

ORIGINAL ARTICLE

(Un)aware of change? Objective and subjective reactivity to the sensor-based measurement of physical activity and sedentary behaviour

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Funding information

European Commission, Grant/Award Number: 728018 and 847879

Abstract

Objectives: Despite being the gold standard for assessing physical activity (PA) under free-living conditions, accelerometer-based assessments are prone to measurement reactivity, that is, changes in people's cognitions, emotions or behaviour due to being measured. Little is known about whether participants are aware of these changes. This pre-registered secondary analysis assesses objective and subjective reactivity to the sensor-based measurement of PA (steps, light PA [LPA], moderate-to-vigorous PA [MVPA]) and sedentary behaviour (SB) in adults with and without attention-deficit/hyperactivity disorder (ADHD), depression and insulin resistance.

Design: Intensive longitudinal design.

Methods: Two existing datasets were used, comprising 354 adults (64% female; $M_{\text{age}} = 35.63$, $SD_{\text{age}} = 13.98$; $M_{\text{BMI}} = 26.27$, $SD_{\text{BMI}} = 5.85$) who wore an accelerometer for 7 days and self-reported whether they changed their PA due to the activity tracker (i.e. subjective measurement reactivity). Objective measurement reactivity was defined as decreases in PA and increases in SB.

Results: Multilevel models found small, but significant decreases of PA over the study period and from the first study day(s) to the remaining study days. Yet, over 90% of participants indicated to have (*rather*) *not* changed their PA. SB did not systematically change. Subjective measurement reactivity and clinical diagnoses were not related to measurement reactivity.

Laura M. König and Silke Matura share last authorship.

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Conclusions: Steps, LPA and MVPA, but not SB, systematically changed in line with common definitions of measurement reactivity. Yet, most participants were unaware of these changes, potentially because changes were small. Measurement reactivity may be predominantly driven by unconscious mechanisms and appears universal, with no differences found by diagnoses.

KEYWORDS

accelerometer, measurement, physical behaviour, research participation effects, sedentary behaviour

Statement of Contribution

What is already known on this subject?

- Device-measured physical activity may be equally, if not more, prone to measurement reactivity (MR), that is, changes in people's cognitions, emotions or behaviour due to being measured.

What does this study add?

- Small MR effects were found for physical activity, but not sedentary behaviour.
- The unawareness of these changes suggests that MR may be driven by unconscious mechanisms.
- With no differences found across clinical diagnoses, MR may be a universal phenomenon.

INTRODUCTION

The accurate assessment of health behaviours is central to building robust theory and evidence in health psychology. Accelerometers are considered the gold standard for the measurement of physical activity (PA) under free-living conditions (Gabrys & Vogt, 2024). Accelerometers allow the continuous recording of PA in daily life and are often referred to as *objective* assessments (e.g. Prince et al., 2008), which may suggest that their assessments are free of biases present in other (subjective) PA assessments (e.g. self-reports). However, research suggests that device-measured PA may be equally, if not more, prone to measurement reactivity (König et al., 2022), that is, changes in people's cognitions, emotions or behaviour due to being measured (French & Sutton, 2010). Measurement reactivity in the context of health behaviours is commonly understood as short-lived increases in healthy and decreases in unhealthy behaviours in the first study day(s) which then return to normal levels (König et al., 2022).

A meta-analysis found small effects of measurement reactivity in the digital in-the-moment assessment of PA, which may introduce bias into PA measurement (König et al., 2022). Although these effects might be short-lived and are heterogeneous across studies (König et al., 2022), the risk of systematic changes in the outcome measurement and thereby in the conclusions of studies should be taken seriously (French & Sutton, 2010). In behavioural intervention studies, small-to-medium effect sizes are typically expected and considered clinically meaningful. Consequently, even small measurement reactivity effects may complicate the interpretation of behavioural intervention studies (Baumann

et al., 2018). Although randomized controlled trials are less susceptible to bias in between-group comparisons when both groups are equally affected by the measurement procedure, measurement reactivity may still influence estimates of PA, particularly when interpreting within-group changes and absolute activity levels. Similarly, measurement reactivity can also cause bias in observational studies. For instance, accelerometer-based PA measures are often averaged across days to get an estimate of the participants' typical level of PA (König et al., 2025). Even small changes at the beginning of the measurement period can bias these averages and produce inaccurate conclusions (König et al., 2025).

Importantly, the results of the meta-analysis were somewhat heterogeneous and more consistent for some PA indicators than for others (König et al., 2022). For instance, a larger number of studies found evidence for measurement reactivity when more easily modifiable PA indicators (i.e. steps and activity counts) were studied, compared to PA indicators that are potentially harder to change (i.e. moderate-to-vigorous PA [MVPA]). Yet, these conclusions are predominantly based on cross-study comparisons, since only few studies reported on more than one PA indicator. Studies testing measurement reactivity effects for a range of PA indicators obtained from the same sample are required to draw more substantial conclusions.

Furthermore, most studies included in the meta-analysis assessed measurement reactivity in the context of PA, while only four studies assessed reactivity to the measurement of sedentary behaviour (SB). Given that SB is a risk factor for health independent of PA (Patterson et al., 2018) and is frequently assessed through accelerometers (e.g. Ekelund et al., 2020), more attention should be directed to measurement reactivity in relation to SB. This is especially important because in the context of health behaviours, measurement reactivity is commonly operationalized as increases in healthy (e.g. PA) and decreases in unhealthy behaviours (e.g. SB) in the first study days which then return to normal levels (Arigo & König, 2024; Maher et al., 2024). Reactivity to the measurement of PA and SB is thus expected to produce diverging patterns in the data.

Arigo and König (2024) highlight that measurement reactivity is a particular concern in patient populations in which PA and SB changes are closely linked to clinical outcomes. Psychological and behavioural factors that influence responses to monitoring may differ between healthy individuals and clinical populations. Measurement reactivity may be stronger in clinical populations than in healthy populations, as the measurement context may increase the salience of PA and thereby facilitate greater attention to or self-regulation of this behaviour. For example, in populations where PA is closely linked to disease management and where individuals are more frequently exposed to recommendations to increase PA, monitoring may have different implications for how individuals perceive their own activity levels and whether they consider changing their behaviour. Given that PA and SB play an important role in the development, maintenance and treatment of several mental and physical disorders, clinical populations represent relevant contexts in which to investigate potential differences in measurement reactivity. For instance, individuals with major depressive disorder typically show lower levels of PA and higher levels of SB (Schuch et al., 2017). Beyond that, PA is a promising adjunctive treatment in mental disorders, including attention-deficit/hyperactivity disorder (ADHD) and depressive disorders (Vancampfort et al., 2025). Another population in which PA and SB are highly relevant are individuals with insulin resistance: Physical inactivity promotes the development of insulin resistance (Hamburg et al., 2007), while PA is associated with improved insulin sensitivity (Bird & Hawley, 2017; Mensberg et al., 2025). Even though accelerometers are often used to study these at-risk populations (e.g. Balkau et al., 2008; Chapman et al., 2017; Kruisdijk et al., 2017), reactivity to the sensor-based assessment of PA has not been studied specifically for them.

