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Goal Setting and Achievement for Walking: A Series of N-of-1 Digital Interventions

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Objective: Despite evidence that goal setting is valuable for physical activity promotion, recent studies highlighted a potential oversimplification in the application of this behavior change technique. While more difficult performance goals might trigger higher physical activity levels, higher performance goals might concurrently be more difficult to achieve, which could reduce long-term motivation. This study examined (a) the association between performance goal difficulty and physical activity and (b) the association between performance goal difficulty and goal achievement. ***Method:*** This study used data from an e-Health intervention among inactive overweight adults ($n = 20$). The study duration included a 2-week baseline period and an intervention phase of 80 days. During the intervention, participants received a daily step goal experimentally manipulated by taking participants' baseline physical activity median (i.e., number of steps) multiplied by a pseudorandom factor ranging from 1 to 2.6. A continuous measure of goal achievement was inferred for each day by dividing the daily number of steps by the goal prescribed that day. Linear and generalized additive models were fit for each participant. ***Results:*** The results confirm that, for a majority of the participants involved in the study, performance goal difficulty was positively and significantly associated with physical activity ($n = 14$), but, concurrently, negatively and significantly associated with goal achievement ($n = 19$). These associations were mainly linear. ***Conclusion:*** At the daily level, setting a higher physical activity goal leads to engaging in higher physical activity levels, but concurrently lower goal achievement.

Keywords: physical activity, idiographic, goal difficulty, goal achievement, e-health

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Goal setting is among the most often applied behavior change techniques within behavioral intervention and there is clear evidence suggesting its utility for increasing physical activity (Howlett et al., 2019). A performance goal is a personal representation of desired

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outcome or behavior, such as walking 10,000 steps per day (Locke & Latham, 2002). The importance of goal setting for health behavior change has been acknowledged in several prominent behavioral theories, such as social cognitive theory (Bandura, 1977). Among these, the *goal setting theory* (see Latham & Locke, 2007; Locke & Latham, 2002) is commonly used to guide intervention development, particularly for physical activity (Swann et al., 2020). One of the key hypotheses of the goal setting theory is that performance goals, in specific situations, are positively related to behavioral outcomes, with specific and difficult goals leading to higher performance than vague, easy, or no goals (Latham & Locke, 2007; Locke & Latham, 2002). In terms of mechanisms, the theory assumes that consciously setting performance goals increases the targeted behavior by guiding individual attention, motivation, and strategies toward a specific objective (Latham, 2016). The goal setting theory also specified several factors that moderate the degree to which a performance goal will influence behavioral performance, including: (a) an individuals' ability to attain the goal; (b) task complexity; (c) commitment toward the goal; (d) feedback on performance; and (e) resources for attaining the performance goal (see Swann et al., 2020 for a discussion in the physical activity literature). In the physical activity domain, a meta-analysis of experimental trials suggests that physical activity levels improved when goal-setting was included in an intervention compared with when it was not included (Cohen's $d = .55$) McEwan et al., 2016. This positive effect was observed across a range of delivery modes, intervention lengths, and physical activity measurement approaches, and across populations that varied in relation to age, baseline weight, activity status prior to the intervention, and gender (McEwan et al., 2016).

Despite clear evidence of the value of goal-setting, recent work suggests the risk of a possible oversimplification of the concept (Baretta et al., 2019; Swann & Rosenbaum, 2018; Swann et al., 2020). Specifically, Swann et al. (2020) has highlighted the potential unintended consequences of focusing exclusively on specific, challenging performance goals to promote physical activity. The authors argued that performance goals might have deleterious effects on physical activity if the performance goal is beyond the person's capabilities in context. In accordance with the initial theory, the authors also highlighted that a person could become increasingly dissatisfied over time if they continue to not meet their performance goals, which could result in progressive disengagement over time. Hence, the authors suggested that interventionists should not only focus on performance when setting a physical activity goal, but should also consider goal achievement (e.g., how close the person was to achieving her/his goal) and learning goals (e.g., creating skills and capabilities for increasing physical activity; see Swann & Rosenbaum, 2018; Swann et al., 2020). Within this article, we examine issues of performance and goal achievement but do not focus on learning goals.

To the best of our knowledge, there are only two articles that have examined the interrelationship between goal difficulty, behavioral performance, and goal achievement in the physical activity domain (Anson & Madras, 2016; Moon et al., 2016). The most relevant of the two in the context of the present study was conducted by Moon et al. (2016). In this study, performance goal difficulty was experimentally manipulated to examine its impact on behavioral performance and goal-achievement. They randomized adults between 40 and 65 years old who were mostly physically active (8,243 steps per day on average at baseline), into five different groups for a 1-week period, with daily step goals set as percentages above their previous 7-days of steps: (a) the "easy goal group" was instructed to increase their daily steps by 10%; (b) the "medium goal group," was asked to increase daily steps by 20%; (c) the "difficult goal group," was instructed to increase daily steps by 40%; (d) the "as much as possible" was not given a specific target and, instead, just asked to "do your best"; and (e) the control group did not receive any goal setting intervention. In accordance with the goal setting theory, both the medium and difficult goal groups increased their steps more than the do-your-best and control groups. No significant differences were found between groups for goal achievement, measured as the number of days over a week when participants reached their goals.

