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SURVEY ARTICLE

Persuasive Strategies and Their Implementations in Mobile Interventions for Physical Activity: A Systematic Review

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ABSTRACT

Unhealthy lifestyle behaviors such as spending too many hours sitting and inadequate physical activity (PA) can contribute to different chronic diseases. Research has revealed the capabilities of digital technology interventions such as persuasive technologies (PTs) for providing health support and encouraging healthy behavior changes to assist people in preventing chronic diseases and having healthier lifestyles. Thus, the use of mobile technology to deliver PT interventions has dramatically increased, especially for promoting PA and reducing sedentary behavior (SB) by employing various persuasive strategies (PSs). This paper provides a systematic review of 16 years of research from 2006 to 2021. The review aims to (1) explore the various ways each strategy is implemented on mobile-based PTs for PA and SB, (2) evaluate the effectiveness of different ways of implementing the PSs on mobile-based PT interventions for PA and SB, (3) provide a comparison of the different ways of implementing each PS, (4) show the weaknesses and strengths of the interventions based on the strategies and implementations, (5) highlight the limitations and pitfalls of the existing research, and (6) give recommendations and directions for future research.

1. Introduction

"Sitting has become the smoking of our generation" (Merchant, 2013). It is well-established that prolonged sedentary behavior (e.g., sitting, laying on the couch) is unhealthy, as it correlates with avertible diseases, such as high blood pressure, obesity, diabetes, cardiovascular diseases, and cancer (Dunstan et al., 2011; Knaeps et al., 2018; Thorp et al., 2011). Therefore, there is a need to maintain or increase individuals' physical activity (PA) levels. In many cases, maintaining a good level of PA requires a change in the individual's behaviors or lifestyles (Ghanvatkar et al., 2019), which is not an easy task. Thus, a wide range of mobile-based persuasive technologies (PTs) has been introduced to help individuals increase their PA by promoting desirable behavior change.

PTs are interactive systems or applications created to increase people's awareness of their unhealthy behaviors and encourage them to change them and adopt healthy ones (Orji & Moffatt, 2018). They are used in various domains (e.g., sales, health, and management) and deploy different technology platforms such as social networking sites, ambient public displays, mobile phones and handheld devices, wearable devices, and games. These PTs often incorporate and rely on psychological and social theories, such as persuasive strategies (PSs), to motivate users to change their undesirable behaviors. For instance, providing feedback based on the user's PA progress is an example of a PS called a tracking/self-monitoring strategy. Each PS can be implemented in diverse ways based on different factors such as the technology platforms employed, targeted behavior domain (e.g., PA, smoking, or mental health), targeted populations and their needs, and the aim of the study.

Researchers and practitioners have recognized the role of PTs, and a large number of applications and studies have been introduced in a wide variety of domains The health and wellness domain has received particular attention. Despite the increased attention toward deploying PT in health and wellness, different factors are yet to be explored. Specifically, there is a lack of research examining how PSs can be implemented and the effectiveness of different implementations across various PT contexts, including problem domains, technology platforms, and target audiences. These contexts can affect not only the choice of strategy but also its implementation and effectiveness. Thus, there is a need to investigate the different ways PSs can be implemented and evaluate PTs' effectiveness based on various implementations. Mobile technologies have been widely employed in PT interventions to promote PA and reduce sedentary behavior (SB). Due to the ubiquitous nature of mobile technology in our daily lives, our research focused on mobile-based PTs for promoting PA and reducing SB.

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This paper provides a comprehensive systematic review of mobile-based PTs along with the PSs employed and their different forms of implementation for promoting PA and discouraging SB. Our review covers 198 research articles published in the last 16 years (from 2006 to 2021). The main objectives of this review are to (1) explore the various ways PSs are implemented on mobile-based PTs for PA and SB, (2) evaluate the effectiveness of different ways of implementing each PS on mobile-based PT interventions for PA and SB, (3) provide a comparison of the different ways of implementing each PS, (4) show the weaknesses and strengths of the interventions based on the choice of strategies and their implementation, (5) highlight the limitations and pitfalls of the existing research, and (6) give recommendations and directions for future research.

2. Background and literature review

This section introduces the Persuasive System Design (PSD) model (Harri & Marja, 2009) and behavioral change theories.

2.1. Persuasive system design (PSD) model

The PSD model is a framework for developing and evaluating persuasive systems (Harri & Marja, 2009). It is developed based on several other frameworks and theoretical constructs, such as the theory of reasoned action/planned behavior (Ajzen, 1991), goal-setting theory (Locke & Latham, 2002), and the elaboration likelihood model (Petty & Cacioppo, 1986). The literature demonstrated that the PSD model provides a suitable framework to investigate, design, and assess the persuasion context and its associated strategies (Lehto & Oinas-Kukkonen, 2011). Thus, it is one of the most common models used in the literature. In this paper, we applied the PSD model to identify different PT strategies (or techniques) implemented in the reviewed articles.

The persuasive system principles of the PSD model are divided into four categories (Harri & Marja, 2009):

- The *Primary Task Support* category includes strategies that help users execute their primary behavior change task. It includes seven strategies: reduction, tunnelling, tailoring, personalization, self-monitoring, simulation, and rehearsal.
- The *Dialogue Support* category includes strategies that provide the means of implementing computer-human dialogue to encourage users to continue working and make progress towards their target behavior or desired goal. It includes strategies that facilitate interaction between the user and the persuasive system through praise, rewards, reminders, suggestions, similarity, liking, and social roles.
- The *Credibility Support* category includes strategies employed in the design of PT systems to make them more credible and persuasive. This category includes strategies that increase the system's trustworthiness, expertise, surface credibility, real-world feel, authority, third-party endorsements, and verifiability.
- The *Social Support* category includes strategies that motivate users to obtain the desired behavior by leveraging social influence (Harri & Marja, 2009). The social support category involves strategies that use social influence such as social learning, social comparison, normative influence, social facilitation, cooperation, competition, and recognition. Table 1 summarizes these strategies.

2.2. Literature review

This section discusses the limitations of the current research and the gaps we aim to fill through this study. Ghanvatkar et al. (2019) focused on revealing the different types and ways of implementing a personalization strategy in PT interventions for promoting PA. Their review offers a basis for a comprehensive review of other strategies. They categorized six different ways of implementing the personalization strategy in the form of recommendations and feedback: educational content, motivational content, fitness partner recommendations, goal recommendations, activity recommendations, and intervention timing. This work, however, focused on one strategy only (the personalization strategy), and it focuses on using PT for promoting PA.

Other studies, such as Aldenaini et al. (2020), provided a systematic review focusing on personalized PTs for promoting PA and reducing SB. They analyzed different ways of implementing personalization in the PTs in their reviewed articles (in the form of feedback and recommendations) and compared their effectiveness. Their findings show that personalizing PT interventions in motivating PA and discouraging SB is a promising way of increasing their effectiveness. Their study focused only on the personalization strategy while ignoring other strategies implemented in the PTs in the reviewed articles.

There are several other articles published in the domain of PT for PA and SB. However, these articles suffer from one or more limitations. Some articles are limited in terms of the technology platform used. For instance, McCallum et al. (2018), Stephens and Allen (2013), Tong and Laranjo (2018), and Lau et al. (2011) focused only on promoting PA employing mobile applications and wearable devices, while Dunn et al. (2018) focused on mitigating SB using mobile applications. The work done by Rao (2019) focused only on promoting PA in wearable activity tracking devices. Other works, such as Almutari and Orji (2019), targeted different PT interventions while focusing only on employing social support strategies. Some other review papers are limited in terms of the domain. For example, Wang et al. (2018), Healy et al. (2012), and Shrestha et al. (2015) concentrated their revision on reducing SB mainly in the workplace environment. Another limitation is that some papers emphasized a single intervention, such as games (e.g., Yim and Graham (2007); and Lister et al. (2014)). In contrast, others focused only on reviewing articles that employ smartphone apps, such as Schoeppe et al. (2016). Also, none of these review papers considered the various ways their PSs were implemented and their effectiveness.

Table 1. PSD model strategies (Harri & Marja, 2009).

Category	Strategy	Principle Explanation
Primary Task Support	Reduction	• Reducing a complex behavior into simple and easy tasks to assist users in performing the target behavior change.
	Tunneling	• Providing means and instructions to guide users through a process to perform a targeted behavior.
	Tailoring	• Providing tailored information to meet specific interests, possible needs, the usage context, personality, or other aspects related to a particular group of users.
	Personalization	• Delivering personalized services or content to users.
	Self-monitoring	• Tracking a user's performance, status, behavior changes, and progress to encourage the user to obtain their target goals.
	Simulation	• Letting the users immediately observe the cause-effect connection regarding their behavior or attitude.
	Rehearsal	• Allowing users to rehearse a target behavior.
Dialogue Support Strategies	Praise	• The system uses praise via words, images, symbols, or sounds to provide user feedback information based on their behaviors.
	Rewards	• The system gives credits and provides virtual rewards to users for their performance and the progress of their target behavior.
	Reminders	• Reminding users of their target behavior goals will increase their opportunities to achieve their desired behavior goals.
	Suggestions	• Offering appropriate suggestions for users to perform a target behavior.
	Similarity	• Reminding users of themselves by imitating them in some particular and meaningful way.
	Liking	• Being visually appealing and having an attractive look and feel for users.
	Social Roles	• Offering communication between the system professionals and the users.
System Credibility Support	Trustworthiness	• Offering fair, unbiased, and truthful information to persuade users.
	Expertise	• A system that is viewed as incorporating expertise will have increased powers of persuasion.
	Surface Credibility	• The system has a competent look and feel.
	Real-World Feel	• Indicating real organizations or individuals regarding the system's services and content.
	Authority	• The system leverages authority roles will have enhanced powers of persuasion.
	Third-Party Endorsements	• To employ a third-party endorsement strategy in a system, the system needs to offer reliable and recognized sources.
	Verifiability	• Allow users to clearly verify and confirm the accuracy of the system's content through outside sources.
Social Support	Social Learning	• To employ a social learning strategy in a system, the system has to let the user observe others doing the intended behavior.
	Social Comparison	• When a user of a system has the ability to compare their performance with others, the user will be more encouraged and motivated to accomplish a target behavior change.
	Normative Influence	• Grouping together individuals who share the same target behavior goal.
	Social Facilitation	• Allowing users to discern that other people are performing and adopting the target behavior.
	Cooperation	• The system provides a means for users to cooperate and work together to adopt a target attitude or behavior.
	Competition	• Influence users and drive them through competing with other users and winning challenges.
	Recognition	• A system can implement the potential for an individual or a group to adopt a target behavior change by employing public recognition for a user or a team.

