Ranking Persuasive System Design Strategies for mHealth Apps Using Fuzzy AHP

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Abstract

The development of mobile health (mHealth) applications has revolutionized health and fitness management by providing users with innovative digital tools to monitor and improve their well-being. These apps integrate features such as step counting, health tracking, and activity monitoring, making them valuable for personalized health interventions. However, ensuring effective user engagement remains a critical challenge. Persuasive System Design (PSD) strategies are essential for influencing user behaviour, improving adherence to health interventions, and enhancing app usability. Despite extensive research on PSD strategies, a structured framework that prioritizes the most effective strategies for mHealth apps is lacking. This study aims to address this gap by utilizing the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) to identify and rank the most influential PSD strategies for health and fitness mobile applications. By gathering expert opinions from product managers, this research will develop a structured Top 10 PSD Strategies Model that offers product designers a prioritized framework for implementing persuasive techniques. The findings will help improve user retention, engagement, and overall app success.

Keywords: mHealth, Fuzzy AHP, Persuasive System Design, Multi-criteria Decision Making

JEL classification: L86, L15

Paper type: Research article
Received: 6 May 2025
Accepted: 17 June 2025

DOI: 10.54820/entrenova-2025-0051

Citation: Pezer, M., Odak, M., & Marušić, Ž. (2025). Ranking Persuasive System Design Strategies for mHealth Apps Using Fuzzy AHP. ENTRENOVA - ENTerprise REsearch InNOVAtion, 11(1), https://doi.org/10.54820/entrenova-2025-0051.

Introduction

The rise of mobile technology has significantly transformed the healthcare landscape by enabling a shift from traditional in-person care models to more proactive and personalized health management solutions. Among the most impactful innovations in this digital health revolution are mobile health (mHealth) applications, which allow users to continuously monitor, manage, and improve various aspects of their health and fitness. These applications harness the power of mobile devices and built-in sensors to track physical activity, sleep quality, heart rate, dietary habits, and more, offering users real-time insights into their well-being.

According to Trifan et al. (2019), integrated sensors in mobile devices enable seamless data collection that supports a wide range of health objectives. As such, mHealth apps have emerged as one of the most promising innovations in the broader field of digital healthcare (Levine et al., 2020).

Despite their growing popularity and potential, a critical challenge remains: sustained user engagement. Many users discontinue app use after initial downloads, limiting the effectiveness of these tools in delivering long-term health benefits. To address this challenge, developers have turned to Persuasive System Design (PSD)—a field that focuses on using design strategies to influence user behaviour and decision-making. PSD strategies, such as goal-setting, social support, self-monitoring, and reminders, have been shown to increase user motivation and adherence to health interventions (Oinas-Kukkonen & Harjumaa, 2009).

The major model used to evaluate and design such systems, based on an extensive literature review, is the Persuasive System Design (Oinas-Kukkonen & Harjumaa, 2009) model. However, this model does not consider usability constructs that can be measured early in the prototype design and, overall, cannot objectively measure the usability of persuasive systems except when other usability models or methods are used.

Assessing the usability of emerging technologies continues to pose significant challenges, primarily because traditional evaluation methods are time-consuming and costly. Consequently, there is a growing need to integrate appropriate usability constructs into the design phase of Persuasive Health Systems (PHS) (Kasali et al., 2017). As usability is recognized as a critical quality attribute across various theoretical models, these frameworks often aim to categorize and quantify its characteristics. However, most models do not adequately address usability attributes during the early stages of development, when the user interface is still being constructed. Instead, they tend to rely on fully functional prototypes, which limits their applicability in the initial design phase. This oversight is particularly concerning given that usability, often manifested in the software interface, represents one of the most significant risks in software development.

In response, this study extends the Persuasive Systems Design (PSD) model—an influential framework for designing and evaluating persuasive technologies (Oinas-Kukkonen & Harjumaa, 2009)—by introducing measurable usability constructs applicable during the early stages of development. The goal is to enhance usability from the outset while simultaneously reducing development costs and resource expenditure.

