I Track, Therefore I Walk – Exploring the Motivational Costs of Wearing Activity Trackers in Actual Users

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ABSTRACT

Personal quantification is one fundamental mechanism of gamification. Activity trackers constitute a prototypic case for studying the psychological dynamics of this mechanism. Despite their high potential to increase physical activity, health and well-being, the effects of trackers on users' motivation to be physically active have yet rarely been explored. The present research examines the notion that quantified feedback of gamified systems can create a dependency that can harm motivation, which becomes apparent through activity reduction when the tracker is not available. To generalize findings from experimental studies to a naturalistic setting, we examined motivational effects of activity trackers in 210 actual users through a scenario- and questionnaire-based survey. Moreover, facets of user diversity (i.e., need for cognitive closure, affinity for technology interaction, achievement motivation, and the Big Five personality traits) were taken into account. Results indicated that a decrease of motivation for physical activity in situations when the tracker is not available plays a role in everyday usage. This dependency effect was stronger for participants with high extrinsic motivation for physical activity and tracker usage, high need for cognitive closure, and low hope of success. In contrast, high intrinsic motivation for physical activity was related to a less strong dependency effect.

Keywords: activity tracking, wearables, quantified self, personal quantification, self-determination theory, gamification

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1 INTRODUCTION

Wearable activity trackers are promoted as a promising tool to nudge behavioral change. Indeed, activity trackers have been found to increase physical activity (i.e., number of steps and stairs; Coughlin and Stewart, 2016; Randriambelonoro et al., 2017) and well-being (Etkin 2016; Giddens et al., 2017), fight obesity (Cheatham et al., 2017; Coughlin and Stewart, 2016; Wilson et al., 2017) and, thus, may help to support e.g. cardiovascular disease prevention (Franklin and Pratt, 2016; Hickey and Freedson, 2016). At the same time, it is assumed that continuous usage of habit formation tools is necessary for lasting behavioral change (Renfree et al., 2016). Activity trackers can help to form activity habits by providing external rewards (e.g., quantified feedback) when activity goals are met. Whereas these rewards might boost motivation to be physically active in the early stages of usage, they might create a dependency over time, and users might experience a kind of reattribution of the reason to be physically active: They might be active to get positive feedback from the tracker, instead of being active for their own health. Subsequently, if external circumstances (e.g., tracker unavailable) impede continuous tracker usage, external rewards for activity behavior are absent, users' motivation for physical activity might decrease, and, consequently, users might be less active. In short: Disrupted tracker usage might lead to disengaging from activity behavior (for a similar argument see Duus et al., 2017). Consequently, understanding the interaction between activity tracker usage and users' motivation for physical activity behavior is of central importance for fostering the beneficial effects of lasting activity tracker usage. However, despite their high popularity – over 100 million activity trackers were sold worldwide in 2016 (IDC, 2017) – research regarding effects of trackers on users' motivation to be physically active is still in a relatively early stage.

Viewed from the overarching perspective of gamification (i.e., the application of game design elements to a non-game context; Deterding et al., 2011), activity trackers can be viewed as a prototypical example for a gamified application. Activity trackers quantify and visualize physical behavior (e.g., by counting and displaying steps and burned calories). In addition, some manufacturers offer smartphone applications with leaderboards, awards, and the possibility to arrange competitions among interconnected users. Gamification research suggests that using such gamified elements holds the potential to increase motivation (e.g., learners' motivation in educational settings; Buckley and Doyle, 2014; van Roy & Zaman, 2017). However, it has repeatedly been noted that gamification can also harm motivation (e.g., Groh, 2012; Hamari et al., 2014). Classic experiments have shown that external rewards may corrupt intrinsic motivation for a certain task, which becomes observable when the external reward is no longer granted (Deci, 1971; Lepper, et al., 1973). Scholars assume that this principle has to be kept in mind when designing gamified applications (e.g., Kim, 2015). However, empirical studies that aim to test this assumption in the field of gamification are relatively sparse (Richter et al., 2015). Hence, understanding the dependency effect of activity trackers is key to advance knowledge of motivational effects of gamified systems in general, to prevent tracker abandonment, and to support lasting behavioral change.

The objective of the present research was to advance knowledge on the relation of one essential element of gamification, personal quantification, to users' motivation for physical activity. We argue that activity trackers might elicit a dependency effect, resulting in increased cognitive occupancy by tracker-related thoughts, devaluation of not or not correctly tracked activities, and decreased motivation for physical activity that manifests on a behavioral and affective level in situations when the tracker is not at hand. Theoretically grounded on self-determination theory (Deci and Ryan, 1985b) and related findings regarding the undermining effect of external rewards on intrinsic motivation (Deci, 1971), we aimed at developing assessment methods and empirically testing this dependency effect in a naturalistic setting.

Whereas classic studies (e.g., Lepper et al., 1973) and recent first studies on personal quantification (e.g., Etkin, 2016) regarding motivational costs of external rewards apply experimental approaches, we complement this research by focusing on everyday interaction with activity trackers. Such a field-study approach is essential to estimate the generalizability of findings from controlled experiments to everyday usage. However, because of lower controllability of influencing variables, studying motivational effects in an everyday usage setting based on behavioral indicators of motivational strength is challenging. Thus, we invested considerable effort in deriving a methodological approach to allow deducing first conclusions regarding motivational costs of activity trackers in a sample of actual users. Moreover, to understand the dependency effect comprehensively, we also aimed to consider relevant individual differences regarding motivational effects and, thereby, to contribute to the general research agenda of integrating user diversity research into research on human-technology interaction (see e.g., Attig et al., 2017; Szalma, 2009) and gamification (van Roy and Zaman, 2017).

2 BACKGROUND

2.1 Self-Determination Theory and the Role of Feedback on Motivation

Research suggests that activity trackers convey their positive effects on health behavior by providing quantified behavioral feedback which facilitates self-monitoring (Painter et al., 2017), strengthens empowerment (Karapanos et al., 2016; Nelson et al., 2016; Pettinico and Milne, 2017), and increases goal focus and anticipated motivation (Pettinico and Milne, 2017). However, positive behavioral feedback can both increase and decrease motivation for a certain activity (Deci and Ryan, 1980; Henderlong and Lepper, 2002).

In their self-determination theory, Deci and Ryan (1985b) distinguish between intrinsically and extrinsically motivated behavior. Intrinsically motivated behavior is performed just for the sake of doing it (e.g., because the behavior is fun). In contrast, extrinsically motivated behavior serves a certain superior goal (e.g., monetary rewards). Intrinsically motivated behavior is perceived as self-determined and autonomous whereas extrinsically motivated behavior can be perceived as externally controlled (Deci and Ryan, 1985b). In the field of sports and exercise, intrinsic motivation is robustly connected to initial

adoption and long-term adherence (Teixeira et al., 2012), highlighting the crucial role of intrinsic and autonomous motivation in initiating and maintaining health behavior (Hagger and Chatzisarantis, 2008).

A key question is thus: What impact does feedback (e.g., quantified feedback as provided by an activity tracker) have on intrinsic motivation? According to cognitive evaluation theory (Deci and Ryan, 1985b), a facet of self-determination theory, first, if positive feedback is perceived as emphasizing competence (i.e., self-determination and autonomy), it can increase intrinsic motivation (Deci and Ryan, 1985b; Henderlong and Lepper, 2002). Second, if positive feedback is perceived as a pressure to behave in a particular way (i.e., if it is perceived as an extrinsic control), it can decrease intrinsic motivation (Deci and Ryan, 1980; Deci and Ryan, 1985b; Deci et al., 1999a; Ryan and Deci, 2000). These principles are central for understanding the motivational effects of wearing activity trackers because quantified feedback (e.g., steps count, burned calories) can either increase or decrease intrinsic motivation to be physically active (i.e., create a type of dependency effect), depending on its perception.

The decline of intrinsic motivation through external rewards has been empirically investigated for more than 40 years (for an overview see Cerasoli et al., 2014), summarized under the terms undermining effect (Deci et al., 1999b) or overjustification effect (Lepper et al., 1973). A cognitive reevaluation of the behavior leads to the implicit assumption that the behavior is not performed out of intrinsic motivation but to obtain external rewards (i.e., the behavior is attributed to the external reward; Hewett and Conway, 2015). Consequently, the intrinsic motivation is suppressed through the external reward and the behavior becomes less likely (Deci, 1971). Thus, it can be argued that a shift from an internally to an externally perceived locus of causality (i.e., from perceived self-determined to perceived externally controlled behavior) is causative for the occurrence of the undermining effect (Deci and Ryan, 1985b).