To summarize, the literature contains a number of systematic literature reviews in the domain of PTs for PA and SB. However, these reviews did not provide a comprehensive systematic review that sheds light on mobile-based PT interventions for promoting PA and reducing SB or investigates their effectiveness based on the strategies employed and their different implementations. In general, these studies are limited in one form or another, which can be summarized as follows:

- Most of the existing systematic review papers ignore the different ways of implementing each PS from their reviewed articles for PA or SB.
- Few papers address the PSs' implementation. They focus only on a particular strategy, such as personalization, while ignoring other strategies.

Thus, to the best of our knowledge, our work is the first to provide a comprehensive overview of mobile-based PT interventions by highlighting the different PSs employed, their different forms of implementation, and their effectiveness.

3. Materials and methods

This review reveals the different forms of implementation of each PS of the mobile-based PT interventions for promoting PA and decreasing SB in the existing articles. This paper is guided by the following research questions:

- *RQ1*: What PSs were used in designing mobile-based PTs for PA and SB?
- *RQ2*: What are the various ways that PSs were implemented in mobile-based PTs for PA and SB?
- *RQ3*: What is the relationship between the PS's implementation type and its effectiveness?
- *RQ4*: What are the gaps, pitfalls, and limitations in the present literature on mobile-based PTs for PA and SB?

- *RQ5*: What are the directions and recommendations for future research in the area of mobile-based PTs for PA and SB?

3.1. Search methodology

Our search process was based on searching different online databases, including ACM Digital Library, Google Scholar, PubMed, Springer, IEEE Xplore, ProQuest, Elsevier Scopus, and EBSCOHost. In addition, we employed the snowball search method such that we reviewed the references of the retrieved articles.

We used different keywords to search different terminologies and their combinations such as "Mobile Health Applications/App and Physical Activity," "Smartphone and Physical Activity," "Exergames or Mobile Exergames," "Persuasive Technology and Physical Activity," "Persuasive Technology and Exercise," "Smartphone Applications/Apps and Physical Activity," "Persuasive Technology and Sedentary Behavior," "Persuasive Technology and Fitness," "Smartphone and Sedentary Behavior," "Persuasive Technology and Physical Activity and Sedentary Behavior," "Fitness Applications/Apps," "Smartphone Applications/Apps and Sedentary Behavior," "Physical Activity and Persuasive Strategies' Implementations," "Sedentary Behavior and Persuasive Strategies' Implementations," "Implementations of Strategies and Physical Activity Applications/Apps," "Implementations of Strategies and Sedentary Behavior Applications/Apps," "Implementations of Strategies and Fitness Applications/Apps," "Persuasive Technology and Persuasive Strategy," "Physical Activity and Persuasive Technology and Persuasive Strategy," "Sedentary Behavior and Persuasive Technology and Persuasive Strategy," "Employment of Strategies and Physical Activity," "Employment of Strategies and Sedentary Behavior," "Mobile Applications/Apps and Persuasive Strategies," and "Fitness Applications/Apps and Persuasive Strategies." We used Boolean terms through the search process, such as "Persuasive Technology *AND* Physical Activity," along with different terms to ensure comprehensive coverage of mobile-based PT interventions in the fields of PA and SB.

We retrieved a total of 2723 articles, of which 2272 were identified through online database searching, and 451 were identified through snowballing. After excluding the duplicate articles, we identified 2040 unique titles, of which 1107 articles were eliminated by examining their titles. We obtained 255 eligible articles after eliminating 678 articles by evaluating their abstracts. Finally, 198 articles were retained and included for this study according to our inclusion criteria. We only included articles published between 2006 and 2021, written in English, and that identify the use of mobile-based PT in their systems for promoting PA and reducing SB. We summarized the inclusion and exclusion process in Figure 1 using the PRISMA flow diagram (Liberati et al., 2009).

Two reviewers evaluated the reviewed papers against the inclusion/exclusion criteria. The two authors then worked together to systematically review and synthesize the considered 198 papers. In case of any disagreement or confusion, a third author was consulted. We used a quantitative analysis methodology that uses contrast and comparison and gives different data classifications through various aspects and concepts (Orji & Moffatt, 2018; Riffe et al., 1997). We also applied qualitative content analysis, which is essential in analyzing large numbers of qualitative data such as verbal or textual data gathered from various venues (e.g., focus groups and interviews). Furthermore, this type of analysis facilitates the quantification of categories and classifications (Demuth & Mey, 2015; Fallik & Francis, 2017; Pohontsch, 2019). We can also collect qualitative data from surveys based on the types of questions provided to participants. We gathered the qualitative data in this review study by investigating the different ways of implementing each PS and their examples. We performed the qualitative analysis by reading, comprehending, and addressing each example of PS implementation. Based on that, we provide different categorizations and types of implementations for each PS employed in the reviewed articles.

3.2. Analysis and coding scheme

We categorized the articles included in this review paper based on different criteria by adapting and extending the coding scheme developed by Orji and Moffatt (2018) and validated by Almutari and Orji (2019), Alqahtani et al. (2019), and Aldenaini et al. (2020). We used some classifications of the coding scheme, which are summarized in Table 2.

Supplemental Appendix I summarizes the coding sheet of the reviewed articles. We also created different coding sheets to extract and determine the different ways of implementing each PS. Thus, we extract, sort, classify and name the implementations of each PS based on the way they were implemented in the review articles. Moreover, we used the PSD model (Harri & Marja, 2009) to analyze the PSs from the review articles.

4. Results and findings

The analysis of mobile-based PT interventions for promoting PA and decreasing SB shows significant and valuable findings. We delivered and presented our findings across various aspects, including the year and country of the study, and investigated the PSs employed and their different forms of implementation.

4.1. Persuasive technologies (PTs) for PA and SB trends by year and country

Figure 2 shows an increase in the number of studies on mobile-based PTs starting from 2012. However, the figure shows some fluctuations in the number of papers published after 2012 and before 2011, while the number peaked in 2020 with 61 studies. It is essential to mention that the year 2021 seems to have a lower number of published articles compared to 2020. This is because we conducted our review

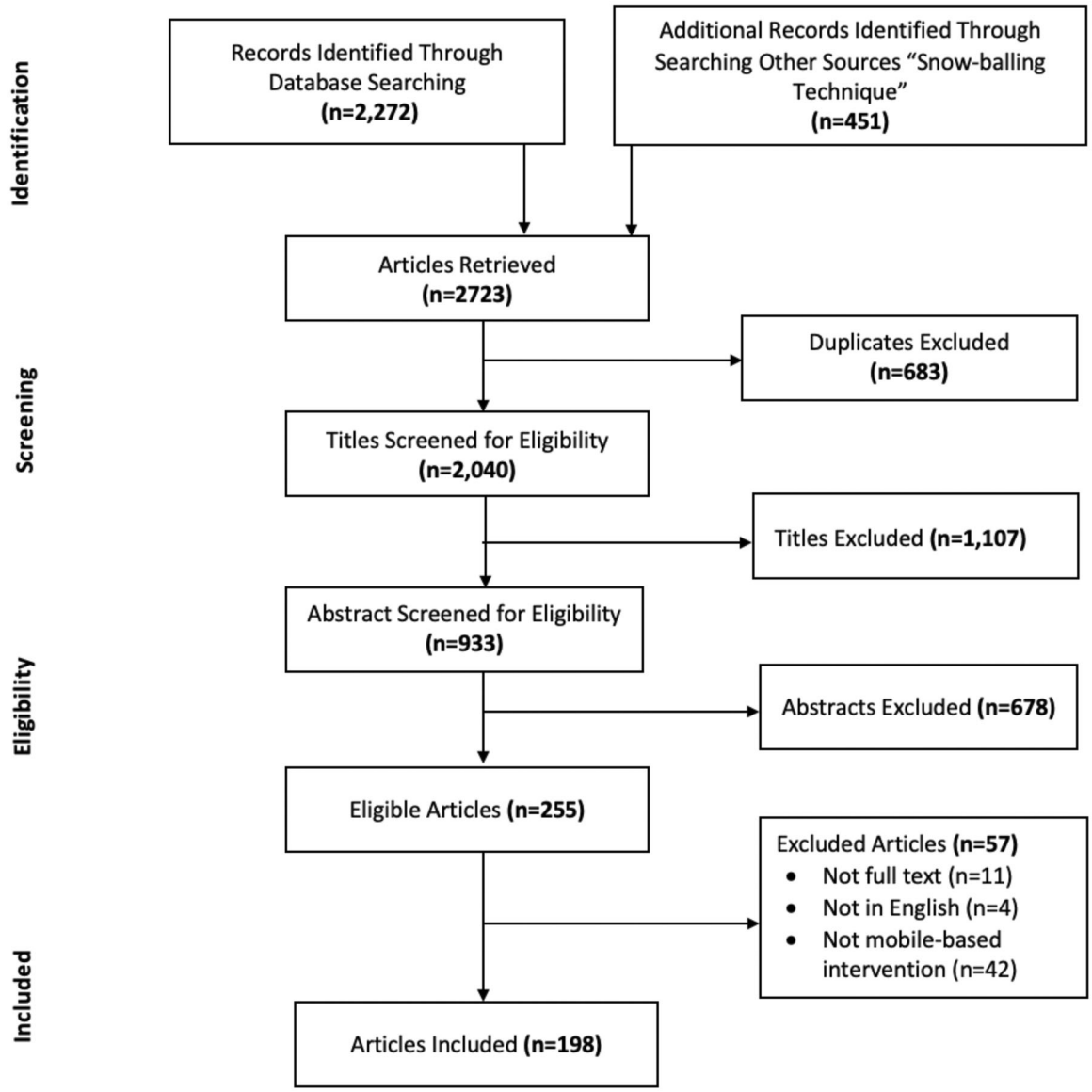

Figure 1. The study selection workflow as a PRISMA flow diagram.

Table 2. Coding scheme classifications.

#	Coding scheme classifications
1	The study author(s)
2	Title of article
3	Year of publication
4	Targeted health domain
5	The technology employed (e.g., social networking sites, games, web, activity trackers, desktop, etc.)
6	Persuasive strategies (PSs) employed
7	Findings
8	Country of the study

study in the third quarter of 2021, when some of the papers were still pending to be published.

Figure 3 shows that the studies were developed in 32 different countries. Most of the studies were conducted in the USA with a total of 63 studies, followed by the UK, Netherlands, Germany, Canada, and Australia with a total of twenty, fourteen, twelve, nine, and eight studies, respectively. Portugal, South Korea, and Sweden are in the seventh place, with six studies for each. Italy, Switzerland, Ireland and Brazil are in the eighth place, with five studies for each.

