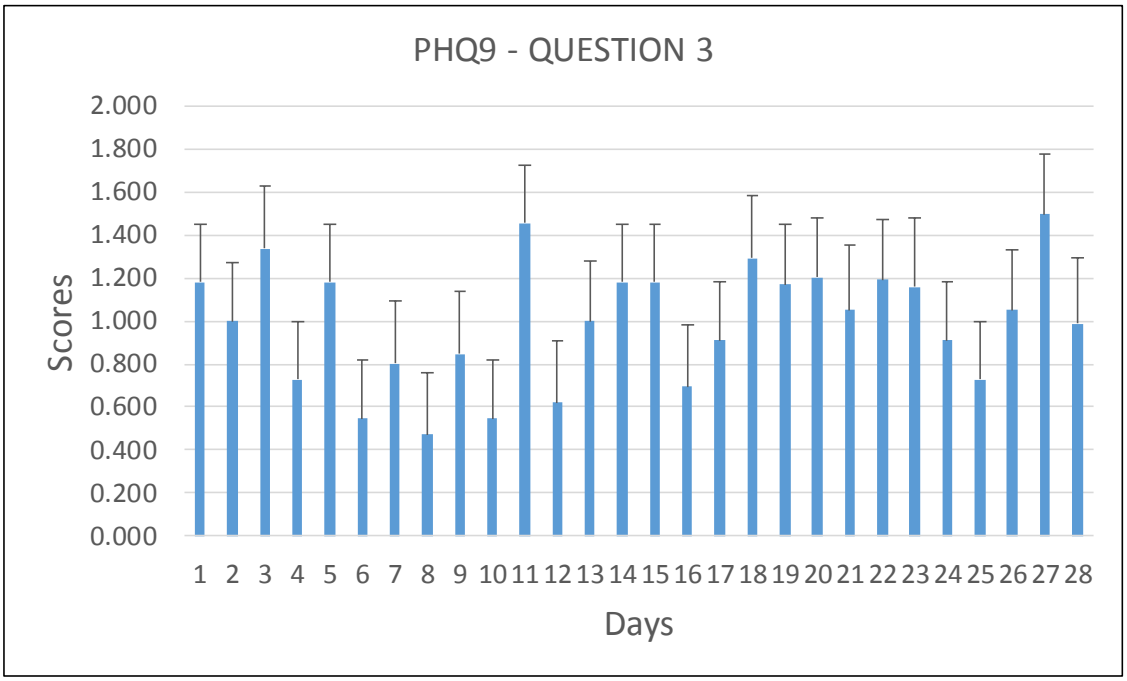


FIGURE 2. MEAN SCORES ACROSS PARTICIPANTS FOR THE THIRD QUESTION OF THE PHQ-9 BY DAY.

3.2.4. PHQ-9: QUESTION4:

Question 4 from the PHQ-9 covers fatigue and feelings of low energy. It asked participants: "Over the last 24 hours, have you experienced feeling tired or having little energy?" The relationship between days and PHQ-9-4 showed significant variance in intercept across participants, $\text{Var}(u_{0j}) = .036$, $\chi^2(1) = 63.36$, $p < .01$. Days did not significantly affect question 4 of the PHQ-9.

3.2.5. PHQ-9: QUESTION5:

The PHQ-9's fifth question deals with appetite, asking the participants: "Over the last 24 hours, have you experienced poor appetite or over eating?" The relationship between

days and PHQ-9-5 showed significant variance in intercept across participants, $Var(u_{0j}) = .028$, $\chi^2(1) = 52.5$, $p < .01$. The variation in scores for question 5 of the PHQ-9 were significantly affected by Days $F(27,159.46) = 2.32$, $p = .001$. Pairwise comparisons with Bonferroni correction confirmed that question 5 for Day 27 differs from Day 5 ($p = .004$), Day 13 ($p = .016$), Day 24 ($p = .005$), and Day 28 ($p = .011$). Table 1 summarizes the mean and standard deviation of the scores for these questions. On Day 27, participants averaged a score just under 2 (moderately experiencing poor appetite or over eating) while scores for Days 5, 13, 24, and 28 are below .7 (between not at all experiencing poor appetite or over eating and lightly experiencing poor appetite or over eating, Table 1). Participants had more concern for food on Day 27 than any other days of interest.