While several mechanisms of measurement reactivity are discussed in the literature, for example, social desirability and elevated motivation to be physically active (Barta et al., 2012; König et al., 2022), little is known about whether participants are aware of measurement reactivity-related changes. Only very few studies assessed *subjective measurement reactivity* by explicitly asking participants whether they believe their behaviour was influenced by the device and the monitoring procedure (Ebner-Priemer et al., 2007) or study participation (Eisele et al., 2023), overall pointing to low subjective measurement reactivity. Yet, no such study exists in the context of reactivity to the sensor-based measurement of PA

and SB. However, this could help to better understand whether reactivity to the sensor-based measurement of PA/SB is driven by conscious or unconscious mechanisms. For instance, if measurement reactivity results from changes intentionally initiated by participants, they could be mitigated through clear communication that the study aims to measure their normal PA and that PA should not be actively altered during study participation. This might help minimize participants' intentional efforts to alter their behaviour. Beyond that, subjective reports of measurement reactivity could be used as an indicator for the severity of the potential bias. In contrast, non-intentional or even unconscious reactivity is likely harder to control and may cause more subtle changes that can only be identified by data-driven approaches.

Present study

Given the need to assess measurement reactivity simultaneously for several PA indicators and SB as well as in at-risk populations, the present study assesses reactivity to the sensor-based measurement of three PA indicators as well as SB in healthy adults and adults with ADHD, depression and/or insulin resistance. This preregistered secondary analysis (<https://osf.io/yp2m9>) uses data from two Ambulatory Assessment studies to provide insights into the following four research questions: (1) Does reactivity occur in the measurement of different PA indicators (steps, light PA [LPA] and MVPA) over a 7-day sensor-based assessment? Is the effect stronger for steps and LPA than for MVPA? (2) Does reactivity occur in the measurement of SB over a 7-day sensor-based assessment? (3) Do participants feel that their PA changed (intentionally or non-intentionally) due to the measurement of PA, and is this related to actual changes in PA and SB?¹ In this study, 'non-intentional' (i.e. non-deliberate) subjective measurement reactivity refers to an individual's belief that their PA changed as a result of wearing the accelerometer, without intentionally initiating this change and that they became aware of this change during or after the monitoring period. (4) Does measurement reactivity differ across individuals with ADHD, depression and insulin resistance versus healthy adults?

Based on prior work (König et al., 2022), measurement reactivity is defined as a decrease in PA as well as an increase in SB over the 7-day study period. In addition to these linear effects, PA and SB on the first day and first 2 days of the study are compared to the remaining study days, since prior research indicated that measurement reactivity might be especially pronounced in this period (Arigo & König, 2024; Maher et al., 2024). Hypotheses for research questions 1 and 2 can be found in Table 1. Research questions 3 and 4 are exploratory.

METHODS

The present paper conducts secondary analyses using data from the two following studies: APPetite study (Ruf et al., 2021), part of the European Union Horizon2020 project Eat2beNICE, and mPRIME study (Gruber et al., 2024), part of the European Union Horizon2020 project PRIME. Research questions of the present paper including planned analyses were preregistered prior to data analyses (<https://osf.io/yp2m9>). The local ethics committee of the Faculty of Medicine of Goethe University Frankfurt (Ethikkommission des Fachbereichs Medizin der Goethe-Universität) approved both studies (reference numbers: 192/18 [APPetite study] and 20-767 [mPRIME study]). All participants declared that they understood the study procedure and signed a written informed consent.

¹Please note that the wording of research question 3 was revised after preregistration to improve conceptual clarity. The underlying research question and the corresponding analyses remain unchanged.

TABLE 1 Hypotheses for research questions 1 and 2.

Research question 1	
<i>Steps are expected to ...</i>	
H1.1a	Linearly decrease over the 7-day study period
H1.2a	To decrease between study Day 1 versus all other days in the study
H1.3a	To decrease between study Days 1 and 2 versus all other days in the study
<i>Minutes of light physical activity are expected to ...</i>	
H1.1b	Linearly decrease over the 7-day study period
H1.2b	To decrease between study Day 1 versus all other days in the study
H1.3b	To decrease between study Days 1 and 2 versus all other days in the study
<i>Minutes of moderate-to-vigorous physical activity are expected to ...</i>	
H1.1c	Linearly decrease over the 7-day study period
H1.2c	To decrease between study Day 1 versus all other days in the study
H1.3c	To decrease between study Days 1 and 2 versus all other days in the study
H1.4	The <i>effect of measurement reactivity</i> is expected to be larger for steps and LPA compared to MVPA.
Research question 2	
<i>Minutes of sedentary behaviour are expected to ...</i>	
H2.1	Linearly increase over the 7-day study period
H2.2	To increase between study Day 1 versus all other days in the study
H2.3	To increase between study Days 1 and 2 versus all other days in the study

Study samples

Study cohort 1

The APPetite study is a prospective, observational Ecological Momentary Assessment (EMA) study. The study recruited 257 participants from four existing study samples: Adults with ADHD and/or depression were invited from (1) the PROUD (Prevention of Comorbid Depression and Obesity in Attention-Deficit/Hyperactivity Disorder) study (Mayer et al., 2018), (2) the BipoLife-A1 study that follows up individuals with an increased risk for bipolar disorders, including patients affected by ADHD or depression (or both) (Pfennig et al., 2020; Ritter et al., 2016) and (3) the PROBIA (Treating Impulsivity with Probiotics in Adults) study, which recruited patients with ADHD or borderline personality disorder (or both) (Arteaga-Henríquez et al., 2020). Healthy adults were recruited from the Longitudinal Resilience Assessment study, which enrolled individuals not affected by psychiatric conditions and followed them up since 2016 (Chmitorz et al., 2021). The APPetite study collected data from 186 healthy individuals as well as 71 individuals with ADHD and/or depression from 2018 to 2021. Participants completed two in-person sessions as well as a 7-day ambulatory assessment period.

Study cohort 2

The *m*PRIME study is a prospective, observational, longitudinal study. Between 2021 and 2023, 124 adults were enrolled in the study. Participants met the following inclusion criteria: at least 18 years of

age and provided written consent for participation. Beyond that, they did not meet any of the following exclusion criteria: use of antidiabetic medications or insulin, diagnosis of type 1 diabetes mellitus or gestational diabetes, corticosteroid use, psychiatric diagnoses including bipolar I disorder, schizophrenia, organically caused mental disorders and substance dependence (other than nicotine and cannabis dependence), severe neurological disorders, pregnancy and breastfeeding, non-correctable visual impairments, participation in medication-related studies within the last 6 months, weight-reducing medications or dieting in the last 3 months and language barriers. Participants were categorized into two groups based on the Homeostasis Model Assessment of Insulin Resistance (HOMA-IR) index: (1) individuals with insulin resistance and (2) individuals who are insulin-sensitive (i.e. healthy). Participants attended four in-person sessions across a year and completed a 7-day ambulatory assessment period.