4.2. PSs and the frequency of use

The most frequently and commonly employed PSs in the reviewed articles are displayed in Figure 4. Our findings show that the tracking/self-monitoring strategy was employed in 192 articles reviewed (97%). The second most employed PS was the goal-setting strategy with 90 studies (45%). This is followed by the reminder strategy, reward strategy, and personalization strategy, with a total of 87 studies (44%), 82 studies (41%), and 77 studies (39%),

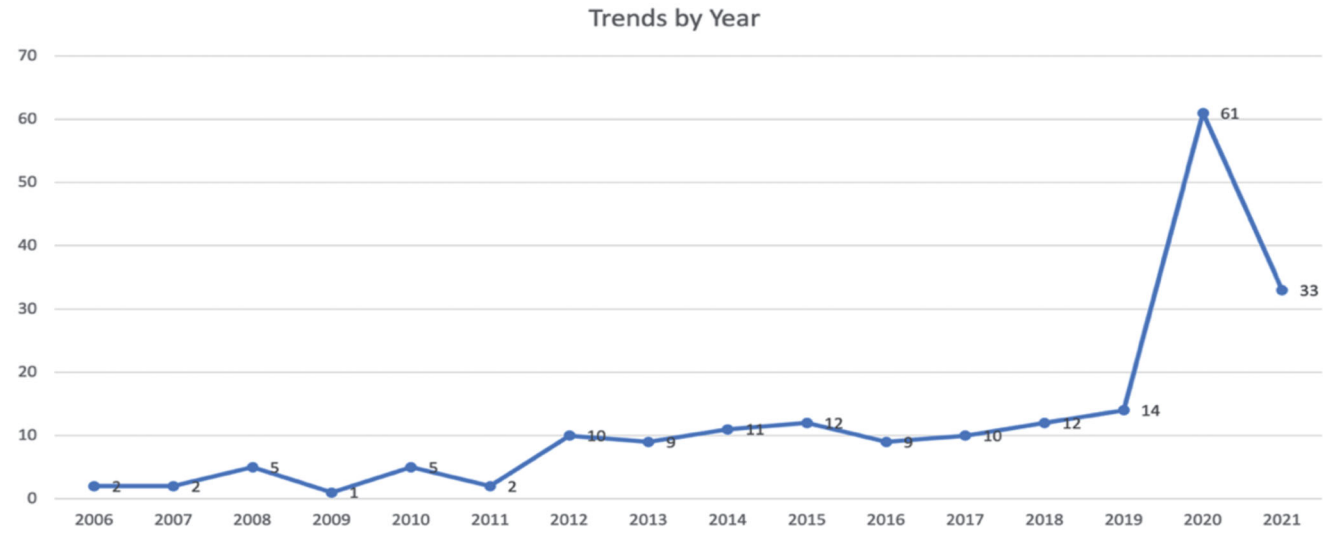

Figure 2. Studies distribution based on year.

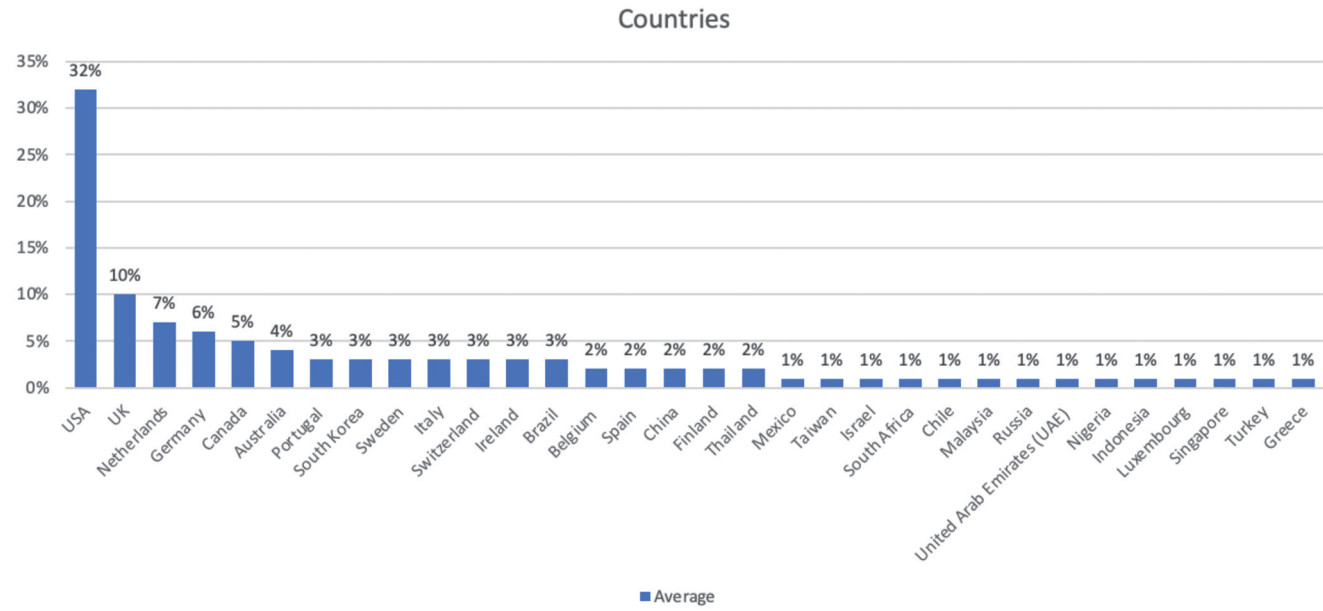

Figure 3. Studies distribution based on country.

respectively. A praise strategy ranked sixth with 61 studies (31%), followed by a tailoring strategy, reduction strategy, and tunnelling strategy, with a total of 47 studies (24%), 46 studies (23%), and 43 studies (22%), respectively. A social competition strategy is in the tenth position with 37 studies (19%), followed by a suggestion strategy with 35 studies (18%). Figure 4 also shows that the least employed PSs are the real-world feel strategy with 4 studies (2%), similarity strategy and social facilitation strategy with 2 studies (1%) for each, and rehearsal strategy with one study (1%).

4.3. Frequency analysis based on the PSD model and other classifications

The following sub-sections show the most and least employed PSs according to the four main categories of the persuasive system principles in the PSD model (discussed in Section 2).

4.3.1. Primary task support strategies

Our findings identify the most frequently and least employed PSs in the primary task support category from the 198 reviewed articles. The tracking/self-monitoring strategy was the most employed PS in the primary task support category with a total of 192 studies (97%). The personalization strategy ranked second with a total of 76 studies (38%), followed by the tailoring strategy with 47 studies (24%), and the reduction strategy with 46 studies (23%). The tunneling strategy came next with 41 studies (21%), followed by the simulation strategy with 24 studies (12%). The least employed primary task support strategy was the rehearsal strategy with only one study (1%).

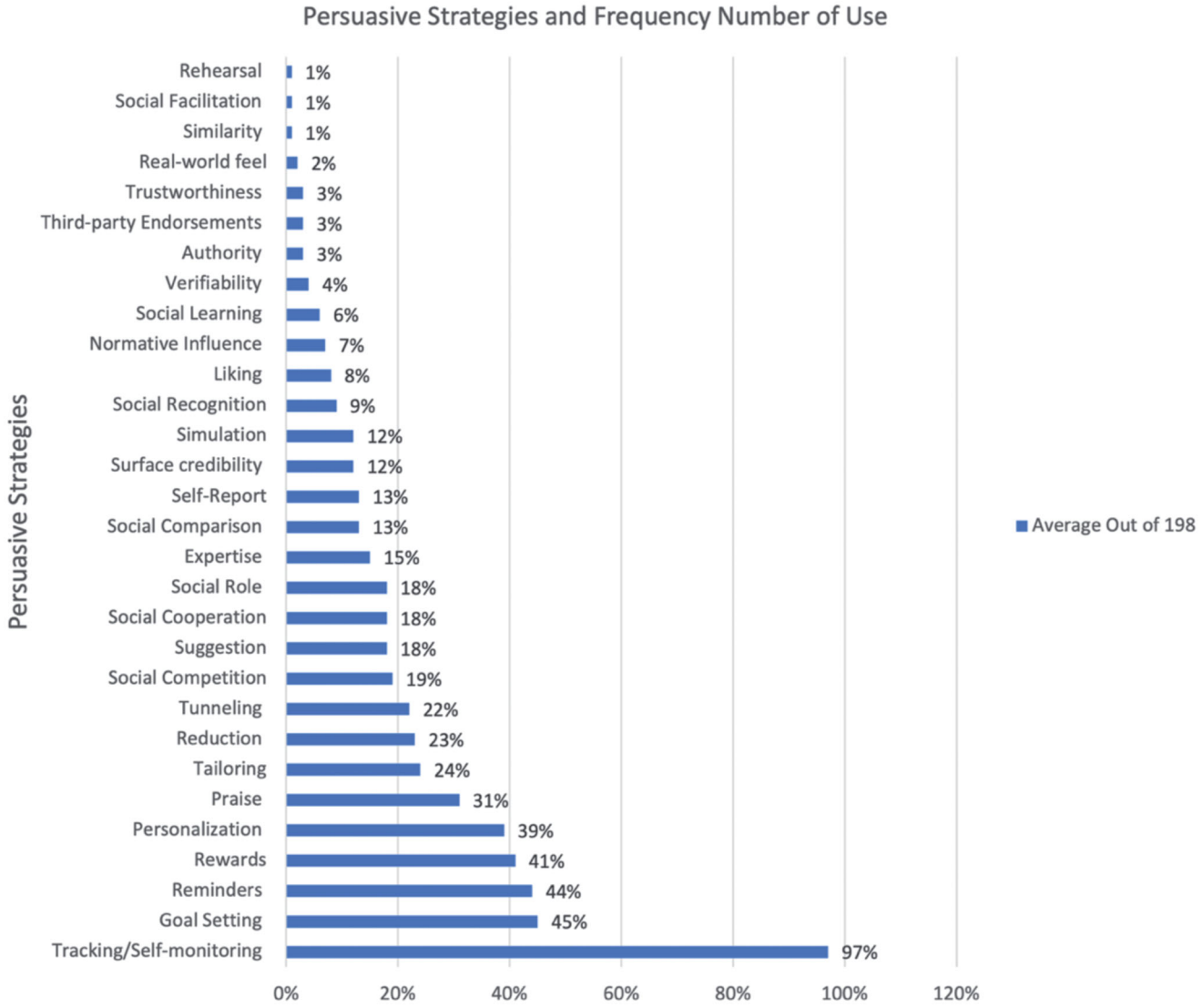

Figure 4. Persuasive strategies and the average of use.

