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Introducing the Fundamental User Needs (FUN) Scales: Assessing Need Satisfaction and Frustration in Design-Mediated Interactions

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ABSTRACT

This paper introduces the Fundamental User Needs (FUN) Scales, tailored to measure need satisfaction and frustration in design-mediated interactions. The development and initial validation process included a preparation phase and four studies. Adopting a deductive approach, we generated a pool of 780 items and distilled them into the first version of the FUN Scales: a 52-item Need Satisfaction Scale and a 52-item Need Frustration Scale. Content validity was assessed by nine experts, leading to a refined second version. Exploratory and confirmatory factor analyses with 502 participants examined the scales' factorial structure, reliability, and validity, resulting in a finalized version with 39 items per scale. Finally, we proposed two scoring approaches to facilitate scale application. The FUN Scales can serve as a robust diagnostic tool for quantifying the psychological impact of design and technology through the lens of need fulfillment, offering structure and inspiration for human-centered design research and practice.

KEYWORDS

Human-centered design; human-computer interaction; need satisfaction; need frustration; scale development

1. Introduction

The 2016 Triennale de Milano featured the celebrated "Neo-Prehistory" design exhibition, which displayed 100 human-made objects paired with 100 verbs. From Hold, Destroy, and Kill to Restore and Regenerate, each verb was connected to one object, strung together by the guest curators Andrea Branzi and Kenya Hara to a journey across the history of design and technology (Santi & Mazzoleni, 2017). Beyond the beauty of the displayed artifacts, the exhibition told a more profound tale in the landscape of design evolution—one of the complex interplays between technological advancement and *fundamental human needs*. The curators masterfully demonstrated how every design, from rudimentary tools to the most sophisticated technologies, is inherently a means to fulfill human needs.

In today's human-centered design research and practice, the premise that satisfying basic psychological needs contributes to effective functioning and well-being often serves as a foundational guiding principle (Vansteenkiste et al., 2020; von Hippel, 1986). This principle is exemplified by IDEO's field guide for human-centered design, which emphasizes the importance of crafting solutions that are deeply rooted in people's needs (IDEO, 2015). Central to this approach is that it starts with a thorough understanding of the needs of end-users and other stakeholders, which then informs the development of design requirements and principles during the ideation and conceptualization stages. In the implementation and evaluation stages, user tests are often conducted to assess whether the design effectively fulfills the intended needs within the relevant context. This approach is well-supported by previous research, which has demonstrated that need satisfaction in product use and interaction leads to positive experiences and enhanced overall satisfaction with the product (e.g., see Borsci et al., 2015; Hassenzahl, 2007, 2018).

Scholars in Human-Centered Design (HCD) and Human-Computer Interaction (HCI) have underscored the significance of fundamental human needs. Hassenzahl et al. (2010) developed an approach that links quality experiences to basic needs, proposing that needs can serve as categories for positive experiences in human-technology interactions. In their introduction to *Positive Design*, Desmet and Pohlmeyer (2013) suggested that products can promote well-being and happiness by facilitating need-satisfying activities. Likewise, Calvo and Peters (2014) highlighted in *Positive Computing* that technology should be designed to promote users' well-being, happiness, and overall life satisfaction by addressing basic psychological needs. In his recent book, *Design for a Better World*, Norman (2023) advocated a humanity-centered approach to problem framing and solving. He emphasized that measuring subjective experiences is essential for creating solutions that improve quality of life and contribute to a more sustainable, meaningful, and equitable world.

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The growing interest in understanding the impact of design and technology on user needs has generated a demand for adequate assessment tools (Fokkinga et al., 2020; Norman, 2023; Riva et al., 2012). Given the subjective nature of need fulfillment, which is shaped by individual perceptions and experiences, self-report psychometric instruments offer a practical and systematic assessment approach (Coolican, 2017). While various instruments that measure psychological need fulfillment within specific life domains (e.g., education, work, and sports) are available, there remains a gap in tools explicitly developed for human-centered design (Kermavnar et al., 2024). We propose that such tailored instruments substantially benefit HCI and design research and practice. To start, they can provide a shared and consistent language for discussing user needs and enable standardized evaluations and comparisons across different projects and studies. In doing so, they will facilitate collaborations between HCI experts, designers, engineers, and other stakeholders. In addition, design-focused need fulfillment scales can help bridge the gap between theoretical research on basic psychological needs and practical HCI and design applications, facilitating the development of need-oriented design principles grounded in empirical evidence. Combined, this can support informed design decisions regarding features and functionalities that prioritize basic needs in design-mediated interactions. Therefore, we introduce the Fundamental User Needs (FUN) Scales to assess the need satisfaction and frustration in design-mediated interactions.

The paper is organized into four parts. We first introduce the theoretical background. Second, we provide a detailed report of the scale development and initial validation process. To facilitate scale application, we propose two scoring and analysis approaches. Finally, we discuss research implications, limitations, and future developments.

2. Related work

2.1. A design-focused need typology

> People don't need enormous cars; they need admiration and respect. They don't need a constant stream of new clothes; they need to feel attractive, and they need excitement, variety, and beauty. People don't need electronic entertainment; they need something interesting to occupy their minds and emotions. (Meadows & Randers, 2012, pp. 261–262).

The FUN Scales were developed to measure *basic* psychological needs in the design context. The adjective "basic" is noteworthy because in design discourse, the term "need" is often used broadly, encompassing various concepts, such as goals, wants, desires, and values. For example, in practice, a car manufacturer might argue that customers *need* a cup holder, heated seats, or a panorama roof. The same goes for user research, where needs are often explored and discussed as design requirements, such as the space and maintenance needs identified by Lee et al. (2022) in designing fully automated vehicles. Although these preferences may represent genuine desires, their fulfillment is probably not indispensable for the customer's growth and well-being. Scholars like Kasser (2011) and Manzini (2003) have criticized the prioritization of such desires, or "non-basic" needs, noting that these are neither instrumental nor inspiring for human-centered design and will result in designs that fail to compensate for psychological deficits or emptiness. In our research, we embrace the definition of motivation researcher Richard Ryan, who defines basic needs as "nutrients that are essential for individuals' growth and integrity" (Ryan, 1995, p. 410). These basic needs are considered fundamental because they form the basis for human development and flourishing.

In motivation research, a variety of needs theories and typologies have been proposed, reflecting diverse research perspectives and evaluation criteria (for a recent overview, see Desmet & Fokkinga, 2020). In design and HCI research, the most widely adopted theoretical frameworks are probably Maslow's Hierarchy of Needs (Maslow, 1943), Self Determination Theory (SDT; Ryan & Deci, 2017), and the ten candidate psychological needs tested by Sheldon et al. (2001). While this diversity in scope provides designers with a broad range of perspectives for understanding human needs, it can also hinder effective analysis and envisioning of which specific needs should be incorporated into design solutions. A key challenge in applying these and similar needs theories to design research and practice is that they lack a design-oriented perspective. A more nuanced and applicable overview of basic user needs could, therefore, be more informative and inspiring for design evaluation and applications.

To address these challenges, Desmet and Fokkinga (2020) developed a design-focused need typology that includes thirteen distinct psychological needs: autonomy, beauty, comfort, competence, community, fitness, impact, morality, purpose, recognition, relatedness, security, and stimulation (see Table 1). This typology was derived from a structured thematic analysis of need theories in motivation research, supplemented by the authors' extensive experiences in design education and practice. Since its publication, it has found widespread application in design education, practice, and research (e.g., Krueger & Minet, 2022; Louwers et al., 2024; Rohles et al., 2022), making it a promising theoretical foundation for the new psychometric instrument.

We posit that the typology in itself is not directly usable as an assessment tool for several reasons. First, each need within the typology can encompass different facets or dimensions that may not be easily captured by a single definition or description (see Section 3.1 for an example of autonomy). Second, while the typology provides a framework for understanding needs, it does not offer the metrics or scales required to quantify need fulfillment. Third, the typology, being theoretical, did not undergo the empirical validation process that ensures accurate and reliable evaluation. For these reasons, we aimed to follow a standardized procedure to develop a new psychometric instrument grounded in this design-focused need typology to offer the granularity and rigor required for assessing design-mediated need fulfillment.[1]

2.2. Design-mediated need fulfillment

The present research focuses on design-mediated need fulfillment. First, by "design," we refer to a spectrum of

Table 1. Overview of the thirteen fundamental psychological needs for human-centered design (adapted from Desmet & Fokkinga, 2020).

