Inadvertent User Outcomes of Wearable Health Technology

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ABSTRACT
Wearable health technologies are designed to improve a user's self-awareness of their state of health and increase motivation and physical activity, but there is limited understanding of the psychological and behavioral impact these devices have. The present research attempts to further clarify the influence of individual characteristics on the cognitive, affective, and behavioral outcomes of activity tracker usage, including the development of dependency. A cross-sectional study of 212 college students who used activity trackers was conducted to evaluate the psychological and behavioral impact of activity tracker usage and users' affective response to their device. Participants expressed more positive affect while wearing their device as opposed to when they were unable to wear it. Female participants exhibited more positive affect than male participants while wearing their device but less when unable to wear it. Only 9% of the sample reported a dependency effect. The dependency effect was negatively associated with intrinsic motivation to be physically active, motivation by the idea of success, and the personality traits of agreeableness and conscientiousness. The dependency effect was positively associated with extrinsic motivation for physical activity and tracker usage, as well as need for cognitive closure. This research elucidates the unintended outcomes of activity tracker usage along with the individual characteristics that present as predictors of these outcomes.

KEYWORDS
Health Wearables; Activity Trackers; Physical Activity; Motivation; Dependency; Gamification; Personality

INTRODUCTION

From tracking vital signs to continuous monitoring of blood levels of a specific substrate related to a disease of concern, individuals appear to be aiming to maximize awareness of their body state and enhance their ability to manage their own health.[1] The Apple Watch, Fitbit, Whoop, and other wearable lifestyle devices have taken the world by storm as hundreds of millions of active users across the globe have integrated the technology into their health and fitness regimen.[2]

The present study attempts to clarify the overall impact of health wearable usage on physical activity and subjective well-being through a replication and extension of Ryan et al. (2019) and Attig and Franke (2019).[8,11] These studies suggested user outcomes may be associated with individual traits and that users can develop a dependency on their devices. The present research will investigate whether users experience differing levels of positive affect during use vs. when they are unable to wear their device. The prevalence of physical and emotional dependency on one's device will also be assessed, along with its association with user variables, such as personality traits and sources of motivation.

Use and effects of activity trackers

Wrist-mounted devices, the main focus of the present research, have become one of the most popular forms of biosensors.[1] Physical activity is commonly tracked, including steps taken or distance walked, and an estimate of calories burned throughout the day. Many of these devices are also capable of non-invasively monitoring heart rate and blood pressure, along with glucose and sodium levels through sweat contents.[1] The data tracked can be used to interpret sleep quality, exercise, hydration, nutrition, and whatever other parameters are deemed relevant to the user. Many health wearables are programmed to use this data and, in turn, send both reactive and proactive messages acting as small cognitive punishments or rewards to motivate the user.[3]

While little research has been shown to support the positive impact of these wearable technologies on long-term behavioral change, research has exhibited their ability to act as early detectors of certain diseases by tracking vital signs and their role in providing ill users with valuable information on their current state of health.[4] Li et al. (2017), for example, explored the utility and accuracy of portable biosensors for 43 participants and found that the wearable devices were capable of uncovering early signs of Lyme disease and could differentiate between insulin-sensitive and -resistant people when measuring their blood glucose level.[4] Some research also suggests that health wearables can have a positive psychological impact on ill users. Lynch et al. (2022)

compiled data from three case studies investigating different wearable assistive technologies and discovered a positive association between the usage of these devices and feelings of reassurance. Many users felt comforted by the idea of their device continuously monitoring and validating their state of health.[5]

Researchers have recently begun to take an interest in the motivational impact of the gamification of physical activity via activity trackers.[6, 7] Gamification is defined as "the use of game design elements in non-game contexts," a mechanism used to increase the motivation of users.[6] The data tracked by these devices–distance traveled, steps, heart rate, sleep, etc.--are not innately game-like, but the tracker gamifies this data by presenting the self as quantified, and many devices also incorporate rewards, often intangible in the form of rankings on community leaderboards and competitions among users. A meta-analysis of empirical studies of gamification suggests that it appears to be a viable method to promote motivation, but the outcomes can be influenced by situational and individual factors.[7] Gamification appears to play into a user's extrinsic motivation, and depending on several variables, can enhance or hinder the intrinsic motivation of the user. If the means of gamification contribute to basic psychological needs, such as autonomy and competence, then intrinsic motivation is generally shown to be sustained or increased. Tangible rewards, competitive aspects, and a sense of being controlled by the gamification of the activity appear to work in the opposite manner and can compromise the individual's intrinsic motivation. These effects are moderated, however, by user characteristics and past experiences, such as age, personality traits, and familiarity with games.[7]

Consumers and healthcare professionals must be aware of the holistic influence these technologies have in order to make an informed decision on integrating them into their lives and potential treatment plans. There are conflicting findings on the impact of wearable health technology, specifically regarding its association with motivation, affect, and other psychological and behavioral constructs. Some studies have shown that the devices better the mental and physical health of their users,[5, 8] while others have identified a negative impact of health wearables on mental health, often leading to decreased motivation and life satisfaction.[9, 10] A dependency effect has also been uncovered.[11] Some users appear to become dependent on their activity tracker over time and their engagement in the desired behavior becomes externally motivated (i.e. driven by rewards) by positive feedback from their device. Thus, when a situation arises when the device can no longer be used or the user stops using their device, their activity level often regresses.[11]