4.3.2. Dialogue support strategies

We present the most and least frequently employed PSs in the dialogue support category. The reminder strategy was the most employed PS in the dialogue support category with 87 studies (44%), followed by the reward strategy with 82 studies (41%). The praise strategy ranked third with 61 studies (31%). The suggestion strategy and social role strategy came in fourth place with 35 studies (18%) for each, followed by the liking strategy with 15 studies (8%). The least employed dialogue support strategy was the similarity strategy with only two studies (1%).

4.3.3. System credibility support strategies

Our findings depict the frequency of the employed PSs in the system credibility support category from the 198 reviewed articles on promoting PA and reducing SB. The expertise strategy was the most employed PS in the system credibility support category with 30 studies (15%). The surface credibility strategy ranked second with a total of 24 studies (12%), followed by the verifiability strategy with seven studies (4%). The authority strategy, third-party endorsement strategy, and trustworthiness strategy ranked fourth with five studies (3%) for each. The least employed system credibility strategy was the real-world feel strategy, which ranked fifth with just four studies (2%).

4.3.4. Social support strategies

We show the frequency of the social support PSs from the 198 reviewed articles considered in this study. The social competition strategy is the most employed PS in the social support category with 37 studies (19%), followed by the social cooperation strategy with 35 studies (18%). The social comparison strategy ranked third with 25 studies (13%). The social recognition strategy ranked fourth with seventeen studies (9%), followed by the normative influence strategy, which ranked fifth with thirteen studies (7%). The social learning strategy ranked sixth with twelve studies (6%). The least employed social support strategy was the social facilitation strategy, with only two studies (1%).

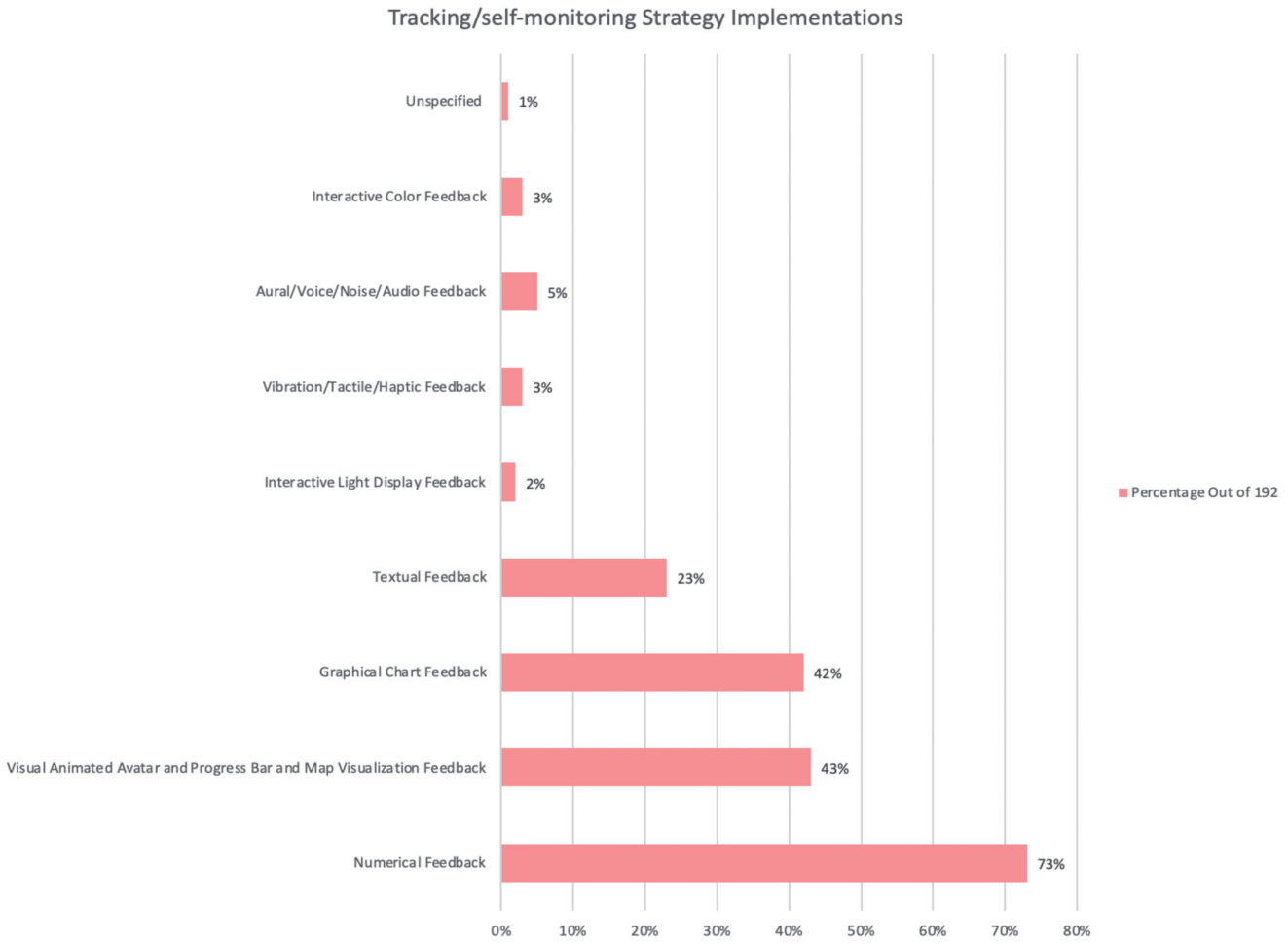

Figure 5. Self-monitoring implementations in the reviewed articles.

4.3.5. Other strategies not belonging to the PSD model

In addition to the PSs categorized under the PSD model, some articles used other strategies that are not considered under the PSD model. These strategies are the goal-setting strategy and the self-report strategy. Our findings show that the goal-setting strategy is more common than the self-report strategy as it was considered by 91 studies (46%), while the self-report strategy was considered by 25 articles (13%). These numbers indicate that the goal-setting strategy is the second most common strategy.

4.4. PSs and their implementations

In the following sub-sections, we provide a detailed description of each PS and how they are implemented in the reviewed articles. We also provide some examples of each classification/category of each implementation, along with the frequency of each form of implementing each PS and the effectiveness of each PS based on their implementation.

4.4.1. Self-monitoring strategy

Figure 4 shows the employment of a self-monitoring strategy in the mobile-based PT interventions in the reviewed articles. The self-monitoring strategy was applied in 192 articles (97%). We think this is due to the importance of tracking a user's PA performance, monitoring the time spent sedentary and the PA levels and progress towards their target behavior goal. Thus, we found that the dominant factors in inspiring users in maintaining or increasing their PA levels were providing them with precise feedback, measurements (e.g., step counts, duration of walking, progress towards goals, calories burned, etc.), and notifications of their activities and sedentariness through the use of activity tracker devices and software (Aldenaini et al., 2020). Figure 5 shows the various ways the self-monitoring strategy was implemented in the PA and SB areas, along with the most and least frequent forms of implementation.

Figure 6 shows more details and examples of the different ways of implementing the self-monitoring strategy. It shows the frequency of each type of implementation of the self-monitoring strategy in the reviewed articles. Table 3 shows some examples of each implementation of the self-monitoring strategy in the reviewed articles. It is worth mentioning that most of the articles included employing more than one type of self-monitoring strategy implementation (e.g., numerical feedback and visual feedback). Thus, we present each implementation example separately regardless of any other type of self-monitoring implementation.

Our findings present the effectiveness of the self-monitoring strategy for various implementations. Numerical feedback was employed in 140 studies, out of which 78

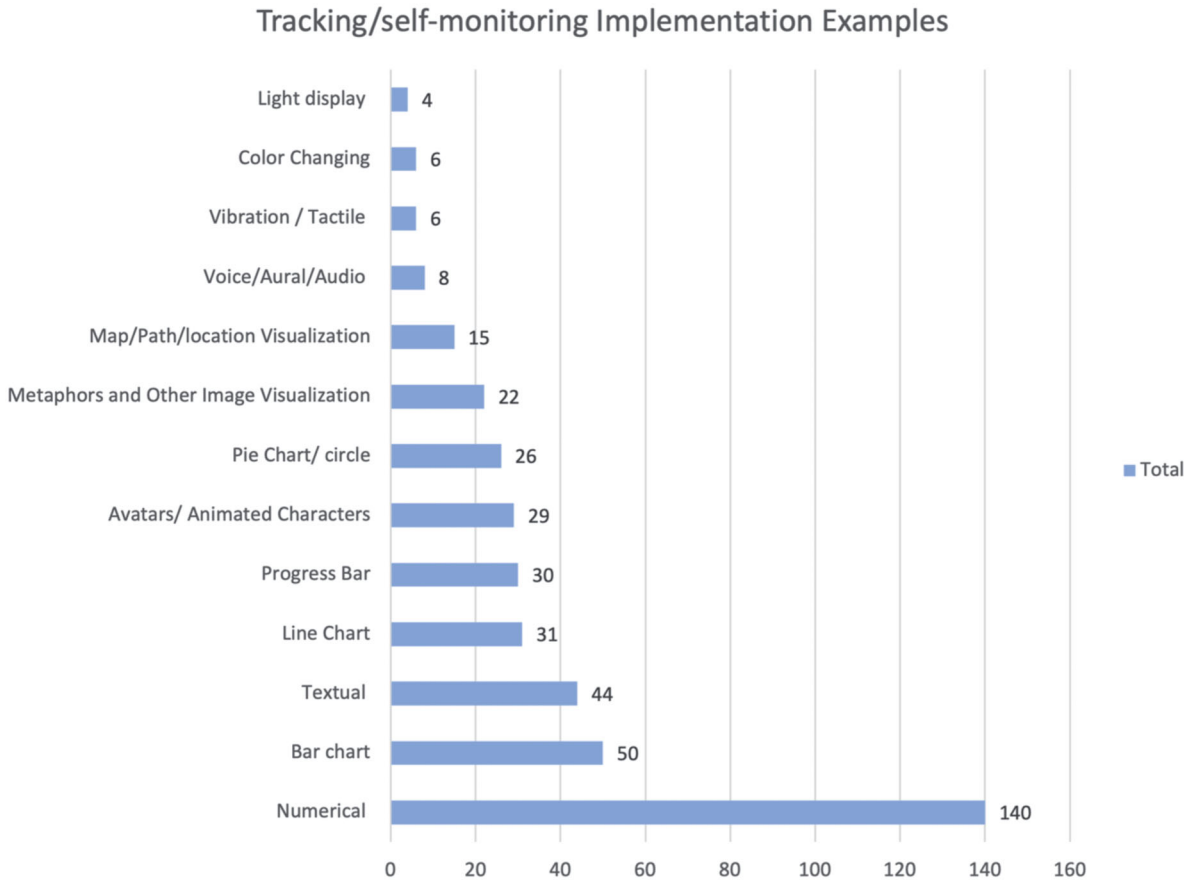

Figure 6. Self-monitoring strategy implementation examples in the reviewed articles.

studies (56%) reported fully successful outcomes, 36 studies (26%) were partially successful, 17 studies (12%) did not provide any evaluation of their mobile-based PT designs, seven studies (5%) did not specify their outcomes, and only two studies (1%) were unsuccessful.