Study procedure

In both studies, participants wore an accelerometer for seven consecutive days and nights on the non-dominant wrist, while completing eight EMA prompts per day on three of the 7 days (either Thursday to Saturday or Sunday to Tuesday). Details on the study procedures can be found in Ruf et al. (2021) and Gruber et al. (2024). Sociodemographic and anthropometric information was collected before the ambulatory assessment period, while subjective measurement reactivity was captured after the ambulatory assessment period.

Measures

Only measures relevant to the present analyses are listed below; for a comprehensive overview see Ruf et al. (2021) and Gruber et al. (2024).

Sociodemographic information

Participants were asked to report their age in years and to indicate their gender.

Anthropometric measures

Body weight (in kg) and body height (in m) were measured in an in-person session and used to calculate body mass index (BMI) according to the following formula: $\text{weight}/(\text{height} \times \text{height})$.

Physical activity and sedentary behaviour

The software DataAnalyzer (movisens GmbH, Karlsruhe, Germany; Version 1.13.7) was used to calculate steps and metabolic equivalents of task (MET) per minute based on the raw acceleratory data captured by the accelerometers (Move3 or Move4 from Movisens GmbH, Karlsruhe, Germany). MET values were adjusted to account for the sensor placement on the wrist using a conversion factor obtained by a sensor validation study (Giurgiu et al., 2020). Nonwear and sleep times were excluded. The sum of all *steps* across each study day was calculated. Minutes of *LPA* were determined by MET values above 1.5 and below 3 and summed up for each study day. Minutes with MET values of 3 and above were categorized as *MVPA* and added up for each study day. Minutes with MET values of 1.5 or below were categorized as *SB* and summed up for each study day.

Subjective measurement reactivity

Participants were asked to indicate if they changed their PA intentionally ('I intentionally changed my physical activity because of the activity tracker.'/'Ich habe meine körperliche Bewegung aufgrund des Bewegungssensors bewusst geändert.') or non-intentionally ('I believe I unintentionally changed my physical activity due to the activity tracker.'/'Ich glaube, ich habe meine körperliche Bewegung aufgrund des Bewegungssensors unbewusst geändert.') due to the activity tracker with two items on a 5-point scale (0 = *not applicable*, 1 = *rather not applicable*, 2 = *partly*, 3 = *rather applicable*, 4 = *applicable*).

Data preprocessing

Across both cohorts, PA data were available for 364 participants with a total of 2504 days. In the first step, days on which the sensor was worn for less than 10h while being awake were excluded ($n=172$), resulting in PA data of 362 participants with 2333 days. In the second step, participants with only one valid day of PA data were excluded ($n=8$), resulting in a final sample of 354 participants with 2324 days of PA data (see Table 2). In addition, participants who did not report subjective measurement reactivity were excluded from the analysis of research question 3 ($n=3$).

Data analysis

Preregistered analyses

As study days (Level 1) were nested in participants (Level 2), multilevel models with a random intercept for participants as the cluster variable were used for analyses. All models were first run with random slopes for the time variable. However, several models showed singular fit, wherefore the random slopes for the time variable were removed. Some models failed to converge with the default optimizer and converged only after switching to an alternative optimizer (i.e. bobyqa). To control for the cohorts, each model includes the dummy variable *cohort* indicating if participants belong to the APPetite (=0) or *m*PRIME cohort (=1). Shapiro tests indicated that the residuals of the null models of the four outcomes (i.e. linear multilevel models without predictors) did not follow a normal distribution (see results in Additional File S1, Table S1). However, visual inspection of the residual distribution confirmed only minor deviations from normality for steps, LPA and SB (see density and quantile-quantile plots in Additional File S1, Figure S1), wherefore linear multilevel models are reported for steps, LPA and SB. This allows direct comparison with previous studies, as they also used linear multilevel models (e.g. Arigo & König, 2024). In contrast, MVPA showed strong deviations from normality, as it included many zero values and was highly right-skewed, a commonly observed pattern in daily PA data (Baldwin et al., 2016). Thus, a negative binomial distribution was used for MVPA, reflecting the count-like nature of PA measures (Green, 2021; Ma et al., 2025). Estimates in negative binomial regressions are modelled on the log scale, wherefore (1) the exponential of the intercept represents the intercept in the original metric and (2) the exponential of the predictor estimates represents rate ratios associated with a one-unit increase in the respective predictor, for example, $\exp(.08)=1.08$ which indicates that a one-unit increase in the respective predictor is associated with an 8% increase in the outcome. For all models, alpha was set to .05.

Following Arigo and König (2024) as well as Maher et al. (2024), three separate multilevel models were run for each PA indicator (RQ1) and for SB (RQ2): (1) time included as a linear predictor (i.e. study day coded from 0 on Day 1 to 6 on Day 7), to examine if there are linear changes in the respective outcome over time (testing H1.1a, H1.1b, H1.1c and H2.1, respectively); (2) the first day in the study versus all other days included as a dummy predictor (Day 1=1; Days 2–7=0) to examine if there are differences between the first day of the study versus all other days (testing H1.2a,

H1.2b, H1.2c and H2.2, respectively); (3) the first 2 days in the study versus all other days included as a dummy predictor (Days 1–2=1; Days 3–7=0) to examine if there are differences between the first 2 days of the study versus all other days (testing H1.3a, H1.3b, H1.3c and H2.3, respectively). If the time predictor in model 1 reached statistical significance, but not in models 2 and 3, we planned to run a fourth model, including dummy-coded variables for each day separately (but without random slopes). This was, however, not the case. For research question 1, effect sizes are descriptively compared to determine whether the effect of measurement reactivity is larger for steps and LPA compared to MVPA (H1.4).

For research question 3, the mean and standard deviation of the two variables assessing subjective measurement reactivity are reported. Beyond that, the same models as for research question 1 and 2 with additional cross-level interaction between the respective time variable (Level 1) and the perceived intentional and non-intentional change in behaviour (i.e. subjectivity measurement reactivity; Level 2) were run to test whether participants who felt that their behaviour changed because of the activity tracker showed stronger measurement reactivity effects. Subjective measurement reactivity was grand-mean centred.

For research question 4, the same models as for research question 1 and 2, with additional cross-level interactions between the respective time variable (Level 1) and three dummy variables (i.e. *ADHD*, *depression* and *IR*) indicating which diagnoses participants have (Level 2) were run to test whether the measurement reactivity effects differ between participants with ADHD (*ADHD*=1), depression (*depression*=1), ADHD and depression (*ADHD*=1 and *depression*=1) or insulin resistance (*IR*=1) versus healthy adults (all three dummy variables=0).

Analyses were run using R (R Core Team, 2025), RStudio (Posit team, 2025) and the R packages *lme4* (Bates et al., 2015), *lmerTest* (Kuznetsova et al., 2017), *glmmTMB* (Brooks et al., 2017) and *performance* (Lüdtke et al., 2021). The dataset, including the codebook, and the R code used in this paper can be found Additional Files S2, S3 and S4.