Moon et al.'s (2016) study thus validated the main hypothesis of the goal setting theory; higher goals are positively related to higher performance, at least in the short term and among relatively active individuals. The study did not find a relationship between goal difficulty and goal achievement. With that said, the study had some key limitations for examining this hypothesis. First, the intervention only lasted one week. Based on this, it's possible that participants made efforts to reach their medium to difficult goals during this short period, but that a different pattern of response to goal achievement would have occur over a longer time period. Second, goal achievement was expressed as a sum of binary outcomes (i.e., number of days when the goals were achieved vs. not achieved). While this is the current dominant way of conceptualizing goal achievement, there are theoretical, practical, and statistical reasons for conceptualizing goal achievement as a continuous concept. Specifically, we contend that goal achievement should be conceptualized as the percentage to which a person did not meet, meet, or exceeded their target goal. This is theoretically justifiable as there could be different psychological experiences based on how close one is to not meeting, meeting, or exceeding one's performance goal. For example, the experience of performing only 50% of one's performance goal would likely be experienced differently from 95% of one's performance goal. For practical reasons, a continuous conceptualization is likely valuable in making future intervention decisions. For example, it is likely that a health coach would offer different recommendations between a person who did not meet their performance goal at 60% of the goal compared with another person who did not meet their goal but was at 99% of their goal. Similarly, future intervention adaptations might differ if a person achieves 150% of their performance goal compared to just meeting their performance goal at 101%. Statistically speaking, a continuous variable provides the variance needed to examine the possible added value of a continuous as opposed to binary conceptualization (Iselin et al., 2013). Thus, there are theoretical, practical, statistical, and, if our analyses show meaningful results, empirical reasons to conceptualize performance goal achievement as a continuous variable, which has not been done in prior work. As a final limitation to the Moon et al. (2016) article, baseline physical activity levels were relatively high in each group and, as highlighted in the literature, different results might be expected with less active participants, who, ultimately, are the target of physical activity interventions (Swann & Rosenbaum, 2018).

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The Present Study

To summarize our interpretation of this prior work (Bandura, 1977; Latham & Locke, 2007; Moon et al., 2016; Swann et al., 2020), more difficult performance goals will trigger higher physical activity levels but higher performance goals will also be more difficult to achieve, and, over time, failing to achieve one's goals will lead to discouragement. Thus, an "optimal goal setting zone" might exist for goals that trigger high behavioral performances while still being doable (i.e., an "ambitious but doable" goal; see Figure 1 and Hekler et al., 2018). Our primary hypotheses are that: (a) setting goals with higher difficulty leads to higher physical activity, and (b) setting goals with higher difficulty leads to lower goal achievement.

Beyond this, we also theorize potential nonlinear relationships between goal difficulty, physical activity, and goal achievement. Specifically, we see four plausible relationships, which are visualized in Figure 1. Figure 1A visualizes the hypothesis of a positive linear relationship, which fits with prior observations from industrial and organizational psychology areas (Locke & Latham, 2019). Figure 1B visualizes a hypothetical possibility that a plateau exists with regard to the relationship between goal difficultly and physical activity. This plateau is theoretically plausible based on Swann et al.'s (2020) postulation that physical activity would not be able to go beyond one's capabilities. Thus, goal difficulty will only influence physical activity up to a person's capability and, anything beyond that, the relationship will plateau as visualized in Figure 1B. A third possibility for the relationship between goal difficulty and performance, is an inverted U-shape. If this shape were observed, it would suggest that setting overly difficult goals could result in decreases in motivations to be physical activity, and, thus, as goal difficulty increases, physical activity actually reduces from feelings of being demotivated (Figure 1C; see also Grant & Schwartz, 2011). We believed that this hypothesis of nonlinearity might occur with specific types of behaviors, such as walking, which are necessarily constrained by a combination of physical capabilities, contextual barriers (e.g., time availability), and self-regulation skills. These hypotheses, notably the inverted U-shape postulated, are also aligned with assumptions made in the *social cognitive theory* (Bandura, 1977) and has already been postulated elsewhere in the physical activity context (Hekler et al., 2018).