TABLE 1. MEANS AND STANDARD DEVIATION FOR QUESTION 5 OF THE PHQ-9 FOR DAYS 5, 13, 24, 27, AND 28

DAY	**Mean (M)**	**SD**
DAY 5	.64	.25
DAY 13	.69	.26
DAY 24	.82	.25
DAY 27	1.88	.26
DAY 28	.66	.28

3.2.6. PHQ-9: QUESTION6:

Question 6 of the PHQ-9 focuses on feelings of failure and disappointment in oneself. Participants were asked: "Over the last 24 hours, have you experienced feeling bad about yourself – or that you are a failure or have let your family down?" The relationship between days and PHQ-9-6 showed significant variance in intercept across participants, $Var(u_{0j}) = .023$, $\chi^2(1) = 55.07$, $p < .01$. Question 6 of the PHQ-9 was almost significantly affected by Days ($p = .09$). As shown on Figure 3, it seems that participants' concerns about disappointment and failures decrease over the first 13 days of the experiments but start changing quickly on a daily basis until the end of the experiment. Again, no correlation between the number of steps and the scores of question 6 were found for each participant.

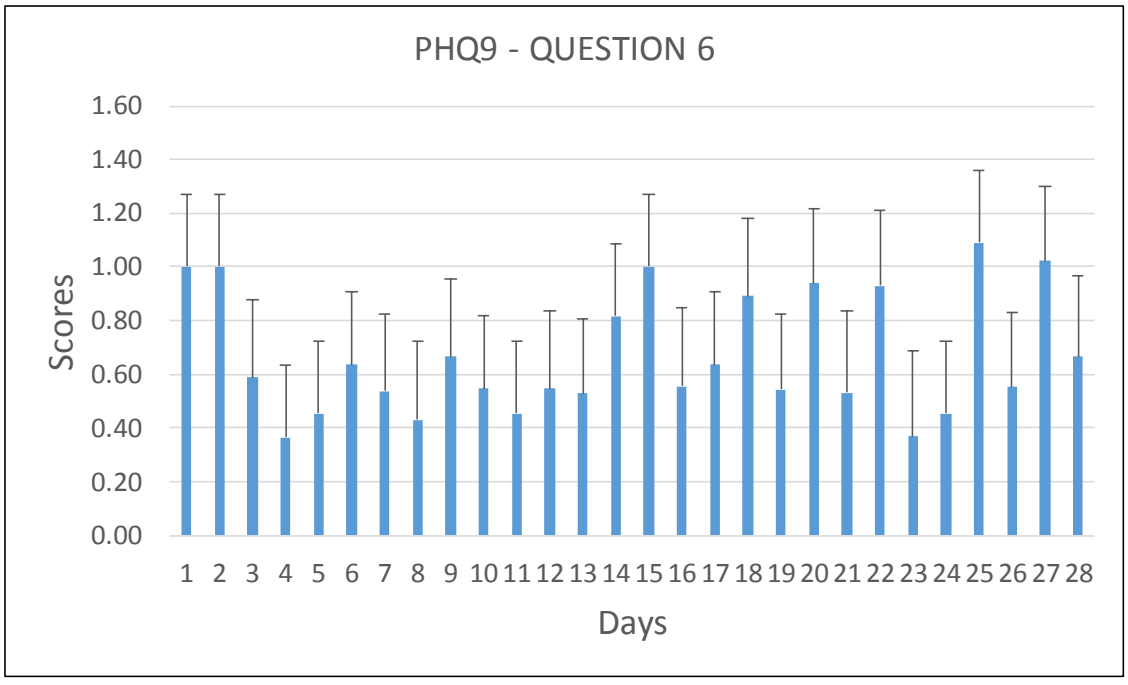


FIGURE 3. MEAN SCORES OF PHQ-9 QUESTION SIX BY DAY.