Visual feedback (e.g., animated avatar, progress bar, or map visualization) was employed in 82 studies, out of which 42 studies (51%) were fully successful, 23 studies (28%) were partially successful, 13 studies (16%) did not evaluate their system's designs, two studies (2.5%) were unsuccessful, and two studies (2.5%) did not specify their outcomes. Out of the six studies that employed vibration, tactile, or haptic feedback, two studies (33%) were fully successful, three studies (50%) were partially successful, and one study (17%) had no evaluation.

4.4.2. Goal-setting strategy

A goal-setting strategy does not belong to the PSD model's principles or strategies. However, we included the goal-setting strategy in this review due to the importance of this PS in persuading users to change their unhealthy behaviors, such as prolonged time spent sitting and encouraging them to engage more in PA. Another reason for including a goal-setting strategy is the number of articles that did employ this strategy, 90 studies (45%), which is close to half of the 198 reviewed articles. Figure 4 shows the employment of a goal-setting strategy in the mobile-based PT interventions in the reviewed articles on PA and SB.

Based on our findings in reviewing the mobile-based PT interventions in PA and SB, there are two types of goal-setting strategies: (1) User-driven goals, which allow the users to have control in setting their own PA goals and customize them as they prefer, and (2) default or system-based goals, which mean the system is responsible for setting suitable and automatic PA goals for the users. Some of the reviewed articles included both types of goal-setting strategies, and other articles employed only one type.

Figure 7 shows the number of articles that employed each type of goal-setting strategy. Out of the 90 articles that employed a goal-setting strategy, customized or user-driven goal setting was employed in 55 studies (61%), default or system-based goal setting was employed in 25 studies (28%), and only 11 studies (12%) employed both types of goal-setting strategies. Table 4 shows some examples of each implementation of a goal-setting strategy in the reviewed articles.

Our findings show the effectiveness of a goal-setting strategy-based implementation for mobile-based PT interventions for promoting PA and reducing SB. A customized or user-driven goal implementation of a goal-setting strategy was employed in 55 studies, out of which 27 studies (49%) reported fully successful outcomes, 15 studies (27%) were partially successful, 12 studies (22%) did not provide any evaluation of their mobile-based PT designs, and one study (2%) did not specify their outcomes. Out of the 25 studies that employed a default or

Table 3. Examples of self-monitoring strategy implementations in the reviewed articles.

#	Self-monitoring implementation	Examples	
1	Numerical Feedback	Step counts, floor counts, stair counts, calories burned, walking duration, sitting duration, running duration, point counts, time, heart rate, speed, distance, percentage, daily or weekly goals, date, number of training sessions, frequency of breathing and stride, frequency of stand-up transition, weight, pace, number of activities, number of breaks, average, etc.	• The On11 application by He and Agu (2014) provides numerical feedback to users by displaying a percentage of the user's sitting time, total calories burnt, walking duration, and running duration. The system also tracks each activity's intensity. • The PersonA application by Ayubi and Parmanto (2012) provides real-time numerical feedback to the user, such as step counts, speed per m/h, calories per kcal, distance per mile, and duration per minute. • In the Breaksense application by Cambo et al. (2017), the users are provided with a summary dashboard when they return to their office after taking a break. The dashboard displays the user's breaks during the day as step counts, heart rate, duration, time, and the number of stars the user has collected. • In the HealthyTogether application by Chen and Pu (2014), the users can view their performance history of the last week (last seven days) as floor counts, floor points, step counts, and step points.
2	Textual Feedback	Text Messages	• The Alert Me application by Fahim et al. (2017) sends text messages to the users regarding their PA performance and sedentary behavior. • The *Twitter Me* system by Young (2010) provides automated text messages that are sent in real-time to the users' group and show the overall performance of the group, indicating each group member's calories burnt and PA level achieved.
		Textual Notifications	• The mobile application by Munson and Consolvo (2012) displays a textual summary of the user's PA progress and the target goal accomplishments. • The SitCoach application by Dantzig et al. (2013) sends timely persuasive messages to users and recommends active breaks while monitoring the user's PA and SB. • The Super Starfish Mania application by Schagen et al. (2015) sends textual notifications to the user according to their tracked activity measurements. These notifications encourage the user to take short but active breaks periodically during the day. • Neat-o-Games (Fujiki et al., 2008) displays real-time feedback as pop-up textual notifications to motivate users to exercise more.
3	Visual Feedback	Avatars/Animated Characters	• The Virtual Social Gym system by Far et al. (2014) employs an animated avatar to represent the elderly user on the virtual gym screen. • The stApp system by Arrogi et al. (2019) employs a standing/sitting human avatar to reflect and represent the user's standing or sedentary activity.
		Progress Bars	• The Teenpower system by Carvalho et al. (2018) employs progress bars to display the user's activity progress. • The mobile web application by Ly et al. (2014) provides real-time visualization as progress bars on a large screen to represent each group's aggregated movement and performance.
		Metaphors and Other Images Visualization	• The Virtual Social Gym system by Far et al. (2014) employs an animated avatar to represent the elderly user on the screen as well as a virtual metaphor of a gym environment. The system shows the user's activity progress using metaphors, including, for instance, growing flowers. • The PersonA system (Ayubi & Parmanto, 2012) employs two visual metaphors: garden and aquarium metaphors to deliver feedback to the users based on their performance.
		Maps, Paths, Locations Visualization	• The LocoSnake game by Chittaro and Sioni (2012) provides a real-time map rotation on the game screen that represents the player's performance using the Global Positioning System (GPS) localization on the visualized satellite map. • The *GeoFit* fitness application by Terry et al. (2015) employs a map visualization to help the user find directions based on a running human avatar that represents the user's movements on a map.
4	Graphical Chart Feedback	Bar Chart	• The Accupedo application by Glynn et al. (2013) provides a graphical display of the user's step count history as bar charts.
		Line Chart	• The WragaFit application by Mohadis and Ali (2016) and PersonA application (Ayubi & Parmanto, 2012)

(*continued*)

Table 3. Continued.

#	Self-monitoring implementation	Examples	
		Pie /Circle Chart	employ graphical chart feedback as a line chart to show a summary of the user's step count progress. • The Bounce system by Marcu et al. (2018) employs graphical feedback as pie charts (circles) representing the user's activity performance. • The Social Coaching application by Simoski et al. (2019) employs pie charts that display meters showing the user's walking and running activities as distance, duration, and percentage.
5	Interactive Light Display Feedback	• The Alert Me application by Fahim et al. (2017) provides interactive light display feedback as a green, yellow, or red LED light with alert messages. The green light indicates the need to take a short active break from sedentary status, while the yellow light shows that the user did not take an active short break after receiving the last alert. The red light indicates the robust importance for the user to take a short active break.	
6	Vibration, Tactile, or Haptic Feedback	• The Neat application (Pellegrini et al., 2015) sends a noise or vibration prompt to encourage the user to stand up after 20 minutes of continuous sedentary time. • The *Backtive* system (Van Almkerk et al., 2015) provides real-time tactile feedback to the user through chairs to notify them to adjust their posture immediately when they have bad posture.	
7	Aural, Voice, Noise, or Audio Feedback	• The Tandern Track system by Luo et al. (2020) provides voice/aural feedback according to the user's PA performance. The system provides interactive voice feedback using the Amazon Echo smart speaker "Alexa." • According to the user's rank of the activity levels, the UP Health or Instant Messaging IM system by Sohn and Lee (2007) provides audio feedback through messages with different sounds depending on whether their rank has descended or ascended.	
8	Interactive Color Feedback	• The Habito application by Gouveia et al. (2015) provides interactive color feedback by labeling the locations with different colors (red, orange, green) based on the user's PA levels. The green color indicates that the user is physically active, while the red color indicates the sedentary status of the user.	

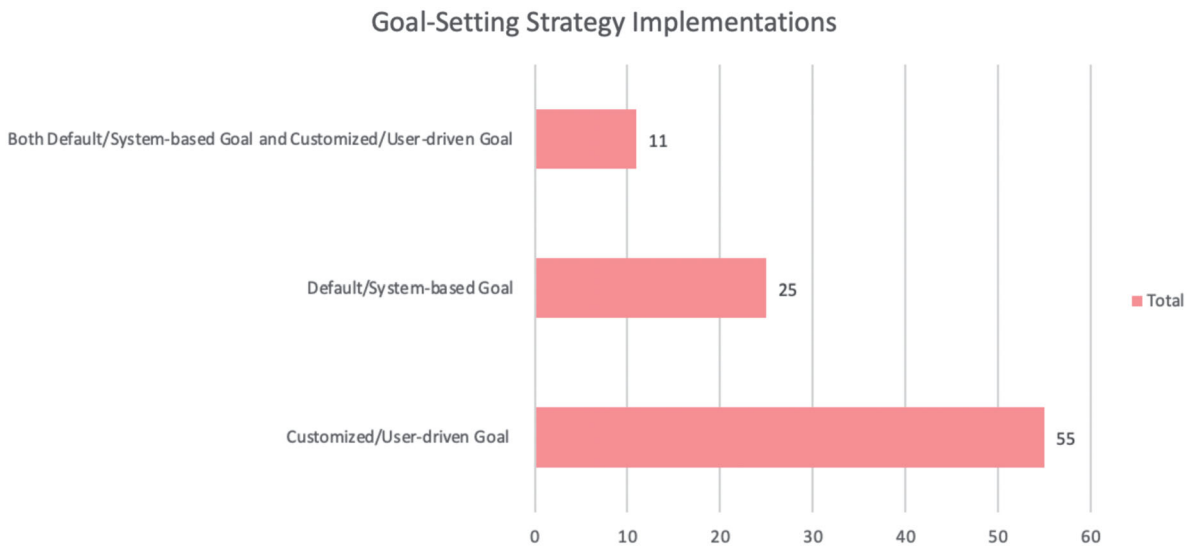

Figure 7. Goal-setting strategy implementations in the reviewed articles.