One study elucidated the consequences of wearable fitness devices on the well-being of users in a sample of employees from a financial institution in the southern United States.[9] The company had noted high rates of diabetes and heart disease, among other chronic illnesses, within their employee population and began a workplace wellness program that included a free Fitbit for each employee. Participants were interviewed on their reasoning for participation and the extent to which they used Fitbit, and they responded to open-ended questions to express their perceptions of the pros and cons of the device in their daily lives. Results suggested that the implementation of health wearables in a corporate wellness program negatively impacted the job satisfaction and overall well-being of employee participants.[9] A similar study with adolescents in physical education classes was conducted and uncovered a significant decrease in psychological need satisfaction and autonomous motivation as well as short-term increases in motivation due to feelings of competition, guilt, and internal pressure.[10]

Affective response, dependency, and user characteristics

Psychological and physical outcomes of health wearable usage have been shown to be largely dependent on the characteristics of the individual user. Personality traits and sociodemographic identifiers, for example, are two predictors of these outcomes. People who measure high levels of neuroticism, a trait associated with negative emotionality, and low levels of openness, a trait associated with creativity and broad-mindedness, have been shown to be at greater risk of having their mental health negatively affected by a health wearable.[8] The source of motivation (i.e. intrinsic vs extrinsic motivation) to improve or maintain health has been associated with the dependency effect resulting from wearable usage.[11] Skin color can also impact the effectiveness of certain devices, as data recorded for people of darker skin tones has been shown to be less accurate.[12] Finally, socioeconomic status (SES) can play a role in how these devices impact behavioral changes, with people of higher SES experiencing a more substantial increase in physical activity upon usage,[13] further exacerbating already apparent health disparities.

Two recent studies have examined the cognitive and behavioral impact of health wearables and the possible development of dependency. Ryan et al. (2019) examined the affective response to health wearable usage and how it can potentially be explained by individual characteristics and personality traits.[8] This study sampled Australian residents above the age of 18 years old who were current users of "smart" wearable activity monitors. The participants completed a questionnaire that consisted of socio-demographic questions asking for the participant's sex, age, and education level along with the approximate frequency with which they checked the data tracked by their device. Participants' affective responses relating to their wearable technology were measured, specifically describing their affect while wearing their device and when they were unable to wear their device. The participants' Big Five personality traits (i.e. extraversion, agreeableness, conscientiousness, neuroticism, and openness to experience) were also assessed to see if individual differences in personality moderate any effect of wearing condition (i.e. during use vs. when unable to wear) on affective response. Results suggested that wearable activity trackers can have a positive

psychological influence on their users' psychological state, specifically regarding motivation and sense of accountability. Participants with low degrees of conscientiousness or openness to experience, however, were more prone to an increase in negative affect, including feelings of anxiety, guilt, and self-consciousness.[8] This study's findings appear to endorse the use of activity trackers but note personality traits may play a role in how positive or negative a certain individual's experience with them will be.

Attig and Franke (2019) examined the possible dependency effect associated with tracker usage.[11] On average, users expressed that their physical activity would decrease if they did not have their wearable device on them or if they were unable to use it to track their activity for whatever reason. Not all users, however, encountered this dependency effect to the same degree. People who exercised and used their activity trackers due to extrinsic motivation, such as for external rewards, and those who felt a stronger need for cognitive closure were more susceptible to experiencing a strong dependency effect and would more likely reduce their activity levels if they were not being tracked. Conversely, people who exercised for more intrinsic reasons of motivation, such as inherent enjoyment of the activity, were more likely to avoid acquiring a dependency or would exhibit it to a lesser extent.[11] These findings put into question the habit-forming capabilities of health wearables.

The Present Research

Fitness- and health-focused wearables are designed to support their users in reaching their health goals, but their holistic impact on individual well-being and the future of healthcare disparities is overlooked. As recent research has suggested the possibility that health wearables can have a negative inadvertent impact on individual outcomes,[9, 10, 12] people must be more aware of their consumption. A greater understanding of the effects of these devices is necessary for current and prospective users to make informed decisions on integrating them into their daily practice. The current literature on health wearables mostly focuses on the basic relationship between health wearable usage and users' mental responses without providing substantial evidence describing how other variables may explain the differing impacts of the devices on users' mental states. More evidence is needed to clarify why certain people have more or less positive relationships with their wearable health devices, and what individual characteristics present as risk factors for experiencing these negative outcomes.

Thus, the aim of the present research is to further the understanding of how health wearables impact a user's psychological state as well as how certain individual characteristics may impact psychological and behavioral outcomes. This study will replicate portions of both Ryan et al. (2019) and Attig and Franke (2019) to further investigate the dependency effect and the cognitive and behavioral impact of health wearables, as well as clarify specific personality traits and other individual characteristics that may act as risk or protective factors for their usage.[8, 11] Specifically, this study will assess Q1) whether users' affective response to their activity tracker differs when measured during use vs. when unable to wear it; Q2) how many participants exhibit a dependency effect relating to their activity tracker; Q3) what user variables are associated with dependency; and Q4) how relative intrinsic and extrinsic motivation for both physical activity and tracker usage is associated with dependency.