3.2.7. PHQ-9: QUESTION7:

The seventh question of the PHQ-9 focuses on issues of concentration, asking the participants: "Over the last 24 hours, have you experienced trouble concentrating on things, such as reading the newspaper or watching television?" The relationship between days and PHQ9-7 showed significant variance in intercept across participants, $Var(u_{0j}) = .025$, $\chi^2(1) = 31.75$, $p < .01$. Days did not significantly affect question 7 of the PHQ-9.

3.2.8. PHQ-9: QUESTION8:

In question 8 of the PHQ-9, participants were asked: "Over the last 24 hours, have you experienced moving or speaking so slowly that other people could have noticed? Or the opposite – being so fidgety or restless that you have been moving around a lot more than usual?" The relationship between days and PHQ-9-8 showed significant variance in intercept across participants, $Var(u_{0j}) = .21$, $\chi^2(1) = 42.17$, $p < .01$. Days did not significantly affect question 8 of the PHQ-9.

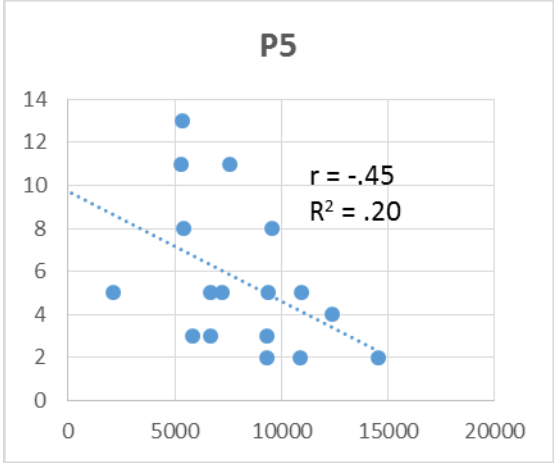
3.2.9. PHQ-9: QUESTION9:

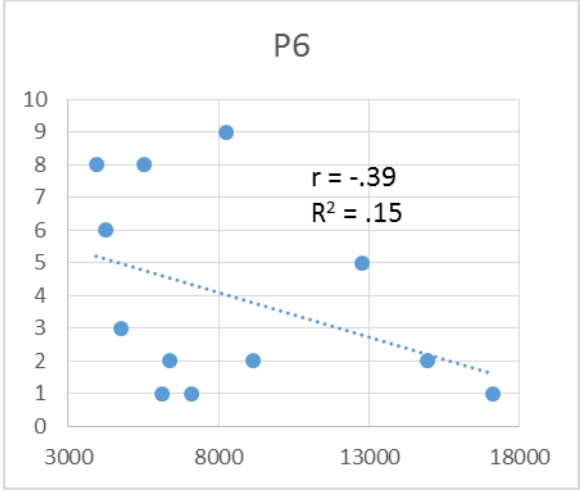
Question 9 of the PHQ-9 concerns thoughts of wanting to hurt oneself. The participant is asked: "Over the last 24 hours, have you experienced thoughts that you would be better off dead or hurting yourself in some way?" The relationship between days and PHQ-9-9 showed significant variance in intercept across participants, $Var(u_{0j}) = .09$, $\chi^2(1) = 17.97$, $p < .01$. Days did not significantly affect question 9 of the PHQ-9

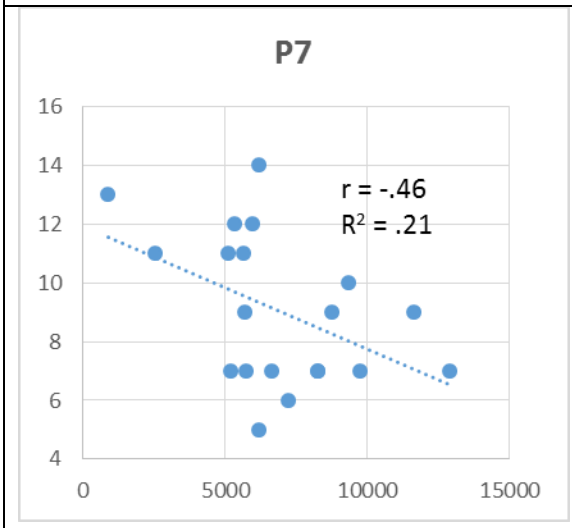
3.3. RESULTS: STEPS AND PHQ-9 SUM SCORES