It should be noted that the dependency effect does not exclusively mean that decreased activity behavior after discontinued tracker usage results from the same mechanism as the undermining effect (i.e., decreased *intrinsic* motivation for physical activity). Discontinued tracker usage (i.e., absent external rewards) probably also affects *extrinsic* motivation for physical behavior. Indeed, when extrinsically motivated behavior is no longer justified by extrinsic rewards, the behavior becomes less likely (a principle known for decades under the term extinction; Skinner, 1953). However, as we assume the suggested cause of the undermining effect (i.e., shift from perceived self-determined to perceived externally controlled behavior) to be one central mechanism for the dependency effect, we focus on research regarding the undermining effect for the formulation of our hypotheses and the development of our methodological approach.

2.2 Empirical Findings for Effects of Gamification and Personal Quantification on Motivation

Despite the relatively frequent remark that gamification can have detrimental effects on intrinsic motivation (e.g., Kim, 2015), empirical investigations testing this assumption are relatively rare and, unfortunately, report inconclusive results. Some research has shown that gamification approaches which

provide external rewards for accomplished goals (Richter et al., 2015) can harm intrinsic motivation. For example, students were found to have lower intrinsic motivation and empowerment in a gamified version (badges, leaderboard) of a university course (Hanus and Fox, 2015). However, there are also contradicting findings indicating no harmful, but also no beneficial effect of gamification on intrinsic motivation (Mekler et al., 2013; 2017) as well as findings suggesting beneficial effects of gamification elements on enjoyment and perceived motivation (Fitz-Walter et al., 2017). These inconsistent results indicate, as Perryer et al. (2016) point out, that the effectiveness of gamification approaches for facilitating users' motivation is highly context-dependent. Moreover, several gamification mechanisms (e.g., leaderboards, achievements, levels) were incorporated in these studies, making conclusions about specific effects of gamified features difficult.

Empirical research regarding personal quantification as one key feature of gamification is still sparse as well. A first experimental study in this field demonstrated that personal quantification can undermine intrinsic motivation (Etkin, 2016). Participants engaged in enjoyable activities with or without receiving quantified feedback. Results showed that personal quantification increased behavioral outcomes while, simultaneously, it decreased enjoyment of these activities. Moreover, also evidence for the undermining effect was found: Participants showed less effort after information about their activity level was removed, because they perceived a decreased intrinsic motivation (i.e., they felt less joy) and an increased feeling of external control (i.e., the activity felt more like work; Etkin, 2016).

To conclude, quantified/gamified feedback can be a potential risk to intrinsic motivation. Personal quantification is one very specific and prototypic gamification mechanism that, in one sophisticated study (Etkin, 2016), has been proven fruitful to better understand decreases in intrinsic motivation by gamified features. However, inconclusive results suggest that contextual variables need to be taken into account to gain a comprehensive understanding of such motivational effects. When examining the dependency effect of activity trackers in a naturalistic setting (i.e., low controllability of environmental factors), it is of particular importance to assess user diversity as possible influencing factors (for a similar argumentation, see Franke et al., 2018; Szalma, 2009). This leads to the question: Which personality-related individual differences can contribute to motivational costs of activity tracker usage?

2.3 The Role of Personality-Related User Diversity in Activity Motivation

In general gaming and gamification research, it has long been suggested that individual differences (i.e., player types) play a role regarding user preferences and motivation (Bartle; 1996; Tondello et al., 2016). For instance, it is assumed that users differ regarding the extent to which they are motivated by intrinsic (e.g., exploration, customization) or external rewards (e.g., badges, achievements; Tondello et al., 2016). However, empirical investigations regarding interactions between user personality and motivational costs through external rewards barely exist.

With regard to the undermining effect of rewards on motivation, to the best of our knowledge, only two individual-difference variables have been examined as moderators so far: causality orientation (Hagger and Chatzisarantis, 2011), and dialectical thinking style (Li et al, 2015). First, causality orientation reflects the interpretation of one's actions as self-determined (i.e., autonomy orientation), as controlled either by themselves or an external control in the environment such as a deadline (i.e., control orientation), or as entirely beyond their intentional control (i.e., impersonal orientation; Deci and Ryan, 1985a; 1985b; Hagger and Chatzisarantis, 2011). Research has revealed that autonomy-oriented individuals are, to some degree, protected from the undermining effect whereas control-oriented individuals are more strongly affected (Hagger and Chatzisarantis, 2011). Second, dialectical thinking refers to the tendency to accept contradictive statements. Research showed that individuals with a dialectical thinking style are more able to maintain their intrinsic motivation after receiving an external reward. One explanation for this finding may be that such individuals believe that their intrinsic and extrinsic motivation can coexist and do not necessarily interact (Li et al, 2015).

While these findings indicate that individual differences and environmental factors interact regarding the occurrence of undermining effects of extrinsic rewards to intrinsic motivation, personality traits have not been investigated yet as moderators (causality orientation is not considered a facet of personality but a characteristic adaptation of dispositional traits; Olesen et al., 2010). In the following, we discuss several personality-related individual difference variables that we assume to play a role regarding motivational costs with respect to activity tracker usage. The assumed effects are summarized in our conceptual framework in Figure 1. As can be seen in the figure, we assume intrinsic and extrinsic motivation for physical activity and tracker usage to act as mediators between personality variables and the dependency effect. Thus, we focused on specific personality variables that are empirically or theoretically connected to intrinsic and extrinsic motivation in different contexts (as described below). Moreover, to shed light on the role of broad personality dimensions in the occurrence of the dependency effect, we also examined the Big Five personality traits.

2.3.1 Need for Cognitive Closure

The need for cognitive closure (NCC) can be defined as a relatively stable personality trait reflecting the desire for clear-cut answers, predictability, order, and the avoidance of ambiguity. Moreover, it is connected to close-mindedness (Webster and Kruglanski, 1994; 1997). Investigating the relationship between the need for structure, which is conceptually related NCC, and the effect of feedback on motivation, it was found that individuals high in need for structure benefit from any type of feedback (i.e., also controlling feedback) because it decreases ambiguity. In contrast, for individuals who scored low on need for structure, controlling feedback impaired intrinsic work motivation (Slijkhuis et al., 2013).

Based on the conception of NCC and the aforementioned finding, we expect NCC to be positively related to the intrinsic motivation to use an activity tracker. In addition, NCC should have a direct effect on the dependency effect: Situations, in which the tracker is not at hand can be perceived as ambiguous – thus, individuals high in NCC should tend to avoid situations in which they are not able to receive feedback regarding their physical activity. Consequently, their motivation to be physically active when the tracker is not available should be reduced.

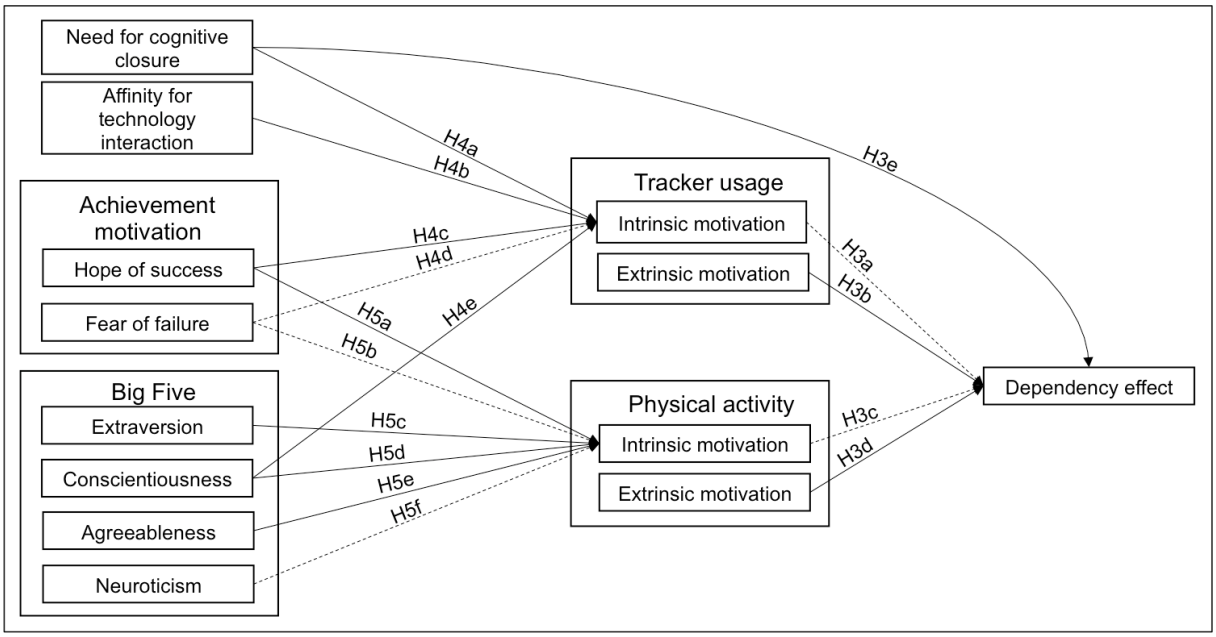

Figure 1. Hypothesized research framework. Solid arrows represent hypothesized positive relationships; dashed arrows represent hypothesized negative relationships.