Psychological Need	Definition
Autonomy	Being the cause of your actions and feeling that you can do things your own way, rather than feeling as though external conditions and other people determine your actions.
Beauty	Feeling that the world is a place of elegance, coherence, and harmony, rather than feeling that the world is disharmonious, unappealing, or ugly.
Comfort	Having an easy, simple, relaxing life, rather than experiencing strain, difficulty, or overstimulation.
Community	Being part of and accepted by a social group or entity that is important to you, rather than feeling you do not belong anywhere and have no social structure to rely on.
Competence	Having control over your environment and being able to exercise your skills to master challenges, rather than feeling that you are incompetent or ineffective.
Fitness	Having and using a body that is strong, healthy, and full of energy, rather than having a body that feels ill, weak, or listless.
Impact	Seeing that your actions or ideas have an impact on the world and contribute to something, rather than seeing that you have no influence and do not contribute to anything.
Morality	Feeling that the world is a moral place and being able to act in line with your personal values, rather than feeling that the world is immoral and your actions conflict with your values.
Purpose	Having a clear sense of what makes your life meaningful and valuable, instead of lacking direction, significance or meaning in your life.
Recognition	Getting appreciation for what you do and respect for who you are, instead of being disrespected, underappreciated, or ignored.
Relatedness	Having warm, mutual, trusting relationships with people who you care about, rather than feeling isolated or unable to make personal connections.
Security	Feeling that your conditions and environment keep you safe from harm and threats, rather than feeling that the world is dangerous, risky or a place of uncertainty.
Stimulation	Being mentally and physically stimulated by novel, varied, and relevant impulses and stimuli, rather than feeling bored, indifferent, or apathetic.

artifacts or structures. This includes HCI designs such as smart devices, mobile applications, and interactive media, as well as physical products, services, systems, and built environments. Second, aligning with recent advancements in motivation research, we use the term "need fulfillment" to address the mutual existence of "need satisfaction" and "need frustration." *Need satisfaction*, the bright side of need fulfillment, is typically linked with positive experiences and increased well-being. Studies have shown that this is a unipolar concept, implying that low need satisfaction does not necessarily evoke negative experiences (Vansteenkiste & Ryan, 2013). This further means a complete understanding of need fulfillment should also include *need frustration*, a concept representing the dark side of need fulfillment (Church et al., 2013). Need frustration occurs when one's needs are actively thwarted or undermined, leading to negative emotions and diminished well-being (Bhavsar et al., 2020; Cordeiro et al., 2016).

The notions of both need satisfaction and frustration apparently apply to need fulfillment in design-mediated interactions. Designed things typically aim to satisfy users' needs. Take Instagram as an example. It was initially developed to enhance users' need for social interactions (e.g., relatedness or community) and self-expression (e.g., autonomy; Serafinelli, 2017). However, oftentimes, design can hinder need fulfillment, whether intended or unintended. For instance, Instagram has been shown to thwart the need for recognition by stimulating unhealthy social comparisons (Haferkamp & Krämer, 2011; Verduyn et al., 2020). Moreover, over-engagement and the obligation to respond to messages can make users feel like they are losing control over their time and choices, frustrating their need for autonomy (Chen, 2019; Manago et al., 2020). Recognizing that need satisfaction and frustration inevitably coexist, our goal was to develop an instrument comprising two related yet distinct scales to assess both the need-satisfying and frustrating states. This approach will create opportunities for uncovering need-fulfillment tensions that emerge in design-mediated interactions, providing nuanced insights into how such interactions can simultaneously satisfy some needs while frustrating others (see, e.g., Ozkaramanli et al., 2016).

Third, the term "mediated" reflects our intent to assess both the direct and indirect impact of design and technology on users' need fulfillment. Direct impact refers to needs fulfilled through the design itself, and indirect influences denote needs fulfilled within the broader context of activities in which the design or technology has played a role. For example, a fitness tracker like Fitbit can directly fulfill the need for fitness through its goal-setting and progress-monitoring features. For the indirect effects, the tracker can influence the fulfillment of the need for community by enabling users to engage in group exercises and fostering a sense of participation in a collective effort.

2.3. Existing design-focused need scales

Numerous psychometric instruments exist to measure need fulfillment in life-in-general situations or specific life domains such as work, education, and sports (Kermavnar et al., 2024). However, few tools are available that are tailored to assess the impact of design and technology on users' psychological need fulfillment. To our knowledge, only four published psychometric instruments match our research objectives. Table 2 presents a summary of their main characteristics. They share the following qualities: (a) focused on psychological needs, (b) applied to the general population, (c) developed for broad application in design and HCI, and (d) have clear descriptions of their development process.

Based on Sheldon and colleagues' work (2001) on assessing ten candidate needs, Hassenzahl et al. (2010) developed a measure that included seven basic psychological needs to evaluate users' positive experiences with interactive technologies. The study results showed that basic psychological needs can serve as experiential patterns to conceptualize positive emotions, meaning, and happiness. This work was a

Table 2. Overview of existing design-focused need scales.

Characteristic	Instrument			
	1	2	3	4
Name	No name	The User Needs Scales (UNeedS)	Technology-based Experience of Need Satisfaction (TENS) Scales	Basic Psychological Need Satisfaction for Technology Use (BPN-TU) Scale
Language	German and Swedish	German	English	German and English
Research area	Experience Design	HCI	HCI	HCI
Theoretical basis	Sheldon et al. (2001).	Design-focused Thirteen Psychological Needs (Desmet & Fokkinga, 2020)	The Motivation, Engagement and Thriving in User Experience (METUX) model (Peters et al., 2018)	Self-Determination Theory (Ryan & Deci, 2017)
State of need fulfillment	Need Satisfaction	Need Satisfaction; Need Frustration	Need Satisfaction/Support; Need Frustration	Need Satisfaction
Psychological needs	Relatedness; Competence; Meaning; Stimulation; Security; Popularity[a]	Autonomy; Beauty; Comfort; Community; Competence; Fitness; Impact; Morality; Purpose; Recognition; Relatedness; Security; Stimulation	Autonomy; Competence; Relatedness	Autonomy; Competence; Relatedness to Others; Relatedness to Technology
Studies	Hassenzahl et al. (2010, 2015)	Wolf et al. (2022)	Burnell et al. (2023), Peters et al. (2018)	Moradbakhti et al. (2024)

[a]According to Hassenzahl et al. (2010), all the Autonomy items from the original questionnaire adapted from Sheldon et al. (2001) were excluded due to cross-loadings.

ground-breaking contribution to demonstrating how fundamental needs can drive positive user experiences in a way that is both systematic and inspiring. However, the authors acknowledged that a limitation of the devised measure was the incomplete set of needs, suggesting that additional needs should be incorporated to capture the full breadth of basic psychological needs in human-technology interaction. Another noteworthy issue was that this scale focuses solely on the dimension of need satisfaction.

The second measure in Table 2 is the User Needs Scale (UNeedS), developed by Wolf et al. (2022). This scale aligns well with our research objectives, as it incorporates the full spectrum of thirteen psychological needs and measures both need satisfaction and frustration. UNeedS represents the first significant attempt to transform the conceptual framework introduced by Desmet and Fokkinga (2020) into measurable variables, highlighting both the growing interest in a more granular approach to analyze the influences of technology use on users' need fulfillment and the practical value of a design-focused need typology. While UNeedS is an important contribution, several limitations could impact its broader applicability. First, the item generation process does not fully consider previous research or similar scales, potentially limiting the scale's foundation. Second, although the researchers used think-aloud sessions and reverse mappings to assess item clarity and comprehensibility, a more formal content validity assessment would enhance the rigor of the development process (Haynes et al., 1995). Third, the current study lacks empirical validation data, such as exploratory and confirmatory factor analyses and reliability assessments, which raises concerns about the scale's utility and robustness. Last, considering that the UneedS is developed for German-speaking users, its applicability to the English-speaking population can be constrained without cross-cultural adaptation and validation (Beaton et al., 2000).

The third is the Technology-based Experience of Need Satisfaction (TENS) instrument, which features four sub-scales designed to assess the impact of interactive technologies' on need fulfillment across four spheres of experience: life, behavior, task, and interface (Burnell et al., 2023). A key contribution of the TENS instrument, as indicated by the authors, is its ability to combine four sub-scales to evaluate human experiences across various levels, which can help prevent the development of technologies that satisfy needs at one level while frustrating them at another (Peters et al., 2018). However, a potential issue with this tool lies in the inconsistent use of key terminology. Specifically, the terms "need satisfaction" and "need support" are used interchangeably within the manuscript and developed scales, which might lead to confusion in application. Motivation research clearly distinguishes between these two concepts: *Need satisfaction* refers to the personal and subjective experience of having one's needs adequately met, while *need support* denotes one's perceived support from the environment, such as social support (see Vansteenkiste & Ryan, 2013). Another concern relates to the construct of the scales. Because they are based on the METUX model (Peters et al., 2018) within the framework of SDT (Ryan & Deci, 2017), there is a risk of oversimplifying human experience and lacking the granularity to inspire need-focused human-centered design research and practice.

The fourth scale, developed by Moradbakhti et al. (2024), focuses on evaluating Basic Psychological Need Satisfaction for Technology Use (BPN-TU). Like the TENS instrument, the BPN-TU scale adopted the SDT as the theoretical underpinning, with the main distinction that it adopted a four-factor structure, separating the need for relatedness into relatedness to others versus relatedness to technology. Despite the value of adding this nuance, the authors also mentioned some limitations of the proposed new measure, such as high correlations between scale constructs and unexpected correlations with other measures (e.g., self-identity and the need for competence; see Moradbakhti et al., 2024). Additionally, this instrument assesses exclusively the state of need satisfaction, overlooking the other equally important aspect, need frustration.

In summary, the existing design-focused need scales have made commendable strides in advancing our understanding of how design and technology affect users' psychological needs. While they offer valuable insights, they also come with certain limitations. In this study, we aim to address these limitations and take a significant step forward in developing a reliable and applicable new psychometric measure to further support and inspire human-centered design research and practice.