In this study, we used an idiographic statistical approach, meaning that each study participant was treated separately from the others (i.e., not pooled in groups) and, instead statistical models of each person's time series data were generated. We did this for a variety of reasons. Overall, prior work suggest the high likelihood that physical activity is influenced by a variety contextual factors that would be experienced differently across individuals and also individual differences in factors such as fitness (Swann & Rosenbaum, 2018). Further, an idiographic approach has a series of statistical, conceptual and practical advantages that have been articulated in prior works (see Chevance, Perski & Hekler, 2020; Hekler et al., 2019, and Kwasnicka & Naughton, 2020). Finally, an idiographic approach is uniquely valuable for examining our exploratory hypotheses related to different plausible responses to goal difficulty (e.g., Figures 1A, 1B, or 1C). Specifically, if results were pooled, it is likely that these patterns would average out across participants and, thus, be missed. All hypotheses were examined at the daily level (e.g., how goal difficulty on 1 day impacts physical activity on that day), which is in accordance with goal setting recommendations for physical activity (i.e., daily goals are more effective than weekly goals to increase physical activity; McEwan et al., 2016). This study focuses only on performance goals (e.g., walking 10,000 steps), it does not focus on "learning" goals (see Swann et al., 2020 for the distinction).

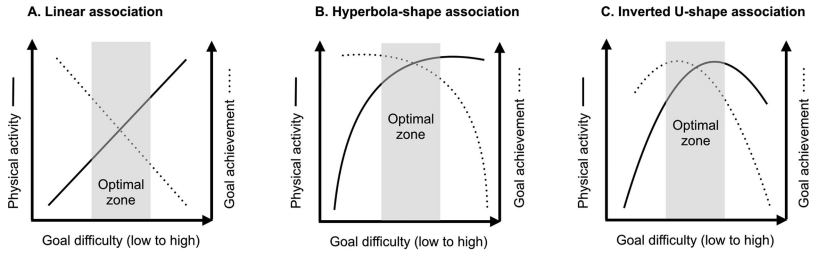
Method

Study Design

In the current study we performed secondary data analysis of the *Just Walk* study dataset. *Just Walk*, as described elsewhere (Korinek et al., 2018; Phatak et al., 2018), is a physical activity e-Health intervention for inactive, overweight adults. The intervention included a front-end Android app, a backend server, and a pedometer (i.e., Fitbit Zip) to measure participants' steps and automatically sync with the smartphone app. The total study duration included an initial 2-week baseline period and an intervention phase of 80 days.

Figure 1

Potential Shapes of the Associations Between Goal Difficulty, Physical Activity and Goal Achievement



Note. Figure 1A Represent a linear relationship between (a) goal difficulty and physical activity (plain line), and (b) goal difficulty and goal achievement (dotted line). Figures 1B and 1C represent these relationships with two different nonlinear patterns. The gray squares represent and hypothetical "optimal goal setting zone" where high behavioral performance and high goal achievement level are reach simultaneously.

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The baseline period assessed each participant's baseline level of physical activity (i.e., no goal setting interventions were delivered during this phase). During the intervention phase, participants received a daily step goal through the *Just Walk* app every morning. Each daily step goal was experimentally manipulated by taking participants' baseline physical activity median and multiplied by a pseudorandom factor ranging from 1 to 2.6. Therefore, the difficulty of the daily assigned goals ranged from "doable/easy" (i.e., 1*baseline median) to "challenging/difficult" (i.e., up to 2.6*baseline median). This experimental manipulation of goal difficulty was designed in order to "excite" variability into the step goals, for the primary purpose of conducting a system identification study (see Hekler et al., 2018).

Participants

We recruited healthy adults who were not meeting general physical activity recommendations (i.e., less than 1,000 metabolic equivalent of task [MET] minutes/week as measured by the International Physical Activity Questionnaire; Craig et al., 2003) and who were willing to take part in a walking e-Health intervention in which they would receive daily step goals via the *Just Walk* app. Individuals were excluded if they did not speak English, were pregnant, had a body mass index (BMI) >45 kg/m^2, indicated potential medical problems that precluded unsupervised physical activity based on the Physical Activity Readiness Questionnaire (PAR-Q; Adams, 1999), or were currently participating in a commercial or research-related diet or exercise program.

Participants were recruited in the United States through nationwide university listservs and through social media advertisements. After completing the screening survey (see Korinek et al., 2018), eligible participants were sent the online informed consent and invited to participate. Those who enrolled in the study were provided with a Fitbit Zip physical activity tracker. All participants completed informed consent and all study procedures were approved by the appropriate institutional review board.

Experimental Manipulation

Goal Difficulty (Independent Variable)

Daily step goals were experimentally manipulated by taking the median of the participants' baseline steps (measured for 2 weeks, prior to the intervention), and multiplied by a pseudorandom factor ranging from 1 to 2.6, ranging from a daily "easy" to "challenging" goal, respectively. For example, a participant with a baseline median of 2,000 steps per day would receive goals between 2,000 (2,000*1) and 5,200 (2,000*2.6). In the present study, the variable "goal difficulty" ranged from 1 to 2.6, as a ratio of their goal relative to their baseline median steps. The median has been chosen instead of the mean to limit potential issues of skew distribution in steps. The factor of 2.6 has been chosen arbitrarily based on early pilot testing.[1]

Measures

Physical Activity (Dependent Variable). Daily steps were measured through the Fitbit Zip, a wearable physical activity device that has been validated against criterion measures (e.g., direct observation) for steps (Evenson et al., 2015). Nonwear days, defined as days with fewer than 500 steps were removed. The Fitbit Zip was also used to measure the baseline level of steps (i.e., average steps per day during 2 weeks before the start of the intervention).