2.3.2 Affinity for Technology Interaction

The affinity for technology interaction (ATI) is conceptualized as the tendency of an individual to actively explore (new) technological devices and can be seen as a resource for successful interaction with technology (Franke et al., 2018). The higher the ATI, the higher the interest in technology. Thus, we expect ATI to be positively related to the intrinsic motivation for using an activity tracker.

2.3.3 Achievement Motivation

The achievement motive explains why and when an individual tends to approach or avoid situations that can result in success or failure (i.e., situations that are concerned with a standard of excellence; Atkinson, 1957). Thus, achievement motivation splits into an approach (i.e., hope of success) and an avoidance (i.e., fear of failure) tendency (Lang and Fries, 2006). Hence, there are relatively stable individual differences regarding expectations concerning the outcome of performance situations, and these differences determine if an individual approaches or avoids such situations (Atkinson, 1957).

Achievement motivation is linked to intrinsic motivation. For instance, in educational contexts, achievement motivation predicts the achievement goal (i.e., performance-approach goal, mastery goal, or performance-avoidance goal), which then predicts intrinsic motivation (Elliot and Church, 1997). A high approach tendency is connected to mastery goals (e.g., deepened knowledge, mastering challenging learning material), which are positively connected to intrinsic motivation (Cerasoli and Ford, 2014; Elliot and Church, 1997). In contrast, a high fear of failure is connected to performance-avoidance goals (e.g., worrying about low performance, wish not to be graded), which are negatively connected to intrinsic motivation (Elliot and Church, 1997). Thus, we expect a high approach tendency to be connected to a high intrinsic motivation for physical activity whereas a high avoidance tendency should be connected to a low intrinsic motivation for physical activity (see also Standage et al., 2003). Moreover, as the approach tendency describes the anticipation of positive feedback and the avoidance tendency can be seen as the avoidance of negative feedback, we expect a high approach tendency to be positively related, and a high avoidance tendency to be negatively related to a high intrinsic motivation to use the activity tracker.

2.3.4 Big Five Personality Traits

Besides the aforementioned specific personality facets, it is also important to examine the general personality dimensions, because they comprise personality aspects that more specific traits might not cover (Buckner et al., 2012). The Big Five personality traits represent the fundamental dimensions of personality (McCrae and Costa, 1999). In the context of motivation for sports and exercising, they have been investigated only a few times. Positive correlations with intrinsic motivation to exercise were found for extraversion, agreeableness, and conscientiousness (Huang et al., 2007; Ingledew et al., 2004). Negative correlations were found for neuroticism, but connections to openness to experience remain unclear (Huang et al., 2007; Ingledew et al., 2004). Similar patterns were found for the connection of personality to physical activity (Rhodes and Smith, 2006; Wilson and Dishman, 2015). Connections to extrinsic motivation are inverse: Higher neuroticism, lower openness, lower conscientiousness, lower extraversion, and lower agreeableness are connected to higher extrinsic motivation to be physically active (Ingledew et al., 2004). However, results are more inconsistent and highly dependent on the type of extrinsic motivation (i.e., external, introjected, identified, and integrated regulation; see Ryan and Deci, 2000). A first study examining personality differences in the field of personal quantification found a positive correlation between conscientiousness and usage of a self-tracking app (Chatzigeorgakidis et al., 2016).

In sum, we can conclude and expect that extraversion, agreeableness, and conscientiousness should be positively related to intrinsic motivation whereas the relationship to neuroticism should be negative. Because of inconclusive findings, we do not hypothesize specific relationships to extrinsic motivation.

3 PRESENT RESEARCH

3.1 Research Questions and Hypotheses

The objective of the present research was to advance knowledge on the relation of personal quantification to users' motivation for physical activity. Hence, we aim at examining the occurrence and extent of the dependency effect in the context of everyday activity tracker usage. Thus, we intend to generalize findings from experimental investigations regarding motivational costs of activity trackers to everyday usage settings. Moreover, we address the issue of user diversity in human-technology interaction and gamification by investigating effects of relevant personality-related individual difference variables. Thus, we aim at contributing to filling the research gap regarding individual differences in the occurrence of demotivation effects of external rewards. To this end, a study with actual users of activity trackers was conducted to examine five research questions (Q1-Q5) and test the following hypotheses (see Table 1).

Q1 focuses on the occurrence of the dependency effect: Does the dependency effect play a role in everyday usage? How many users know the effect from their daily tracker interaction? Forming the basis for the subsequent research questions, the degree of motivational costs in our sample will be investigated exploratively (thus, no hypothesis is formulated).

With Q2, we examine group differences regarding the dependency effect. Following self-determination theory (Deci and Ryan, 1985b), we hypothesize (H2a) a stronger dependency effect for those who use the tracker more out of extrinsic motivation than those who use the tracker more out of intrinsic motivation. In addition, group differences can also be assumed between those participants who are more intrinsically and those who are more extrinsically motivated to be physically active. In general, we expect the dependency effect to occur regardless of the type of motivation for physical activity. However, the type of motivation for physical activity (intrinsic vs. extrinsic) can give insights into the process that leads to the dependency effect (similar to undermining effect vs. extinction). As intrinsic motivation for physical activity is positively related to long-term adherence to exercise (Teixeira et al., 2012), we hypothesize (H2b) the dependency effect to be stronger for those who are more extrinsically motivated to be active than those who are more intrinsically motivated. Lastly, we expect a cumulative effect of extrinsic motivation for tracker usage and physical activity regarding the extent of the dependency effect: Participants who are extrinsically motivated for both tracker usage and physical activity should experience the strongest effect, whereas participants who are intrinsically motivated for both tracker usage and physical activity should experience the weakest effect (H2c).

Q3 focuses on direct antecedents for the dependency effect. Based on the empirical finding that the undermining effect occurs when individuals receive external rewards for initially intrinsically motivated behavior, we hypothesize that the dependency effect is more likely when tracker usage is extrinsically motivated (e.g., to be fitter). Hence, if tracker usage is intrinsically motivated (e.g., because it is fun) the

effect should be less likely and, thus, intrinsic motivation for tracker usage should be negatively related to the dependency effect (H3a). In contrast, the effect should be positively related to extrinsic motivation for tracker usage (H3b). Moreover, the higher the initial intrinsic motivation to be physically active, the less likely the effect (H3c). Further, we hypothesize extrinsic motivation for physical activity to be positively related to the effect (H3d). Finally, we expect NCC to be positively related to the effect (H3e), as individuals high in NCC should tend to avoid ambiguous situations (e.g., activity situations in which no information regarding step count is available).

Within Q4 we investigate factors connected to intrinsic motivation for tracker usage, thus representing possible indirect effects on the dependency effect. NCC is related to the desire for clear-cut answers and the avoidance of ambiguity (Webster and Kruglanski, 1994; 1997), thus, we hypothesize NCC to be positively related to intrinsic motivation for tracker usage (H4a). ATI is defined as a stable tendency to actively engage in technology interaction (Franke et al., 2018), therefore, we expect ATI to be positively related to intrinsic motivation for tracker usage (H4b). Considering achievement motivation and the connected anticipation or avoidance of feedback, we hypothesize hope of success to be positively (H4c) and fear of failure (H4d) to be negatively related to intrinsic motivation for tracker usage. Based on the finding of Chatzigeorgakidis et al. (2016) we further hypothesize conscientiousness to be positively related to intrinsic motivation for tracker usage (H4e).

With Q5, factors connected to intrinsic motivation for physical activity are examined, again representing possible indirect effects on the dependency effect. Following the aforementioned findings regarding relationships of achievement motivation and intrinsic motivation (Cerasoli and Ford, 2014; Elliot and Church, 1997), we hypothesize hope of success to be positively (H5a) and fear of failure to be negatively (H5b) related to intrinsic motivation for physical activity. Based on findings regarding the Big Five personality traits and intrinsic motivation (Huang et al., 2007; Ingledew et al., 2004), we hypothesize extraversion (H5c), conscientiousness (H5d), and agreeableness (H5e) to be positively and neuroticism (H5f) to be negatively related to intrinsic motivation for physical activity.