3. Introducing the FUN Scales

This section introduces the development and initial validation of the Fundamental User Needs (FUN) Scales. We organized the procedure following the recommendations of Hinkin (1995), Worthington and Whittaker (2006), and Yusoff et al. (2021). Figure 1 outlines the overall process, including a preparation phase and four studies. Specifically, the preparation involved building a detailed theoretical framework and reviewing items from thirty-one existing need measures identified from a systematic search. In Study 1, three researchers with expertise in human needs adopted a deductive approach to create an initial item pool. Through internal discussions, we compiled the FUN Scales Version 1, consisting of a 52-item Need Satisfaction Scale and a 52-item Need Frustration Scale. Study 2 focused on content validation with nine experts to assess the items in each subscale for clarity, relevance, and coverage, resulting in FUN Scales Version 2. In Study 3, we employed exploratory factor analysis with 252 participants to examine the factor structure, through which we obtained a refined third version. Study 4 examined the scale structure and psychometric properties using confirmatory factor analysis with 250 participants, which led to a finalized version including a 39-item Need Satisfaction Scale and a 39-item Need Frustration Scale. In addition to factor validity and reliability, we examined the criterion validity by exploring the relation between need fulfillment and product satisfaction in Studies 3 and 4.

3.1. Preparation

The design-focused typology of thirteen psychological needs introduced by Desmet and Fokkinga (2020) served as the starting point for the scale development process. To ensure rigor in item generation, we systematically reviewed thirty-one original scales measuring psychological need fulfillment across general and specific life domains (see Kermavnar et al., 2024). Second, we collected and categorized 665 items from these scales based on the definitions of the thirteen psychological needs, yielding 9 (purpose) to 159 (autonomy) items for each need. This categorization indicated significant diversity among items representing the same need, which prompted us to deconstruct each need concept for a more nuanced understanding.

Our approach was informed by the work of Ng et al. (2011) and Reeve et al. (2003), who suggested that each basic psychological need can be a multi-faceted concept containing multiple distinctive yet fundamental aspects, coined as "need facets." For example, in the study by Ng et al. (2011), autonomy was conceived to encompass volition, perceived choice, and internal perceived locus of causality. Although a standardized approach and criteria for identifying need facets are lacking in existing literature, a common principle that emerged was balance parsimony while enhancing granularity (Vansteenkiste et al., 2020). To create a more actionable basis for item generation, we implemented a three-step deconstruction process: (1) initial generation, (2) internal review, and (3) external review.

Given the items collected from existing need scales and the theoretical framework, Step 1 involved a need expert from the research team formulating three facets per need and corresponding definitions. Through this, we obtained an initial set of thirty-nine need facets. In Step 2, two researchers from the research team reviewed the thirty-nine facets independently. Following the criteria of Baumeister and Leary (1995), the two researchers conducted an internal discussion session with the need expert to resolve disagreements. This step distilled the initial thirty-nine need facets into a refined set of twenty-six need facets, with two for each need. To ensure no important aspects were removed and no new issues were introduced, we subsequently employed Step 3, where eight design researchers and three design practitioners were invited to evaluate the conceptual links between need facets and their corresponding needs (Purpose 1) and the coverage of the proposed facets representing each need (Purpose 2).

This external review step consisted of two parts. In the first part, reviewers completed an online questionnaire via Qualtrics. Each reviewer was asked to watch a video explaining the concepts of the thirteen needs from the original need typology. They were then presented with the title and definition of each need facet. Following this, they were asked to associate each need facet with its corresponding need

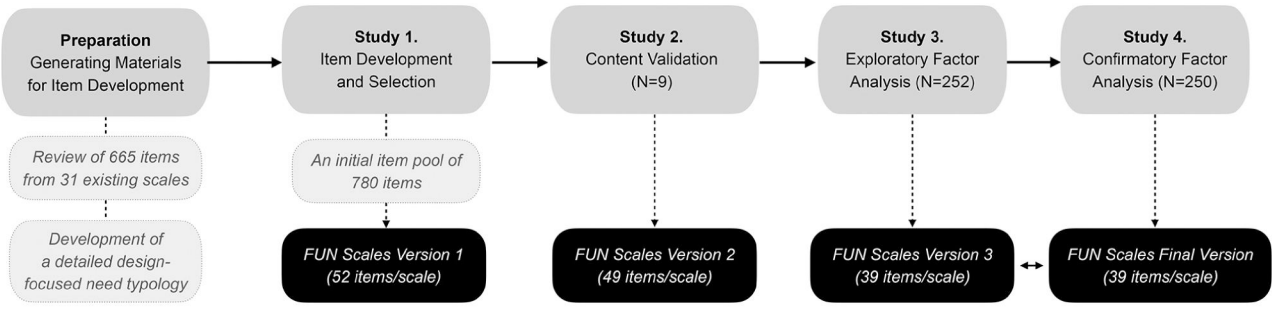

Figure 1. Flowchart of the development and initial validation process of the FUN Scales.

based on their understanding of the concepts (Purpose 1). The second part consisted of four workshops (three with design researchers and one with design practitioners) focused on discussing mismatches in the questionnaire and collecting suggestions for refining the proposed need facets (Purposes 1 and 2). By integrating insights from a series of external and internal reviews throughout the process, we developed a detailed design-focused need typology of thirteen psychological needs, each explained by two distinct yet complementary need facets (for a complete list, see Huang & Desmet, 2023).

3.2. Study 1: Item development

Hinkin (1995) and Morgado et al. (2017) noted that item generation typically follows one of three approaches: deductive, inductive, or a combination of both. We adopted the deductive approach, as we built on a detailed theoretical framework and review of items collected from thirty-one validated need scales. The goal of Study 1 was to formulate a comprehensive list of items for each need across two fulfillment states and to compile the first version of the scales. To do so, we undertook three steps: (1) generation of the initial item pool, (2) item review and refinement, and (3) scale creation.

The first step involved three researchers independently generating a preliminary list of items. This effort was supported by (a) definitions of the thirteen psychological needs and their corresponding need facets, (b) 665 item descriptions in previously validated need scales, and (c) consideration of various human-design interaction situations. Combining the items created by the three researchers, we obtained an initial pool of 780 items, ranging from 16 (impact frustration) to 38 (comfort satisfaction). Step 2 was an item review and selection procedure to select adequate items for each need to compile the FUN Scales. Two researchers independently selected eight items from the initial item pool to represent the satisfying and frustrating states for each of the thirteen needs. This resulted in a pool of 208 items—104 addressing need satisfaction and 104 for frustration. Subsequently, these two researchers engaged in two discussion sessions to exchange ideas and reduce the number of items. This process was facilitated by the evaluation criteria proposed by Peasgood et al. (2021) and Robinson et al. (1991), such as eliminating negatively worded, overly long, or ambiguous items, especially those with double-barreled phrasing.

Over two weeks of contemplation and refinement of item descriptions, in Step 3, we compiled the first version of the FUN Scales, consisting of a 52-item Need Satisfaction Scale and a 52-item Need Frustration Scale (see Appendices A and B, Supplementary material). The scale stem was set as "When using/interacting with …," and responses were measured using a seven-point unipolar Likert scale ranging from "not true at all" to "completely true." The scale anchors were designed to be consistent with widely validated scales measuring need satisfaction and frustration in domain-general situations, such as the Basic Psychological Need Satisfaction and Frustration Scales (BPNSFS) developed by Chen et al. (2015).

3.3. Study 2: Content validation

The aim of Study 2 was to assess the content validity of the FUN Scales Version 1. As Boateng et al. (2018) and Streiner et al. (2015) suggested, content validation is one of the most widely adopted validity tests at the early stages of new instrument development and a common approach for item reduction. It typically involves a panel of experts evaluating whether the included set of items adequately covers each construct it aims to measure before the scale is administered to the target population.

3.3.1. Methods

3.3.1.1. Participants. Considering the recommended number of experts (six to ten) and its implication on the thresholds of content validity measures (see Haynes et al., 1995; Yusoff, 2019), we invited nine experts with diverse expertise in relevant areas of HCI and design to evaluate the FUN Scales Version 1. Table 3 shows the background information of the experts.

3.3.1.2. Procedure and materials. Following the approach suggested by Yusoff (2019), Study 2 was organized into four steps: (1) preparing evaluation materials, (2) recruiting eligible experts, (3) conducting the assessment using the Qualtrics online platform, and (4) data analysis. Specifically, we provided each expert with an introduction letter and an information kit to ensure clarity and consistency in the evaluation process. The introduction letter explained the research purpose, asked for consent, and provided detailed instructions. The information kit consisted of several components: (a) envisioned scales to provide the experts with a clear understanding of the research outcome and the intended use of the scales, (b) a detailed overview of the theoretical framework, (c) explanations and examples illustrating the two different need fulfillment states (i.e., need satisfaction and frustration), and (d) a specification of the three evaluation criteria. We received feedback from nine experts within one month of sending the evaluation materials.

Table 3. Background overview of the experts involved in the content validity assessment.

No.	Affiliation	Work experience	Research expertise (indicated on academic profile)
1	Delft University of Technology	over 20 years	Aesthetics, User Experience, Social Design, Design for Behavior Change
2	Georgia Institute of Technology	over 20 years	Design for Health and Well-being, User Experience
3	University of Twente	10–20 years	Cognitive Psychology, Design for Well-being, Packaging
4	Delft University of Technology	over 20 years	Food Design, Eating Behaviour, Packaging, User Experience
5	Beijing Normal University	10–20 years	Applied Psychology, Human-Computer Interaction, User Experience
6	Cornell University	10–20 years	Human-Centered Design, Design and Emotion, Computer Science
7	Delft University of Technology	10–20 years	Machine Learning, Human-Centered Design, Games and Learning, Learning Science
8	University of Amsterdam	10–20 years	Product Experience, Marketing, Social and Economic Psychology
9	Design Consultancy	10–20 years	Emotion Design, Product Experience, Human factors

Table 4. Evaluation criteria for study 2.