Table 4. Examples of goal-setting strategy implementations in the reviewed articles.

#	Goal-setting implementation	Examples
1	Customized or user-driven	• The On11 application by *He and Agu (2014)* provides a customization feature for setting PA goals by the users. Thus, the user can select their desirable goal from a list of pre-defined PA goals.
2	Default or system-based	• The StepByStep application by *Zuckerman and Gal-Oz (2014)* provides default and automatic system-based goals to motivate users and prevent them from setting PA goals that are too difficult to achieve or too simple and thus not motivational enough. An automated message recommending the user to increase their PA goal by 10% is generated by the system when the daily goal is achieved three days in a row.
3	Both (user-driven and system-based)	• The Habito application by *Gouveia* et al. *(2015)* provides a system-based default walking goal to users of 1 km per day. Furthermore, the application also provides a customization feature that enables the users to set their own walking goals.

system-based goal implementation of a goal-setting strategy, 16 studies (64%) were fully successful, five studies (20%) reported partially successful outcomes, one study (4%) did not specify their outcomes, one study (4%) was unsuccessful, and two studies (8%) had no evaluation. For the studies that employed both ways of implementing a

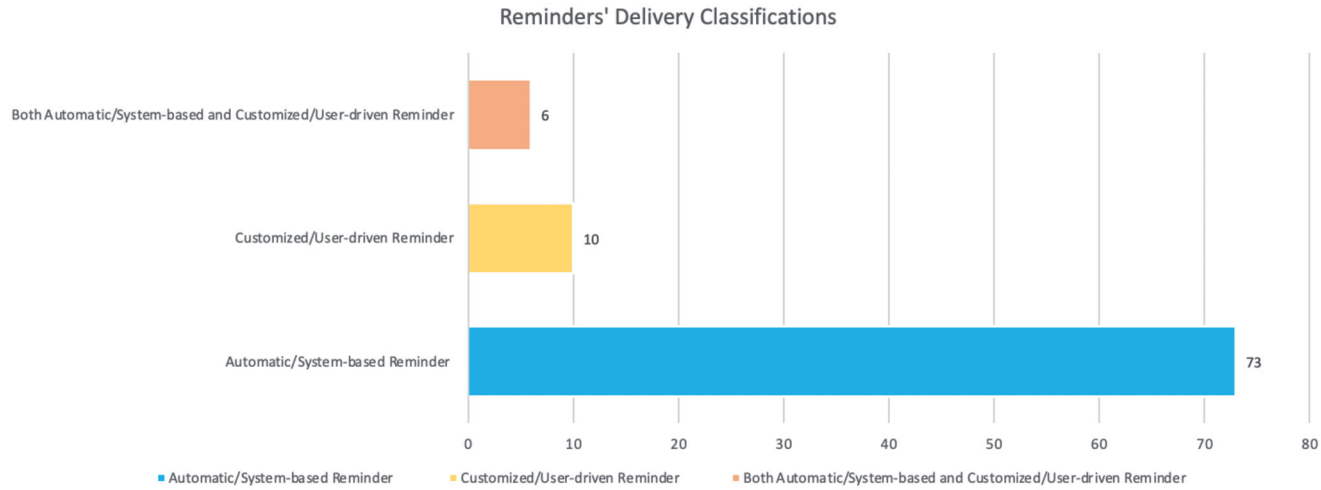

Figure 8. Reminder strategy delivery classifications.

Table 5. Examples of the different ways of delivering reminders to the users in the reviewed articles.

#	Way of delivering reminders	Examples
1	Automatic or System-based Reminders (Push Reminders)	• The On11 application by He and Agu (2014) sends automatic reminder notifications to the users when they have remained sedentary for more than 90% of the last half hour (30 minutes).
2	Customized or User-driven Reminders (Pop-up Reminders)	• The users of the Active 10 application by Ciravegna et al. (2019) can set and schedule reminders on the system according to their preferable and suitable times.
3	Both (system-based and user-driven)	• The Puzzle Walk mobile game application by Lee et al. (2018) employed both forms of reminders: system-based and user-driven reminders. Thus, the system sends automatic daily goal reminder notifications to the user based on their activity performance, and the user can also customize the times of receiving reminders.

goal-setting strategy (system-based and user-driven goals), out of the 11 studies that employed them, four studies (36%) showed fully successful outcomes, five studies (45%) were partially successful, one study (9%) was unsuccessful, and one study (9%) did not specify their outcomes.

4.4.3. Reminder strategy

Based on our findings, a reminder strategy is considered one of the main and essential PSs employed in mobile-based PT interventions to encourage PA and decrease SB. Figure 4 shows that a reminder strategy was employed in 87 studies (44%) of the total 198 reviewed articles.

From the reviewed studies, we found that a reminder strategy was delivered to the users of mobile-based persuasive systems in two main ways. Thus, we classified the delivery of a reminder strategy as automatic or system-based reminders and customized or user-driven reminders. Automatic or system-based reminders (Push Reminders) are usually issued from a system to the users based on tracking their PA performance and SB status. Thus, the system-based reminders are delivered to the users randomly and are not scheduled. On the other hand, customized or user-driven reminders (Pop-up Reminders) are set by the users of a persuasive system according to their suitable times and availability. Figure 8 shows that out of the 87 studies that employed a reminder strategy, 73 studies (85%) employed automatic or system-based reminders, ten studies (10%) employed customized or user-driven reminders, and just six studies employed both types of reminders (system-based and user-driven). Table 5 provides examples of the different ways of delivering reminders to the users in the reviewed articles.

Our findings show the effectiveness of a reminder strategy based on the two main ways of delivering reminders to users in mobile-based PT interventions for promoting PA and reducing SB. Out of the 73 studies that employed automatic or system-based reminders, 41 studies (56%) were fully successful, 20 studies (27%) reported partially successful outcomes, three studies (4%) did not specify their outcomes, one study (1%) was unsuccessful, and eight studies (11%) had no evaluation. Customized or user-driven reminders were employed in ten studies, out of which seven studies (70%) reported fully successful outcomes, and three studies (30%) were partially successful. For the studies that employed both forms of reminders (system-based and user-driven), out of the six studies that employed them, one study (17%) was fully successful, three studies (50%) showed partially successful outcomes, and two studies (33%) did not provide any assessment for their persuasive designs.

The reminder strategy in the mobile-based PT interventions was implemented in many ways. Figure 9 shows the various ways the reminder strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation. Table 6 provides examples of each implementation of a reminder strategy in the reviewed articles.

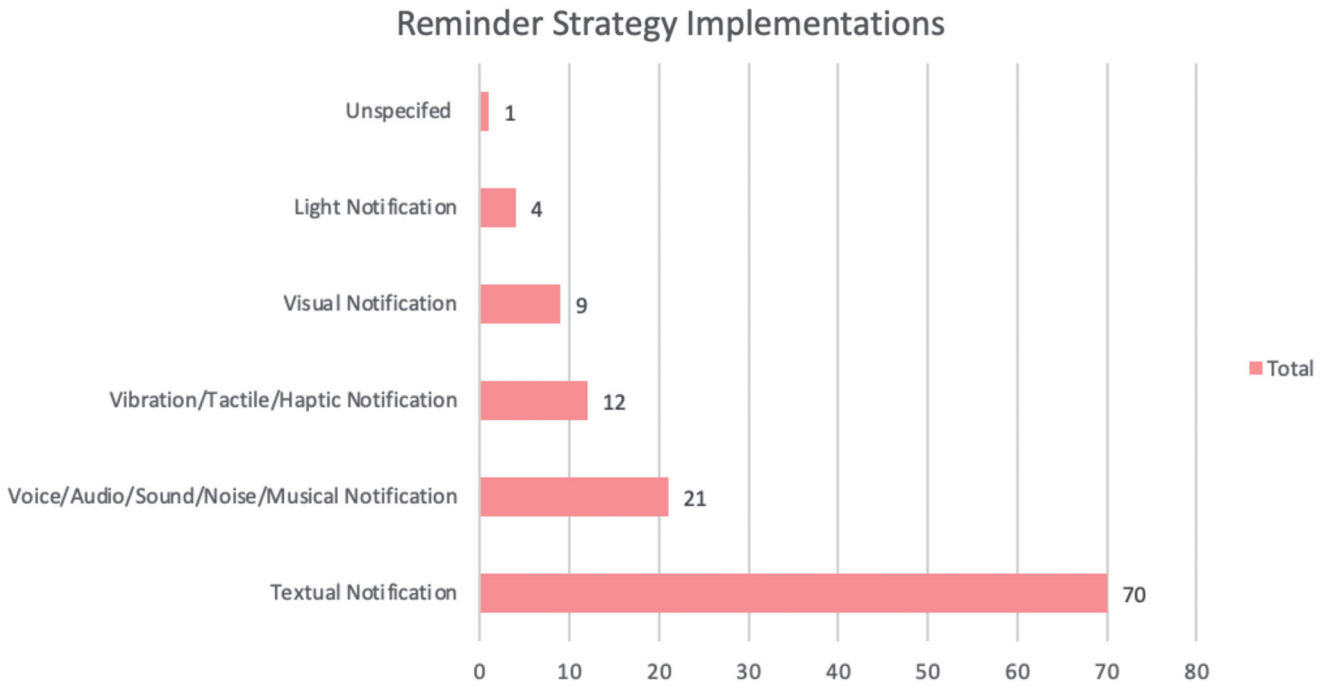

Figure 9. Reminder strategy implementations in the reviewed articles.

Table 6. Examples of reminder strategy implementations in the reviewed articles.

#	Reminder strategy implementation	Examples
1	Textual Reminder Notifications	• The TRavelVU application by Ek et al. (2018) introduced a smart city active mobile phone intervention (SCAMPI) that sends push notification messages to the users as textual reminder notifications.
2	Voice Reminder Notifications	• The NEAT! application (Pellegrini et al., 2015) sends noise prompts to the user every 20 min of consecutive sedentary time detected.
3	Vibration Reminder Notifications	• The NEAT! application (Pellegrini et al., 2015) initiates vibration prompts to the users every 20 min of consecutive sedentary status detected.
4	Visual Reminder Notifications	• The GoalPost and GoalLine applications by Munson and Consolvo (2012) provide a persistent visual reminder as a notification badge icon to display the number of days since performing PA by the user. • The UbiFit Garden application by Consolvo and Klasnja (2008) provides a persistent visual reminder by displaying a virtual green garden with virtual flowers and butterflies. Each flower represents the completion of a particular type of PA such as walking, cardio, flexibility exercises, primary goals met, strength exercises, and secondary goals met.
5	Light Reminder Notifications	• The On11 application (He & Agu, 2014) flashes an LED notification on the phone to remind the user to take a walk. • The ActiConverge and ActiSit systems by Beck et al. (2019) unobtrusively provide ambient light reminders to remind users to engage more in PA. The light colors range from white light to yellow light or red light.