Table 1. *Hypotheses of the present study.*

Dependent Variable	Hypo-thesis	Specification of hypothesis
Dependency effect (decrease of motivation for physical activity; Q1-3)	H2a	The dependency effect is stronger for participants who are more extrinsically motivated to use the tracker than those participants who are more intrinsically motivated to use the tracker.
	H2b	The dependency effect is stronger for participants who are more extrinsically motivated to be physically active than those participants who are more intrinsically motivated to be physically active.
	H2c	The dependency effect is strongest for those participants who are more extrinsically than intrinsically motivated for both tracker usage and physical activity and weakest for those participants who are more intrinsically than extrinsically motivated for both tracker usage and physical activity.
	H3a	Intrinsic motivation for tracker usage is negatively related to the dependency effect.
	H3b	Extrinsic motivation for tracker usage is positively related to the dependency effect.
	H3c	Intrinsic motivation for physical activity is negatively related to the dependency effect.
	H3d	Extrinsic motivation for physical activity is positively related to the dependency effect.
	H3e	Need for cognitive closure is positively related to the dependency effect.
Intrinsic motivation for tracker usage (Q4)	H4a	Need for cognitive closure is positively related to intrinsic motivation for tracker usage.
	H4b	Affinity for technology interaction is positively related to intrinsic motivation for tracker usage.
	H4c	Hope of success is positively related to intrinsic motivation for tracker usage.
	H4d	Fear of failure is negatively related to intrinsic motivation for tracker usage.
	H4e	Conscientiousness is positively related to intrinsic motivation for tracker usage.
Intrinsic motivation for physical activity (Q5)	H5a	Hope of success is positively related to intrinsic motivation for physical activity.
	H5b	Fear of failure is negatively related to intrinsic motivation for physical activity.
	H5c	Extraversion is positively related to intrinsic motivation for physical activity.
	H5d	Conscientiousness is positively related to intrinsic motivation for physical activity.
	H5e	Agreeableness is positively related to intrinsic motivation for physical activity.
	H5f	Neuroticism is negatively related to intrinsic motivation for physical activity.

3.2 Research Approach

To meet the study's objective to investigate the dependency effect of activity trackers in everyday usage, we decided to recruit a large online sample of actual users. We used the paradigm usually applied for testing the undermining effect (three-phase experiment with external rewards for intrinsically motivated behavior as independent variable and free-choice behavior after the removal of the reward as dependent

variable; e.g. Deci, 1971) as a foundation to develop a scenario-based study framework for examining the extent of dependency effects in naturalistic usage of activity trackers. The undermining effect becomes measurable in the third phase when the external reward is no longer present and we assume the same for the dependency effect. Accordingly, we focused on situations in which the tracker is not available anymore (e.g., when it is forgotten at home).

In addition to the scenario-based assessment of the undermining effect, a multidimensional questionnaire scale measuring behavioral, affective, and cognitive outcomes of a dependency on the tracker was established. This combination of methods made it possible to assess the extent of the dependency effect on several dimensions.

4 METHOD

4.1 Participants

To recruit actual users of wearable activity trackers, we focused recruitment on interest groups on social media websites (Facebook, Instagram) regarding fitness, weight loss, and activity tracker usage. Participants were not compensated for their participation. Data of *N* = 210 participants entered the analysis (212 of 269 participants completed the questionnaire; two users stated to only use activity tracking on their smartphone without wearable tracking device and were therefore excluded from the analyses). Sample characteristics are depicted in Table 2.

With 194 (92.4%) out of 210 participants, the large majority was female. Regarding usage duration, 13.8% had been using their current tracker for more than one year and 36.7% had been using activity trackers in general for more than one year. Regarding their typical daily tracker usage, 70.0% stated that they typically wore the tracker for more than 23 hours on a typical day and 64.8% wore the tracker 24 hours a day. Most of the participants (87.6%) stated to wear the tracker 7 days a week in typical weeks. Only 0.5% stated that they exclusively used the tracker to track their sporting activities, while the rest of the participants (99.5%) stated that they used the tracker fully or primarily to track their entire everyday activities.

The large majority (96.2%) used an activity tracker that is worn on the wrist while the rest (3.8%) used trackers that can be attached on the clothes (e.g., belt, bra). The most highly represented brand was Fitbit (67.6%), followed by Garmin (11.0%), Polar (8.1%), Apple (4.3%), and Samsung (3.3%). The remaining 5.7% used activity trackers by other brands (e.g., Jawbone, Xiaomi). Participants stated that their tracker is able to gather the following type of data: step count (100%), calorie consumption (99.0%), sleep activity (91.4%), heart rate (81.9%), stairs (72.4%), distance (14.6%), active minutes (13.8%), and type and amount of sporting activities/exercise (8.9%).

Table 2. *Characteristics of the participant sample.*

	M	*SD*	Range	25th percentile	75th percentile
Age	23.93	7.74	15.00-61.00	24.75	34.00
Usage duration of current tracker (in months)	7.26	6.71	1.00-48.00	3.00	10.00
Usage duration of current tracker on a typical day (in hours)	21.20	4.69	1.00-24.00	18.00	24.00
Usage duration of current tracker in a typical week (in days)	6.81	0.54	3.00-7.00	7.00	7.00
Usage duration of activity trackers in general (in months)	13.12	11.97	1.00-72.00	4.00	18.00

4.2 Scales and Measures

Descriptive statistics and internal consistency values for all scales are depicted in Table 3. Cronbach's alpha was interpreted according to common practice (see e.g., Cripps, 2017) as poor ($.5 \leq \alpha < .6$), questionable ($.6 \leq \alpha < .7$), acceptable ($.7 \leq \alpha < .8$), good ($.8 \leq \alpha < .9$), or excellent ($\geq .9$).

4.2.1 Dependency Effect (Decrease of Motivation for Physical Activity)

To assess motivational costs of wearing activity trackers in a non-experimental setting, we developed two approaches. The first is based on four fictional scenarios depicting typical situations in which a loss of motivation to be physically active due to the non-availability of the tracker becomes apparent. The second is a questionnaire scale, which additionally assesses behavioral, cognitive, and affective indicators of the dependency effect. The scenarios (Table A1) and the questionnaire (Table A2) are included in the appendix.

The scenarios were theoretically grounded on empirical findings regarding the undermining effect (i.e., a loss of intrinsic motivation after the external reward is removed, e.g., Deci, 1971; Lepper et al., 1973). Personal experiences of the first author and statements made from other activity tracker users in social media groups facilitated item formulation. We presented four different situations in which the activity tracker is not available due to mostly uncontrollable circumstances (e.g., "Imagine you have just arrived at work/university. The first thing you need to do is to go to the fourth floor to take care of something. You notice that you forgot your tracker at home. Thus, no steps or other activities will be counted on this day. You now have the choice to take the staircase or the elevator to get to the fourth floor."). The participants were asked to imagine themselves in these situations as vividly as possible or, if they already encountered similar situations, to remember how they reacted. Then, two alternatives were presented which the participants were asked to state their agreement to ("To reach the fourth floor, I will very likely take the staircase instead of the elevator"; "To reach the fourth floor, I will very likely take the elevator instead of the staircase"). Thereby, we aimed to assess the level of activity maintenance or reduction. The separate

presentation of both alternatives was chosen to reveal invalid response styles. Answers were provided on 6-point Likert scales ranging from 1 (*completely disagree*) to 6 (*completely agree*). Thus, higher scores represent a stronger dependency effect (i.e., less activity). Internal consistency was good.

The questionnaire scale consisted of 13 items measuring the dependency effect on five dimensions: shift to external attribution (e.g., "Sometimes I have the feeling that I collect steps or carry out activities for the tracker instead of myself"; two items), behavioral outcomes of not wearing the tracker (e.g., "When I do not wear my tracker, I nevertheless collect as many steps as possible, resp. carry out my usual physical activities"; reverse coded; three items), activity evaluation (e.g., "When I do not wear the tracker, I have the feeling that steps or activities are 'less valuable'"; three items), affective outcomes of intrinsic motivation loss (e.g., "I am only proud of myself when my tracker makes me sure that I met my activity goals", three items), and cognitive occupancy (e.g., "When I take some exercise, I virtually automatically think about the collected steps or burned calories that my tracker is going to display"; two items). Answers were provided on 6-point Likert scales ranging from 1 (*completely disagree*) to 6 (*completely agree*). Again, higher scores represent a stronger dependency effect. Internal consistency was excellent.

4.2.2 Motivation for Tracker Usage

To measure the extent of intrinsic and extrinsic motivation to use the tracker, we developed six items based on self-determination theory (Deci and Ryan, 1985b; for full scale see Table A3 in the appendix). Three items assessed intrinsic (e.g., "I use my activity tracker because it is fun to deal with my activity data") and three items assessed extrinsic motivation (e.g., "I use my activity tracker because it assists me in taking care of my physical fitness"). Participants answered on 6-point Likert scales ranging from 1 (*completely disagree*) to 6 (*completely agree*). Internal consistency was good (intrinsic motivation) resp. acceptable (extrinsic motivation).

In addition, two items from the Incentive-Focus Scale (Rheinberg et al., 1997) were modified to measure if participants used the tracker primarily for fun ("In case of doubt, my slogan is 'The fun I have through using my tracker comes before the gain!'") or for gain ("In case of doubt, my slogan is 'The gain I have through using my tracker comes before the fun!'"). Again, answers were provided on 6-point Likert scales ranging from 1 (*completely disagree*) to 6 (*completely agree*). The arithmetic mean between the two item scores was calculated with greater numbers indicating using the tracker for fun. Internal consistency was acceptable.