Criteria	Explanation	Means of assessment
Clarity	the degree to which the item is easy to read and understand, rather than causing ambiguity and confusion.	four-point Likert scale (1 = not clear, 2 = somewhat clear, 3 = quite clear, 4 = highly clear).
Relevance	the degree to which the item reflects the corresponding need.	four-point Likert scale (1 = not relevant, 2 = somewhat relevant, 3 = quite relevant, 4 = highly relevant).
Coverage	the degree to which a set of items adequately covers the corresponding need.	open-ended questions (modify existing items or suggest new items).

3.3.1.3. Measures and analyses. Experts were asked to assess the items included in FUN Scales Version 1 using three criteria: relevance, clarity, and coverage (see Table 4). Relevance was evaluated on a four-point Likert scale adapted from the studies of Lynn (1986) and Yusoff (2019). To assess the content validity of individual items, we calculated the item-content validity index (I-CVI) by counting the number of experts who rated an item as either 3 (quite relevant) or 4 (highly relevant), then dividing this by the total number of experts. We also computed the average content validity index (Ave-CVI) for the two scales to indicate item quality independent of the experts' performance. Additionally, we assessed the modified kappa, which adjusts each I-CVI value for the chance of agreement (DeVellis & Thorpe, 2021; Polit et al., 2007; Wynd et al., 2003). Clarity was evaluated using a four-point Likert scale. When experts rated an item as 1 (not clear) or 2 (somewhat clear), they were asked to provide modification suggestions. The coverage of each need across satisfaction and frustration states was evaluated through open-ended questions, with experts suggesting changes to existing items or the addition of new items.

3.3.2. Results

Based on the assessment results for relevance, we calculated the item-level and scale-level CVI values, and the modified kappa values for the two scales (see Appendices A and B, Supplementary material). According to Lynn (1986) and Polit and Beck (2006), the minimum acceptable cut-off score for the CVI with nine experts should be .78. In line with this criterion, 90 out of 104 items were deemed relevant to their corresponding factors. The accepted standard for scale-level CVI ranges from .80 to .90 (Almanasreh et al., 2019). In our study, the Ave-CVI for the Need Satisfaction Scale was .89, and for the Need Frustration Scale, it was .86, indicating good content validity. For modified kappa, one item on the Need Satisfaction Scale and two items on the Need Frustration Scale were considered fair (.40-.59), while five items on the Need Satisfaction Scale and six on the Need Frustration Scale were rated as good (.60-.74). The remaining items were rated as excellent (> .74).

Given the I-CVI score, we retained items with a score of .78 (22 items) or higher (68 items) and removed those with scores of .67 (11 items) or .56 (3 items). Specifically, we eliminated six items from the Need Satisfaction Scale and eight items from the Need Frustration Scale. Next, we considered the results from the other two measures (clarity and coverage) and conducted four rounds of discussions to refine the items on both scales. Following the guidance of Almanasreh et al. (2019), we either revised items reported as unclear or somewhat clear or replaced them with new ones according to experts' suggestions. In total, we added eight items to the FUN Scales (three for need satisfaction and five for need frustration), such as "I can develop my competence" to competence satisfaction and "I am unable to develop my competence" to competence frustration. This modification led to a slightly streamlined version of the FUN Scales, reducing the number of items from 52 to 49 per scale.

Last, two design researchers, who are native English speakers, were invited to proofread and rephrase the 98 items based on the same assessment materials provided to the experts, such as suggesting synonyms to enhance comprehensibility. For example, the item "I can develop my competence" was modified to "I can develop my skills" because the term "skills" is more commonly used in daily conversation, easy to interpret, and more relatable to different contexts. As a result, we obtained the refined FUN Scales Version 2, including a 49-item Need Satisfaction Scale and a 49-item Need Frustration Scale.

3.4. Study 3: Exploratory factor analysis

The main objective of Study 3 was to investigate the factor structure and reliability of the FUN Scales Version 2 using exploratory factor analysis (EFA).

3.4.1. Methods

3.4.1.1. Participants. According to MacCallum et al. (1999) and Comrey and Lee (2013), a sample size of 200 to 300 respondents is reasonable for factor analysis. To ensure a sufficient sample size, we followed the recommended ratio of at least five respondents per item per scale (Costello & Osborne, 2019). Eligible participants were recruited through the crowdsourcing platform Prolific, which offers advantages such as enabling the recruitment of more diverse samples globally and providing high information transparency (e.g., expected payments, rights, and obligations; see Palan & Schitter, 2018). Participant eligibility criteria included proficiency in English as the first language (with no restrictions on ethnicity, country of birth, country of residence, and nationality), a 100% approval rate of previous surveys taken on the platform, and the frequent use of the iPhone 11. After excluding incomplete responses and the ones that failed attention checks, we obtained 252 valid responses (see Table 5 for demographic information). Participants were compensated £1.50.

3.4.1.2. Procedure. Eligible participants who agreed to join the survey were directed to the online survey platform Qualtrics, where the survey was structured into three

Table 5. Demographic information of participants involved in study 3 and study 4.

Sample Characteristics	Study 3 n (percentage)	Study 4 n (percentage)
Age	33.5 (SD = 6, 18–76 y)	34.6 (SD = 22, 18–70 y)
Gender		
Female	127 (50.4)	125 (50)
Male	118 (46.8)	125 (50)
Binary	6 (2.4)	N/A
Preferred not to disclose	1 (0.4)	N/A
Education		
Having a high school education or less	35 (13.9)	29 (11.6)
Having a completed/partial college education	189 (75)	182 (72.8)
Having a Master's or Doctoral degree	28 (11.1)	39 (15.6)
Product usage (Duration)		
Less than a year	22 (8.7)	3 (1.2)
A year to three years	143 (56.7)	22 (8.8)
Over three years	87 (34.5)	225 (90)
Product usage (Frequency)		
Once a week	1 (0.8)	3 (1.2)
Once in two or three days	3 (1.2)	14 (5.6)
Almost daily	9 (3.6)	74 (29.6)
Many times a day	238 (94.4)	159 (63.6)
Nationality		
United Kingdom	99 (39.3)	150 (60)
United States	91 (36.1)	57 (22.8)
Canada	24 (9.5)	15 (6)
Australia	11 (4.4)	9 (3.6)
Other	27 (10.7)	19 (7.6)
Student status		
Yes	74 (29.4)	48 (19.2)
No	153 (60.7)	177 (70.8)

sections. First, participants provided informed consent and answered questions about their product usage, including duration and frequency. Next, they assessed their feelings about using the iPhone-11 using two measures. The iPhone 11 was chosen because (a) it is sufficiently comprehensive to satisfy and frustrate the thirteen psychological needs and (b) covers a wide range of users across different ages and geographic locations that align with the target population intended for the FUN Scales. Two attention-check questions were included to verify the quality of their responses. The survey concluded with participants providing basic demographic information such as age, gender, and educational background.

3.4.1.3. Measures. The first measure asked about participants' overall satisfaction with iPhone-11 using a bipolar seven-point Likert scale ranging from "-3 (extremely dissatisfied)" to "3 (extremely satisfied)." The second measure asked about the iPhone 11-mediated need satisfaction and frustration using the FUN Scales Version 2. Participants rated on a 49-item Need Satisfaction and a 49-item Need Frustration scale using a unipolar seven-point Likert scale ranging from "1 (not true at all)" to "7 (extremely true)."

3.4.2. Analyses and results

To assess the normality of the data distribution, we calculated the skewness and kurtosis values for all items in the FUN Scales Version 2. The results showed that some items, such as "I can express myself freely" in autonomy satisfaction and "there is nothing to discover" in stimulation frustration deviate from a normal distribution according to the ±2 range (Mallery, 2019; Sarstedt et al., 2022). Following this, we performed a series of Spearman correlation analyses to examine the correlation of each need across two different states. The results indicated significant negative correlations between need satisfaction and frustration for all thirteen needs, with correlation coefficients ranging from −.16 to −.43 (see Appendix C, Supplementary material). This general trend of increased satisfaction corresponding with decreased frustration (i.e., no absolute correlation) supports our initial assumption that individuals may experience both states simultaneously in product use and interaction.

The Kaisere-Meyere-Olkin (KMO) criterion of sampling adequacy ($KMO_{satisfaction} = .921$, $KMO_{frustration} = .918$) and the Bartlett test of sphericity ($\chi2(1176)_{satisfaction} = 11083.465$, $p < .001$, $\chi2(1176)_{frustration} = 11243.896$, $p < .001$) confirmed that the data were suitable for factor analysis (Kaiser, 1974). We subsequently examined the factor structure and loadings through EFA using IBM SPSS Statistics 23.0. Principal axis factoring (PAF) was chosen due to its lower sensitivity to normality violations (Costello & Osborne, 2019). Promax rotation, an oblique rotation method, was applied to allow for a degree of correlation between factors (Rennie, 1997). We next explored several factor retention methods, including Kaiser's criterion, parallel analysis, Jolliffe's criterion, and the visual scree plot (VSP) analysis (Howard, 2016; Fabrigar et al., 1999).