Percentage of Goal Achievement (Dependent Variable). A continuous measure of goal achievement was inferred for each day by dividing the daily number of steps from the goal prescribed that day and then converting this to a percentage by multiplying this value by 100. For this, 100% corresponds to the achievement of a goal, a value superior to 100% corresponds to a goal that has been surpassed and, values below 100% indicate the extent to which a goal was not met. For example, if a participant received a goal of 6,000 steps, and performed 7,000 steps that day, the participant would receive a score of 117%, meaning that the goal was surpassed by 17%.

Data Analyses

Our primary aim was to examine the relationships between goal difficulty and steps and goal difficulty and goal achievement. This study employed an idiographic approach, meaning that each participant was analyzed separately from the others (see Molenaar & Campbell, 2009). To study these primary aims, linear regression models were used to fit to the data. Linear models included the daily number of steps as a dependent variable, the daily goal difficulty factor (ranging from 1 to 2.6) as the independent variable, and the study day as a control variable to account for the effect of time over the intervention period. Model 2 was similar with the exception that goal achievement was the dependent variable. The syntax of the models was the following:

Model 1:

$$\textit{Daily steps} = \beta_0 + \beta_1\, \textit{goal difficulty} + \beta_2\, \textit{study day} + \varepsilon$$

Model 2:

$$\textit{Goal achievement}(\%) = \beta_0 + \beta_1\, \textit{goal difficulty} + \beta_2\, \textit{study day} + \varepsilon$$

As our exploratory hypotheses included the possibility of nonlinear relationships (see Figure 1), we also fitted generalized additive models (GAM; Hastie & Tibshirani, 1986), which is a method that has been previously recommended for analyzing N-of-1/single case design studies (Shadish et al., 2014). Notably, GAMs allow the relationships between the independent and dependent variables to be modeled by smooth curves, thus providing a tool to model potential nonlinearity in an additive structure.

The two generalized additive models were conducted with a similar structure to the linear models but included one-dimensional smoother terms (*f*) for the two independent variables to discover

[1] The recommended step goals never increased during the 80 days of intervention. Based on this point, it was initially hypothesized that there would be a significant increase in daily steps from the 2-week baseline period to intervention phase but no major increases during the intervention phase. This point is empirically controlled for with our modeling efforts. Consequently, this unique study design enables these secondary analyses examining how varying level of goal difficulty affects daily behavioral performances and goal achievement. That said, the study design was less appropriate to study dynamic changes over time (e.g., goal difficulty that would increase progressively in relation with previous day physical activity and goal achievement).

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their functional forms. We chose the commonly used knot based cubic regression splines for the smoothing term for goal difficulty and a cyclic version of it for the study day smoother. The cyclic cubic regression splines are useful for fitting models with cyclic components, such as time and seasonal effects. Regarding the number of knots, we used 10 for the smoothing term for study day. Meanwhile the knots for the second smoother was set to the number of unique daily goal difficulty values for each participant (see Hastie & Tibshirani, 1986).

Model 3:

$$Daily\ steps = \beta_0 + f_1(goal\ difficulty) + f_2(study\ day) + \varepsilon$$

Model 4:

$$Goal\ achievement(\%) = \beta_0 + f_1(goal\ difficulty) + f_2(study\ day) + \varepsilon$$

Both the linear and generalized additive models were compared using Akaike's information criterion (AIC), with smaller values for the information criterion indexes indicating a better model (Vrieze, 2012). GAMs estimate nonlinearity using the effective degrees of freedom (edf) of the smoothing terms, with edf >3 indicated some form of nonlinearity (Shadish et al., 2014).

The frequent longitudinal nature of the data involved potential autocorrelation issues in the outcome and residuals of the models. However, in the present study, most of the participants did not show a statistically significant autocorrelation in the residuals (i.e., values were mostly within the 95% CI around zero). Moreover, accounting for this autocorrelation issue with generalized additive mixed models (GAMM) for the few participants that were of concern did not significantly improve models' fit. Because the few significant autocorrelations were scattered over all lags and we can expect roughly 5% to be significant by chance, we decided to not account for autocorrelation in the present analyses.

The amount of missing data in steps and goal achievement was marginal (11%), so no imputations were applied. No specific transformations of the variables were performed either. Outlier values were inspected before running the models; goals that were outperformed by 200% (less than 5% of the data) were trimmed to 200% (i.e., each value exceeding "200" was replaced by the value "200"); and this rule was also applied to the raw number of steps (i.e., steps = 2*prescribed steps goal on that day when goal achievement >200%). No adjustments were made for multiple testing.

The packages *mgcv* (see, Wood, 2017) and *visreg* (Breheny & Burchett, 2017) from the statistical software *R* (Version 3.6.2; R Core Team, 2017) were used to conduct and visualize the models. The data and code used for the main analyses are provided on the Open Science Framework repository platform (see https://osf.io/2sw6a/).