4.2.3 Motivation for Physical Activity

We used eight items based on the Situational Motivation Scale (Guay et al., 2000) to measure the intrinsic and extrinsic motivations to be physically active. To gain insight into the possible mechanisms of the dependency effect (i.e., similar to undermining effect vs. extinction due to absent reinforcement), it is important to assess the motivation for physical activity before the participants used their tracker.

Therefore, we framed the items to this time period ("It is of crucial importance for us which factors were central for you before the tracker usage"). Four items assessed intrinsic motivation (e.g., "I am physically active or exercise because this activity is fun") and four items assessed external regulation (e.g., "I am physically active or exercise because I am supposed to do it"). Items were translated into German for the present study (for full scale see Table A4 in the appendix). Participants answered on 6-point Likert scales ranging from 1 (*completely disagree*) to 6 (*completely agree*). Internal consistency was good.

4.2.4 Need for Cognitive Closure

The German 16-item Need for Cognitive Closure Scale (NCCS; Schlink and Walther, 2007) was used. Participants provided answers on a 6-point Likert scale ranging from 1 (*strongly disagree*) to 6 (*strongly agree*). Internal consistency was good.

4.2.5 Affinity for Technology Interaction

We assessed the unidimensional construct ATI with the 9-item ATI scale (Franke et al., 2018). Answers were provided on a 6-point Likert scale from 1 (*completely disagree*) to 6 (*completely agree*). Internal consistency was excellent.

4.2.6 Achievement Motivation

Achievement motivation was assessed using the German version of the 10-item Achievement Motives Scale (AMS-R; Lang and Fries, 2006). Five items measured the hope of success and five items measured the fear of failure. Participants provided answers on a 4-point Likert scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*). Internal consistency was good (fear of failure) resp. acceptable (hope of success).

4.2.7 Big Five Personality Traits

Conscientiousness, extraversion, agreeableness, and neuroticism were assessed with the 10-item BFI-10 (Rammstedt and John, 2005). Answers were given on a 5-point Likert scale ranging from 1 (*completely disagree*) to 5 (*completely agree*). Internal consistency varied from poor (agreeableness, conscientiousness), over questionable (neuroticism) to acceptable (extraversion). However, Cronbach's alpha is not a meaningful indicator for very short scales covering broad personality facets (for details see Freudenthaler et al., 2008; Rammstedt and John, 2007) and low internal consistency values of very short scales are not uncommon (Gosling et al., 2003; Romero et al., 2012). Given the high correlations with more comprehensive Big Five scales and high test-retest correlations (Rammstedt and John, 2005), the BFI-10 is estimated to be reliable.

Table 3. *Internal consistency and descriptive statistics of all variables.*

	Cronbach's alpha	*M*	*SD*	Range	Possible range
Loss of intrinsic motivation – Scenarios	.82	2.67	0.92	1.00-5.25	1.00-6.00
Loss of intrinsic motivation – Scale	.91	2.99	1.02	1.00-5.15	1.00-6.00
Loss of intrinsic motivation – Composite Score	.92	2.83	0.88	1.08-5.20	1.00-6.00
Intrinsic motivation for tracker usage	.86	5.23	0.78	3.00-6.00	1.00-6.00
Extrinsic motivation for tracker usage	.76	4.98	1.04	2.00-6.00	1.00-6.00
Incentive focus regarding tracker usage	.75	3.45	1.08	1.00-6.00	1.00-6.00
Intrinsic motivation for physical activity	.88	4.62	0.97	1.25-6.00	1.00-6.00
External regulation of physical activity	.80	2.95	1.16	1.00-6.00	1.00-6.00
Need for cognitive closure	.82	3.68	0.72	1.94-5.50	1.00-6.00
Affinity for technology interaction	.93	3.97	1.09	1.00-6.00	1.00-6.00
Achievement motivation – hope of success	.74	3.18	0.48	1.80-4.00	1.00-4.00
Achievement motivation – fear of failure	.83	2.68	0.65	1.00-4.00	1.00-4.00
Conscientiousness	.42	3.38	0.82	1.50-5.00	1.00-5.00
Extraversion	.83	3.10	1.09	1.00-5.00	1.00-5.00
Agreeableness	.08	3.12	0.78	1.50-5.00	1.00-5.00
Neuroticism	.60	3.19	0.98	1.00-5.00	1.00-5.00

Note. *N* = 210.

5 RESULTS

5.1 Data Analysis

For investigating Q1 and Q2, difference values between intrinsic and extrinsic motivation for physical activity and for activity tracker usage were computed. Regarding activity tracker usage, scores for intrinsic and extrinsic motivation did not differ for *n* = 52 participants. Regarding physical activity, scores for intrinsic and extrinsic motivation did not differ for *n* = 9 participants. These participants were excluded from the respective analyses. Differences regarding the dependency effect between groups of users were tested via independent *t*-tests (H2a, H2b), resp. one-way analysis of variance with Bonferroni-corrected post hoc tests (H2c).

Hypotheses regarding Q3-Q5 were analyzed with a path analysis based on the R-package 'lavaan' (Rosseel, 2012). Thus, several regressions reflecting relationships between variables are tested in one model (Garson, 2008). The maximum likelihood method was applied to test three multiple regressions simultaneously: (1) Intrinsic and extrinsic motivation for tracker usage, intrinsic and extrinsic motivation for physical activity and NCC as predictors, and the dependency effect as criterion; (2) NCC, ATI, achievement motivation, and conscientiousness as predictors, and intrinsic motivation for tracker usage as

criterion; (3) Achievement motivation, extraversion, conscientiousness, agreeableness, and neuroticism as predictors, and intrinsic motivation for physical activity as criterion.

All variables were tested for univariate outliers according to Grubbs (1969). No outliers were detected. Correlations between all variables in the study are presented in Table 5. Because of the strong correlation between the scenario-based and the scale-based approaches (r = .65, p < .001), a unit weighted composite score was calculated for the dependency effect. As incentive focus (i.e., using the tracker for fun) only weakly correlated with intrinsic motivation for tracker use (r = .17, p = .011) we decided against computing a composite score and did not incorporate incentive focus into the path analysis. Results of the path analytic modeling are depicted in Table 6 and Figure 3.

5.2 Degree of the Dependency Effect in Everyday Usage (Q1)

The interpretation of absolute response values to the questionnaire scale is not without problems (i.e., influenced by item wording and sample structure). This problem is less severe with the scenario approach (clear behavioral decision criterion) than with the scale (more diverse items). We still provide this information to give a first indication of the extent of the dependency effect.

Regarding Q1, participants' responses regarding the scenario and the questionnaire scale to assess the dependency effect show that the effect is not relevant for the majority, but still for a substantial amount of users. First, regarding the scenarios the mean for the dependency effect was M = 2.67 (SD = 0.92; see Table 3), differing significantly from the center of the response scale 3.5 (t(209) = -13.11, p < .001, d = 0.90) meaning that participants on average tended towards the more active option (see also distribution of values in Figure 2). When dichotomizing the responses, 17.6% of the participants agreed to the less active option. This approval was highest for Scenario 2 (45 minutes without activity tracker), 58.6%, and lowest for Scenario 4 (entire workday without activity tracker), 13.8%.

Second, regarding the questionnaire scale, the mean for the dependency effect was M = 2.99 (SD = 1.02), which also differed significantly from the scale mean 3.5 (t(209) = -7.19, p < .001, d = 0.50). When dichotomizing the responses, 36.2% of the participants scored >3.5, thus tending towards the dependency effect. Regarding the five subscales, participants' approval was higher for affective outcomes (48.6%), cognitive occupancy (48.1%), and external attribution (38.1%) and lower for activity evaluation (31.0%) and behavioral outcomes (19.5%).

Third, the mean composite score of the scenario and scale-based measurements was M = 2.83 (SD = 0.88), thus significantly different from 3.5 (t(209) = -11.02, p < .001, d = 0.76), and 23.3% of all participants scored >3.5. To summarize, the majority of tracker users in our sample stated that they do not experience the dependency effect, but the amount of users who do is still substantial and the variance between individuals, situations and outcomes is considerable.