According to the Kaiser's criterion, an eleven-factor model was suitable for both scales (Kaiser, 1960). However, this "eigenvalues-greater-than-one" rule is generally more accurate for datasets with fewer than 30 items and communalities exceeding .70 (Field, 2013). We have 49 items on each scale, and communalities ranged from .49 to .95 on the Need Satisfaction Scale and from .45 to .92 on the Need Frustration Scale. While these values were above the acceptable cut-off range of .25 and .40, they did not meet the stated requirements (Beavers et al., 2019; Kaiser, 1958). Subsequently, we performed Horn's parallel analysis using R 4.1.1. The results recommended a fourteen-factor model for the Need Satisfaction Scale and a thirteen-factor model for the Need Frustration Scale (Horn, 1965; see Appendix D, Supplementary material). Nevertheless, given the non-normality of our datasets, the reliability of parallel analysis may be limited (Hayton et al., 2004). Next, following the guidelines of Field (2013) and Yong and Pearce (2013), we applied Jolliffe's criterion, a method to capture nuanced dimensions in complex datasets with an eigenvalue threshold of .70 and displayed the data points before the points of inflection using VSP (Jolliffe & Cadima, 2016; see Appendix E, Supplementary material). Finally, considering the convergence of (a) the scree plots, (b) Jolliffe's criterion, and (c) conceptual interpretability, we adopted a thirteen-factor structure, explaining 81 percent of the total variance in each scale (Cattell, 1966).

Item-factor loadings for the FUN Scales Version 2 can be found in Appendices F and G, Supplementary material. As a rule of thumb, factor loadings above .30 are adequate, and above .40 are stable (Guadagnoli & Velicer, 1988; Joseph et al., 2010; Tabachnick et al., 2013). Aligned with this, we

first removed three items with factor loadings below .40 (i.e., "I am in control of what I am doing" in competence satisfaction, "I act irresponsibly" in morality frustration, and "my actions damage my reputation" in recognition frustration). Second, to produce more parsimonious scales, we eliminated nine items from the Need Satisfaction Scale and eight items from the Need Frustration Scale based on the lowest value of the item loadings in each subscale across two scales. This decision was combined with three additional criteria: (a) alpha if the item was deleted (Gliem & Gliem, 2003), (b) item communalities (Worthington & Whittaker, 2006), and (c) minimum of three items per factor (Tabachnick et al., 2013). As a result, we obtained the FUN Scales Version 3, consisting of a 39-item Need Satisfaction Scale and a 39-item Need Frustration Scale.

Last, after the scale-length optimization procedure, we reperformed EFA to verify the scale structure. The results showed that the thirteen-factor model still holds for the FUN Scales Version 3, with only one item having a factor loading slightly below 0.4 but considered adequate ("I contradict my moral principles" in morality frustration has a loading score of .38).

3.5. Study 4: Confirmatory factor analysis

In Study 4, we employed Confirmatory Factor Analysis (CFA) with a new sample to assess the scales' model fit, reliability, and validity (Hinkin, 1995; Yusoff et al., 2021).

3.5.1. Methods

3.5.1.1. Participants. We applied the same qualification criteria as in Study 3 and recruited eligible participants through the crowdsourcing platform Prolific. We obtained 250 valid responses after removing incomplete responses and the ones that failed attention checks (detailed demographic information can be found in Table 5). Participants received £1.50 for their contribution.

3.5.1.2. Procedure. The online questionnaire was conducted on Qualtrics, following the same procedure as in Study 3. The main difference is that the participants were invited to rate their feelings about using Instagram. Instagram was chosen because it meets the same criteria previously listed for the iPhone 11, and it can represent social network applications, allowing us to assess the scale's applicability across different product categories. Again, two attention-check questions were included to verify the response quality. The survey concluded with participants providing basic demographic information.

3.5.1.3. Measures. The first measure assessed the overall satisfaction with Instagram using a bipolar seven-point Likert scale ranging from "-3 (extremely dissatisfied)" to "3 (extremely satisfied)." The second measure asked about Instagram-mediated need satisfaction and frustration using the FUN Scales Version 3. Participants rated on a 39-item Need Satisfaction and a 39-item Need Frustration scale using a unipolar seven-point Likert scale ranging from "1 (not true at all)" to "7 (extremely true)."

3.5.2. Analyses and results

We first assessed the normality of the data distribution by computing the skewness and kurtosis values for all the items in the FUN Scales Version 3. The results showed that some items (e.g., "I act responsibly" in morality satisfaction, "my self-expression is constrained" in autonomy frustration) deviated from a normal distribution according to the ±2 range (Mallery, 2019; Sarstedt et al., 2022). Subsequently, we conducted a series of Spearman correlation analyses to examine the relations between each need across two states. The results showed significant negative correlations for all thirteen needs, including two moderate (correlation coefficients range from −.43 to −.44) and eleven strong (correlation coefficients range from −.52 to −.72) negative correlations following the strength of correlation summarized by Hinkle et al. (2003) (see Appendix H, Supplementary material).

We next performed CFA using the Amos 23.0. As shown in Figure 2 (Need Satisfaction Scale) and Figure 3 (Need Frustration Scale), the correlation coefficients between the different factors within each scale (see the bidirectional arrows in both figures) were below 0.85, indicating that each observable variable (i.e., need factor) measures a distinct dimension of the corresponding need fulfillment state (Brown, 2015). For the Need Satisfaction Scale, factor loadings ranged from 0.57 to 0.96; for the Need Frustration Scale, factor loadings ranged from 0.45 to 0.97. As suggested by Comrey and Lee (2013), item loadings in CFA should be treated more stringent than in EFA, with scores above 0.45 considered fair, 0.55 good, 0.63 very good, and 0.71 excellent. Consistent with this standard, one item ("I contradict my moral principles" in morality frustration) was fair, three items ("I am treated fairly" in morality satisfaction, "I can do things my way" in autonomy satisfaction, and "I experience something as well-balanced" in beauty satisfaction) were good. The remaining ones were very good (5) or excellent (69).

The goodness-of-fit indices for the two scales were evaluated using the Root Mean Square Error of Approximation (RMSEA), Standardized Root Mean Square Residual (SRMR), Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI). As shown in Table 6, the results met the satisfactory thresholds (Yusoff et al., 2021). Convergent validity was supported by Average Variance Extracted (AVE) values above 0.5 for all factors. For discriminant validity, the AVE of each construct was greater than its Maximum Shared Variance (MSV), defined as the highest squared correlation of the construct with any other construct. This suggests that each construct shares more variance with its indicators than others, confirming their distinctiveness (Fornell & Larcker, 1981). Scale reliability was assessed through Cronbach's alpha and Composite Reliability (CR). Cronbach's alpha values ranged from 0.78 to 0.95, and CR values ranged from 0.811 to 0.966, all exceeding the acceptance level of 0.70 (Costello & Osborne, 2019; see Table 7). These findings