Results

Participants and Descriptive Statistics

Participants (n = 20) were overweight (mean BMI = 33.79 kg/m^2, SD = 6.82), mostly female (90%; mean age = 47 years, SD = 6.16), and, on average, moderately active before the intervention (mean steps/day = 4,863, SD = 2,097). Overall, there was high adherence for the steps' assessment (average number of valid physical activity days per participants = 71/80; see Table 1 in online supplemental material).

Participants systematically increased their daily steps count between the baseline and intervention period (average levels of steps performed during the baseline and intervention period were 4,863 and 7,185 steps/day, respectively). The average level of goal achievement during the intervention was 104%. Information for each participant are provided in the Table 1 in online supplemental material.

Model Outcomes

For steps as the dependent variable, AIC were comparable between participants for the linear and generalized additive models, meaning that the addition of a smoothed (i.e., nonlinear) term did not improve models' fit, but did not deteriorate it either (see Table 2 in online supplemental material). The edf of the smoothing term were mainly around 1.0 and systematically under 3.0 indicating a linear trend between goal difficulty and steps for the participants. This linear trend was positive for all participants, excluding participant #16, and significant for 14 participants out of 20 (70%) after controlling for time (i.e., study day).

Plots of the relationships between goal difficulty and steps are presented in Figure 2. Positive trends appear between the two outcomes, except for Participants #3, #4, #7, #9, #16, and #17, for whom goal difficulty was not significantly related to steps.

For most participants, linear and generalized additive models fit were also comparable for goal achievement as the dependent variable (Table 2 in online supplemental material). Participants #8, #10, and #15 had effective degrees of freedom >3, indicating some form of nonlinearity in the relationship between goal achievement and goal difficulty for those participants. This relationship was systematically negative across participants, and significant for all excluding one (Participant #6) after controlling for time (i.e., study day). Plots of the relationship between goal difficulty and goal achievement are presented in the Figure 3.

Ancillary Analyses

During the revision process, an anonymous reviewer asked us to verify whether the associations observed between goal difficulty, goal achievement and physical activity were consistent over the study duration (i.e., time varying effect). The results of these ancillary analyses are presented in the online supplemental material.

Discussion

Results confirm that goal difficulty is positively associated with physical activity, but, concurrently, negatively associated with goal achievement. In other words, at the daily level, setting a higher physical activity performance goal leads to engaging in higher physical activity levels, but also lower goal achievement. Contrary to our hypotheses, however, these relationships were mainly linear and relatively consistent across individuals.

Regarding the first hypothesis (i.e., setting goals with higher difficulty leads to higher physical activity performances), the positive association found between goal difficulty and physical

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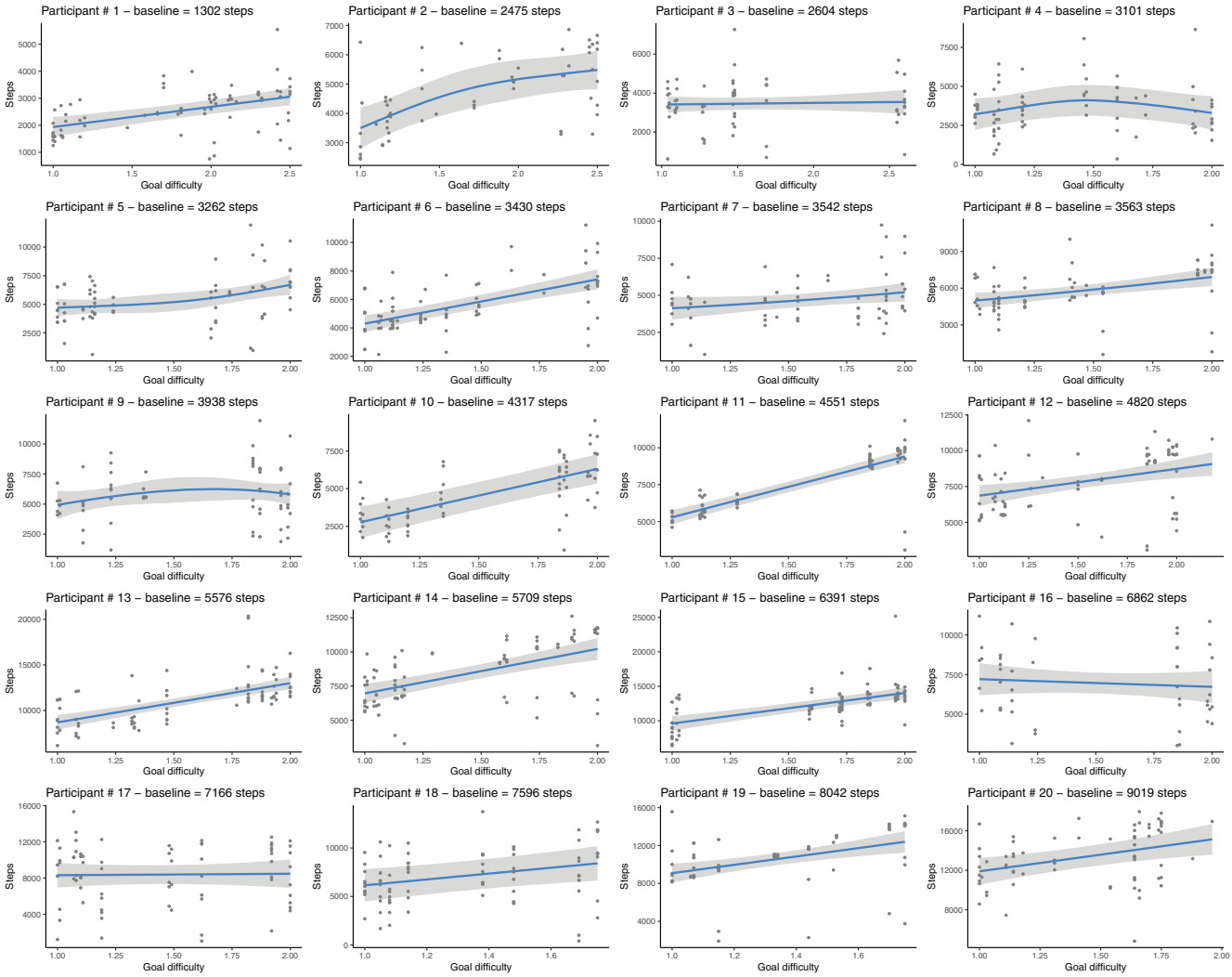
Figure 2