Deviations from the preregistered analyses

In the preregistration it was planned to report sample characteristics for the total sample as well as for each study group: healthy, ADHD, depression and insulin resistance. To avoid overlapping study groups, we decided to separately report sample characteristics for the group of individuals who have a comorbidity of ADHD and depression. Hence, Table 2 describes the total sample and five study groups (i.e. healthy, ADHD, depression, ADHD & depression, insulin resistance) based on gender (*n*/ % women, *n*/ % men, *n*/ % other), age (*M*, *SD*) and BMI (*M*, *SD*).

To account for systematic changes in PA due to variations in PA between weekends and weekdays (Baumann et al., 2018) and days with and without EMA prompts, all models included the variable *weekend* that indicates if the day is a weekday (=0) or a weekend (=1) and the variable *ema* which indicates whether participants received EMA prompts on this day (=1) or not (=0). The inclusion of the *weekend* and *ema* variable was not preregistered. It was decided to deviate from the preregistration and control for these two covariates as it has been shown that the day of the week may affect measurement reactivity (Baumann et al., 2018), and it is likely that the awareness of the PA measurement is higher on days on which participants receive EMA prompts compared to days on which they only wear the accelerometer. Random slopes for these two covariates were included if model fit and convergence allowed.

Instead of the preregistered semi-partial correlation, semi-partial R^2 was calculated as the effect size measure. The semi-partial R^2 represents the unique proportion of variance in the outcome explained by a predictor, reflecting its incremental contribution beyond the other predictors in the model. Note, however, that the estimation of semi-partial R^2 in multilevel models is approximate and depends on the underlying variance decomposition.

RESULTS

The following results are presented in the metric corresponding to the respective statistical model. Accordingly, estimates for steps, LPA and SB are reported in their original units (i.e. number of steps and minutes of LPA and SB), whereas estimates for MVPA are presented as rate ratios (i.e. relative changes) because MVPA was analysed using a negative binomial multilevel model.

Sample characteristics

The final sample includes 354 participants. Sociodemographic characteristics for the total sample as well as for each study group can be found in Table 2. On average 6.57 valid days of PA data (SD=1.01) were available per participant in the final sample.

Research question 1: Does reactivity occur in the measurement of different PA indicators (steps, LPA and MVPA) over a 7-day sensor-based assessment? Is the effect stronger for steps and LPA than for MVPA?

Figure 1a–c shows the distribution and the average number of steps as well as minutes of LPA and MVPA across the seven study days. In the following, model results for the relationships between the three time variables and daily PA indicators are reported. For simplicity, only fixed effect estimates of the time variables are shown (see Figure 2). Estimates of the intercepts and covariates as well as random effects can be found in the model summaries provided in Additional File S5.

A significant linear trend of study day was found for all three PA indicators (see Figure 2). With each study day, steps decreased on average by 122 steps (semi-partial $R^2=.001$), LPA by 3.0 min (semi-partial $R^2=.003$) and MVPA by 1.9% (semi-partial $R^2=.0009$). The effect sizes indicate that the effect was strongest for LPA, followed by steps and MVPA.

As hypothesized, participants engaged on average in 11.6 more minutes of LPA (semi-partial $R^2:.002$) and in 7.0% more MVPA (semi-partial $R^2:.0004$) on Study Day 1 compared to the following study days. However, against expectations, no significant differences between Study Day 1 versus all other study days were found for steps (semi-partial $R^2:.0005$). Again, the effect was strongest for LPA, followed by steps and MVPA.

When comparing Study Days 1 and 2 versus all other study days, results of all PA indicators confirmed the hypotheses, that is, a decrease between Study Days 1 and 2 versus all other days in the study.

TABLE 2 Sociodemographic characteristics of the total sample as well as each study group separately.

	Total sample (N=354)	Healthy (n=237)	ADHD (n=25)	Depression (n=26)	ADHD & depression (n=15)	IR (n=51)
Variable	n (%) / M (SD)	n (%) / M (SD)	n (%) / M (SD)	n (%) / M (SD)	n (%) / M (SD)	n (%) / M (SD)
Gender						
Female	227 (64.12)	162 (68.35)	9 (64)	14 (53.85)	10 (66.67)	32 (62.75)
Male	127 (35.88)	75 (31.65)	16 (36)	12 (46.15)	5 (33.33)	19 (37.25)
Age (years)	35.63 (13.98)	32.89 (12.59)	37.24 (12.80)	27.81 (5.56)	32.07 (10.17)	52.59 (11.91)
BMI	26.27 (5.85) ^a	24.29 (3.73) ^a	29.42 (7.20)	28.17 (7.04)	27.33 (8.73)	32.58 (6.16)

^aBMI missing for one participant.