Based on our findings, we present the effectiveness of reminder strategy-based implementations for mobile-based PT interventions for promoting PA and reducing SB. A textual reminder notification was employed in 70 studies, out of which 38 studies (54%) reported fully successful outcomes, 20 studies (29%) were partially successful, one study (1%) was unsuccessful, two studies (3%) did not specify their outcomes, and nine studies (13%) did not provide any evaluation of their mobile-based PT designs. A visual reminder notification was employed in nine studies, out of which four studies (44%) reported fully successful outcomes, three studies (34%) reported partially successful outcomes, one study (11%) did not specify their outcomes, and one study (11%) did not provide any evaluation of their system.

4.4.4. Reward strategy

Based on our findings, a reward strategy ranked as the fourth most frequently employed PS in the mobile-based PT interventions for encouraging PA and decreasing SB in the reviewed articles. As mentioned in Section 4.2, a reward strategy was employed in 82 studies (41%) out of the 198 reviewed articles.

The reward strategy in the mobile-based PT interventions was implemented in many ways. Figure 10 shows the various ways the reward strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation. Table 7 provides examples of each implementation of a reward strategy in the reviewed articles.

Figure 11 shows the general classifications of reward strategy-based implementations in the mobile-based PT

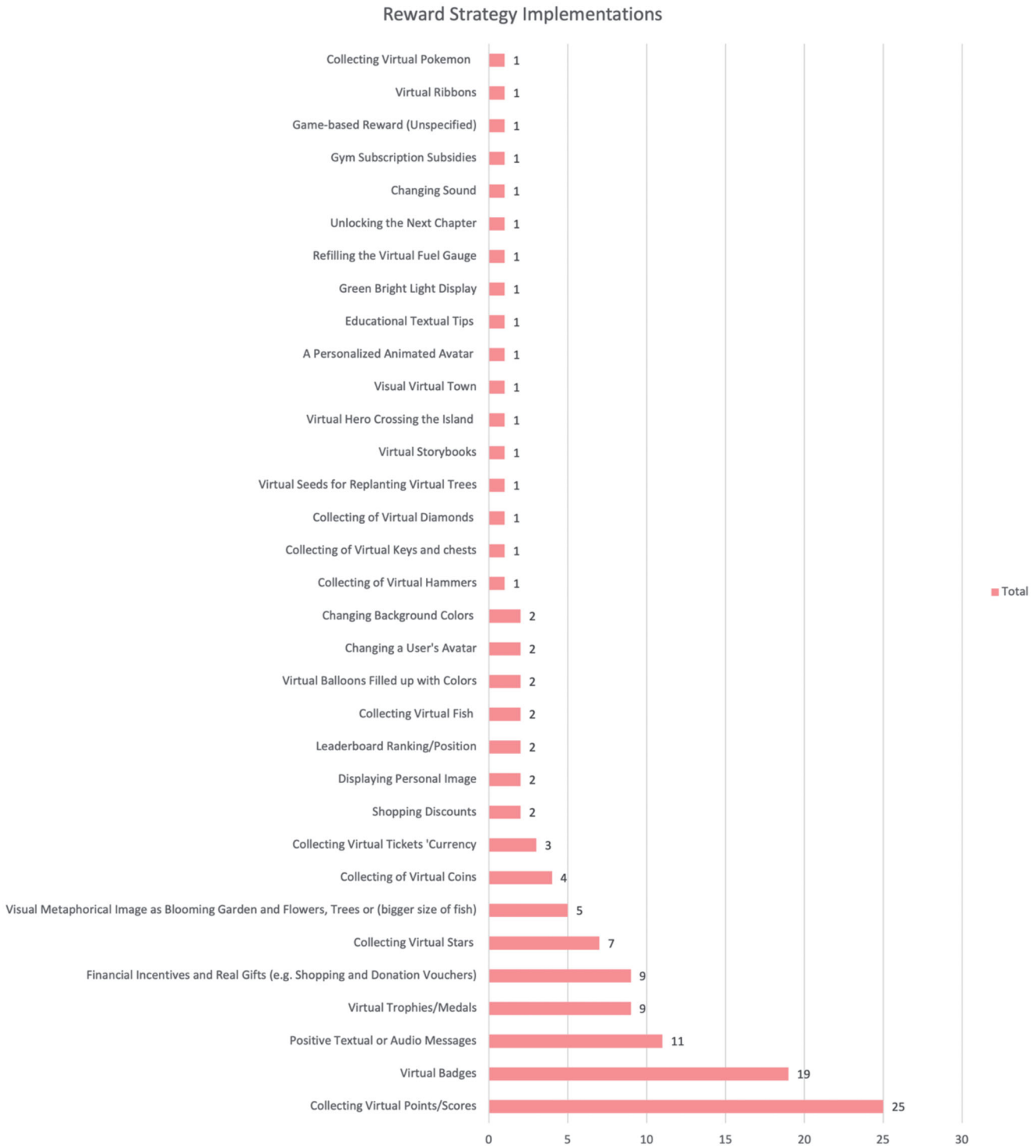

Figure 10. Reward strategy implementations in the reviewed articles.

interventions in the reviewed articles for promoting PA and reducing SB. The most frequent form of reward strategy was the collecting of virtual objects or items not usable in the real world with 56 studies (68%) out of the 82 studies that employed a reward strategy. Providing positive textual or audio messages ranked as the second most frequent way to reward users with 11 studies (13%). The collecting of virtual items usable in the real world (e.g., financial incentives and real gifts) also ranked as the second most frequent form of implementing a reward strategy with 11 studies (13%), followed by the displaying of vital metaphorical images with seven studies (9%), and changing a user's avatar, sound, and background colors with three studies (4%). Each reward of shopping discounts, leaderboard rankings or position, unlocking the next chapter, virtual storybooks, displaying balloons and heroes, and displaying personal images ranked as the fifth most frequent forms of implementing a reward strategy with two studies (2%) for each.

Table 7. Examples of reward strategy implementations in the reviewed articles.

#	Reward strategy implementation	Examples	
1	Collecting Virtual Items or Objects Not Usable in the Real World	Collecting Virtual Points or Scores	• Out of the 82 studies that employed a reward strategy, 25 studies (30%) implemented virtual points or scores to reward users for their PA progress. Thus, collecting virtual points or scores was the most frequent form of reward strategy implemented in the reviewed studies; this was used, for example, in the StepByStep application (Zuckerman & Gal-Oz, 2014), HealthyTogether application (Chen & Pu, 2014), iFitQuest application (Macvean & Robertson, 2013), and CoviHealth application (Villasana et al., 2019).
		Virtual Badges	• Providing virtual badges to reward users for their PA performance ranked as the second most common form of reward strategy implemented with 19 studies (23%) such as the BunnyBolt application (Keung et al., 2013), Bounce application (Marcu et al., 2018), and MobileMen application (Newton et al., 2019).
		Virtual Trophies or Medals	• Displaying virtual trophies or medals came in fourth place in the most common ways of implementing a reward strategy with nine studies (11%) such as in the GeoFit (Terry et al., 2015), GoalPost and GoalLine applications (Munson & Consolvo, 2012).
		Collecting Virtual Stars	• The collecting of virtual stars ranked as the fifth most employed form of a reward strategy with seven studies (9%); this was used, for example, by the Twitter-like micro-blogging site (Young, 2010), BEN'FIT application (Oyibo et al., 2019), and a mobile application by (Stephenson et al., 2020).
		Collecting of Virtual Coins	• Out of the 82 studies that employed a reward strategy, four studies (5%) employed the collecting of virtual coins as a reward for users; as shown in the CAMMInA application by Rodríguez et al. (2013).
		Collecting Virtual Tickets as Currency	• Three studies (4%) employed the collecting of virtual tickets as currency as a reward for users, including the smartphone exergame app by Francillette et al. (2018).
		Collecting Virtual Fish	• Two studies (2%) employed the collecting of virtual fish as a reward for users, including the Super Starfish Mania application by Schagen et al. (2015).
		Collecting of Virtual Diamonds	• One study (2%) implemented the collecting of virtual diamonds as a reward for users; this was the CAMMInA application by Rodríguez et al. (2013).
		Virtual Seeds for Replanting Virtual Trees	• Employing virtual seeds for replanting virtual trees was done in only one study (1%) to reward users; this was the Woody application by Spiesberger et al. (2015).
		Virtual Ribbons	• One study (1%) employed the displaying of virtual ribbons as a reward for users; this was the GoalPost and GoalLine applications by Munson and Consolvo (2012).
		Collecting Virtual Pokémon	• One study (1%) used the collecting of virtual Pokémon as a reward for users; this was the Pokémon GO application (Howe et al., 2016), (Pokémon Company, 2016).
		Collecting of Virtual Hammers	• Only one study (1%) employed the collecting of virtual hammers as a reward for users; this was the WordFit app application by Tabak et al. (2020).
		Collecting of Virtual Keys	• Only one study (2%) employed the collecting of virtual keys as a reward for users; this was the exergame mobile application by Magnusson et al. (2020).
2	Positive Textual or Audio Messages	• Some of the reviewed articles considered positive textual messages as one way of rewarding users for their PA performance. Furthermore, positive textual messages ranked as the third most frequent form of reward strategy implemented with 11 studies (13%), including the Habito application (Gouveia et al., 2015), PersonA application (Ayubi & Parmanto, 2012), Mobile phone text messaging app (Mutsuddi & Connelly, 2012), and Smartphone application (Ek et al., 2018).	
3	Collecting Virtual Items that are Usable in the Real World (e.g., Financial Incentives and Real Gifts)	Shopping and Donation Vouchers	• Nine studies (11%) provided financial incentives and real gifts to reward users for their PA performance, including the Vitality Active Rewards application by Patel et al. (2018).
		Shopping Discounts	• Only two studies (2%) provided shopping discounts to users to reward them on their PA performance; these studies were the CoviHealth application (Villasana et al., 2019) and Vitality Active Rewards application (Patel et al., 2018).
		Gym Subscription Subsidies	• One study (1%) provided gym subscription subsidies as rewards for users; this was the Vitality Active Rewards application by Patel et al. (2018).
4	Displaying a Vital Metaphorical Image	Visual Metaphorical Image as a Blooming Garden and Flowers, Trees or bigger size of fish`	• Five studies (6%) employed the metaphorical visual image of a blooming garden and flowers to reward users, which ranked as the sixth most common form of reward strategy implementation; these three studies are the Ready ~ Steady application (McMahon et al., 2013), UbiFit Garden (Consolvo

(*continued*)

Table 7. Continued.