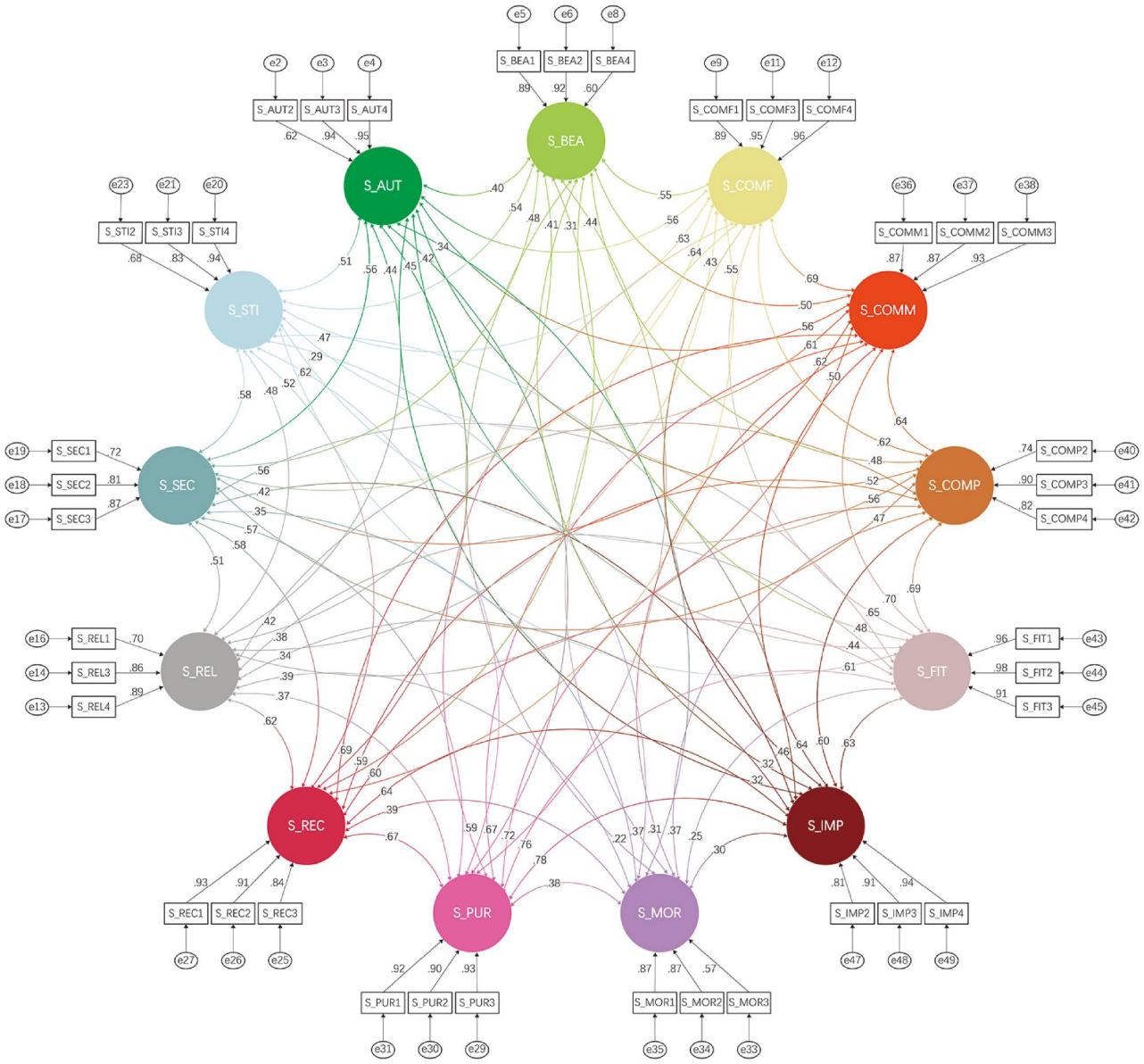

Figure 2. Path analysis diagram of the Need Satisfaction Scale in study 4 ($N = 250$).
Note. S_AUT = Autonomy Satisfaction; S_BEA = Beauty Satisfaction; S_COMF = Comfort Satisfaction; S_COMM = Community Satisfaction; S_COMP = Competence Satisfaction; S_FIT = Fitness Satisfaction; S_IMP = Impact Satisfaction; S_MOR = Morality Satisfaction; S_PUR = Purpose Satisfaction; S_REC = Recognition Satisfaction; S_REL = Relatedness Satisfaction; S_SEC = Security Satisfaction; S_STI = Stimulation Satisfaction.

indicate that the items within each construct reliably measure their intended underlying concepts.

Overall, Study 4 validated the thirteen-factor structural model, with each factor represented by three items. The results provided empirical evidence for the psychometric properties and reliability of the FUN Scales (see Appendix I, Supplementary material for the final version).

3.6. Design-mediated need fulfillment and product satisfaction

As described in Study 3 and Study 4, participants reported their overall satisfaction with the corresponding product in addition to need satisfaction and frustration. Using these data, we examined the criterion validity of the FUN Scales in relation to product satisfaction, as they are theoretically correlated (Borsci et al., 2015; Hassenzahl, 2007, 2018). Specifically, we explored two questions: (Q1) What are the associations between overall need satisfaction and frustration with product satisfaction? And (Q2) What are the associations of need satisfaction and frustration across the thirteen psychological needs with the overall product satisfaction?

For the first question, we conducted Spearman correlation analyses to examine the relationship between need satisfaction and frustration with users' overall satisfaction with the corresponding product. The results showed that there was a significant positive correlation between need satisfaction and product satisfaction (Study 3, $r(250) = .27$, $p = <.001$; Study 4, $r(248) = .61$, $p = <.001$) and a significant negative correlation between need frustration and product satisfaction (Study 3, $r(250) = -.23$, $p = <.001$; Study 4, $r(248) = -.56$, $p < .001$). Following this, we also attempted to examine the predictability of the need satisfaction and frustration scores on product satisfaction using multi-linear

Table 6. Goodness-of-fit indices for FUN scales Version 3 in study 4.

Model fit indices	Threshold	Need Satisfaction Scale	Need Frustration Scale
χ2(df)	Less than 3	2.025	1.954
RMSEA	Less than .08	.064	.062
CFI	More than .90	.929	.934
TLI	More than .90	.916	.922
SRMR	Less than .10	.091	.061

Note. χ2(df) = Chi-square value with degrees of freedom; RMSEA = Root Mean Square Error of Approximation; CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; and SRMR = Standardized Root Mean Square Residual.

regression analysis. In two studies, need satisfaction significantly predicted product satisfaction (Study 3, $\beta = .41$, $p < .001$; Study 4, $\beta = .26$, $p < .001$;). However, the results for need frustration varied. Only Study 4 indicated a significant regression coefficient (Study 3, $\beta = -.12$, $p = .068$; Study 4, $\beta = -.23$, $p = .003$). Additionally, judging from the correlation coefficients, the results obtained in Study 4 (assessing Instagram-mediated need fulfillment using the FUN Scales Version 3) showed higher correlations between need fulfillment in two different states and product satisfaction than that of Study 3 (evaluating iPhone 11-mediated need fulfillment using the FUN Scales Version 2). The regression coefficients from the two studies also indicate that need satisfaction implied greater predictability of overall product satisfaction than need frustration.

For the second question, we applied Spearman correlation analysis to examine the associations of need satisfaction and frustration across the thirteen needs with overall product satisfaction. The results, listed in Table 8, showed a generally significant positive correlation between need satisfaction and product satisfaction across both studies, except for impact satisfaction in Study 3. Likewise, both studies observed a significant negative correlation between need frustration and product satisfaction, except for impact, morality, purpose, and security frustration in Study 3. In both studies, need frustration demonstrated a weaker correlation with product satisfaction than need satisfaction.

4. Scale scoring and analysis

Accurate scoring of psychometric measures is essential for clear and meaningful evaluations. With the seven-point Likert scale and the number of items in each scale and subscale, using raw mean (1–7) or sum scores (13 to 91 for Need Satisfaction or Need Frustration Scale and 3 to 21 for each subscale) may limit their utility for benchmarking and comparison. To address this, we propose calculating a percentage-converted score as a composite metric for each scale and its subscale (see Appendix J, Supplementary material for detailed instructions). This approach is similar to the method for scoring the System Usability Scale (SUS), a widely applied tool for assessing system or product utility (Brooke, 1996; Lewis, 2018). In addition to an overview of need satisfaction and frustration, probing into each of the thirteen needs, or a set of predominant needs that are most relevant to the research objectives, allows scale users to produce deeper and more actionable insights, especially when implementing FUN Scales with other metrics to gain a more integrated and

Table 7. Construct validity and reliability measures of the FUN scales Version 3 in study 4.

	Need Satisfaction Scale				Need Frustration Scale			
Need	α	CR	AVE	MSV	α	CR	AVE	MSV
Autonomy	0.87	0.883	0.712	0.318	0.84	0.853	0.633	0.446
Beauty	0.81	0.853	0.667	0.301	0.88	0.898	0.749	0.211
Comfort	0.95	0.953	0.871	0.472	0.95	0.954	0.874	0.601
Community	0.92	0.920	0.793	0.496	0.91	0.906	0.762	0.483
Competence	0.85	0.859	0.672	0.517	0.87	0.811	0.713	0.426
Fitness	0.97	0.966	0.905	0.570	0.92	0.926	0.808	0.601
Impact	0.92	0.917	0.787	0.608	0.94	0.945	0.850	0.537
Morality	0.78	0.820	0.610	0.154	0.79	0.823	0.628	0.497
Purpose	0.94	0.939	0.838	0.608	0.92	0.924	0.802	0.537
Recognition	0.92	0.922	0.799	0.482	0.94	0.938	0.835	0.497
Relatedness	0.85	0.860	0.675	0.386	0.89	0.904	0.760	0.304
Security	0.85	0.845	0.647	0.404	0.84	0.845	0.648	0.397
Stimulation	0.85	0.858	0.671	0.402	0.90	0.904	0.759	0.416

Note. α = Cronbach's alpha; CR = Composite Reliability; AVE = Average Variance Extracted; MSV = Maximum Shared Variance.

comprehensive view (for examples, see chapter 9 of Albert & Tullis, 2022). This nuanced understanding, therefore, helps identify key strengths or weaknesses and uncover innovation opportunities through the combination of different needs.

Overall, computing an easy-to-read percentage metric offers several advantages, including (a) enhancing communication and decision-making, particularly when sharing results with stakeholders from different backgrounds, (b) supporting benchmarking and enabling comparisons between designs—either against competitors or across iterations within a design and development process, (c) tracking performance across user groups and over time, and (d) providing a clear-cut basis for making concept decisions.

5. General discussion

Despite the ever-changing wishes and desires accompanying today's rapid pace of technological innovation, basic psychological needs remain enduring sources for human functioning, development, and well-being (Tay & Diener, 2011). The "Neo-Prehistory" design exhibition we introduced earlier illustrated this timeless quest to fulfill these universal needs. A shared language about user needs can provide a clear structure and guiding framework for human-centered design researchers and practitioners. Central inquiries often revolve around how these fundamental user needs have been and ought to be (better) addressed in human-design interaction or, in a broader sense, how we can, in various ways, incorporate them into everyday design-mediated activities. Additionally, there is a growing interest in envisioning and embodying these needs in future design scenarios, especially in the face of advancements in artificial intelligence (Bingley et al., 2023). These questions have underscored the demand for design-oriented measurement tools to assess and distill the subtle yet significant impact of design and technology on psychological need fulfillment. To respond, we present the Fundamental User Needs (FUN) Scales to measure need satisfaction and frustration in design-mediated interactions through the lens of thirteen psychological needs. Below, we discuss the theoretical and practical implications of the present study, together with limitations and directions for