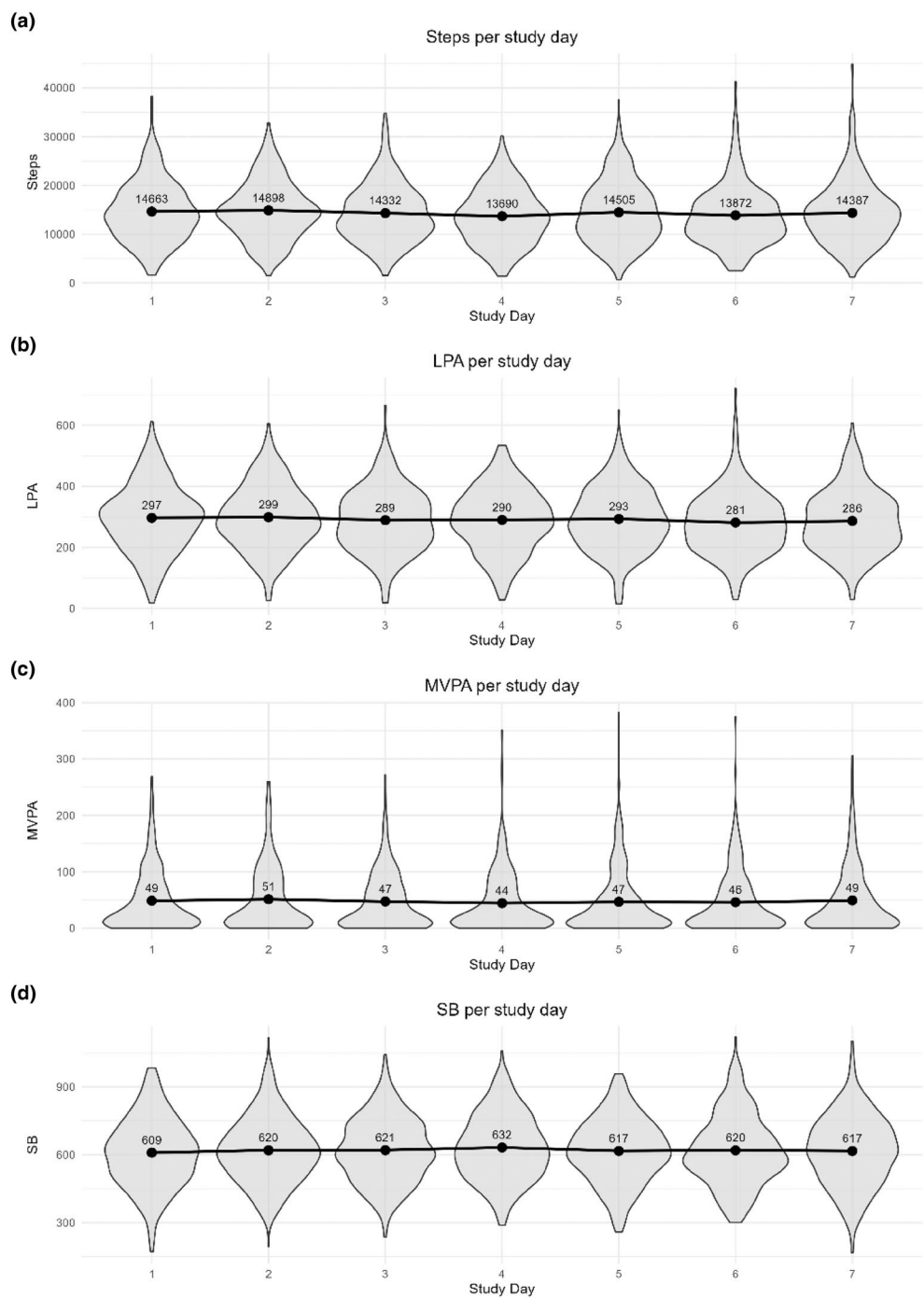


FIGURE 1 Distribution and average of steps (Panel a) as well as minutes of LPA (Panel b), MVPA (Panel c) and SB (Panel d) across the seven study days. LPA, light physical activity; MVPA, moderate-to-vigorous physical activity; SB, sedentary behaviour.

Accordingly, participants took on average 668 more steps (semi-partial R^2 : .002), engaged in 13.7 min of LPA more (semi-partial R^2 : .004) and in 9.0% more MVPA (semi-partial R^2 : .001) on Study Days 1

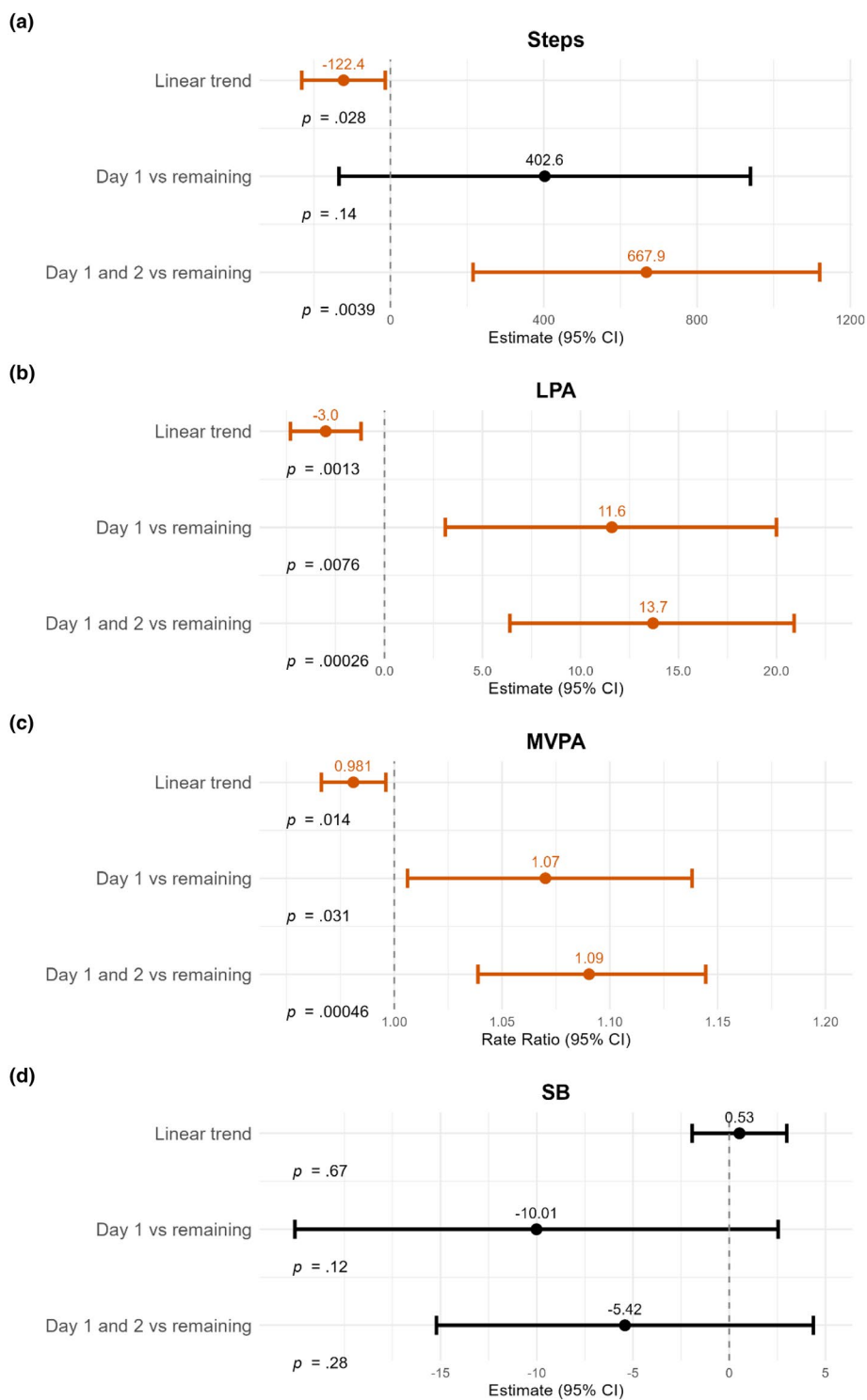


FIGURE 2 Point estimates and 95% confidence intervals (CI) of the fixed effects of the three time variables for steps (Panel a), LPA (Panel b), MVPA (Panel c) and SB (Panel d) with significant effects highlighted in orange. LPA, light physical activity; MVPA, moderate-to-vigorous physical activity; SB, sedentary behaviour. Estimates for steps, LPA and SB are in the original metric (i.e. number of steps, minutes of LPA and MVPA), while estimates for MVPA represent rate ratios due to applying a negative binomial model.

and 2 compared to the following study days. The effect was again smallest for MVPA, followed by steps and LPA.

Research question 2: Does reactivity occur in the measurement of SB over a 7-day sensor-based assessment?

The distribution and average number of minutes of SB across all participants for each of the seven study days are illustrated in Figure 1d. Contrary to expectations, no linear trend across the seven study days (semi-partial R^2 : $-.0007$) and no difference between Day 1 versus all other study days (semi-partial R^2 : $.0005$) and between Days 1 and 2 versus all other study days (semi-partial R^2 : $.0002$) were found (see Figure 2d).

