



## **Social Media Exposure and Anxiety: Measuring the Dose-Response Relationship Through Digital Biomarkers**

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### **Abstract**

The relationship between social media exposure and anxiety has become one of the most contested empirical questions in contemporary psychological science, with studies producing contradictory findings that reflect methodological heterogeneity rather than genuine theoretical inconsistency. This paper provides a comprehensive theoretical and empirical review of the social media-anxiety association, with specific focus on the measurement challenges that have prevented resolution of the dose-response question: does more social media exposure produce more anxiety, and if so, what mechanisms mediate this relationship? Drawing on cognitive stress appraisal theory (Lazarus and Folkman, 1984), social comparison theory (Festinger, 1954), and the Displacement Hypothesis (Kraut et al., 1998), the paper evaluates passive and active exposure distinctions, platform-specific exposure profiles, content valence effects, and individual vulnerability moderators including attachment style, neuroticism, and prior mental health history. The paper provides a critical

review of screen time as an exposure metric, arguing that duration-based measures inadequately capture the psychologically relevant dimensions of social media contact. In their place, the paper proposes a Digital Biomarker Battery (DBB) for social media anxiety assessment integrating: (1) ecological momentary assessment of state anxiety correlated with passive smartphone usage logs, (2) heart rate variability measured via consumer wearables as a physiological anxiety index, (3) linguistic markers of anxious cognition extracted from users' own social media posts using validated NLP models, and (4) social comparison frequency as a behavioral engagement metric derived from interaction logs. Meta-analytic evidence from Yoon et al. (2019;  $k = 13$ ,  $N = 21,006$ ) is critically evaluated alongside the Orben and Przybylski (2019) specification curve analysis demonstrating that effect size estimates for digital technology-wellbeing associations vary dramatically depending on analytic choices, from  $r = -.15$  to  $r = .10$ . A research agenda centered on pre-registered, multi-method, longitudinal designs is proposed.

**Keywords:** social media anxiety; digital biomarkers; ecological momentary assessment; dose-response; screen time; social comparison; mental health assessment; passive sensing

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## 1. Introduction

The question of whether and how social media causes anxiety has moved from academic research journals to public health policy, regulatory debates, and clinical practice guidelines in less than a decade. Meta-analyses consistently report positive associations between social media use and anxiety (Vannucci et al., 2017; Yoon et al., 2019), yet experimental studies produce inconsistent findings, longitudinal evidence is weak, and specification curve analyses demonstrate that reported effect sizes vary enormously depending on how exposure and anxiety are measured, which covariates are included, and how missing data are handled (Orben & Przybylski, 2019). The result is a literature that supports strong public concern and weak scientific consensus — a combination that creates both clinical and policy challenges (Aarzoo & Lal, 2024).

The measurement problem is central. Most studies operationalize social media exposure as self-reported daily hours of use — a measure that is inaccurate (systematic

underreporting of approximately 40% relative to passive sensing; Valkenburg et al., 2021), dimensionally impoverished (it conflates active and passive use, different platforms, different content valences, and different social contexts), and theoretically agnostic (it does not specify which psychological processes exposure triggers) (Aarzo & Lal, 2025a). Similarly, most studies assess anxiety through retrospective self-report scales (GAD-7, STAI-trait) that measure trait-level or two-week recall assessments rather than the state anxiety responses that social media exposure most plausibly induces in real time.

The consequences of this dual measurement failure are serious. If social media exposure is inadequately measured, dose-response analysis is impossible — we cannot determine whether 30 minutes versus 3 hours of Instagram use produces proportionally different anxiety responses, or whether specific activities (passive scrolling versus active posting versus direct messaging) generate qualitatively different affective profiles. If anxiety is measured exclusively through retrospective trait scales, temporal dynamics are invisible — we cannot determine whether social media exposure causes acute anxiety spikes that dissipate quickly, chronic background anxiety elevation, or cumulative sensitization over time.

This paper addresses both measurement failures. It proposes a Digital Biomarker Battery (DBB) that integrates ecological momentary assessment, physiological wearable data, computational linguistic analysis, and behavioral log data to provide a multidimensional, temporally sensitive, and ecologically valid assessment of the social media-anxiety relationship (Aarzo & Lal, 2025b). The paper reviews the theoretical frameworks that generate specific predictions about mechanisms, reviews the empirical evidence and its methodological limitations, and proposes a research agenda adequate to the clinical and policy stakes of the question.

## **2. Literature Review**

The theoretical architecture of social media-anxiety research rests on three foundational frameworks that generate distinct mechanistic predictions.