Although prior research has examined various PSD principles in the context of mobile health (mHealth) applications, there remains a lack of a systematic, evidence-based framework for ranking and prioritizing these strategies by effectiveness. This absence impedes developers and product designers from making informed choices regarding the most impactful persuasive techniques.

To bridge this gap, the current study proposes a structured decision-making framework utilizing the Fuzzy Analytic Hierarchy Process (Fuzzy AHP). This multi-criteria decision-making approach effectively incorporates human judgment and uncertainty into the evaluation process. Initially developed by Van Laarhoven and Pedrycz (1983) and later enhanced by Chang (1996) using triangular fuzzy numbers, Fuzzy AHP is well-suited for complex problems involving subjective assessments and multiple criteria. The method has been successfully applied across various domains for strategic prioritization and planning (Ataei et al., 2012).

This research aims to utilize Fuzzy AHP to identify and rank the Top 10 most influential PSD strategies for health mobile applications. Expert insights will be gathered from experienced product managers and mHealth practitioners to build a prioritized model. The resulting framework will serve as a valuable tool for app developers and designers seeking to enhance user engagement, improve app usability, and ultimately, increase the success of their health-focused digital interventions. This will be especially useful in the early stages of product design to ensure a top-performing mHealth app.

Background and Literature Review

Health promoters, like many medical and public health professionals, have been eager to seize the opportunities they perceive for using what have been dubbed 'mHealth' ('mobile health') technologies to promote the public's health (Lupton, 2013). Health apps are primarily used in two contexts: professional medical practices and self-monitoring of healthy habits. This second category is the focus of this study. It involves people tracking their own activity levels to adopt healthy lifestyles or take preventive measures against disease.

One of the most concerning aspects of global health, especially in developed but also emerging nations, is the high prevalence of obesity, which is especially rising among children (Anderson et al., 2019). Because of this, the WHO advises people of all ages to lead active lifestyles and consume balanced diets. Lifestyle-based interventions for population self-management are successful in lowering risk factors and the prevalence of non-communicable diseases (Burke, 2011).

In recent years, there has been a surge in research focusing on the intention to use new technologies across various contexts. However, despite extensive research, a clear understanding of the factors driving sports fans and consumers to use smartphones or apps to benefit from new sports experiences remains elusive (Ha et al., 2015).

Mobile applications may improve the quality of life for patients with chronic conditions, for example, through personalized self-monitoring, goal setting, and behavior change (e.g., increasing physical activity), available anytime, anywhere. The Persuasive System Design (PSD) model emerges as a formidable analytical framework that delineates the intricate dynamics of persuasive technologies (Oinas-Kukkonen & Harjumaa, 2009).

With its multifaceted approach, PSD serves as a compass for designers and evaluators alike, guiding them through the intricate maze of system development and assessment (Ko et al., 2015).

According to the reviewed mHealth literature and apps for sleep-related purposes, digital interventions are changing the landscape of sleep health and clinical sleep medicine (Ko et al., 2015). In particular, mHealth interventions can improve or impair collective and individual sleep health. This study focuses on the functionality and features of the apps but neglects their potential to change behaviour.

As presented above, there are several research and literature surveys concerning the use of smartphones in the health domain but there is a continuous need for new research to cover the proliferating increase in mHealth apps. Our review of the related work revealed several limitations in the existing literature, which can be summarized as follows:

- Most of the studies investigated the domain based on the academic literature (e.g., Han & Lee, 2018; Monge Roffarello & De Russis, 2019; Alhasani et al., 2020) rather than reviewing the apps in the real world.
- Most published literature on mHealth apps is descriptive (Milne-Ives et al., 2020). These studies emphasize the gaps in the literature, employed strategies, and other descriptive statistics, but they neglect to evaluate the effectiveness of mHealth apps in promoting behavior change.
- Most of the existing reviews are limited in terms of domain (e.g., Milne-Ives et al., 2020; Powell et al., 2016; Rilla, 2008), audience groups, or both. This limitation was confirmed by a previous study (Kaptein, 2012), which also called for new studies to explore the mHealth domain more comprehensively.
- Most of the previous reviews are not theory-based. That is, they do not rely on well-defined theories or frameworks to conduct their studies. Examples of these studies include Orji et al. (2017), Monge Roffarello & De Russis (2019), and Matthews et al. (2015). Few studies have considered well-known frameworks. However, even these studies were limited to a single framework. Our work is the first to combine two well-known frameworks for a comprehensive evaluation of apps still in development.