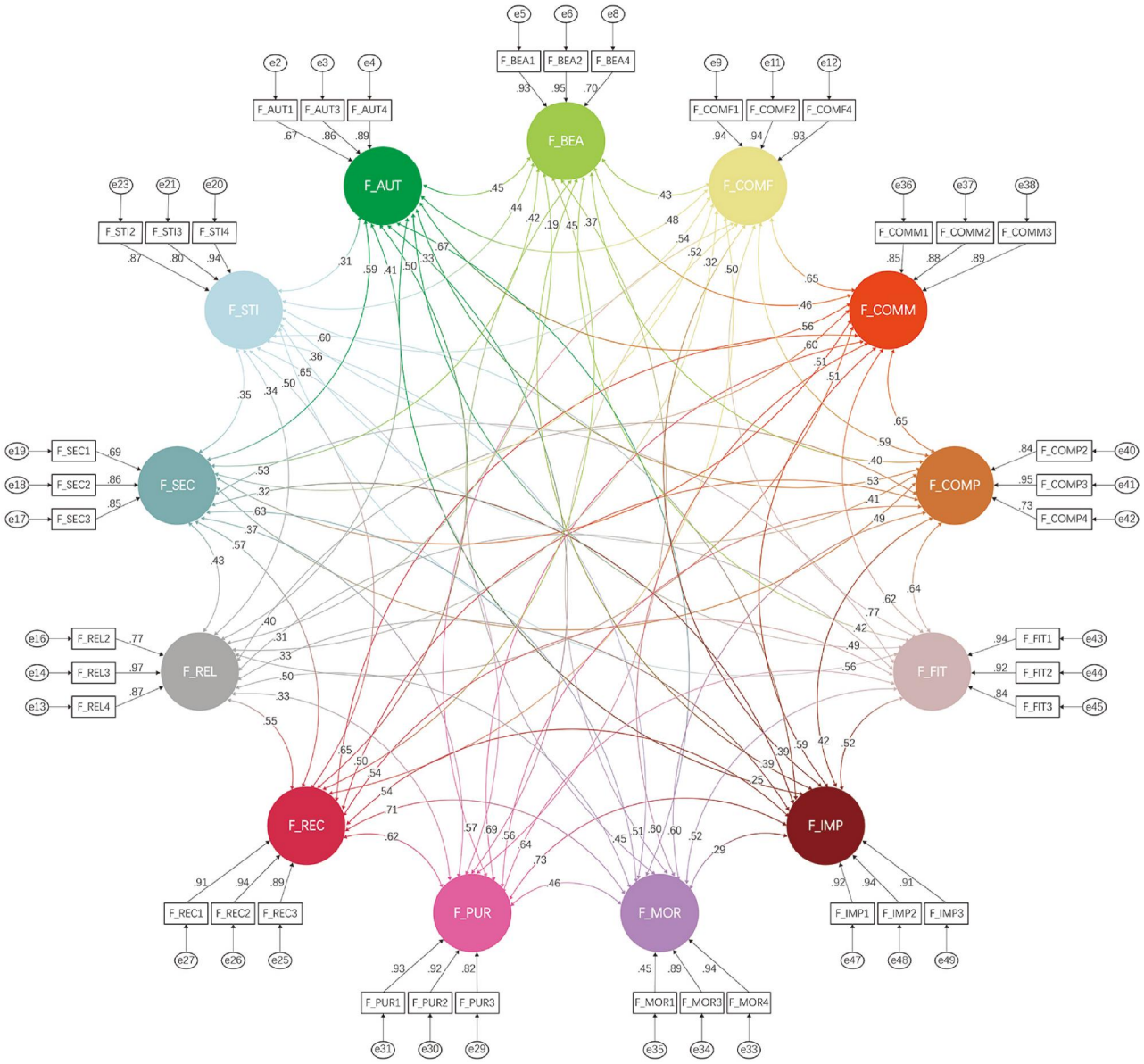

Figure 3. Path analysis diagram of the Need Frustration Scale in study 4 ($N = 250$).
Note. F_AUT = Autonomy Frustration; F_BEA = Beauty Frustration; F_COMF = Comfort Frustration; F_COMM = Community Frustration; F_COMP = Competence Frustration; F_FIT = Fitness Frustration; F_IMP = Impact Frustration; F_MOR = Morality Frustration; F_PUR = Purpose Frustration; F_REC = Recognition Frustration; F_REL = Relatedness Frustration; F_SEC = Security Frustration; F_STI = Stimulation Frustration.

Table 8. Correlations between product satisfaction and need satisfaction and need frustration in studies 3 ($N = 252$) and 4 ($N = 250$).

	Need Satisfaction		Need Frustration	
Need	Study 3	Study 4	Study 3	Study 4
Autonomy	.143*	.464**	−.208**	−.392**
Beauty	.287**	.505**	−.235**	−.425**
Comfort	.311**	.597**	−.245**	−.418**
Community	.176**	.569**	−.168**	−.500**
Competence	.388**	.472**	−.246**	−.362**
Fitness	.221**	.494**	−.238**	−.420**
Impact	.069	.410**	−.102	−.357**
Morality	.218**	.346**	−.119	−.392**
Purpose	.160*	.494**	−.119	−.467**
Recognition	.131*	.415**	−.132*	−.400**
Relatedness	.212**	.348**	−.046	−.339**
Security	.185**	.388**	−.153*	−.322**
Stimulation	.261**	.473**	−.287**	−.523**

Note. **. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

future research to further expand the utility of the proposed new measure.

5.1. Theoretical implications

This research advances the theoretical clarity and operationalization of the design-focused typology of thirteen psychological needs, translating abstract theoretical constructs into measurable and actionable variables (Corley & Gioia, 2011; Whetten, 1989). The findings from Studies 3 and 4 further support this theoretical framework with empirical evidence, building on the qualitative foundation initially developed by Desmet and Fokkinga (2020).

Beyond their diagnostic role, the FUN Scales offer a promising pathway for future theoretical advancements in need-

focused or need-relevant user research. This potential has been demonstrated by sustained progress in motivation research, where scales grounded in frameworks like Maslow's (1943) hierarchy of needs, Self-Determination Theory (SDT; Ryan & Deci, 2017), the ten candidate needs by Sheldon et al. (2001), and Murray's (1938) theory of needs have contributed to theoretical development (for details, see Kermavnar et al., 2024; Vansteenkiste et al., 2020).

Finally, the present study suggests several avenues for future design research: (a) generating new knowledge and insights about and for human-centered design, (b) refining existing design processes and methods with empirical reflections, and (c) improving methodologies and workflows about need-centered design innovation, especially helpful for multidisciplinary collaboration (Horvath, 2004).

5.2. Implications for practice

The main merits of the FUN Scales can be summarized into four aspects: (1) facilitate a nuanced and comprehensive overview of need fulfillment in human-design interaction, (2) offer flexibility in evaluation, (3) enhance consistency and efficiency in communication and collaboration, and (4) broaden the design and innovation space.

Firstly, the FUN Scales balances the granularity required for design inspiration with the brevity that supports practical usability. As illustrated in Section 4, for different research purposes, researchers can interpret the scale results holistically or delve into each specific need for an in-depth analysis, thereby leveraging their relevance within varied projects. Additionally, using a percentage-converted score to compute a single metric for each scale or subscale significantly improves utility in diverse research contexts, enabling efficient comparisons and tracking of performance over time, across scenarios, or among different user groups.

Secondly, the FUN Scales offer flexibility, accommodating evaluations across various design categories, including physical and digital products, service systems, and environments. This versatility, on the one hand, stems from the broad applicability of the scale stem and item phrasing. On the other hand, the FUN Scales ask people to reflect on and report their perceived actual need fulfillment during product use and interaction rather than judging the product qualities (i.e., the potential of a design to fulfill one's needs). This subjective experience-centered evaluation provides a more intuitive and practical approach for comparing different products (for differences between experience- and product-centered evaluation, see Hassenzahl et al., 2010). In addition, the FUN Scales support measurement at various time scales, such as reflective assessments of need fulfillment in past and ongoing human-design interaction, or envisioned evaluation of need fulfillment mediated by new or future designs (e.g., during the prototype or mockup testing stage).

Thirdly, the FUN Scales can facilitate consistent and efficient communication and collaboration, especially contributing to interdisciplinary work, as they support understanding and discussing needs among individuals from diverse cultural and professional backgrounds. In qualitative-methods-based user research, needs can sometimes be operationalized and measured at a non-basic level, focusing on function- or feature-related desires (e.g., ambient lighting or more legroom in the car). The FUN Scales, in contrast, explicitly prompt people to contemplate and express needs at a basic level. As these needs are universal (i.e., design and context-independent), this approach enables scale users to obtain data that can be compared across studies, which is also particularly useful for building large user datasets and models.

Lastly, FUN Scales can guide decisions made throughout the design process, ensuring alignment with design goals and sparking inspiration at the start of the process, suggesting new avenues for innovation (Desmet & Hassenzahl, 2012). The evaluation results can be used to develop need-centered design profiles, suggesting design directions such as enhancing satisfied needs to support well-being, addressing frustrated needs to diminish ill-being, incorporating needs that are deemed neither satisfied nor frustrated (i.e., overlooked needs), as well as examining the interplay among various sets of needs (Desmet & Fokkinga, 2020). For instance, a *product-focused* need profile can show the relationship between psychological need fulfillment and product design, such as the need fulfillment state associated with a single product or multiple design iterations within a specific product category (e.g., see the need profiles of sixteen alarm clock designs by Desmet, 2020).