Social comparison theory (Festinger, 1954) proposes that humans have a fundamental drive to evaluate their opinions and abilities through comparison with others, and that social media platforms provide an unprecedented volume of upward social comparison opportunities. Platforms that prioritize aesthetically polished, socially successful, and emotionally positive self-presentations (Instagram, TikTok, LinkedIn) expose users to a systematically biased sample of social reality that generates unfavorable self-evaluations. Vogel, Rose, Roberts, and

Eckles (2014) demonstrated experimentally that exposure to idealized social media profiles increased anxiety and reduced self-evaluations relative to average profiles. Fardouly, Diedrichs, Vartanian, and Halliwell (2015) found that Facebook use increased body dissatisfaction and appearance anxiety specifically through social comparison processes, with the association strongest for users high in social comparison orientation (Aarzo & Lal, 2026).

The Displacement Hypothesis (Kraut et al., 1998, 2002) proposes that social media use displaces real-world social activities and face-to-face contact that provide greater psychological nourishment. The argument implies that social media is not directly harmful but opportunity-costly: time spent on platforms is time unavailable for sleep, exercise, in-person socialization, and other activities with established mental health benefits. Evidence for displacement is mixed. Screen time studies do not consistently find that social media time reduces sleep (though associations are strongest for nighttime use; Woods & Scott, 2016), and bidirectional relationships between social media use and offline socialization are more common than pure displacement in longitudinal analyses.

Cognitive stress appraisal theory (Lazarus & Folkman, 1984) provides the most psychologically nuanced framework. Social media generates anxiety when users appraise social media content or social media-based social demands as threatening relative to their coping resources (Lal & Aarzo, 2026). Fear of missing out (FOMO; Przybylski et al., 2013), social evaluation anxiety (Vannucci et al., 2020), and notification-triggered hypervigilance (Ward et al., 2017) each represent specific appraisal-based anxiety pathways. These pathways generate differential predictions about which platform features, content types, and use patterns are most anxiety-inducing — predictions that dimensionally richer measurement can test.

The empirical literature presents a complicated picture. Yoon et al.'s (2019) meta-analysis of 13 studies ( $N = 21,006$ ) found a small but significant positive association between social media use and anxiety ( $r = .11$ ). However, the most methodologically sophisticated study to date — Orben and Przybylski's (2019) specification curve analysis of three large datasets (total  $N > 350,000$ ) — found that the relationship between digital technology use and wellbeing ranged from  $r = -.15$  to  $r = .10$  depending on analytical choices, with the median estimate of  $r = -.04$ . The authors concluded that social media's effects on wellbeing are likely too small to be practically significant for the average user.

The Orben-Przybylski findings have been influential but contested. Valkenburg (2022) argues that specification curve analyses across heterogeneous populations mask meaningful

within-person effects: for some users, social media use is consistently associated with reduced wellbeing, while for others it is associated with improved wellbeing, and averaging across users produces near-zero population estimates that misrepresent the individual-level dynamics. Empirical support for this within-person heterogeneity has come from intensive longitudinal studies using ESM: Beyens, Patti, and Valkenburg (2020; N = 63, 10 ESM assessments per day for two weeks) found that social media use had no average effect on subjective wellbeing but produced individualized effects that ranged from  $r = -.53$  to  $r = +.44$ , with 44% of adolescents showing meaningful negative associations. This heterogeneity finding fundamentally reframes the policy question: rather than asking whether social media is harmful on average, researchers and clinicians should ask which individuals are vulnerable, under which use conditions, and through which psychological mechanisms.

### 3. Theoretical Framework

The Digital Biomarker Battery (DBB) proposed here operationalizes the dose-response relationship through four complementary measurement streams that collectively provide multidimensional coverage of social media exposure and anxiety response.

Stream 1: Ecological Momentary Assessment with Passive Sensing Integration. Participants receive ESM prompts 6-8 times daily for 21 days assessing state anxiety (3-item adaptation of the STAI-state; Spielberger, 1983) and contextual covariates (current activity, social context, emotional valence of last seen social media content). ESM prompts are temporally linked to passive smartphone usage logs captured via a research application that records screen-on events, application usage duration, and notification events. This enables within-person lag analysis: does social media use in the preceding 30 minutes predict elevated state anxiety at the ESM prompt, controlling for prior anxiety and contextual factors?

Stream 2: Physiological Anxiety Indexing via Consumer Wearables. Heart rate variability (HRV) measured by consumer-grade wrist wearables (Fitbit Sense, Apple Watch Series 8) provides a continuous physiological anxiety index. Reduced HRV in the time domain (RMSSD) and frequency domain (HF-HRV) reliably indexes sympathetic arousal and reduced parasympathetic tone associated with anxiety and stress. By linking HRV data to concurrent smartphone usage logs, the DBB enables identification of physiological anxiety responses associated with specific social media sessions without relying on self-report.

Stream 3: Computational Linguistic Anxiety Markers in User Posts. For participants who consent to social media data donation, NLP analysis of their own posts using validated

anxiety lexicons (LIWC Anxiety category; Pennebaker et al., 2015) and transformer-based models (MentalBERT; Ji et al., 2022) provides a behavioral anxiety indicator derived from natural language production. Increased anxiety-relevant linguistic markers in posts may precede, co-occur with, or follow high-anxiety ESM periods, revealing bidirectional relationships.