Plots of the Generalized Additive Models for Steps



Note. Plots of the models for steps as a dependent variable. See the online article for the color version of this figure.

activity is in alignment with prior work (Anson & Madras, 2016; Moon et al., 2016) and expands on it. Our results confirmed that the effect of goal setting on physical activity is not only a product of between-participants differences, but also a within-participant process (i.e., within an individual, varying levels of goal difficulty affect daily physical activity performance). This result is important because several studies have shown differences when studying psychological and behavioral phenomena between versus within-person (Chevance et al., 2020; Conroy et al., 2015).

Regarding the second hypothesis (i.e., setting goals with higher difficulty leads to lower goal achievement), this study shows a negative association between performance goal difficulty and goal achievement for physical activity. This result is different from Moon et al.'s (2016) work, which found no significant relationships between goal difficulty and goal achievement. This discrepancy, however, is probably due to a few key differences. In the present study, goal achievement was expressed as a continuous indicator, which enables a more precise analysis in this context and also better powered to detect an effect (Altman & Royston, 2006). In addition, the Moon et al. (2016) study included only a 7-day intervention compared with an 80-day intervention period in the present study. Finally, our study took an idiographic approach to examining the relationships over time, and as opposed to a 7-day between-person snapshot as was the case in the Moon et al. (2016) study.

If one assumes that a low level of goal achievement is deleterious over time (e.g., decrease in motivation; Swann et al., 2020), the results do not rule out the existence of an "optimal goal setting zone," at least for some participants. Indeed, if goal difficulty was positively and significantly associated with physical activity for 14 participants out of 20, goal difficulty was concurrently negatively and significantly associated with goal achievement for 19 participants out of 20.