I expect to find evidence of both beneficial and detrimental effects of health wearables on motivation, physical activity levels, and well-being. I also expect to find that certain user characteristics–personality traits, source of motivation, and need for cognitive closure–moderate these effects as well as the degree of dependency experienced. See **Table 1** for more specific research questions and hypotheses. These expectations are grounded in the past empirical findings reviewed above, as well as an understanding of the mechanisms underlying how tracker devices work to motivate their users.

	Research Question	Hypothesis	
Q1	Do users' affective responses to their activity tracker differ during and when unable to wear it? Are there gender differences?	**H1a**	Participants will exhibit greater positive affect while wearing their activity tracker than when unable to wear it
		H1b	There will be no gender differences in the affective response to their activity tracker
Q2	How many participants exhibit a dependency effect relating to their activity tracker?	**H2a**	The majority of participants will not exhibit a dependency effect
Q3	What user variables are associated with dependency?	**H3a**	Positive affect when unable to wear a tracker is negatively associated with the dependency effect

		H3b	Intrinsic motivation for tracker usage is negatively associated with the dependency effect
		H3c	Extrinsic motivation for tracker usage is positively associated with the dependency effect
		H3d	Intrinsic motivation for physical activity is negatively associated with the dependency effect.
		H3e	Extrinsic motivation for physical activity is positively associated with the dependency effect.
		H3f	Need for cognitive closure is positively associated with the dependency effect.
		H3g	Achievement motivation through fear of failure is positively associated with the dependency effect
		H3h	Neuroticism is positively associated with the dependency effect
Q4	How are relative intrinsic and extrinsic motivation for both physical activity and tracker usage associated with dependency?	**H4a**	Participants who are more extrinsically than intrinsically motivated to use the tracker will exhibit a greater dependency effect than participants who are more intrinsically motivated to use the tracker.
		H4b	Participants who are more extrinsically than intrinsically motivated to be physically active will exhibit a greater dependency effect than participants who are more intrinsically motivated to be physically active.

Table 1. Research questions and hypotheses of the present study.

METHODS AND PROCEDURES

Participants

Study participants were recruited from Colby College, a small liberal arts college in Waterville, Maine. A study questionnaire was approved by the school's Institutional Review Board (IRB; 2023-001). An all-school email was sent to students with a link to the survey included, and they were each compensated $2 upon completion of the survey. Two hundred and twelve students responded and were included in the analysis. The participants ranged from 18 to 23 years old (M = 19.74, SD = 1.28) with the majority being female (n=144; 67.6%), 29.6% male (n=62), and 2.82% non-binary (n=6). Similar to the makeup of the Colby College student population, most participants described themselves as White or Caucasian (71.8%), with Asian (17.8%) being the next most common racial or ethnic identity.

Of the 212 study participants, 71.8% had been using an activity tracker for at least 12 months (M = 30.36, SD = 26.32) and 69.0% reported using their tracker 7 days per week during a typical week (M = 6.34, SD = 1.21). One hundred and forty-four participants (68.0%) reported using their device between 12 and 23 hours and 18.8% wore it for all 24 hours in a typical day (M = 16.62, SD = 5.52). The most popular brand of activity tracker among participants was Apple (66.7%), then Garmin (11.3%), Fitbit (8.9%), and Whoop (7.0%), with the remaining 6.1% using activity trackers from other brands (e.g. Amazon, Samsung). Participants also described the specific data that they regularly track and monitor: heart rate (82.2%), step count (77.0%), active minutes (71.4%), distance traveled (69.5%), type and amount of sporting activities/exercise (68.1%), sleep activity (49.3%), stairs (35.25%), and calories consumed/burned (30.5%).

Measures

The participants' affective responses to their health wearables were assessed according to a ten-item scale constructed by Ryan et al. (2019).[8] This measure is based on the Positive and Negative Affect Schedule[14] but narrows its focus to affect in relation to wearable usage. A total of ten items split into two subscales asked the participants to state their degree of agreement to experiencing a specific affect or emotion during a designated time frame. Six items evaluated the user's affect while wearing their device: "When I am using my wearable it makes me feel [empowered, motivated, accountable, guilty, self-conscious, anxious]." Four items focused on the users' affect when not wearing their device: "When I'm not using/forget/can't use my wearable it

makes me feel [liberated, guilty, frustrated, anxious]." Responses were recorded using a 5-point Likert scale ranging from 1 (*disagree strongly*) to 5 (*agree strongly*). All scores describing the users' agreement to feeling negative affect, like guilt and anxiety, were reverse coded. The scores for each subscale were averaged, with higher scores exhibiting a more positive affective state. Internal consistency was modest for both the "affect during wear" subscale (Cronbach's $\alpha = .55$) and "affect when unable to wear" subscale (Cronbach's $\alpha = .44$). However, all items exhibited positive corrected item-total correlations (mean $r = .30$) and were therefore retained for analysis.