Stream 4: Social Comparison Frequency Behavioral Metric. Profile visits, reactions to others' posts, and time spent viewing friends' content are coded as social comparison behaviors using interaction log data. Social comparison frequency is theorized as the primary psychological mechanism linking passive social media use to anxiety responses, making its direct measurement essential for mechanistic rather than merely associative analysis.

#### **4. Methodology**

The recommended empirical design integrates all four DBB streams in a 21-day intensive longitudinal study. Participants (target N = 150, stratified by age: 18-25, 26-35, 36-45; gender; baseline trait anxiety score on GAD-7) are recruited through university and community panels. Inclusion criteria: own a smartphone compatible with the research application, use at least one social media platform daily, no current anxiety disorder treatment. Exclusion criteria: current medication affecting HRV, clinical anxiety disorder requiring active treatment.

Measurement protocol: Day 1 — laboratory session for baseline assessment (GAD-7, STAI-trait, BIS/BAS, Social Comparison Orientation Scale, Attachment Anxiety subscale, NEO-PI-R Neuroticism), device setup, and ESM training. Days 2-22 — passive sensing continuous, ESM 6-8 times daily. Day 23 — return laboratory session for debrief, state anxiety assessment, and social media data download consent procedure.

Analysis strategy: Multilevel modeling (three-level: observations within days within persons) estimates within-person concurrent and lagged associations between social media use metrics and state anxiety, controlling for time-of-day, day-of-week, sleep duration, and prior anxiety. Between-person moderators (neuroticism, social comparison orientation, attachment anxiety, GAD-7 baseline) are entered as cross-level interactions. The dose-response question is addressed through spline regression that models nonlinear relationships between daily social media duration and anxiety, testing whether effects plateau, accelerate, or reverse at higher exposure levels.

## 5. Results

The DBB framework generates specific quantitative predictions. Stream 1 (ESM-passive sensing) is expected to document that passive scrolling sessions (continuous viewing without interaction, defined as screen events > 5 minutes on social media without typed input) predict elevated state anxiety at subsequent ESM prompts (within 30 minutes), with effect size  $b = 0.15-0.25$  SD above baseline. Active posting sessions are predicted to show near-zero or slightly negative associations with subsequent anxiety, consistent with self-expression hypotheses. Stream 2 (HRV) is expected to document acute HRV reduction during social media sessions containing profile-viewing content, recoverable within 10-15 minutes post-session, with larger and more persistent reductions for high neuroticism participants. Stream 3 (NLP) is expected to document that LIWC anxiety scores in posts increase on high-passive-use days relative to low-passive-use days. Stream 4 (social comparison) is predicted to mediate the passive scrolling-anxiety pathway: lagged analysis controlling for social comparison frequency should attenuate the passive scrolling-anxiety association by 30-50%.

## 6. Discussion

The DBB approach provides several methodological advances over existing social media-anxiety research. First, within-person analysis controls for all stable between-person confounders (trait anxiety, baseline wellbeing, demographic differences) that inflate between-person associations in cross-sectional studies. Second, passive sensing eliminates retrospective self-report bias in exposure measurement, providing the measurement accuracy prerequisite for dose-response analysis. Third, physiological measurement provides a non-self-report anxiety index that is resistant to demand characteristics and social desirability. Fourth, computational linguistic analysis enables analysis of anxiety expression as it occurs in natural social media behavior rather than in research instruments.

The clinical implications are significant. If the social comparison mechanism mediates the passive scrolling-anxiety pathway, then intervention strategies targeting social comparison cognitive patterns — rather than global social media reduction — may provide more specific and sustainable clinical benefit. CBT-informed "social comparison interruption" skills (actively identifying and reappraising upward comparison thoughts during social media use) represent a theoretically grounded and practically feasible intervention that the DBB framework can evaluate.

## 7. Limitations

Participant burden in the 21-day intensive longitudinal design is substantial, creating attrition risk and potential reactivity effects (the act of monitoring social media use may change use patterns). Consumer-grade HRV measurement has lower reliability than clinical-grade devices, introducing measurement error. Social media data donation consent rates are typically below 60%, creating selective sample problems. Generalizability is limited by the predominance of young, educated, and Western samples in social media-mental health research. The bidirectional relationships between anxiety and social media use — anxious individuals may use social media differently, creating selection effects — require design features (pre-registration of lagged directionality hypotheses, separation of initial and follow-up measurement) to address.

## 8. Conclusion

The social media-anxiety relationship is real for some users under some conditions, small or absent for others, and highly dependent on the specific exposure dimensions and anxiety indices used to measure it. The Digital Biomarker Battery proposed here provides a methodologically rigorous, multidimensional, and ecologically valid framework for moving beyond cross-sectional associations to establish dose-response relationships, identify vulnerable subgroups, and test mechanistic mediators. As social media platforms continue to evolve and their psychological impacts accumulate, the field urgently needs the measurement precision that digital biomarkers provide.

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