The literature specifically addressing the application of Fuzzy AHP in the design of pervasive systems remains notably limited, thereby positioning our study as a novel contribution to academic research by bridging this methodological gap and advancing the integration of decision-making frameworks in emerging technological domains.

To address this need, this paper builds on previous reviews to update and expand them, and to offer practical insight into the development of an innovative, modern health and activity mobile app.

Methodology

Persuasive System Design PSD Model

This study employed the Persuasive Systems Design (PSD) model as the core methodological framework to guide the development and evaluation of the system. The PSD model, introduced by Oinas-Kukkonen and Harjumaa (2009), provides a structured approach to designing information systems that aim to influence user behavior and attitudes through persuasive technology. The model is grounded in behavioural and psychological theories and is widely used in domains such as health, education, e-commerce, and environmental sustainability.

The PSD model categorizes 28 persuasive strategies into four main design principles:

- Primary Task Support comprises techniques that facilitate users in achieving their primary objectives: reduction, tunnelling, tailoring, personalization, self-monitoring, simulation, and rehearsal. These strategies assist users in simplifying tasks, guiding them through processes, adapting content to user needs, and enabling them to visualize and practice desired behaviours, thereby increasing task efficiency and effectiveness. In this study, personalization, tunnelling, self-

monitoring, and reduction were incorporated to help users complete key tasks effectively and efficiently.
- Dialogue Support – Features that maintain user engagement and motivation during interactions with the system (praise, rewards, reminders, suggestions, similarity, liking, and social role). This study used reminders, rewards, praise, and suggestions to sustain user interest and reinforce positive behaviours.
- System Credibility Support – Strategies that enhance the perceived trustworthiness and reliability of the system. This was achieved through trustworthiness cues, expertise presentation, and third-party endorsements, ensuring that users perceive the system as credible and authoritative.
- Social Support - Strategies employed in this category include trustworthiness, expertise, surface credibility, real-world feel, authority, third-party endorsements, and verifiability. This study integrated trustworthiness, expertise, surface credibility, and a real-world feel to foster a sense of community and peer accountability.

For this research, a light PSD model has been used that includes 16 of the 28 PSD items. The selection of 16 Persuasive System Design (PSD) strategies in this study is grounded in empirical evidence and theoretical relevance, with a focus on optimizing behavioural change in mHealth applications. While the complete PSD model offers a broader set of strategies, our inclusion criteria were guided by three core principles: (1) these strategies appeared most frequently in successful interventions (Oinas-Kukkonen at all, 2015); (2) frequency of implementation in successful real-world applications (used across the highest-rated mHealth apps on Google Play & App Store); (3) avoiding overload: too many strategies reduce usability and backfire due to cognitive overload (Oinas-Kukkonen & Harjuma, 2009). By narrowing the focus to 16 high-impact strategies, this study ensures both analytical manageability and practical applicability for pervasive system design. This targeted approach enhances the rigor of our fuzzy AHP-based prioritization model while providing a scalable, evidence-based, and directly translatable framework for design decisions in mHealth applications. The application of the PSD framework in this study ensured a systematic, theory-based approach to persuasive technology design, thereby enhancing both the system's usability and its behavioural impact.

Fuzzy AHP

The Analytic Hierarchy Process (AHP), (Saaty, 1980), is a widely adopted multi-criteria decision-making (MCDM) technique that decomposes complex decision problems into a hierarchical structure comprising goals, criteria, and alternatives. AHP relies on pairwise comparisons and a numerical scale (typically 1–9) to elicit expert judgments and compute relative priorities. However, the conventional AHP assumes precise numerical inputs, which may not adequately capture the uncertainty or subjectivity inherent in human decision-making.