The dependency effect caused by wearable usage was assessed using two novel measures constructed by Attig and Franke (2019).[11] The first outlines four situations that wearable users may or may not have experienced which could produce a reduction in physical activity due to the absence of the device on their person. For example, one scenario describes the participant arriving at work/university needing to go to the fourth floor, but they forgot their tracker at home. Another involves the participant's activity tracker being broken, and that it will take five days to fix it. As explained by Attig and Franke (2019), these scenarios were developed based on experimental observations of the undermining effect: losing motivation upon the removal of the external reward.[15, 16] Participants were asked to envision themselves in each of the four scenarios or remember how they responded to the same or a similar scenario if they had previously experienced it. Participants then stated their agreement to two alternative statements regarding their theoretical behavioral reaction to each scenario in order to measure their degree of activity continuity ("I will very likely maintain my activity level as if the tracker was available") or reduction ("I will very likely reduce my activity level"). Answers were provided on a 6-point Likert scale ranging from 1 (*completely disagree*) to 6 (*completely agree*). The statement describing activity continuity was reverse coded and the mean of the two scores for the statements for each scenario was calculated with higher scores depicting a greater dependency effect. Following the methods of Attig and Franke (2019), a score greater than 3.5, the midpoint on the scale, was interpreted as indicating some degree of dependency.[11] Internal consistency was acceptable for this scale (Cronbach's $\alpha = .79$) and all items showed positive corrected item-total correlations (mean $r = .48$).

The second measure took the form of a 13-item questionnaire that assessed the dependency effect through five dimensions: shift to external attribution (i.e. becoming more externally motivated), behavioral outcomes of not wearing the tracker (i.e. experiencing a maintenance or reduction in activity levels), activity evaluation (i.e. perceiving activity as more valuable when it is measured by a tracker), affective outcomes of intrinsic motivation loss (i.e. only feeling successful when the tracker validates adequate activity levels), and cognitive occupancy (i.e. thinking about the tracker). Answers were provided on 6-point Likert scales ranging from 1 (completely disagree) to 6 (completely agree) with higher scores representing a stronger dependency effect. As mentioned previously, a score greater than 3.5 indicated some degree of dependency.[11] Internal consistency for this scale was good (Cronbach's $\alpha = .89$).

A measure constructed by Attig and Franke (2019) based on self-determination theory was used to assess motivation for tracker usage.[11] The 6-item measure was composed of two subscales, in which the first three items appraised intrinsic motivation to use their wearable device (e.g. "I use my activity tracker because I want to learn more about my physical activity"), and the following three appraised extrinsic motivation to use their device (e.g. "I use my activity tracker because reaching my step or activity goals encourages me"). Answers were provided on a 6-point Likert scale ranging from 1 (*completely disagree*) to 6 (*completely agree*). Internal consistency was good for intrinsic motivation (Cronbach's $\alpha = .82$) and acceptable for extrinsic motivation for tracker usage (Cronbach's $\alpha = .71$).

To more explicitly describe each participant's reason for using their device, participants were able to express whether they primarily use their tracker for enjoyment ("In case of doubt, my slogan is 'The fun I have through using my tracker comes before the gain!'") or for health benefits ("In case of doubt, my slogan is 'The gain I have through using my tracker comes before the fun!'") through two additional items taken and modified from the Incentive-Focus Scale.[11, 17] Participants provided their answers on a 6-point Likert scale ranging from 1 (*completely disagree*) to 6 (*completely agree*). The second of these two additional items was reverse coded and the mean of these two scores was calculated with higher scores denoting using the tracker more for reasons of enjoyment. The correlation between these two items was $r = .35$, yielding Cronbach's α of .51.

A measure developed by Attig and Franke (2019)[11] based on the Situational Motivation Scale[18] assessed the users' motivation for physical activity. The 8-item scale was composed of two subscales with the first four items measuring intrinsic motivation for physical activity (e.g. "I am physically active/exercise because this activity is fun") and the next four items measuring extrinsic motivation (e.g. "I am physically active/exercise because I feel that I have to do it"). Answers were provided on a 6-point Likert scale ranging from 1 (completely disagree) to 6 (completely agree). Similar to Attig and Franke (2019), the participants were asked to respond to the items thinking of their motivation for physical activity before they first started using their wearable device. Internal consistency was excellent for intrinsic motivation (Cronbach's $\alpha = .90$) and good for explicit motivation for physical activity (Cronbach's $\alpha = .83$).

The 15-item need for closure scale (NFCS) short version was used to measure the degree to which a person has the desire for certainty.[19, 20] An example item is "I dislike it when a person's statement could mean many different things." Answers were provided on a 6-point Likert scale from 1 (*completely disagree*) to 6 (*completely agree*). Internal consistency was good (Cronbach's α = .87).

The users' affinity for technology was assessed using the 9-item ATI scale given on a 6-point Likert scale from 1 (*completely disagree*) to 6 (*completely agree*).[21] An example item is "I try to make full use of the capabilities of a technical system." Internal consistency was good (Cronbach's α = .81).

Achievement motivation was measured with an adapted version of the 10-item Achievement Motives Scale (AMS-R).[22] This measure is composed of two subscales scored on a 5-point Likert scale ranging from 1 (*completely disagree*) to 5 (*completely agree*) with the first five items measuring hope of success (approach tendency, e.g. " I like situations in which I can find out how capable I am") and the next five measuring fear of failure (avoidance tendency, e.g. "I feel uneasy to do something if I am not sure of succeeding"). Internal consistency was good (Cronbach's α = .81).