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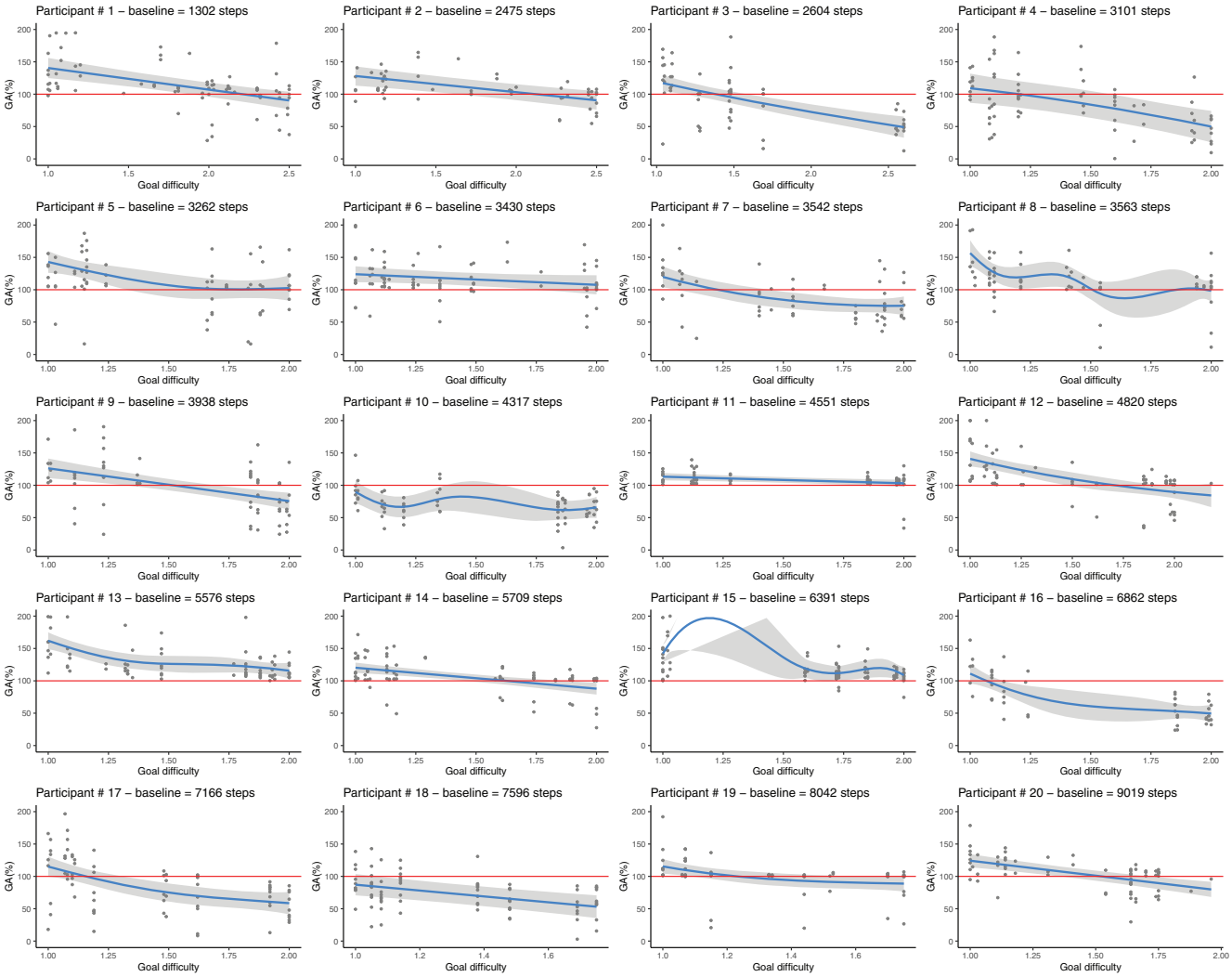
Figure 3

Plots of the Generalized Additive Models for Goal Achievement (Red Lines Represent a Goal Achievement of 100%)



Note. Plots of the models for goal achievement as a dependent variable. GA(%) = Percentage of Goal Achievements. See the online article for the color version of this figure.

Among those 19 participants, roughly 50% presented behavioral performances clearly under the achievement threshold represented by the red line in the Figure 3 (Participants #1, #3, #4, #7, #9, #10, #16, #17; Figure 3). For those participants, respecting the principle of the "optimal goal setting zone" (i.e., setting goal difficulty to be within each person's normative goal achievement levels) might be warranted. However, for the participants that did not cross their achievement threshold (i.e., Participants #5, #6, #11, #13, #15), more difficult goals might be prescribed.

A key possible implication of this result, if it is replicated and extended, is that practitioners or researchers involved in goal setting for physical activity may benefit from "tuning" goal difficulty levels based not on performance only, which is the norm, but performance and goal achievement. This is important because most current physical activity guidelines are still focused on generic, nonpersonalized, goal performance (e.g., 10,000 steps) and do not incorporate performance goal achievement (see Swann & Rosenbaum, 2018; Swann et al., 2020).

Contrary to our hypothesis, however, the relationships between goal difficulty, physical activity, and goal achievement were mainly linear. Indeed, we did not observe a plateau (Figure 1B) or an inverted U-shape curve (Figure 1C) in the physical activity performance or the related goal achievement. This suggests that our participants did not experience a threshold of goal difficulty that, above it, resulted in either a decoupling of difficulty and performance (Figure 1B) or even be deleterious (Figure 1C). While some participants presented nonlinearity for the association between goal difficulty and achievement (see Table 2 in online supplemental materials; Participants #8, #10, #15), visual inspection suggests the differences are likely more of a statistical artifact than a true

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nonlinear process (see Figure 3, Participants #8, #10, #15). This absence of nonlinearity might be due to a sampling-measurement issue (i.e., 80 observations per participant is probably insufficient to model true nonlinear associations for this outcome), or to our experimental manipulation of goal difficulty (i.e., higher goal difficulty levels could be manipulated to explore participants' boundaries). Because a plateau necessarily exists for physical activity (i.e., a physical fitness and temporal limits within a given day), future investigations of this effect are warranted. Further, a longer study period, using methods similar to the present study, would likely be needed to fully test if sustained difficulty goals would result in demotivation over time. Furthermore, measuring a motivational indicator would enable more rigorous testing of the potential impact of goal difficulty on motivation.

Finally, while we expected some interindividual differences with regards to the participants' average physical activity levels, visual inspection of Figures 2 and 3 indicated a relatively high consistency between participants for this association. For example, the shapes of the two relationships for Participants #1 and #20 were mostly similar, although these participants had very different starting physical activity levels (2,520 and 12,474 step/day on average, respectively). If replicated with larger samples, these results would indicate that the relationships between goal difficulty, physical activity, and goal achievement are consistent across individuals.