To address this limitation, the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) integrates fuzzy set theory into the AHP framework. By employing triangular fuzzy numbers (TFNs), Fuzzy AHP enables decision-makers to express imprecise or linguistically vague judgments more effectively. This is particularly valuable in contexts such as evaluating Persuasive System Design (PSD) strategies for mobile health (mHealth) applications, where qualitative factors dominate and expert opinions may be uncertain or subjective. A Triangular Fuzzy Numbers (TFNs) is denoted as a triplet (l, m, u), where:
- l: lower bound (least likely value),
- m: modal value (most likely),

- u: upper bound (most optimistic value).

For example, a comparison described as "moderately more important" may be represented as (4, 5, 6), conveying the uncertainty around that judgment.

After determining the number of expert decision-makers (K), the regular Fuzzy AHP methodology follows a structured multi-step process:

1. Problem Definition: Identify the goal, criteria (Ci), sub-criteria, and alternatives (Aj).
2. Hierarchy Construction: Structure the problem into hierarchical levels: Goal → Criteria → Sub-criteria → Alternatives.
3. Fuzzy Pairwise Comparisons of Criteria: Experts perform pairwise comparisons at each hierarchy level using linguistic terms translated into TFNs. The result is a fuzzy comparison matrix for criteria.
4. Fuzzy Pairwise Comparison of Alternatives (per Criterion): For each criterion, experts compare all alternatives in pairs, generating one fuzzy matrix per criterion.
5. Aggregation of Expert Judgments (if applicable): When multiple experts are involved, individual fuzzy matrices are aggregated using geometric mean or similar methods.
6. Fuzzy Weight Computation: Fuzzy weights are derived from the comparison matrices using methods like extent analysis or fuzzy geometric mean.
7. Defuzzification: Fuzzy weights are converted into crisp values using defuzzification methods (e.g., the centroid method).
8. Overall Ranking: Compute the final score for each alternative by multiplying the alternative's weight under each criterion by the weight of that criterion. Rank alternatives accordingly.

In the regular Fuzzy Analytic Hierarchy Process (Fuzzy AHP), alternatives are evaluated indirectly through a structured hierarchy, where expert judgments are first used to compare evaluation criteria (i.e. effectiveness, feasibility, or ethical soundness) and then to assess how well each alternative performs under each criterion (Saaty, 1980; van Laarhoven & Pedrycz, 1983). In contrast, this study adopts a simplified Fuzzy AHP approach. A subset of 16 persuasive system design strategies (Table 1) was selected and treated as alternatives within the simplified Fuzzy AHP framework. These alternatives were directly compared pairwise based on expert judgment of their overall importance.

This direct-comparison model eliminates the need to define and weight intermediary criteria, allowing for a more intuitive and streamlined assessment of overall strategic importance and thereby reducing the cognitive load on evaluators while improving applicability in scenarios with a high number of alternatives (Chang, 1996;. (Kahraman & Ulukan, 2003).

Table 1
Categories and strategies

Categories	Strategies
Primary Task Support (C1)	**PE:** Personalization, **TU:** Tunnelling, **SM:** Self-monitoring, **RE:** Reduction,
Dialogue Support (C2)	**RW**: Rewards, **PR**: Praise, **RM**: Reminders, **SU:** Suggestion
System Credibility Support (C3)	**TW:** Trustworthiness, **EX:** Expertise, **SC:** Surface Credibility, **RF:** Real-World Feel
Social Support (C4)	**SL:** Social Learning, **CO:** Social Comparison, **SF:** Social Facilitation, **NI:** Normative Influence

Source: Authors' work

To support this study, a questionnaire has been sent to 10 experts in mHealth app design, development, and product management. The purpose was to gather their judgments on the relative importance of Persuasive System Design (PSD) strategies for creating a top-performing mHealth app. Participants performed pairwise comparisons of PSD strategies within each category using a 4-point scale (Table 2). This scale allowed experts to express the degree of importance of strategy pairs, with reciprocal values automatically applied for inverse comparisons. These qualitative judgments were translated into triangular fuzzy numbers (TFNs), aggregated across participants, and defuzzified to yield a final ranking of the strategies' importance.