The Big Five personality traits (openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism) were evaluated using the 10-item BFI-10 measure.[23] Answers were provided on a 5-point Likert scale ranging from 1 (completely disagree) to 5 (completely agree). The inter-item correlations were .33 for openness, .34 for conscientiousness, .46 for extraversion, .18 for agreeableness, and .48 for neuroticism, yielding Cronbach's α values ranging from .31 to .64. Despite these relatively low internal consistency values, which reflect the brevity of the BFI-10, previous research has shown that this instrument shows high test-retest reliability and large associations with more comprehensive Big Five measures.[23]

Data analysis

Several steps were taken to replicate the data analysis conducted by Ryan et al. (2019) and Attig and Franke (2019).[8, 11] Data from survey responses were downloaded and analyzed using IBM SPSS Statistics (Version 27), and all variables were screened for outliers. The responses of one participant were identified as an outlier as the responses provided were the minimum value for all items, and it was excluded from data analysis. After examining the distribution of participant demographic characteristics, Pearson correlations between all variables included in the questionnaire were calculated in order to clarify which user variables were associated with the dependency effect. For all analyses, statistical significance is interpreted using the conventional $p < .05$ criterion. However, due to the large number of associations examined, exact p-values are also provided to indicate whether the key results would also be significant under more stringent criteria (e.g., $p < .01$, $p < .001$).

Next, independent t-tests were conducted to test mean differences between participants' affect scores in the two wearing conditions (wearing and not wearing), as well as between affect scores and participant gender. A repeated measures ANOVA was then conducted to analyze the joint effects of gender and wearing condition on affect.

Next, a one-sample t-test was conducted for each of the three dependency scales–including the calculated composite score–to determine the degree of the dependency effect observed in the sample. Following Attig and Franke (2019),[11] difference values between intrinsic and extrinsic motivation for both physical activity and tracker usage were first calculated in order to determine how relative intrinsic and extrinsic motivation is associated with dependency. Individuals who did not differ in their scores of intrinsic and extrinsic motivation for physical activity or tracker usage were excluded from the respective analyses. After being grouped, independent t-tests were performed to investigate differences in the dependency effect between them. Following this, an independent samples t-test was conducted to investigate a possible gender difference in the dependency effect.

RESULTS

Q1: Affective response to their activity tracker differs by wearing or not wearing

In order to investigate whether users' affective response to their activity differs during vs. when unable to wear their tracker, an independent samples t-test compared positive affect scores between wearing conditions. Participants exhibited significantly greater positive affect during wear ($M = 3.77$, $SD = .57$) than when unable to wear their device ($M = 3.17$, $SD = .74$), $F(1, 211) = 90.89$, $p<.001$, thus aligning with previous research.[8] Independent samples t-tests were then conducted to investigate the relationship between gender and affect during each wearing condition. Female participants ($M = 3.84$, $SD = .54$) showed significantly greater positive affect while wearing their activity tracker than males ($M = 3.65$, $SD = .63$), $F(1, 204) = 4.74$, $p = .031$. Interestingly, the opposite gender difference was observed when unable to wear their device. In these conditions, males ($M = 3.43$, $SD = 0.58$) showed significantly greater positive affect than females ($M = 3.07$, $SD = 0.78$), $F(1, 204) = 10.15$, $p = .002$. This result led me to conduct an exploratory analysis via a repeated measures ANOVA, which showed there was a significant interaction between gender and positive affect during wearing conditions, $F(1, 204) = 15.63$, $p < .001$ (**Figure 1**). These results indicate that females experience more positive affect than males while wearing their device but less positive affect than males

when they are unable to wear their device. This finding goes beyond previous studies, as no gender differences in affect during different wearing conditions nor an interaction between gender and wearing conditions have been found previously.

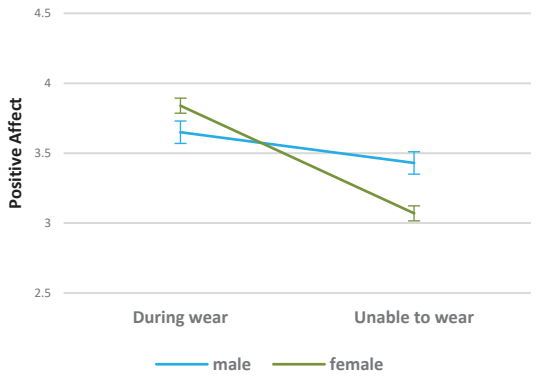

Figure 1. Line graph depicting a *gender* x *wearing conditions* interaction via a repeated measures ANOVA including error bars denoting standard error. *Note.* Participants who did not identify as male or female were not included in this analysis due to the small sample size.

Q2 : Dependency effect of activity tracker

In order to investigate whether participants exhibit a dependency effect relating to their activity tracker, one-sample t-tests were conducted comparing the mean scores of each dependency effect scale to the center of the response scale, 3.5. Regarding the scenario scale for the dependency effect, the mean score was M = 2.30 (SD = 0.86) and was significantly less than the center of the response scale at 3.5, t (211) = -20.38, p < .001, d = 0.86. This result shows that participants tended to choose the more active option in each scenario (e.g. "I will very likely maintain my activity level as if the tracker was available"). Regarding the questionnaire scale for the dependency effect, the mean score was M = 2.57 (SD = 0.93) and was significantly less than 3.5, t (211) = -14.61, p < .001, d = 0.93. This result similarly suggests that participants generally did not feel dependent on their device. The composite dependency score incorporating both the scenario and questionnaire scales found a mean score of M=2.43 (SD=0.78) and was significantly less than 3.5, t (211) = -19.89, p < .001, d = 0.78. Only 9% of participants scored above 3.5 (**Figure 2**). Following Attig and Franke (2019), we interpret a dependency score greater than 3.5 as exhibiting dependency on their device. These results suggest that most participants do not experience such an effect, but there is a notable number of participants who do exhibit dependency. These results align with past research.[11]