Study Strengths, Limitations, and Perspectives

The strengths of this study include its novel design (i.e., open loop system ID experiment), which, combined with the idiographic approach, provides unique information about the relationships between goal difficulty, physical activity performance (i.e., steps), and goal achievement among participants with varying baseline physical activity levels.

The study has several limitations. First, although its unique study design enables the analyses of varying levels of goal difficulty on daily behavioral performance and goal achievement, the use of the baseline median steps as a referent for defining the suggested goals limits the full study of our hypotheses. Goal difficulty varied according to a randomization factor that was not designed to produce significant increases beyond those that would be observed between the baseline week and the first week of the intervention (see also Footnote 1). This is because the goal difficulty did not further increase over the 80-day intervention period. Thus, the current study design was not appropriate to test if sustained poor *g*oal achievement detrimentally influences physical activity over time. A logical next step would be to conduct a "close loop experiment" (see Conroy et al., 2019; Hekler et al., 2018), where the daily allocation of a goal would be determined based on past physical activity and level of achievement during the study. An open loop experiment, the design adopted in the present study, is "open" because the intervention options that are provided to a person are specified a priori, before the intervention; conversely, a closed loop system ID experiment is characterized by interventions options that are adjusted over the course of the intervention on the basis of each person's responsivity to the intervention (see Hekler et al., 2018 for further explanations of these designs). For example, a simple way of "closing the loop" would be to use a "moving horizon" strategy in future system ID experiment. Specifically, rather than use the baseline median as a reference, the median steps from the past "x" number of weeks (e.g., 4 weeks) could be used as the referent that is then multiplied by the pseudorandom goal factor. More advanced closed loop experiments could also incorporate other issues, such as goal achievement. Thus, a closed loop system ID experimental design would enable testing of more dynamic hypotheses about goal setting and determine, for example, how the optimal goal setting zone changes over time and, perhaps, in different contexts (Hekler et al., 2012).

Second, the goal setting theory specifies four moderators that are postulated to impact the association between a performance goal and behavioral performance: ability, commitment, feedback, and situational resources (Latham, 2016). Because the present study only accounted for one of these moderators ("ability" with baseline physical activity levels used as a proxy indicator), future research is needed to explore how other factors may impact the associations between performance goal difficulty, physical activity, and goal achievement. For example, it might be assumed that goal difficulty is more likely to trigger high behavioral performance on those days when participants feel more confident or energetic than usual, more committed to be physically active, or received more encouraging feedback and social support than usual.

Third, this study focused on "performance goals" only, while alternative goal setting practices have been proposed; for example, Swann et al. (2020) have proposed a hypothesis that learning goals (i.e., goals that focus on the number of ideas or strategies needed to accomplish a task effectively) may be preferable among insufficiently active participants in comparison to performance goals. According to the same authors, learning goals might also be particularly relevant in comparison to performance goals when specific moderators are unmet or the conditions unfavorable (e.g., low self-efficacy or low commitment to be physically active). Future work could better incorporate the learning goals and corresponding strategies for supporting a person in building their capabilities to achieve performance goals. In alignment with the goal setting theory, improving one's capability via learning goal setting, could likely increase the goal difficulty range, and, thus is important to take into consideration with regard to this "optimal goal setting range" hypothesis (Latham & Locke, 2007; Locke & Latham, 2002).

As discussed in our supplemental work (see Figure 4 in the online supplemental material), we found a drop in engagement at the middle of the intervention for Participant #2. Difficult goals started to no longer be associated with high behavioral performances and, logically, more difficult goals were less likely to be achieved. Although this result is anecdotical (i.e., this time varying effect was significant for one participant only), it indicates that the relationships between goal difficulty, goal achievement, and steps might vary over time during an intervention. Other studies are needed to better understand this effect of time on these two relationships (see on this topic: Scholz, 2019). Finally, according to recent theoretical propositions (e.g., Papies, 2016; Rebar et al., 2016; Sheeran et al., 2013), it would be interesting to test the effect of goal priming

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techniques that do not rely solely on conscious and rational processes in physical activity promotion.

Conclusion

This study confirms that performance goal difficulty is positively associated with physical activity, but, concurrently, negatively associated with goal achievement at the daily level. In other words, at the daily level, setting higher physical activity goal leads to higher physical activity levels but also lower goal achievement. Taken together, these results, when assuming that not meeting one's performance goals would have a deleterious effect on physical activity over time, suggest the possible existence of an "optimal goal setting zone," which would involve performance goals that are challenging but also achievable. If these findings are replicated and the set of future studies needed to study this "optimal goal setting zone" are conducted and conform with the hypothesis, then practitioners or researchers involved in goal setting for physical activity should consider "tuning" performance goal difficulty levels to not only behavioral performance but performance and goal achievement.

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