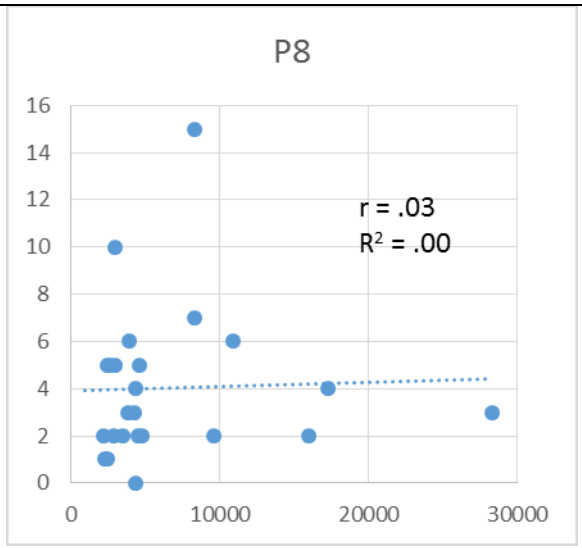
Correlating the number of daily steps to the PHQ-9 sum score by day per participant produced a negative correlation for eight of eleven participants. Two participants

achieved statistical significance for the correlation, $p < .05$. Participant 2 achieved significance at $p = .01$, however their correlation only included five data points and should not be considered representative. Table 2 summarizes the correlation coefficient, the coefficient of determination, and the significance value for each participant. Blue cells denote a negative correlation. Yellow highlights correlations which achieved significance.