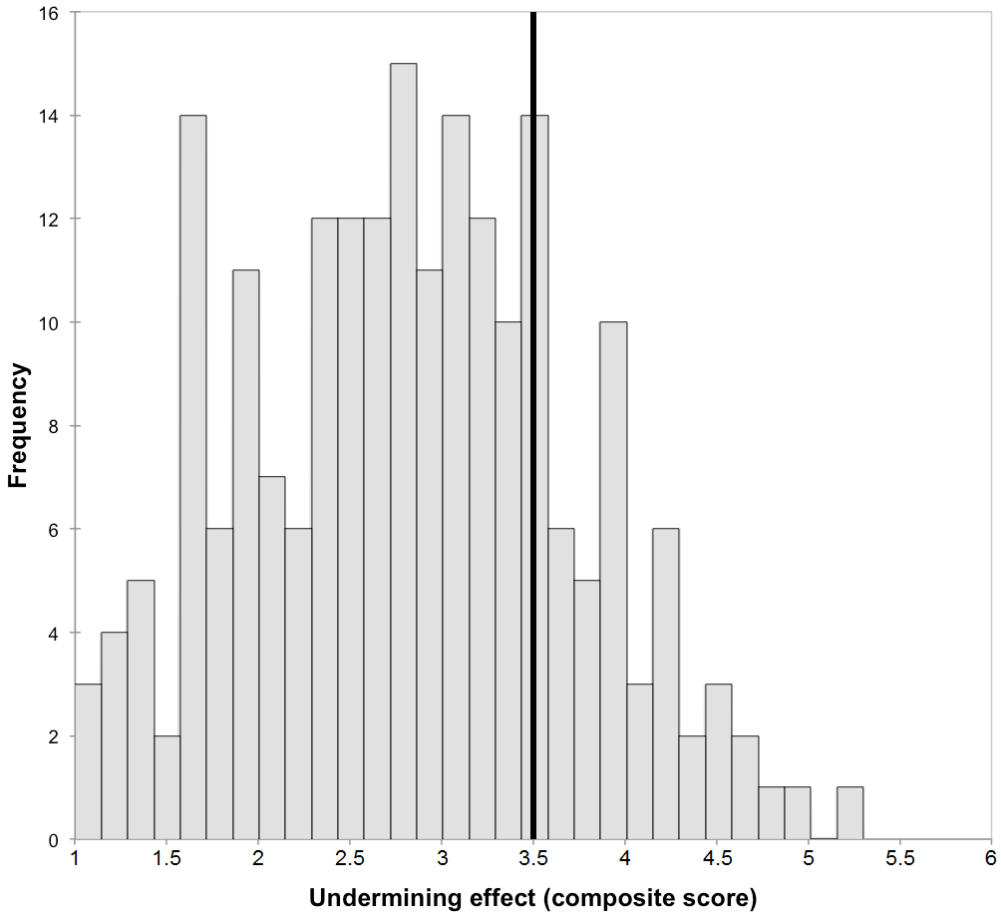

Figure 2. Frequency distribution of composite score values for the dependency effect. The bold line represents the center of the response scale (3.5).

5.3 Group Differences Regarding the Dependency Effect (Q2)

Regarding, Q2, the *t*-test revealed that, on average, participants with a higher extrinsic motivation for tracker usage (n = 67) showed a higher loss in intrinsic motivation to be physically active when the tracker is not available (M = 3.06, SD = 0.82) than those with a higher intrinsic motivation for tracker usage (n = 91, M = 2.49, SD = 0.81). This difference, 0.57, was significant ($t(156) = 4.35$, $p < .001$) and represented a medium-sized effect, d = 0.70 (H2a supported).

Moreover, on average, participants with a higher extrinsic than intrinsic motivation for physical activity (n = 36) showed a stronger dependency effect (M = 3.34, SD = 0.76) than those with a higher intrinsic motivation for physical activity (n = 165, M = 2.68, SD = 0.85). This difference, 0.66, was significant ($t(199) = 4.26$, $p < .001$) and represented a medium to large effect, d = 0.79 (H2b supported).

The one-way ANOVA over all four possible groups (see Table 4; $F(3) = 15.92$, $p < .001$, $\eta^2 = .24$, large effect) showed that the dependency effect was strongest for those participants who are more extrinsically than intrinsically motivated for both physical activity and tracker usage (Group 1) and weakest for those participants who are more intrinsically than extrinsically motivated for both physical activity and tracker

usage (Group 4; M_{diff} = 1.50, *SE* = 0.23, $p < .001$, d = 2.01, large effect, see Table 4; H2c supported). There were no statistically significant differences between Groups 2 and 3.

Table 4. *Means and standard deviations for the dependency effect separately for the four different user groups regarding motivation for physical activity and tracker usage.*

Group No.		*n*	*M*	*SD*
1	Physical activity extrinsic & tracker usage extrinsic	12	3.89	0.46
2	Physical activity intrinsic & tracker usage extrinsic	51	2.82	0.75
3	Physical activity extrinsic & tracker usage intrinsic	12	3.03	0.69
4	Physical activity intrinsic & tracker usage intrinsic	76	2.39	0.78

Note. Intrinsic = intrinsic > extrinsic; extrinsic = intrinsic < extrinsic. A distinction was impossible for *n* = 59 users (score for intrinsic and extrinsic motivation identical).

5.4 Direct Antecedents of the Dependency Effect (Q3)

Regarding Q3, the path analysis (see Table 6) and the correlation analyses (see Table 5) showed that, first, intrinsic motivation for tracker usage was not significantly related to the dependency effect (H3a not supported). However, H1b to H1e were supported by the data. Intrinsic motivation for physical activity (H3c) was significantly negatively related to the dependency effect while extrinsic motivation for tracker usage (H3b), extrinsic motivation for physical activity (H3d), and need for cognitive closure (H3e) were significantly positively related to the dependency effect.

5.5 Factors Predicting Intrinsic Motivation for Tracker Usage (Q4)

Regarding Q4, the path analysis revealed that NCC, ATI, and hope of success were significant predictors for the intrinsic motivations for tracker usage (H4a, H4b, and H4c supported). Neither the correlation nor the path coefficients for the relationships between fear of failure and conscientiousness and intrinsic motivation for tracker use reached statistical significance (H4d and H4e not supported).

5.6 Factors Predicting Intrinsic Motivation for Physical Activity (Q5)

Regarding Q5, the path analysis showed that only hope of success was significantly related to intrinsic motivation for physical activity (H5a supported). Even though correlation analyses revealed significant correlations between intrinsic motivation for physical activity and fear of failure (r = -.21, p = .003), extraversion (r = .16, p = .022), conscientiousness (r = .21, p = .003), and neuroticism (r = -.19, p = .005), these relationships decreased and were not significant when hope of success was accounted for (see Table 6). Consequently, H5b, H5c, H5d, H5e, and H5f were not supported.

Hope of success was the only variable significantly related to intrinsic motivation for physical activity, which in turn significantly predicted the dependency effect. Therefore, the indirect effect of hope of

success on the dependency effect was tested. To this end, a mediation model was deployed in 'lavaan', with hope of success as predictor, intrinsic motivation for physical activity as mediator and the dependency effect as criterion. All other variables were excluded from the analysis and two-sided significance tests were used. A small negative effect was found (β = -.11, p < .001), which based on the positive relationship between hope of success and intrinsic motivation for physical activity (β = .31, p < .001) and the negative relationship between intrinsic motivation for physical activity and the dependency effect (β = -.33, p < .001). This indirect effect shows that individuals with a high hope of success also tended to be more intrinsically motivated to be physically active, which then, to some degree, made the demotivation less likely.

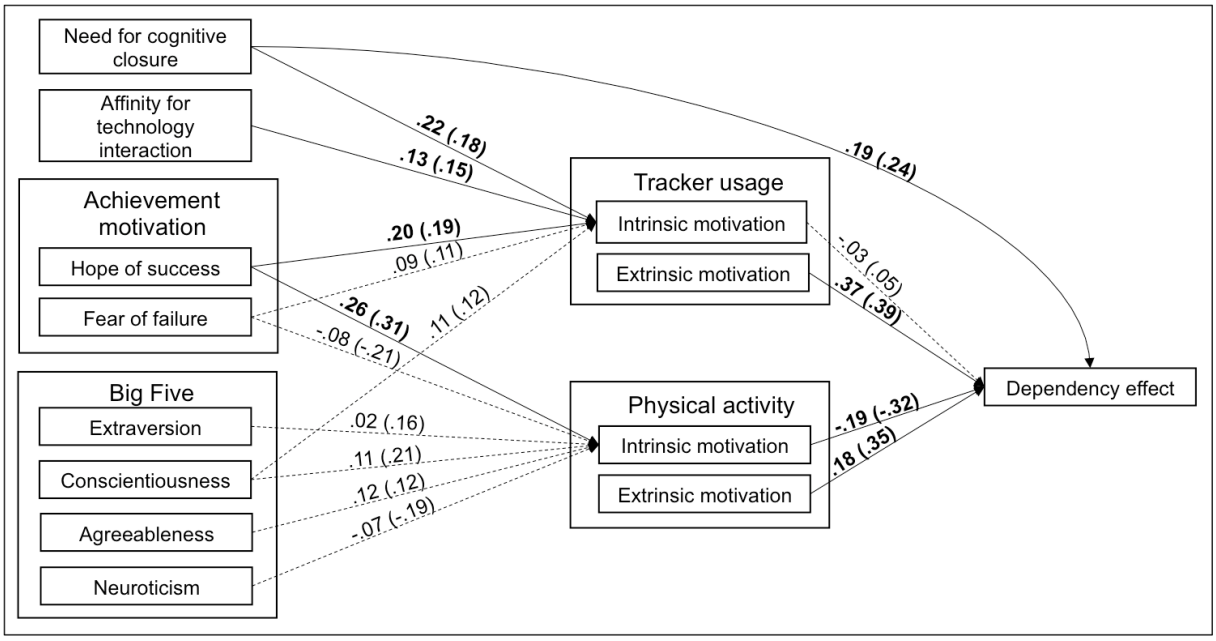

Figure 3. Path model estimated using maximum likelihood method. Standardized path coefficients are shown with bivariate Pearson correlations in parentheses. Significant paths are depicted with solid arrows and in bold face. Nonsignificant paths are depicted with dashed arrows.