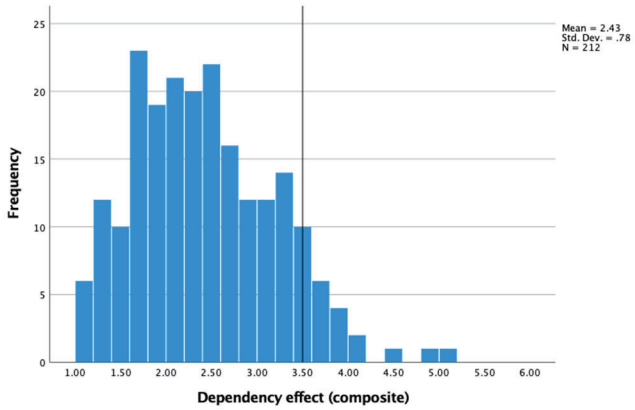

Figure 2. Histogram depicting frequency distribution of composite dependency effect scores with a vertical line denoting the center of the response scale

Due to the observed interaction between gender and wearing condition concerning affect scores noted above, an exploratory analysis was conducted in order to further investigate possible gender differences in dependency. While female participants (n = 144) had slightly higher composite dependency effect scores (M = 2.47, SD 0.79) than male participants (n = 62, M = 2.33, SD = 0.73), this gender difference was not significant, t (204) = 1.17, p = .245. According to the composite dependency effect scores, these results indicate that males and females experience a similar degree of dependency on their activity trackers.

Q3: User Variables Associated with Dependency

In order to investigate which user variables were associated with dependency, correlations were calculated and presented in a correlation matrix (**Table 3**). Many significant relationships were found, thus aligning with previous research suggesting users with

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
(1)	Positive affect during wear																		
(2)	Positive affect when unable to wear	.03																	
(3)	Dependency effect - Scenarios	-.15*	-.31***																
(4)	Dependency effect - Questionnaire	-.19**	-.44***	.53***															
(5)	Dependency effect - Composite	-.20**	-.43***	.86***	.88***														
(6)	Intrinsic motivation for tracker usage	.23***	-.15*	-.07	.02	.03													
(7)	Extrinsic motivation for tracker usage	.09	-.30***	.26***	.42***	.39***	.39***												
(8)	Incentive focus regarding tracker usage	-.04	-.18**	.18**	.33***	.30***	.03	.34***											
(9)	Intrinsic motivation for physical activity	.13	.05	-.32***	-.22**	-.31***	.36***	.05	-.07										
(10)	Extrinsic motivation for physical activity	-.17*	-.25***	.06	.24***	.18**	.10	.23***	.22**	-.05									
(11)	Need for cognitive closure	-.06	-.16*	.23***	.32***	.32***	.15*	.23***	.16*	-.07	.22**								
(12)	Affinity for technology interaction	-.09	-.09	.05	.10	.09	.18**	.09	.12	-.08	.12	.06							
(13)	Achievement motivation – hope of success	.09	-.03	-.20**	-.12	-.19**	.44***	.14*	-.11	.36***	.20**	.06	.15*						
(14)	Achievement motivation – fear of failure	-.08	-.18**	.18**	.31***	.28***	.11	.26***	.13	.01	.26***	.62***	-.01	.03					
(15)	Extraversion	.06	-.05	-.06	.01	.03	-.10	-.04	.01	.12	.08	-.27***	-.05	.16*	-.32***				
(16)	Agreeableness	.07	.06	-.21**	-.14*	-.20**	.01	-.05	.04	.19**	-.16*	-.14*	.04	.06	-.09	.10			
(17)	Conscientiousness	.13	-.01	-.19**	-.11	-.17*	.17*	-.02	-.23***	.31***	-.13	.03	-.06	.35***	-.03	.07	-.03		
(18)	Neuroticism	.10	-.17*	.08	.23***	.18**	-.09	.14	.01	-.01	.21**	.42***	-.07	-.08	.52***	-.21**	-.18**	-.07	
(19)	Openness	.08	-.02	-.12	.07	-.03	-.01	.01	.08	.09	-.02	.04	-.15*	.08	.07	.04	.00	.09	.06

Table 3. Pearson correlation coefficients for all variables. *Note*. * p < .05; ** p < .01; *** p < .001; all p-values refer to two-sided significance

certain characteristics tend to also depict greater levels of dependency. For example, significant correlations were found between dependency and multiple personality traits. The correlations between composite dependency effect scores and agreeableness, conscientiousness, and neuroticism were r = -.20, r = -.17, and r = .18, respectively. Several other user variables, especially those that describe sources of motivation, were found to have significant correlations with the composite dependency score. The strongest of the correlations include but are not limited to extrinsic motivation for tracker usage (r = .39), need for cognitive closure (r = .32), intrinsic motivation for physical activity (r = -.31), and fear of failure (r = .28). These results suggest that user characteristics are associated with differing degrees of dependency. Specifically, individuals who are disagreeable, unconscientious, prone to negative emotions, intolerant of uncertainty and ambiguity, and motivated by extrinsic factors and a fear of failure are most likely to become emotionally dependent on their activity trackers.