Research question 3: Do participants feel that their PA changed (intentionally or non-intentionally) due to the measurement of PA, and is this related to actual changes in PA/SB?

Across the 351 participants who rated subjective measurement reactivity, 335 (95.4%) indicated to have *not* ($=0$) or *rather not* ($=1$) changed their PA *intentionally* ($M=.27$, $SD=.66$) and 326 (92.9%) to have *not* or *rather not* changed their PA *non-intentionally* ($M=.35$, $SD=.70$). Subjective measurement ratings were not related to actual changes in PA and SB, that is, no significant interaction effects of the three time variables and (non-)intentional subjective measurement reactivity were found (see Figure 3).

Research question 4: Does measurement reactivity differ across individuals with ADHD, depression and insulin resistance versus healthy adults?

Only one significant cross-level interaction was found between the linear time variable and ADHD in predicting SB (see Figure 4). However, contrary to the expected measurement reactivity effect (i.e. an increase over the study period), individuals with ADHD decreased their SB over the study. All other cross-level interactions were not significant indicating that overall measurement reactivity effects do not differ between individuals with and without ADHD, depression and insulin resistance.

DISCUSSION

Measurement reactivity can lead to systematic changes in the outcome of interest, potentially reducing the validity of study conclusions. The present study indicates that a 7-day accelerometer-based measurement of steps, LPA and MVPA is affected by reactivity: Small, but significant decreases over the study period as well as from Study Days 1 and 2 to the remaining study days were found for all three PA indicators. Effect sizes indicate that measurement reactivity effects were stronger for LPA and steps, compared to MVPA, although all effects were small. No evidence of reactivity to the measurement of SB was found. Most individuals reported no change in their PA behaviour due to the activity tracker. Subjective measurement ratings were not related to actual changes in PA. Beyond that, the results suggest that measurement reactivity effects do not differ between individuals with and without ADHD, depression and insulin resistance.

In line with a previous meta-analysis (König et al., 2022), small decreases of steps, LPA and MVPA over the study period, in line with common definitions of measurement reactivity, were found. It is important to highlight that these effects were found even though accelerometers were used that do not display any real-time feedback. Generally, measurement reactivity effects are expected to be particularly

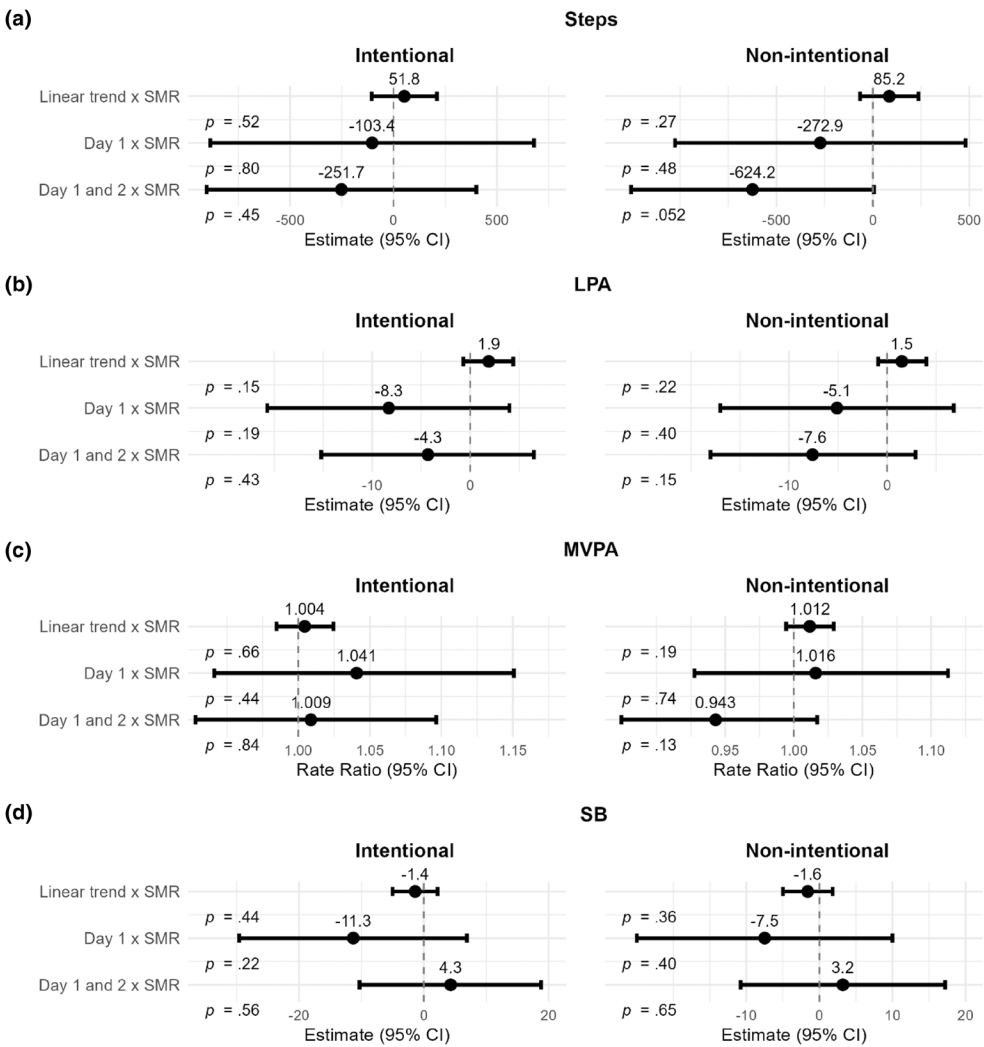


FIGURE 3 Estimates and 95% confidence intervals (CI) of the interaction effects of the time variable and (non-) intentional subjective measurement reactivity (SMR) for steps (Panel a), LPA (Panel b), MVPA (Panel c) and SB (Panel d). LPA, light physical activity; MVPA, moderate-to-vigorous physical activity; SB, sedentary behaviour. Estimates for steps, LPA and SB are in the original metric (i.e. number of steps, minutes of LPA and MVPA), while estimates for MVPA represent rate ratios due to applying a negative binomial model.

pronounced when participants wear a device that provides immediate feedback (Clemes & Parker, 2009). However, in the present studies, participants were aware that they receive a summary of their PA engagement at the end of the study which was offered as an incentive for study participation. Even though participants were instructed not to change their PA, the knowledge about receiving feedback at the end of the study might have influenced measurement reactivity effects.

Our findings differ from the recent study by Häusser et al. (2026), which found no evidence of accelerometer-based measurement reactivity. However, it is important to highlight that the study addressed a different aspect of measurement reactivity. Whereas Häusser et al. experimentally manipulated participants' awareness of the measurement purpose and compared mean PA across two monitoring weeks, the present study examined temporal changes in PA during a 7-day monitoring period. It is therefore possible that short-lived changes occurring during the first days of monitoring are not captured by designs comparing average activity across longer observation periods.