The involvement of domain experts ensured that the data reflected practical insights grounded in real-world experience, thereby enhancing the reliability and applicability of the study's findings.

The following linguistic scale is used for pair-wise comparisons in Fuzzy AHP:

Table 2
Linguistic scale and corresponding triangular fuzzy numbers

Linguistic Scale	Explanation	TFN	Inverse TFN
Equal Importance	Two strategies are equally important for the success of an mHealth app	(1,1,1)	(1,1,1)
Slightly More Important	Experience and judgement slightly favour one strategy over another	(2,3,4)	(1/4,1/3,1/2)
Moderately More Important	Experience and judgement moderately favour one strategy over another	(4,5,6)	(1/6,1/5,1/4)
Strongly More Important	A strategy is very strongly favoured over another	(6,7,8)	(1/8,1/7,1/6)

Source: Authors' work

Results

This research presents rankings of Persuasive System Design (PSD) categories and individual PSD strategies for enhancing user engagement in mobile health (mHealth) applications. These rankings were derived using the Fuzzy Analytic Hierarchy Process (Fuzzy AHP), which enables the integration of expert evaluations under conditions of uncertainty, enabling a more nuanced understanding of which strategies are most influential in motivating user behaviour. This section presents the analysis used to compute the final global weights for each PSD strategy. This was done by aggregating the local weights of the strategies within each category, each weighted by its corresponding category's global weight. Expert evaluations were expressed using triangular fuzzy numbers (TFNs) on the linguistic scale discussed in the chapter Methodology. The defuzzified weights were then used to rank the strategies based on their overall influence on mHealth app success.

The results of this ranking are shown in Table 3. The strategies that emerged as the most influential in enhancing user engagement are:

Table 3
Top 10 PSD Strategies According to Aggregated Values

Rank	PSD Strategy	Category	Defuzzied Weight	Normalized Weight
1	**Reminders**	Dialogue support	6,75	**0.16**
2	**Trustworthiness**	System Credibility Support	6,72	**0.16**
3	**Expertise**	System Credibility Support	5,84	**0.16**
4	**Social Learning**	Social Support strategy	5,69	**0.15**
5	**Reduction**	Primary task support	4,83	**0.15**
6	**Tunneling**	Primary task support	4,51	**0.15**
7	**Self-monitoring**	Primary task support	4,47	**0.14**
8	**Reward**	Dialogue support	3,84	**0.14**
9	**Social Comparison**	Social Support strategy	3,77	**0.13**
10	**Social Facilitation**	Social Support strategy	3,67	**0.13**

Source: Authors' work

Discussion

The global ranking of PSD categories and their constituent strategies reveals key areas of focus for mHealth app design. Among the four main categories—Primary Task Support, Dialogue Support, System Credibility Support, and Social Support—the results indicate that Dialogue Support and System Credibility Support are particularly critical. The highest-ranked strategy was Reminders (Dialogue Support), closely followed by Trustworthiness and Expertise (both in System Credibility Support). This underscores the importance of maintaining ongoing user engagement through timely prompts while simultaneously establishing the app's credibility to foster trust.