Q4: Relative Intrinsic and Extrinsic Motivation for physical and tracker usage associated with dependency

Participants were split into groups depending on their relative degrees of intrinsic and extrinsic motivation for physical activity and tracker usage, thus following the methods of Attig and Franke (2019).[11] Descriptive statistics of all four possible groups are depicted in **Table 4**. An independent samples t-test found that participants with greater extrinsic than intrinsic motivation for physical activity (n = 52) felt a greater dependency effect (M = 2.81, SD = 0.87) than those with greater intrinsic motivation for physical activity (n = 140, M = 2.27, SD = 0.68), t (190) = 4.53, p < .001. The difference represented a medium-to-large effect size (d = 0.74). Similarly, participants with greater extrinsic than intrinsic motivation for tracker usage (n = 40) felt a greater dependency effect (M = 2.87, SD = 0.75) than those with greater intrinsic motivation for tracker usage (n = 146, M = 2.27, SD = 0.71), t (184) = 4.72, p < .001. The difference represented a medium-to-large effect size (d = 0.72). A two-way ANOVA was conducted to shed light on any possible interaction effect involving groupings determined by relative levels of intrinsic and extrinsic motivation for both physical activity and tracker usage, but no interaction was found, F (1) = 0.047, p = 0.829. Aligning with previous research, these results indicate that when extrinsic motivation is greater than intrinsic motivation for physical activity or tracker usage, the user is likely to experience a greater degree of dependency on their device.[11]

Group	n	M	SD
1. Extrinsic physical activity & extrinsic tracker usage	16	3.01	0.82
2. Intrinsic physical activity & extrinsic tracker usage	22	2.66	0.66
3. Extrinsic Physical activity & intrinsic tracker usage	29	2.63	0.87
4. Intrinsic physical activity & intrinsic tracker usage	105	2.17	0.64

Table 4. Means and standard deviations of the composite dependency effect for the four groups composed of possible combinations of relative extrinsic and intrinsic motivation for physical activity and tracker usage. (n= 172). *Note.* To directly replicate the analyses conducted by Attig and Franke (2019), n = 40 users were excluded because there was no difference in their scores for extrinsic and intrinsic motivation for physical activity and/or tracker usage. However, we note that this exclusion criterion may affect some results. Intrinsic = intrinsic > extrinsic; extrinsic = intrinsic < extrinsic.

DISCUSSION

Summary of results

The present study aimed to further clarify the influence of certain individual characteristics on the cognitive, affective, and behavioral outcomes of activity tracker usage. Participants expressed that they had more positive affect while wearing their device as opposed to when they were unable to wear it, thus aligning with past findings.[8] A gender difference was also found, as female participants exhibited more positive affect than male participants while wearing their device but less when unable to wear their device, suggesting greater affective dependency among women. While participants generally exhibited no decline in physical activity when they were unable to use their device, a portion of the sample did. Specifically, this decline in physical activity when the device is not on their person appears to be more salient when people use their device for external goals or rewards as motivation for physical activity, have a large need for closure, are motivated by a fear of failure, and are neurotic. Conversely, dependency appears to be less of a problem for individuals who are innately motivated to be physically active, are motivated by the idea of success, and are agreeable and conscientious. These findings align with past research in suggesting that the dependency effect does not manifest universally and that only some people experience decreases in motivation and physical activity when not wearing their activity tracker.[11]

Implications

The present study enhances our understanding of how an individual's behavior and psychological state can be influenced by the usage of an activity tracker. While these devices are designed to increase motivation, comfortability, and confidence in reaching health goals, a portion of users experience negative affect (i.e. anxiety, guilt, and self-consciousness) and experience a regression in their physical activity in response to the absence of their device. These findings urge consumers to better understand their relationship with their activity trackers to ensure that usage is not detrimental to their overall mental or physical health.

Beginning with the positive psychological effects of activity tracker usage, the present study supports past findings that many users associate a sense of comfort with their device. Similar to Lynch et al. (2022) who examined the role of multiple types of wearable health technology and ultimately discovered an association between wearing the device and feelings of reassurance, study participants generally felt greater positive affect (i.e. empowered, motivated) while wearing their device in comparison to when they were not able to.[5] Activity trackers thus appear to serve an important role in supporting the affective needs of the user.

However, while many people feel a sense of comfort by having their activity tracker on person, the present study confirms the finding that users' psychological states can be negatively impacted when they are not wearing their tracker.[8] Specifically, the finding that people with a high degree of neuroticism are more likely to exhibit less positive affect when unable to wear their tracker was replicated. Among other user variables, greater extrinsic motivation for both tracker usage and physical activity was found to be associated with less positive affect when unable to wear their device. Furthermore, personality traits, including low agreeableness, low conscientiousness, and high neuroticism, along with extrinsic rather than intrinsic motivation, predicted relative participant dependency on their device. These correlations imply that psychological characteristics can predict how positive or negative the health wearable user experience will be, at least in terms of affective response and development of dependency. Practically, these results raise the question: should people with certain psychological characteristics use activity trackers if these characteristics are deemed risk factors for an unhealthier user-tracker relationship?