Despite these benefits, one aspect worth improvement is the time and effort required to complete the 78-item FUN Scales. Considering the need for a "quick and dirty" measurement in real-world applications, reducing the number of items could ensure a more concise evaluation and support its use in large-scale surveys or repeated assessments with the same group of people. Streamlining an initially long scale to more efficient versions is a common goal in usability and user experience research (Albert & Tullis, 2022). Examples can be seen in the iterations of the questionnaire for user interaction satisfaction (QUIS; Chin et al., 1988; Harper & Norman, 1993), the speech user interface service quality (SUISQ) questionnaire (Lewis & Hardzinski, 2015), the user experience questionnaire (UEQ; Laugwitz et al., 2008; Schrepp et al., 2017), and the usability metric for user experience (UMUX; Finstad, 2010; Lewis, 2018; Lewis et al., 2013).

To achieve the purpose of optimization, we propose two feasible approaches. The first approach involves compiling and validating a more concise scale. While we aimed to balance parsimony and validity by retaining at least three items per subscale, there is an increasing trend toward using more compact measures, such as unidimensional scales. For instance, Martela and Ryan (2024) recently introduced single-item scales for assessing the classical need trio—autonomy, relatedness, and competence in SDT. The second approach entails dividing the FUN Scales into sets of subscales, allowing users to focus only on the most relevant needs for their specific research objectives and contexts rather than assessing all thirteen needs at once.

5.3. Limitations and future directions

Developing and validating scales requires theoretical and methodological rigor (DeVellis & Thorpe, 2021). While we

followed the guidelines of Hinkin (1995), Worthington and Whittaker (2006), and Yusoff et al. (2021) and treated each step carefully to ensure a reliable process for the development and preliminary validation of the FUN Scales, there are several limitations worth discussion, together with prospects for future research.

First, we took a deductive approach to generate scale items. This decision was motivated by a detailed theoretical framework and an extensive review of existing scales. We also integrated the different viewpoints of research team members throughout the item generation and development process. While this approach proved suitable, some methodological guidelines recommend combining deductive and inductive approaches (e.g., DeVellis & Thorpe, 2021; Morgado et al., 2017). Future research could consider incorporating the perspectives of the target population and instrument users through interviews and focus groups. This step could also be enhanced by administrating face validity tests among target populations to spot potential misunderstandings at an early stage of scale development, as complementary to the present content analysis with experts (Clark & Watson, 1995). Notably, the detailed typology, including two need facets for each need developed in the preparation stage, served as one of several resources for creating the initial item pool. None of the items were directly derived from or correspond to any specific need facet. The deconstruction of the original theoretical framework aimed to obtain a more nuanced understanding of each need concept and to ensure that no essential aspects were overlooked. Further exploration and refinement of the need facets could be a challenging yet valuable direction for future research.

The second limitation pertains to the evaluation of scale validity. The validation of new psychometric measures is typically an iterative process spanning years of research. This process often involves ongoing studies to develop, refine, and test the robustness and applicability of the scale across different samples (e.g., cultural groups) or experimental settings (e.g., longitudinal studies) (DeVellis & Thorpe, 2021; Morgado et al., 2017; Sheldon et al., 2001). Although we performed only the most essential steps of scale validation, the current research marks a solid beginning of this journey. Our findings provided preliminary evidence for the factor structure, reliability, construct validity, and criterion validity of the FUN Scales. Across two studies, we examined the correlations between need fulfillment (satisfaction and frustration) and product satisfaction. The results suggested that users' overall satisfaction with a design was significantly linked to enhanced need satisfaction and reduced need frustration, consistent with the previous research findings (e.g., see Borsci et al., 2015; Hassenzahl, 2007, 2018). However, follow-up research is needed to explore the causal relationships among these variables further, as indicated by the regression analysis results. Additional studies examining the convergent and divergent validity of the FUN Scales could further strengthen the scale validation process. The next step in this ongoing effort would be to explore whether the FUN Scales and their subscales correlate strongly with similar constructs while showing weak correlations with theoretically unrelated constructs to provide a more comprehensive assessment. However, this might be challenging, given the current scale length. Potential alternative approaches to address this issue can be seen in Section 5.2.

Future research could investigate the psychological and behavioral impact of design and technology by examining how need fulfillment interacts with related phenomena such as affect, user experience, behavioral tendencies, and subjective well-being (Hassenzahl et al., 2015; Sheldon et al., 2001). For instance, FUN Scales data can be correlated with the PANAS scales (Thompson, 2007; Watson et al., 1988) or the Scale of Positive and Negative Experience (Diener et al., 2010), and the User Experience Questionnaire (UEQ; Laugwitz et al., 2008) to explore the relationships between need fulfillment with positive and negative affect and experience. Another promising direction would be to build on the work of Hassenzahl et al. (2010), who categorized positive experiences with interactive technology by the needs they fulfill, using the FUN Scales to extend their work by broadening the lens of analysis from seven to thirteen needs and by including both positive and negative experiences. Further studies can also delve into more specific "spheres of analysis," such as while engaging in technology-specific tasks (for more explanations, refer to Peters et al., 2018).

Third, although the FUN Scales exhibited excellent internal consistency, as demonstrated by Cronbach's alpha above 0.70, high internal consistency may not always be desirable (Morgado et al., 2017). Specifically, the items for comfort satisfaction, frustration, and fitness satisfaction (see Table 7), could suffer from redundancy due to high scores. Our decision to keep three items per factor construct in the second scale evaluation was based on the guideline of Tabachnick et al. (2013) that a minimum of three items per factor is necessary to yield reliable measures. Future research may consider returning to the item generation stage to scrutinize and refine the item wording to better capture all relevant facets of the construct while preserving the parsimony of the scales. Although internal consistency is deemed the most important measure of reliability, other optional but recommended tests, such as test-retest reliability and known-groups validity, can also be conducted (DeVellis & Thorpe, 2021). Specifically, for the former, administrating the FUN Scales to the same respondents at two different time points could help verify the temporal stability of the measure and provide additional support for the scale reliability (Boateng et al., 2018).

In this study, we validated the scales using two different products. Future research could extend scale validation to other cases, such as healthcare devices, autonomous vehicles, digital games, and workplaces, to explore broader application possibilities. Beyond the *product-focused* need profiles introduced in Section 5.2, *activity-focused* need profiles could offer an expanded perspective by demonstrating need fulfillment associated with events or activities (e.g., visiting museums, physical training, or e-learning). In other words, the latter approach could enable designers to adopt a more holistic view of the psychological effects of design-mediated interactions (Hassenzahl et al., 2013). In this way, the scale stem should be modified to "during the activity of…." This

may, however, require additional psychometric evaluations to ensure the scale validity and reliability. Moreover, for the sample size in scale evaluation studies, we followed the recommendation of Costello and Osborne (2019) to invite a minimum of five respondents per item per scale. However, there are no general agreements on these guidelines. For example, Boateng et al. (2018) suggested recruiting ten respondents per item. Follow-up studies may explore whether a larger sample size would affect the scale validity since previous research that compared different ratios found no significant effect of ratio on validity but the absolute number of observations (Barrett & Kline, 1981).

Lastly, beyond answering the "what" question—the extent to which the various psychological needs are satisfied or frustrated—researchers might also be interested in answering the "how" question. Specifically, what design features or elements, interaction qualities, or other subjective and environmental factors have contributed to the measured need satisfaction and frustration? Someone's need for autonomy, for example, can be satisfied or frustrated by many different variables, such as product usability, general product features, social interactions in the context of product usage, or other contextual factors. Therefore, we foresee the value of combining FUN Scales, as quantitative measures, with qualitative methods like open diary studies, interviews, focus groups, or field observations to obtain rich data that can help answer both the "what" and the "why" questions.

6. Conclusion

Building on a design-focused need typology and following a standardized scale development approach, this paper introduced the Fundamental User Needs (FUN) Scales, a new measure designed to assess design-mediated need satisfaction and frustration across thirteen distinct psychological needs: autonomy, beauty, comfort, competence, community, fitness, impact, morality, purpose, recognition, relatedness, security, and stimulation. Beyond developing a psychometric measure, the current research provided empirical evidence for the theoretical framework—the typology of thirteen psychological needs. We propose that the FUN Scales contribute to the field as an effective diagnostic tool for practitioners and researchers in design and HCI communities. In the introduction, we referred to Norman's (2023) recent book, *Design for a Better World*, in which he emphasized the significance of evaluating and understanding the metrics that truly matter to humanity and society for creating solutions that improve quality of life and contribute to a more meaningful, sustainable, and equitable world. By introducing the FUN Scales, our goal was to enrich the human-centered design toolkit with a practical and robust new instrument, aligning with this vision and supporting designers in their efforts to prioritize psychological needs that are both instrumental and inspiring for human-centered design initiatives that contribute to human development and flourishing.

Note

1. In this manuscript, we use the terms 'fundamental (psychological) user needs' and 'basic psychological needs' interchangeably. While not all of the thirteen psychological needs in the design-focused typology strictly meet the criteria for being "fundamental" as established by Basic Psychological Needs Theory (BPNT) within Self-Determination Theory (SDT), their value lies in the relevance and granularity they provide for design research and applications. We use this typology to support discussions in the design discourse, though we acknowledge that their validity for motivation research requires further investigation.

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Ethical approval

This research was conducted in accordance with the Declaration of Helsinki, approved by the Human Research Ethics Committee of the Delft University of Technology, the Netherlands (approval numbers 3022 and 3520). Participants across different studies gave informed consent before joining.

Disclosure statement

The authors report that there are no competing interests to declare. The funders did not play a role in the study's design, data collection, analyses, or interpretation, manuscript writing, or decision to publish the results.

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