P5
r = -.45
R² = .20
14
12
10
8
6
4
2
0
0
5000
10000
15000
20000


P6
r = -.39
R² = .15
10
9
8
7
6
5
4
3
2
1
0
3000
8000
13000
18000


P7
r = -.46
R² = .21
16
14
12
10
8
6
4
0
5000
10000
15000


P8
r = .03
R² = .00
16
14
12
10
8
6
4
2
0
0
10000
20000
30000

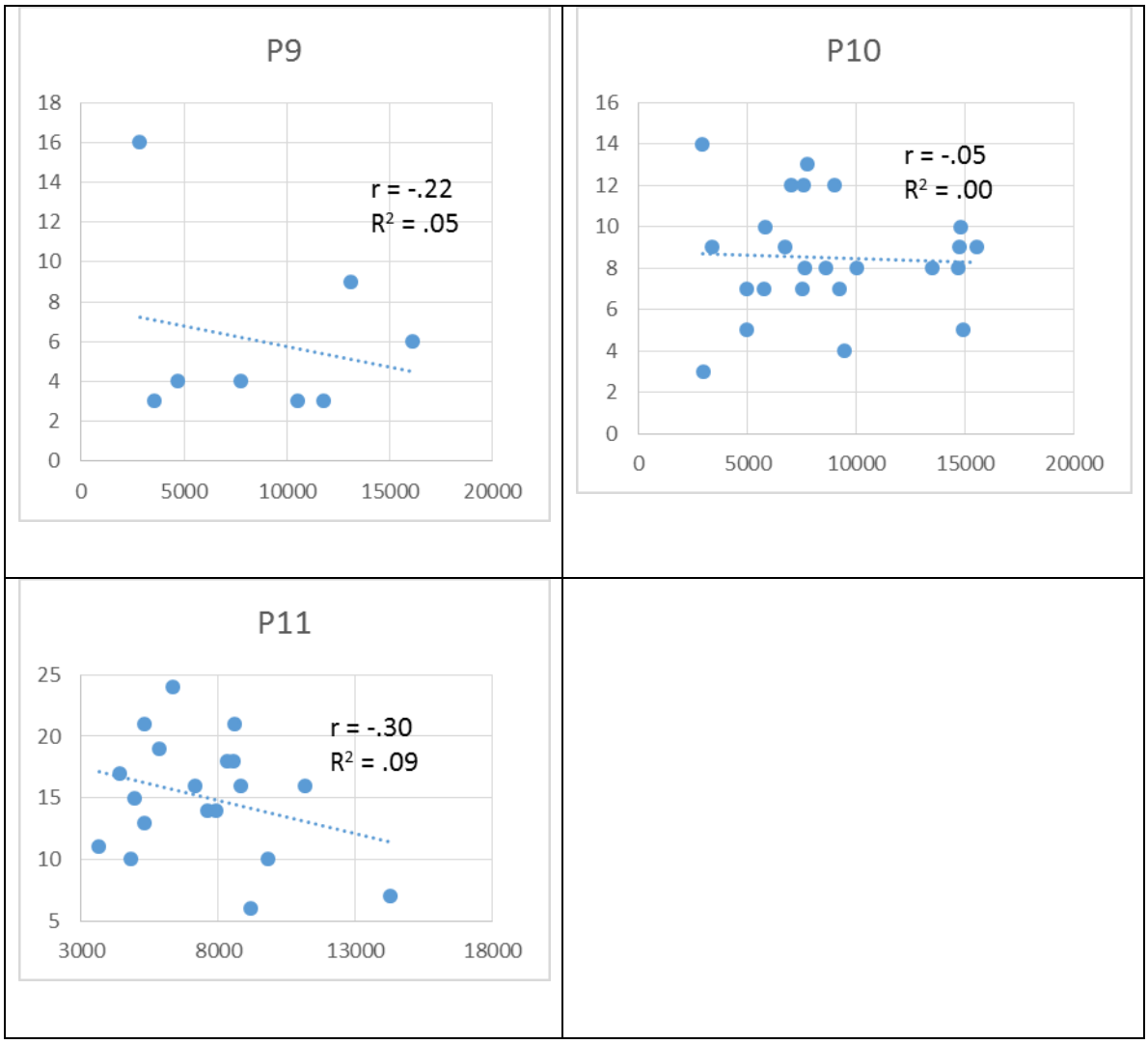


Figure 4. The number of steps per day (X-axis) correlated with the sum symptom score for the daily PHQ-9 (Y-axis) by participant

Table 2. Correlation strength between number of steps and PHQ-9 sum scores

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
Pearson r	-.11	.95	.06	-.25	-.45	-.39	-.46	.03	-.22	-.05	-.30
R^2	.01	.90	.00	.06	.20	.15	.21	.00	.05	.00	.09
Significance	>.05	=.01	>.05	>.05	=.05	>.05	=.04	>.05	>.05	>.05	>.05

4. DISCUSSION

The results shows that relationship between days and all PHQ-9 questions displayed significant variance in intercept across participants. This suggests depression symptoms vary day to day among individuals wearing activity-tracking bracelets. However, there were no significant variations in the question responses between the 28 days, except for question 5 of the PHQ-9 dealing with poor appetite and overeating. The mean scores increased significantly on day 27 and dropped significantly the following day. The question however is confusing for daily tracking, as we cannot really know whether scores increase for overeating or appetite loss, or a mix of both.

Days had no significant effect (p = .08) on Question 3 of the PHQ-9 (sleep concerns), but again because the question deals with two opposing sleep issues, we are unable to determine the measure's relationship with walking over this period as participants might be having trouble falling asleep one day and sleeping too much the following day. Although it is suitable for a bi-weekly screening, monitoring sleep on a daily basis requires a more precise question.

Question 6 scores of the PHQ-9 (Feeling bad about oneself, or as though they have failed their family) were not significant, and no correlation was found with the number of steps.

There was no significant effect of Days on number of steps. We did find a moderate negative correlation between the number of steps taken in a day for a participant and their daily sum score on the PHQ-9. On days where participants reported a higher number of steps their PHQ-9 sum score was generally lower than it was on days where they took a lower number of steps.

The Jawbone Up™ bracelet was used because it was the cheapest on the market, but had the drawback of including minimal features. It also required a USB connection via a phone or a tablet and could not provide any feedback to the participants. The Tudor-Locke & Lutes (2009) study showed that individuals who wrote down their steps increased their daily activity, suggesting that self-monitoring was a greater motivating factor to increase activity than simply wearing an activity tracker. Although their study did not address depression, it is possible that use of more sophisticated bracelets with features that allow tracking and feedback would have been necessary to verify the initial hypothesis that walking can help with depression over time.