Table 5. *Pearson correlation coefficients for all variables.*

	Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1)	Dependency effect – Scenarios														
(2)	Dependency effect – Questionnaire	.65***													
(3)	Intrinsic motivation for tracker use	.00	.09												
(4)	Extrinsic motivation for tracker use	.26***	.44***	.24***											
(5)	Incentive focus regard. tracker use	.01	.04	.17*	-.04										
(6)	Intrinsic motivation for phys. activity	-.29***	-.30***	.22***	-.02	.14*									
(7)	External regulation of phys. activity	.25***	.37***	.01	.16*	-.02	-.46***								
(8)	Need for cognitive closure	.15*	.28***	.18*	-.01	-.12	-.19**	.12							
(9)	Affinity for technology interaction	-.02	-.15*	.15*	.03	.03	.18*	-.16*	-.11						
(10)	Hope of success	-.09	-.02	.19**	.20**	.08	.31***	-.23**	-.26***	.26***					
(11)	Fear of failure	.27***	.36***	.11	.09	.00	-.21**	.26***	.40***	-.05	-.20**				
(12)	Conscientiousness	-.13	-.08	.12	.08	-.02	.21**	-.18	-.10	-.05	.27***	-.18**			
(13)	Extraversion	-.06	-.02	-.03	.14*	.08	.16*	-.04	-.36***	-.03	.27***	-.35***	.11		
(14)	Agreeableness	-.05	-.12*	-.01	-.03	.02	.12	-.04	-.03	.02	-.08	-.05	.06	.06	
(15)	Neuroticism	.18*	.20**	.16*	.10	.02	-.19**	.20**	.37***	-.02	-.19**	.59***	-.07	-.31***	-.08

Note. $N = 210$; * $p < .05$; ** $p < .01$; *** $p < .001$; all p-values refer to two-sided significance tests.

Table 6. *Hypothesized relationships described in the path model.*

Hypo-thesis	Dependent Variable	Independent Variable	β	SE	*z*	*p*
H3a	Dependency Effect	Intrinsic Motivation for Tracker Usage	-.03	0.06	-0.47	.320
H3b		Extrinsic Motivation for Tracker Usage	.37	0.06	5.70	<.001
H3c		Intrinsic Motivation for Physical Activity	-.19	0.06	-3.44	<.001
H3d		Extrinsic Motivation for Physical Activity	.18	0.06	2.79	.003
H3e		Need for Cognitive Closure	.19	0.07	2.67	.004
H4a	Intrinsic Motivation for Tracker Usage	Need for Cognitive Closure	.22	0.08	2.90	.002
H4b		Affinity for Technology Interaction	.13	0.07	1.89	.028
H4c		Hope of Success	.20	0.07	2.88	.002
H4d		Fear of Failure	.09	0.08	1.07	.392
H4e		Conscientiousness	.11	0.07	1.55	.060
H5a	Intrinsic Motivation for Physical Activity	Hope of Success	.26	0.07	3.66	<.001
H5b		Fear of Failure	-.08	0.09	-0.88	.190
H5c		Extraversion	.02	0.07	0.27	.393
H5d		Conscientiousness	.11	0.07	1.52	.064
H5e		Agreeableness	.12	0.07	1.61	.053
H5f		Neuroticism	-.07	0.10	-0.77	.220

Note. N = 210; P-values are based on one-sided significance tests because of directional hypotheses. The whole model showed a strong and significant fit to the data (χ^2 (17) = 74.60; p < .001).

6 DISCUSSION

6.1 Summary of Results

The objective of the present research was to advance knowledge on the relation of personal quantification to users' motivation for physical activity by examining the dependency effect in the context of activity tracker use in a naturalistic setting and to consider aspects of user diversity. Participants stated that their physical activity would diminish when the tracker is not available with a considerable variance. In addition, results indicated that the dependency effect likely manifests on cognitive, affective, and behavioral levels, and that cognitive and affective outcomes are experienced more frequently than behavioral outcomes. Thus, the dependency effect plays a role in everyday usage, however, not everyone experiences the effect, and not everyone adapts his/her behavior

without the tracker. Users who use their activity tracker to achieve a superior goal (i.e., who use it out of extrinsic motivation), who are physically active to achieve a superior goal (i.e., who exercise out of extrinsic motivation), and who score high on NCC tend to choose the less active option when the tracker is not available (i.e., experience a stronger dependency effect). In contrast, users who are physically active because it is fun (i.e., who exercise out of intrinsic motivation) experience the motivational loss to a smaller degree. Moreover, the higher users' hope for success, the higher their intrinsic motivation for physical activity, and, consequently, the less likely the dependency effect. Contrary to our expectations, the path model showed that intrinsic motivation for tracker usage was not related to the dependency effect. Thus, even though NCC, ATI, and hope of success predict intrinsic motivation for tracker usage, no indirect effects on the dependency effect were found.

6.2 Implications

The present research offers insights into motivational effects of wearing activity trackers and contributes to a broader understanding of individual differences in human-technology interaction, particularly in the field of gamified systems. The findings demonstrate that motivational losses when the tracker is not available are indeed experienced by several users in their everyday life. Hence, users feel less motivated to be physically active when they do not wear their trackers. However, there is a large variance in the occurrence of this effect, which can be partly explained through the type of motivation for physical activity and tracker usage and individual differences (see also Duus et al., 2017). In accordance with the assumptions of self-determination theory (Deci and Ryan, 1985b), the effect was stronger for those participants who stated that they use their tracker more out of extrinsic than intrinsic motivation (i.e., they aim at achieving higher goals by using their tracker such as becoming fitter or losing weight, rather than just being interested in their personal data). This supports the notion that the perception of the feedback (in this case the feedback provided by the tracker) influences the strength of the effect on users' intrinsic motivation. Hence, tracker feedback should be designed to minimize its perception as externally controlling and rather to enhance user's interest in his/her own data. Moreover, tracker interaction should be perceived as enjoyable.

Moreover, the effect was positively related to extrinsic and negatively related to intrinsic motivation for physical activity. Hence, on the one hand, the more that participants are physically active because it is fun, the less likely the dependency effect – but, at the same time, if the tracker is used to obtain a higher goal, the dependency effect becomes more likely. In this case, the dependency effect might be a result of a shift from perceived self-determined to perceived externally controlled behavior as in the undermining effect (i.e., *original intrinsic* motivation for physical activity gets undermined by the external reward of quantified activity feedback). On the other hand, the more that participants are physically active because they feel like they have to do it, the more likely the

dependency effect. In this case, the dependency effect might result from a loss of *original extrinsic* motivation when external rewards are absent (i.e., original extrinsic motivation for physical activity is reduced without external reinforcement). Regardless of the underlying mechanisms, the relationships between intrinsic and extrinsic motivation for physical activity and the dependency effect underline the importance of intrinsic motivation for long-term adherence to activity and exercise (Hagger and Chatzisarantis, 2008). The more that physical activity is perceived as self-determined and self-rewarding, the less likely is a demotivation after discontinued tracker usage. This finding underlines the enormous importance of self-determination for sustainable health behavior. Consequently, instead of emphasizing extrinsic control, activity trackers' feedback should be designed to strengthen self-determination and autonomy (see also van Roy and Zaman, 2017), that is, boost user's fun while being active.

Our findings regarding user diversity also stress the importance of incorporating individual differences into research on human-technology interaction to gain a more comprehensive understanding of user interaction and related motivational and affective phenomena (see also Szalma, 2009; Szalma, 2014; van Roy and Zaman, 2017). NCC was found to be positively related to intrinsic motivation for tracker usage and, moreover, directly positively to the dependency effect. Hence, users high in NCC are intrinsically interested in their personal activity data, but tend to reduce their physical activity when the tracker is not at hand. One explanation might be their higher need for predictability and aversion of ambiguity (Webster and Kruglanski, 1994). Such individuals might perceive situations in which they do not wear their tracker as uncertain regarding the attainment of their activity goals. Not being active but knowing that no additional steps are taken or calories are burned might be a solution to reduce uncertainty (rather than being active but without knowing about the quantified extent of their activity). Hence, they might prefer selecting the alternative with higher predictability and smaller ambiguity. Thus, for users high in NCC, the activity tracker might be a tool to enhance predictability and reduce uncertainty but in situations without the tracker, an over-reliance might become apparent and users become less active. It is thus important, especially for users high in NCC, to enhance awareness that every activity counts, also when no feedback is available.