The prominence of Social Learning and other Social Support strategies, such as Social Comparison and Social Facilitation, highlights the growing recognition of social influence in motivating health behaviour change. These results align with established behavioural theories emphasizing the role of social context and peer interactions in promoting sustained engagement. Interpretation of key strategies:

- Reminders, as the top-ranked strategy, suggest that continuous, well-timed prompts are effective in encouraging users to maintain health-related behaviours, addressing the common challenge of user drop-off in mHealth apps.
- Trustworthiness and Expertise reinforce the critical role of system credibility in user adoption and ongoing engagement. Users are more likely to rely on an app that is perceived as authoritative, accurate, and dependable, which supports the inclusion of expert endorsements and transparent information.
- Within Primary Task Support, strategies such as Reduction, Tunnelling, and Self-monitoring emphasize simplifying tasks, guiding users through processes, and enabling self-tracking. These strategies collectively facilitate user progress by reducing barriers to action and fostering self-awareness, both of which are vital in health behaviour interventions.
- The social dimension, represented by Social Learning, Social Comparison, and Social Facilitation, demonstrates the value of integrating community and peer dynamics into mHealth apps. These strategies not only motivate comparison and recognition but also foster a sense of belonging and accountability.

The findings support and extend the PSD framework by empirically validating a subset of 16 strategies most relevant to mHealth contexts, selected to balance comprehensiveness with usability. This "light PSD model" approach addresses concerns about cognitive overload by avoiding excessive complexity, thereby promoting better user experience and adherence.

Applying Fuzzy AHP allowed the incorporation of expert knowledge under uncertainty, capturing the nuanced subjective judgments inherent in evaluating persuasive strategies. The triangular fuzzy numbers accounted for variability in expert opinions, thereby enhancing the robustness of the prioritization compared to traditional crisp AHP methods. For practitioners, these results provide actionable guidance on which persuasive strategies to prioritize in mHealth app design, development, and feature implementation. Emphasizing reminders, credibility signals, task simplification, and social components can substantially improve user retention and behaviour change outcomes.

While this study provides valuable insights into preferred strategies for designing mHealth apps, several limitations must be acknowledged.

The study is primarily descriptive and relies heavily on the Persuasive System Design (PSD) frameworks. While these frameworks are robust, they may not capture all nuances of user behaviour and app effectiveness in real-world settings.

While this study leveraged insights from 10 domain experts, broader sampling across diverse user groups and geographic regions could further validate the generalizability of the PSD strategy rankings. Additionally, the study focused on the importance of strategies rather than direct behavioural outcomes; future work could empirically test the effects of these prioritized strategies on user engagement and health metrics.

Integrating user feedback alongside expert judgments in the Fuzzy AHP process may also refine prioritization, capturing the end-user perspective more comprehensively. Moreover, exploring dynamic, context-aware persuasive strategies that adapt to individual user states is a promising direction for enhancing the effectiveness of mHealth apps.

In conclusion, this research provides a methodologically sound and practically relevant framework for ranking persuasive strategies in mHealth design, offering both theoretical insights and design-oriented guidance for developing more effective digital health interventions.

Conclusion

This study has addressed the pressing need for a structured, evidence-based approach to selecting and prioritizing Persuasive System Design (PSD) strategies for mobile health (mHealth) applications. By integrating the PSD framework with the Fuzzy Analytic Hierarchy Process (Fuzzy AHP), a systematic methodology has been developed for identifying the most impactful persuasive strategies that enhance user engagement and application usability from the early stages of development.

The findings highlight that strategies such as Reminders, Trustworthiness, and Expertise exert the most decisive influence on user retention and behavioural adherence, reflecting the critical roles of both ongoing engagement and perceived system credibility. Additionally, the inclusion of social influence mechanisms—particularly Social Learning, Social Comparison, and Social Facilitation—underscores the growing importance of community-based motivation in health behaviour change.

By capturing expert judgments using fuzzy logic, this study overcomes the limitations of conventional evaluation methods, which often fail to reflect the uncertainty and subjectivity inherent in design decision-making. The final prioritized model of the Top

10 PSD strategies serves as a practical decision-support tool for developers, product managers, and designers working on mHealth solutions, guiding them toward features that are both persuasive and user-centric.

This research contributes to the field of persuasive technology and health informatics by providing a novel usability-informed framework that enhances the early-stage design process, reduces development risk, and promotes sustained user interaction, thereby increasing the potential of mHealth applications to deliver meaningful, long-term health outcomes.

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