An initial idea of the present was to develop a phone application intended to motivate depressed persons and help them complete their daily activities. The application was to be a game where a digital avatar or "friend" would interact with the depressed person through the user's phone or tablet device, proposing engaging challenges and offering encouragement based on the activity levels using a tracker. During the literature review however, studies evaluating the specific act of walking and

its effect on depression were scarce. Different articles explored various types of exercise and their interaction with general mental and physical health. A handful discussed walking and mood changes, but did not focus specifically on depressed persons and the correlation of their daily numbers of steps. Other research focused on guided walking at various points in the week, but did not track participants' walking outside of the sessions with the researchers. The latter study's neglect of that variable led to the current study.

This study recruited participants who exceeded a minimum threshold of depression on a screener PHQ-9; accordingly, it was likely that there could be some issues with data collection, such as missed nightly surveys, absent meet-ups to draw data from the bracelets, or even willingness to participate beyond the prescreening. Weather functioned as a limitation in this study as most of our data were collected in the winter time where walking proves to be challenging or difficult. Additional limitations included bracelets not being charged, resulting in participants wearing them for several days with dead batteries and no data collected. Some participants attempted to submit surveys after the fact for missed days, and some bracelets were damaged or lost all together. The low interest in participation from male participants limited the possibility of comparing the results based on gender. Having a small group of total participants was the greatest limitation, and increasing the sample size would have provided more representative data to describe the relationship between motivation and walking for depressed persons. This study suggests that mild depression should be addressed on an individual basis and that walking or wearing an activity monitor may benefit depression symptoms for some people but not others.

Adding reminders or rewards for reaching specific goals – features supported already in new smartphones – might have improved compliance with the daily walking regimen, and thus enhance any effect of activity monitoring on depression. When this study began, more than two years ago, these features were not yet available. However, since the purchase of the UP bracelet, the market exploded with new trackers that include many features that could support walkers' efforts to reach their goals.

CONCLUSION

Minimal monitoring of daily activity for people suffering from mild depression is not enough to reduce symptoms related to depression. Thus, wearing a basic activity tracker is insufficient motivation for depressed persons to increase their daily walking, but wearing trackers with more features might improve these outcomes. Such additional features might include screens, activity reminders, or wireless connections to other devices (like tablets or televisions) that might enhance the motivational component in studies like this. The new generation of trackers could have sent reminders to the participants' other devices such as tablets or smartphones to help reduce missing information.

The only significant result for Days on a question from the PHQ-9 involved question 5, related to appetite loss or overeating. Two other questions, 3 and 6, which dealt respectively with sleep and feeling bad about oneself yielded no significant results. The drastic fluctuation between scores over days successive suggests additional factors (e.g., procedural limitations, noted above) could have affected the results' stability.

For the majority of participants, their numbers of steps in a day were inversely related to their scores on the PHQ-9. This suggested that the number of steps a person took per day may have had the effect of reducing depression symptom severity by the end of the day, compared to days where the same participants took fewer steps. However, it might also reflect simply that people walked more when less depressed than they did on days when they are more depressed.

APPENDIX A: MODIFIED PHQ-9 QUESTIONNAIRE

Over the last 24 hours, have you experienced the following concerns?

	0 - not all all	1 - lightly	2 - moderately	3 - intensely
Little interest or pleasure in doing things	○	○	○	○
Feeling down, depressed, or hopeless	○	○	○	○
Trouble falling or staying asleep, or sleeping too much	○	○	○	○
Feeling tired or having little energy	○	○	○	○
Poor appetite or overeating	○	○	○	○
Felling bad about yourself - or that you are a failure or have let yourself or family down	○	○	○	○
Trouble concentrating on things, such as reading the newspaper or watching television	○	○	○	○
Moving or speaking so slowly that other people could have noticed? Or the opposite - being so fidgety or restless that you have being moving around a lot than usual	○	○	○	○
Thoughts of being better of dead or hurting yourself in some way	○	○	○	○

APPENDIX B: TYPES OF DEPRESSION LISTED IN THE DSM 5

In this section, the characteristics of each form of depression listed in the DSM 5's chapter "Depressive Disorders" are summarized.