One notable novel finding in the present study is a gender difference in the affective response to wearable health technology. Female participants were found to feel greater levels of positive affect than male participants while wearing their activity tracker, but they felt less positive affect than male participants when unable to wear their tracker. These results go beyond past findings,[11] as no gender differences in the affective response to health wearables have been previously published, and they may suggest greater affective dependency among women. This interaction may be explained by the difference in how men and women tend to value feedback. Women have been shown to perceive informational feedback on achievement as more telling of their accomplishments or abilities than men.[24] Men thus depend more on their own self-perceptions than informative feedback and are less likely to feel a large affective difference based on the presence or absence of a device providing them with such feedback. This gender difference may explain why female participants exhibited a greater difference in affect scores between wearing conditions when compared to male participants.

The effects of gamification can be seen in the results associating sources of motivation with the dependency effect. Individuals motivated to exercise or use their activity tracker by external rewards (i.e. extrinsic motivation) were shown to experience a greater dependency effect than those who are more motivated by inherent enjoyment or desire (i.e. intrinsic motivation). Past research suggests that gamification takes advantage of a user's extrinsic motivation, and depending on other individual characteristics, can hinder the intrinsic motivation of the user.[7] Thus, the integration of an activity tracker can exacerbate the extrinsic motivation of the user and diminish their intrinsic motivation. Upon the loss of the device or when the device cannot be worn, the user's intrinsic motivation has already been reduced and the extrinsic motivation provided by the feedback of the activity tracker is no longer in play, ultimately resulting in the manifestation of the dependency effect.

Limitations and Future Research

The present study had some notable strengths, including its sample size, breadth of variables measured, and its ability to be compared with previous studies. However, there remain several important limitations to our understanding of the role of individual characteristics on the behavioral, cognitive, and affective outcomes of health wearable usage.

Does the current literature suggest individuals become overly dependent on their wearable health devices? Or do the research methods used leave this up to question? The present study and Ryan et al.'s cross-sectional approaches analyzed users' affect during wear and when unable to wear their devices which allowed us to determine which personality traits and socio-demographic identifiers were associated with the affective response of the user to their device; nonetheless, they were not able to compare individuals' affective experiences before vs. after integrating their device into their lifestyle. Users were shown to have more positive affect during wear as opposed to when unable to wear their device. Does this tell us the devices have positive psychological effects? Or is it possible that the users have developed an unhealthy dependence on their devices, in which they rely on their devices to alleviate their health anxiety? Or could their more positive affect while wearing their device be connected to their anticipation of the gratification associated with reaching their activity goals? Furthermore, without comparing their affect

scores to those of a true control group or pretest, it is impossible to discern if their measured positive affect is greater than the affect of individuals who do not use activity trackers. While Ryan et al. (2019) did compare the affective experiences of current device users vs. previous users,[8] the previous users' lower affect scores during wear may have contributed to their decision to stop wearing their devices. Other studies, such as Giddens et al. (2019) and Kerner and Goodyear (2017) studied the impact of health wearables on the users' psychological states over time. These longitudinal studies found that health wearables i) negatively impacted the job satisfaction and overall employee well-being of employees participating in a workplace wellness program[9] and ii) decreased levels of psychological need satisfaction and autonomous motivation and increased short-term motivation due to feelings of competition, guilt, and internal pressure in adolescents in physical education classes.[10]

The results of the present study suggest that activity trackers induce some positive psychological response, but we cannot know this for sure without taking a longitudinal approach or comparing them to a true control group. The longitudinal approach could tell us much more about the psychological power of a health wearable over time. The difference between initial and subsequent levels of mental health would thus be able to be compared, using the initial measurements as controls. The present study utilizes a cross-sectional study design due to time and funding constraints, and thus cannot paint the entire picture. A longitudinal multivariate design involving the periodic administration of the measures used in the present study would better clarify the long-term and gradual development of dependency and change in affect due to health wearable usage.

Another limitation of the study is the general lack of diversity among the sample. Though relatively representative of the Colby College student population, the sample was not very diverse and its cross-cultural replicability is questionable. Furthermore, the sample is largely composed of female participants, with male participants comprising under a third of the sample. This discrepancy may have contributed to the gender difference in affective response to activity trackers found in the present study. Future research involving a larger and more diverse sample would better clarify replicable relationships concerning the affective response to activity trackers and dependency. This would also provide the researchers with a better opportunity to uncover any possible racial, ethnic, or cultural differences in dependency.

CONCLUSIONS

Activity trackers have been successfully designed to promote physical activity for most people, but some users have a negative relationship with their device. The present findings show that individual variables, such as personality traits and sources of motivation, contribute to the disparate efficacy of health wearables and the degree of dependency users are at risk of developing. This research elucidates the unintended consequences of activity trackers and predictors of these outcomes.

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PRESS SUMMARY

The present research attempted to clarify the relationship between individual characteristics, such as personality and sources of motivation, on the cognitive, affective, and behavioral outcomes of activity tracker usage, including the development of dependency. Participants expressed more positive affect while wearing their device as opposed to when they were unable. Female participants exhibited more positive affect than male participants while wearing their device but less when unable to wear their device. Only 9% of the sample exhibited a dependency effect. People who were more intrinsically motivated to be physically active, more motivated by the idea of success, more agreeable and conscientious, less extrinsically motivated for physical activity and tracker usage, and had less of a need for cognitive closure were less likely to be dependent on their device.