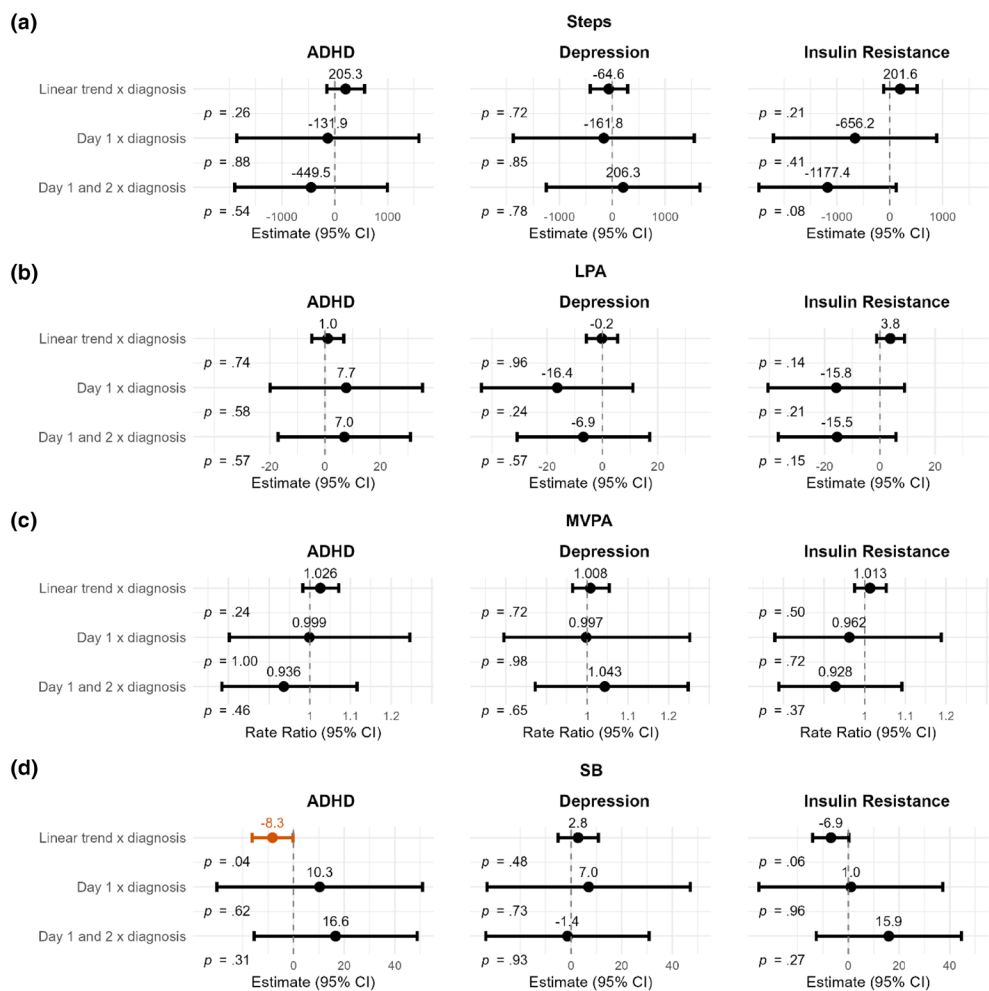


FIGURE 4 Estimates and 95% confidence intervals (CI) of the interaction effects of the time variable and the three diagnosis variables for steps (Panel a), LPA (Panel b), MVPA (Panel c) and SB (Panel d) with significant effects highlighted in orange. LPA, light physical activity; MVPA, moderate-to-vigorous physical activity; SB, sedentary behaviour. Estimates for steps, LPA and SB are in the original metric (i.e. number of steps, minutes of LPA and MVPA), while estimates for MVPA represent rate ratios due to applying a negative binomial model.

Our findings further suggest that the temporal pattern of measurement reactivity may be more nuanced than an immediate response restricted to the first monitoring day. Descriptively, activity levels for all three PA indicators (steps, LPA and MVPA) were highest on Study Day 2. Moreover, for LPA and MVPA, effect estimates were larger when comparing Study Days 1 and 2 with the remaining monitoring days than when comparing Study Day 1 alone with the remaining days. Likewise, for steps, only the comparison of Study Days 1 and 2 versus the remaining days reached statistical significance. At the same time, a small but significant linear decrease in activity was observed across the 7-day monitoring period for all three PA indicators. Taken together, these findings suggest that activity was highest during the first two monitoring days and then gradually declined over the remainder of the monitoring period rather than showing a pattern confined to the first day alone.

The present analysis found no statistically significant changes in SB over the study period, which is contrary to several prior studies (e.g. Arigo & König, 2024; Baumann et al., 2018; Ullrich et al., 2021),

but in line with others, including a study using an experimental design (Vanhelst et al., 2017), that did also not report measurement reactivity for SB. Our findings suggest that SB may show little or no measurement reactivity. One possible explanation for the absence of measurement reactivity effects on SB is that SB is strongly driven by habitual processes (Conroy et al., 2013) and may therefore be relatively resistant to short-term change. However, PA is also shaped by habitual processes, suggesting that habit alone is unlikely to fully explain differences in measurement reactivity across behaviours. Further research is needed to replicate these findings. If replicated, this would be reassuring for studies assessing SB, as measurement alone would be unlikely to systematically influence the behaviour being assessed.

Effect sizes were small for all significant measurement reactivity effects. LPA and steps, behaviours thought to be easier to change, showed minimally stronger effects than MVPA, which has previously been considered more difficult to change. While this is in line with the assumption that measurement reactivity is stronger for behaviours that are easier to change (König et al., 2022), no measurement reactivity effects were found for SB, which has been previously considered a more easily modifiable behaviour in some studies (Arigo & König, 2024). Hence, finding measurement reactivity effects for MVPA, a behaviour that is potentially harder to change, but not for SB challenges this assumption. However, a recently published study found that individuals of a similar age demographic perceive engaging in 300 min of MVPA per week as easier than spending less time sitting (see study 1 in Allmeta et al., 2026). Together with our results, these findings support the notion that measurement reactivity may be stronger for behaviours that are easier to change.

Furthermore, although effects were generally small, they still have the potential to influence conclusions from observational and intervention research, especially since effect sizes in behavioural research, including behavioural intervention research (Baumann et al., 2018) are typically small to medium. Accordingly, researchers may consider implementing protective measures to minimize measurement reactivity from occurring, for example, by blinding participants to the outcome of interest (MERIT Collaborative Group et al., 2021). Another strategy to reduce potential measurement reactivity is to extend the monitoring period and exclude the initial measurement day(s) from analyses, in order to allow participants a familiarization period with the device prior to the observation window of interest. However, further research is needed to determine the optimal length of this familiarization period and how many initial monitoring days should be excluded.