Disruptive Mood Disregulation is distinguished by frequent (three times or more per week) temper outbursts inconsistent with the individual's level of development and includes verbal rages and physical aggression against people or property. For example, tantrums may be common for toddlers, but when constantly performed by a neurotypical eight year old that child would possibly qualify for a diagnosis of Disruptive Mood Disregulation. This diagnosis is generally reserved for children between the ages of 6 and 10 years and must be demonstrated consistently (without a gap of 3+ months) for at least one year. The core feature is severe, persistent irritability.

Major Depressive Disorder requires the presence of five or more symptoms for two consecutive weeks as well as either depressed mood or the loss of interest or pleasure. The nine symptoms of which five must be present for diagnosis include:

- Depressed mood

Markedly diminished interest or pleasure in almost all activities on most days

- Significant weight loss or gain (5% of body weight in a month) when not dieting or intentionally gaining weight

- Sleeping too much or too little (hypersomnia or insomnia, respectively)

- Psychomotor agitation (restlessness) or retardation (sluggishness) observable by others;

- Fatigue

- Feelings of worthlessness or excessive/inappropriate guilt

- Diminished ability to think or concentrate

- Recurrent thoughts of death including suicide attempts, plans for committing suicide, and general suicide ideation without a plan.

The individual must have never had a manic episode. Documentation for this diagnosis on medical forms includes the level of depression (mild, moderate, or severe) and can denote when psychotic features are present.

Persistent Depressive Disorder consolidates chronic major depressive disorder and dysthymic disorder as defined in the DSM-IV. It is a moderate but a persistent form of depression, which is present for at least two years in adults or one year in children. It must, along with depressed mood, include at least two or more of the following symptoms in the same two years without more than a 2 month gap at any interval: poor appetite or overeating; insomnia or hypersomnia; fatigue; low self-esteem; poor concentration or indecision; feelings of hopelessness. The lower threshold for number of symptoms and their persistence (two years rather than the minimum two weeks for Major Depressive Disorder) is what distinguishes Dysthymia from Major Depressive Disorder.

Premenstrual dysphoric disorder is a new addition to the DSM 5 classification after initially appearing in an appendix of DSM-IV only. As its name indicated, it is only

specific to women. The authors of the DSM included it as a new diagnosis after 20 years of research indicating that its onset after ovulation and persists within few days of menstruation by distinctly affecting daily functioning. The diagnosis requires a combination of five symptoms or more from two lists of symptoms. Symptoms on the first list include mood swings, irritability, depression/hopelessness, and anxiety. The second list includes decreased interest in usual activities, subjective difficulty concentrating, lethargy, changes in appetite including specific food cravings, hypersomnia or insomnia, a sensation of being overwhelmed, and physical symptoms such as weight gain, breast tenderness or swelling, joint or muscular pain, or a sensation of "bloating." Premenstrual dysphoric disorder differs from premenstrual syndrome as this latter has no requirement for number of symptoms.

The Substance/Medication-induced depressive disorder is a prominent and persistent disturbance of mood characterized by depressed mood or markedly diminished interest or pleasure in most if not all activities during or following substance intoxication or withdrawal, or exposure to a medication capable of producing the described symptoms. This diagnosis is not appropriate if the depression precedes the exposure to the substance/medication or if the individual is not significantly distressed or impaired in their daily life.

An individual must have a history of another medical condition, which physiologically leads to depression to qualify for **Depressive Disorder due to Another Medical Condition**. Medical conditions related can include stroke, Cushing's disease, hypothyroidism, Huntington's disease, Parkinson's disease, and traumatic brain injury.

This diagnosis is not to be used if the depression is better explained by another mental disorder such as adjustment disorder with depressed mood.

Patients with symptoms characteristic of a depressive disorder but don't qualify for any defined disorder are diagnosed as **Other Specified Depressive Disorder**. This diagnosis is used if a patient reports significant distress or impairment in daily functioning and includes distinctions for 1) recurrent brief depression, 2) short-duration depressive episode (4-13 days), and 3) depressive episode with insufficient symptoms.

Unspecified Depressive Disorder is quite similar to Other Specified Depressive Disorder. This diagnosis is selected if the clinician is unable to specify which depressive disorder their patient is expressing, and is intended for situations where there is not sufficient time for a behavioral evaluation such as in an emergency room.

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