Hope of success is indirectly related to the dependency effect, mediated by intrinsic motivation for physical activity. Moreover, it is positively related to the intrinsic motivation for tracker usage. Thus, users with high hope of success are more interested in their personal activity data and tend to be physically active likely because they perceive such activities as self-rewarding. This implies that hope of success can be seen as a relatively stable individual resilience factor protecting, to some degree, from the dependency effect. ATI is another user diversity facet related to the intrinsic motivation for tracker usage. Users with a high ATI tend to use their tracker because they are interested in their personal data and, probably, the tracker itself as a technical device. In the path model, ATI had no

indirect effect on the dependency effect though. The same holds for the broad personality dimensions extraversion, conscientiousness, agreeableness, and neuroticism. However, the lack of empirical relationships of the Big Five to intrinsic motivation for tracker usage and physical activity might suggest that these personality dimensions are too broad to be valid predictors for these very specific motivations for usage of such a technology. Results implicate that narrower user diversity facets such as NCC and ATI are more valuable in explaining individual differences in motivational aspects, particularly regarding user-technology interaction (see also Franke et al., 2018).

6.3 Limitations and Future Research

Even though our methodological approach for assessing the dependency effect shows good to excellent reliability, it has to be noted that it is still just a first step for investigating the effect in a naturalistic setting with actual users. The scenarios and the questionnaire scale are reliable methods to examine behavioral, cognitive, and affective outcomes in situations when the tracker is not available. Future studies should combine experimental and scale-based approaches by investigating a sample of actual users, varying the presence of activity trackers as independent variable, and utilizing pre-post designs (i.e., measuring intrinsic/extrinsic motivation before and after the usage/non-usage phase) to further investigate the processes and mechanisms that the dependency effect results from. In this regard, measures such as our scale could provide deeper insights into the extent and scope of the dependency effect instead of just the occurrence. In addition, the multidimensionality of both intrinsic and extrinsic motivation (Ryan and Deci, 2000; Vallerand, 1997) should be taken into account.

Furthermore, the type of activity trackers' feedback and the different gamified approaches (e.g., leaderboards, levels, badges) that connected mobile apps provide should be investigated in a more differentiated manner. For instance, investigating effects of different types of feedback (e.g., informal, controlling) on the dependency effect would not only test assumptions of self-determination theory, but also facilitate interface design and boost activity trackers' effectiveness for increasing sustainable physical activity, health, and well-being.

Another limitation is the gender distribution in our sample. Over 90% of the participants were female, which is mainly due to the similar gender distribution in the social media interest groups. However, gender effects have typically not been found for the undermining effect (e.g., Cerasoli et al., 2014).

6.4 Conclusion

The objectives of the present research were to advance knowledge regarding detrimental effects of wearing activity trackers for motivation to be physically active while taking indicators of user diversity into account. By studying actual users in an everyday usage setting, we found that extrinsic motivation

for tracker usage and physical activity, and need for cognitive closure were positively related, whereas intrinsic motivation for physical activity was negatively related to motivational costs. Hope of success was another individual difference factor related to motivational costs. The results implicate that activity tracker feedback can be perceived as externally rewarding, can create a dependency, and can impair users' motivation for physical activity when feedback is not available. High intrinsic motivation for physical activity plays a crucial role in the long-term adherence to physical activity and exercise and, together with hope of success, can be viewed as a resilience factor protecting against the dependency effect. Interface designers should thus design activity trackers' feedback facilitating intrinsic motivation, autonomy, and self-determination.

DECLARATION OF INTEREST

Declarations of interest: none.

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APPENDIX

Table A1. *Translated item texts of self-constructed scenario items for assessing the dependency effect (original German item wording can be obtained from the authors).*

Label	Item text
Scenario 1: elevator	Imagine you have just arrived at work/university. The first thing you need to do is to go to the fourth floor to take care of something. You notice that you forgot your tracker at home. Thus, no steps or other activities will be counted on this day. You now have the choice to take the staircase or the elevator to get to the fourth floor.
1_staircase_r	To reach the fourth floor, I will very likely take the staircase instead of the elevator.
1_elevator	To reach the fourth floor, I will very likely take the elevator instead of the staircase.
Scenario 2: firmware update	Imagine you just connected your activity tracker to your computer to carry out a firmware update. This will take approximately another 45 minutes. During this time, you are not able to use your tracker. However, you planned to go grocery shopping by foot. You now have the choice to wait for 45 minutes and occupy yourself some other way, or to go shopping immediately, but without your tracker.
2_immediately_r	It is very likely that I will go shopping immediately, but without the tracker.
2_wait	It is very likely that I will wait for 45 minutes to go shopping with the tracker.
Scenario 3: Technical problem	Imagine you notice that your tracker does not work anymore. You get in touch with the customer service and learn that a known problem has occurred. The tracker has to be sent in and fixed. This means that the tracker will not be available for at least five days.
3_maintain_r	I will very likely maintain my activity level as if the tracker was available.
3_reduce	I will very likely reduce my activity level.
Scenario 4: Workday	Imagine it is 8:00 am and you are on your way to work/university. You notice that you did not put your tracker back on after showering. You do not have enough time to turn back and get the tracker. Today, you will approximately stay at work/university until 6:00 pm. Thus, the tracker will not be available for one whole workday.
4_maintain_r	I will very likely maintain my activity level as if the tracker was available.
4_reduce	I will very likely reduce my activity level.

Note. Items with an "r" were reversed prior to computing a mean score. Participants answered all items displayed here on a 6-point Likert scale from *completely disagree* to *completely agree*, coded as 1 to 6.

Table A2. *Translated item texts of self-constructed questionnaire scales for assessing the dependency effect (original German item wording can be obtained from the authors).*

Scale label		Item text
External attribution	1	Sometimes I have the feeling that I collect steps or carry out activities for the tracker instead of myself.
	2	Sometimes I have the feeling that I collect steps or carry out activities to get a good result shown, instead of doing it for myself.
Behavioral outcome	3	When I do not have the tracker at hand, I sometimes struggle with myself if I actually carry out the physical activity.
	4r	When I do not wear my tracker, I nevertheless collect as many steps as possible, resp. carry out my usual physical activities.
	5	If I do not wear my tracker during a physical activity, I make less effort than if I wore it.
Activity evaluation	6	When I do not wear the tracker, I have the feeling that steps or activities are “less valuable”.
	7	When I notice after an activity that the tracker does not display the activity correctly, I sometimes think that this activity was pointless.
	8	My activities are only valuable if my tracker records them.
Affective outcome	9	When I do not see my expected activities on my tracker after a very active day, I am disappointed.
	10	I am only proud of myself when my tracker makes me sure that I met my activity goals.
	11	When I am exercising, I have less fun without the tracker than with it.
Cognitive occupancy	12	When I am physically active, I virtually automatically think about the collected steps or burned calories that my tracker is going to display.
	13	When I wear the tracker while being physically active, I wonder if it tracks my activity correctly.

Note. Items with an “r” were reversed prior to computing a mean score. Participants answered all items displayed here on a 6-point Likert scale from *completely disagree* to *completely agree*, coded as 1 to 6.

Table A3. *Translated item texts of scale items for assessing intrinsic/extrinsic motivation for tracker usage (original German item wording can be obtained from the authors).*

Scale label		Item text
Intrinsic motivation	1	I use my activity tracker because I find it interesting to deal with my activity data.
	2	I use my activity tracker because I want to learn more about my physical activity.
	3	I use my activity tracker because it is fun to deal with my activity data.
Extrinsic motivation	4	I use my activity tracker because reaching my step or activity goals encourages me.
	5	I use my activity tracker because it assists me in taking care of my physical fitness.
	6	I use my activity tracker to avoid taking too little exercise.

Note. Participants answered all items displayed here on a 6-point Likert scale from *completely disagree* to *completely agree*, coded as 1 to 6.

Table A4. *Translated item texts of scale items for assessing intrinsic motivation for/external regulation of physical activity based on the Situational Motivation Scale (Guay et al., 2000; original German item wording can be obtained from the authors).*

Scale label		Item text
Intrinsic motivation	1	I am physically active/exercise because I think that this activity is interesting.
	2	I am physically active/exercise because I think that this activity is pleasant.
	3	I am physically active/exercise because this activity is fun.
	4	I am physically active/exercise because I feel good when doing this activity.
External regulation	5	I am physically active/exercise because I am supposed to do it.
	6	I am physically active/exercise because it is something that I have to do.
	7	I am physically active/exercise because I don’t have any other choice.
	8	I am physically active/exercise because I feel that I have to do it.

Note. Participants answered all items displayed here on a 6-point Likert scale from *completely disagree* to *completely agree*, coded as 1 to 6.