In line with previous research (Ebner-Priemer et al., 2007; Eisele et al., 2023), subjective measurement reactivity was very low. Over 90% of the sample indicated to have not or rather not changed their PA intentionally or non-intentionally due to the activity tracker. Given the very low levels of subjective measurement reactivity, it is not surprising that they were not related to actual changes in PA and SB. These findings suggest that participants were either unaware of the changes or unwilling to report them, for example, due to social desirability, as they had been instructed not to change their PA. However, the high consistency of subjective measurement reactivity ratings across participants indicates that they are unlikely to be attributable solely to social desirability. In the preregistration, we referred to the two forms of subjective measurement reactivity as 'conscious' and 'unconscious'. We acknowledge that these terms were imprecise and do not adequately reflect the intended distinction between deliberately initiated and non-deliberately initiated behavioural change, wherefore the terms 'intentional' and 'non-intentional' subjective measurement reactivity are used throughout the present publication. Importantly, this change reflects a clarification of terminology rather than a change in the underlying constructs or analyses. The non-intentional measure captures participants' retrospective perception that their PA changed as a result of wearing the activity tracker without intending to change their behaviour. Thus, it does not provide evidence of objectively observed non-intentional behavioural change or an unconscious behavioural process. Participants' responses may instead reflect their subjective interpretation or attribution of perceived changes in their behaviour. Nevertheless, the possibility that participants were not aware of measurement-related changes highlights that measurement reactivity may involve processes that are not fully accessible to conscious awareness. While instructing participants not to change their behaviour during the study, a common practice in studies assessing PA in daily life, may have weakened measurement reactivity effects, it cannot eliminate them entirely. The limited

controllability of unconscious measurement reactivity effects highlights the importance of models that account for them (e.g. Bendtsen & McCambridge, 2021). In order to reach a consensus on best practice recommendations for mitigating measurement reactivity in the context of PA and SB, more research is needed to better understand the (conscious and unconscious) mechanisms underlying reactivity to the sensor-based measurement.

While other studies assessed measurement reactivity in at-risk populations (e.g. women in midlife with elevated risk for cardiovascular disease, Arigo & König, 2024), this is the first study to test whether measurement reactivity effects are moderated by different clinical diagnoses, including ADHD, depression and insulin resistance. Overall, the results indicate that the presence or absence of a diagnosis does not influence measurement reactivity effects. This is in line with Arigo and König (2024) who found very little variability in PA measurement reactivity across individuals and conclude that PA measurement reactivity represents a general phenomenon rather than one that is particularly pronounced or weak in specific individuals. Strategies to address measurement reactivity in studies on PA thus may be universally needed.

The main strength of the present study is the relatively large and diverse sample, including individuals with and without ADHD, depression and insulin resistance. This allows for more robust and generalizable conclusions regarding PA and SB measurement reactivity. A limitation of the present study is that the residuals of the linear multilevel models for steps, LPA and SB showed minor deviations from normality and the distribution of MVPA was highly skewed with many zero values. Although appropriate modelling approaches were applied (i.e. linear models for steps, LPA and SB, negative binomial for MVPA) and visual inspections indicated that deviations were minor for most outcomes, the non-normality of residuals may still have affected parameter estimates and should be considered when interpreting the results. For the field to move forward, more attention must be paid to appropriate model selection. Daily PA data is known to diverge from normal distribution (Baldwin et al., 2016). This needs to be reflected in the chosen models. Another limitation of the study concerns the placement of the accelerometer. Although wrist-worn devices are generally more acceptable to participants and may increase compliance, they are known to overestimate activity-related metrics. We applied a correction procedure to reduce this bias for the MET values (Giurgiu et al., 2020); however, some overestimation likely remains. In addition, wrist-worn devices can produce higher step estimates under free-living conditions compared with devices worn at other body locations (Tudor-Locke et al., 2015). Therefore, the estimated absolute levels of PA should be interpreted with caution. Importantly, this limitation is unlikely to influence the measurement reactivity effects investigated in the present study, as a systematic overestimation would be expected to affect absolute activity levels rather than the within-person changes that were the primary focus of our analyses. Beyond that, the included clinical cohorts represent only a subset of populations in which PA is relevant for disease management. Although these clinical populations may represent important contexts for investigating measurement reactivity, the small sample sizes of the included cohorts, particularly the ADHD and depression groups, limit the statistical power to detect potential differences between populations. Future research with larger and additional clinical samples is needed to replicate and extend our findings.

CONCLUSIONS

Overall, the study highlights the presence of small reactivity effects in the measurement of PA, but not SB, in adults with and without ADHD, depression and insulin resistance. Although small, these effects should be considered when designing studies and interpreting accelerometer-based assessments of PA. Most participants were, however, unaware of these changes, potentially because changes were small. This highlights that measurement reactivity may be predominantly driven by unconscious mechanisms. More research is needed to better understand the mechanisms underlying reactivity to the sensor-based measurement of PA and SB. This knowledge will help to identify and prevent unwanted measurement reactivity effects.

AUTHOR CONTRIBUTIONS

Alea Ruf: Conceptualization; methodology; data curation; formal analysis; investigation; writing – original draft; writing – review and editing; visualization; project administration. **Judith R. Gruber:** Investigation; data curation; writing – review and editing; project administration. **Ulrich W. Ebner-Priemer:** Writing – review and editing; funding acquisition. **Andreas Reif:** Writing – review and editing; funding acquisition; resources. **Laura M. König:** Conceptualization; methodology; writing – review and editing. **Silke Matura:** Conceptualization; methodology; writing – review and editing; supervision; project administration; funding acquisition.

ACKNOWLEDGEMENTS

This work was supported by the European Union's Horizon 2020 Research and Innovation Program under grant agreement numbers 728018 and 847879. The funding source has had no involvement in the study design, data collection, interpretation of the findings or writing of this manuscript. Open Access funding provided by Universitat Wien.

The authors thank Maren Ballhausen, Franz Bruckner, Julia Christensen, Simone Demmel, Hiba El Jomaa, Jeanne Julia Flemming, Hendrik Friedrichsen, Marion Gekle, Maryam Golzarnia, Philipp Japtok, Julia Kiefer, Krystyna Kotthaus, Josefine Kursiefen, Kristiyana Petrova, Emina Ricciardi, Annika Roth, Yaribe Schmitter, Niklas Schoule, Lisanne Schunicht, Annebirth Steinmann, Christina Werning, Söri Wenz, Maik Wisker and Luise Wortmann for their contribution to data collection as part of the APPetite and mPRIME study.

This work is part of the LOEWE Center 'DYNAMIC', funded by the HMWK Hessen.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available in the [Supporting Information](#) of this article.

ETHICS STATEMENT

The local ethics committee of the Faculty of Medicine of Goethe University Frankfurt (Ethikkommission des Fachbereichs Medizin der Goethe-Universität) approved both studies (reference numbers: 192/18 [APPetite study] and 20-767 [mPRIME study]). All participants declared that they understood the study procedure and signed a written informed consent.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Ruf, A., Gruber, J. R., Ebner-Priemer, U. W., Reif, A., König, L. M., & Matura, S. (2026). (Un)aware of change? Objective and subjective reactivity to the sensor-based measurement of physical activity and sedentary behaviour. *British Journal of Health Psychology*, 31, e70115. <https://doi.org/10.1111/bjhp.70115>