#	Reward strategy implementation	Examples	
			& Klasnja, 2008), and Virtual Social Gym system (Far et al., 2014).
		Visual Virtual Town	• A visual virtual town was employed in only one study (1%) out of the 82 studies that employed a reward strategy; this was the Walk2Build application by Hamilton et al. (2012).
		Refilling the Virtual Fuel Gauge	• One study (1%) employed the refilling of a virtual fuel gauge as a reward for users; this was the B-MOBILE application by Bond et al. (2014).
5	Changing a User's Avatar, Changing Sound, Changing, Background Colors by the System	Changing a User's Avatar	• One study (1%) employed the changing of a user's avatar as a reward for users; this was the UP Health system by Sohn and Lee (2007).
		Changing Sound	• One study (1%) employed changing sounds as a reward for users; this was the UP Health system by Sohn and Lee (2007).
		Changing Background Colors	• One study (1%) employed the changing of background colors as a reward for users; this was the UP Health system by Sohn and Lee (2007).
6	Leaderboard Ranking/Position	• Two of the reviewed studies (2%) considered a leaderboard ranking or position as a way of rewarding users for their PA progress; these were the Phone Row system (Zwinderman et al., 2012) and iGO application (Haque et al., 2016).	
7	Displaying Personal Image by the System	• Similarly, only two studies (2%) provided a display of the personal image of users to reward them on their PA performance; these were the iGO application (Haque et al., 2016) and WeRun application (Gui et al., 2017).	
8	Unlocking the Next Chapter, Virtual Storybooks, Displaying Balloons, Displaying a Hero	Unlocking of Following Chapters	• One study (1%) (Saksono et al. (2020)) employed the unlocking of following chapters as a reward for users.
		Virtual Storybooks	• Virtual storybooks were employed in just one study (1%) as rewards for users; this was the Storywell application by Saksono et al. (2020).
		Virtual Balloons Filled with Colors	• Only one study (1%) employed virtual balloons filled with colors to reward users; this was the Storywell application by Saksono et al. (2020).
		Virtual Hero Crossing an Island	• Only one study (1%) employed a virtual hero crossing an island as a reward for users; this was the Storywell application by Saksono et al. (2020).
9	Educational Textual Tips	• One study (1%) employed educational textual tips as a reward for users; this was the Go Run Go application by Mansart et al. (2015).	
10	Game-based Reward (Unspecified)	• Only one study (1%) employed a game-based reward without specifying the way of rewarding users in their system; this was the mobile game app by Arteaga et al. (2010).	
11	Green Bright Light Display	• One study (1%) employed a green bright light display as a reward for users; this was the B-MOBILE application by Bond et al. (2014).	
12	A Personalized Animated Avatar	• One of the reviewed studies (1%) considered displaying a personalized animated avatar as a way of rewarding users for their PA progress; this was the gamified smartphone app by Schäfer et al. (2018).	

Our findings present the effectiveness of reward strategy-based implementations for mobile-based PT interventions for promoting PA and reducing SB. Collecting virtual points or scores as a reward strategy was employed in 25 studies, out of which 17 studies (68%) reported fully successful outcomes, five studies (20%) were partially successful, two studies (8%) did not provide any evaluation of their mobile-based PT designs, and one study (4%) did not specify their outcomes. Virtual badges were used in 19 studies, out of which 11 studies (58%) were fully successful, three studies (16%) were partially successful, and five studies (26%) did not evaluate their system designs. Collecting virtual stars was implemented in seven studies, out of which five studies (71%) were fully successful, and two studies (29%) reported partially successful outcomes.

4.4.5. Personalization strategy

We adopted the same personalization classifications used by Ghanvatkar et al. (2019): personalized motivational content, personalized educational content, personalized activity recommendations, personalized goal recommendations, personalized fitness partner recommendations, and personalized intervention timing. We also noticed that some of the included articles described a customization feature in their systems or applications. Customization is achieved when a user can modify, edit, or change something in the application or system to suit their needs, desires, or tasks (e.g., from application settings) (Davis, 2018). Thus, personalization is typically a system-based feature, while customization is a user-driven feature (Davis, 2018). Therefore, in this section, we only included the personalization strategy regardless of the customization feature. Figure 4 shows the employment of a personalization strategy in the mobile-based PT interventions in the reviewed articles. A personalization strategy was employed in 77 articles (39%). As we mentioned previously, we found that the fifth most commonly employed PS in the reviewed articles is personalization.

It is worth mentioning that the personalized goal recommendations may look closely related to the system-based goals' implementation of the goal-setting strategy (Section 4.4.2). However, the two concepts are different in the sense

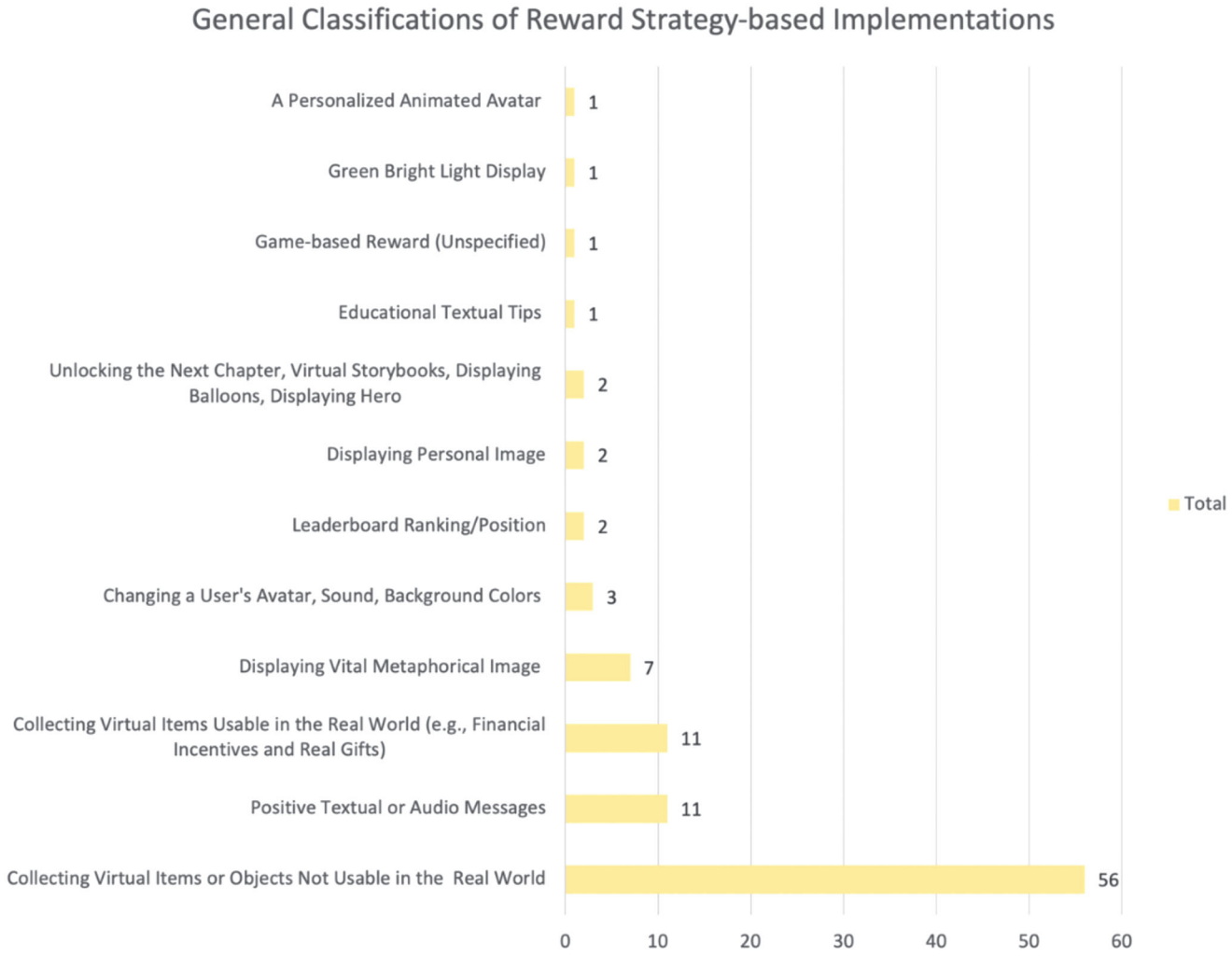

Figure 11. General classifications of reward strategy-based implementations in the reviewed articles.

that the system-based goal indicates that the system is responsible for setting suitable PA goals for the users. On the other hand, personalized goal recommendation means providing personalized goal recommendations (e.g., 30 min walking) based on the user's PA performance to achieve the desired goal, which is either set by the system or the user. That is, the difference is that system-based goals focus on setting suitable goals in a predefined or automatic way while taking the user's ability into consideration, while personalized goal recommendations focus on providing recommendations to achieve the already set goal according to the user's PA progress (e.g., walk for 30 min to work instead of driving to achieve your step count goal). Thus, personalized goal recommendations need the user's permission to accept or reject a suggested personalized goal recommendation.

Figure 12 shows personalization strategy implementations in mobile-based PT interventions in the PA and SB area. The figure displays the most and least frequent forms of implementation. The most commonly employed form of personalization strategy implemented in the reviewed articles is personalized motivational content, with 39 studies (51%) out of 77 articles that employed a personalization strategy. Personalized motivational content is achieved when a persuasive system provides motivational content or messages as feedback to users to motivate them to engage more in PA (Ghanvatkar et al., 2019). Personalized goal recommendations ranked as the second most frequently employed form of personalization strategy implementation with 32 studies (42%). Personalized goal recommendations include only quantified target goals such as step counts, calories burned, or duration of activity (Ghanvatkar et al., 2019). Personalized activity recommendations and personalized educational content came in third place, with 22 studies (29%) for each. Personalized activity recommendations refer to qualified target goals such as walking, cycling, or running (Ghanvatkar et al., 2019). Personalized educational content is fulfilled when a persuasive system provides knowledge feedback to users regarding the usefulness of or techniques for advancing PA (Ghanvatkar et al., 2019). Personalized intervention timing ranked as the fourth most frequently employed personalization strategy with ten studies (13%). Personalized intervention timing refers to finding the right time to deliver the personalization context and feedback to users (Ghanvatkar et al., 2019). The least frequently employed form of personalization strategy implementation was personalized fitness partner recommendations with only two studies (3%). Personalized fitness partner recommendations refer to finding suitable

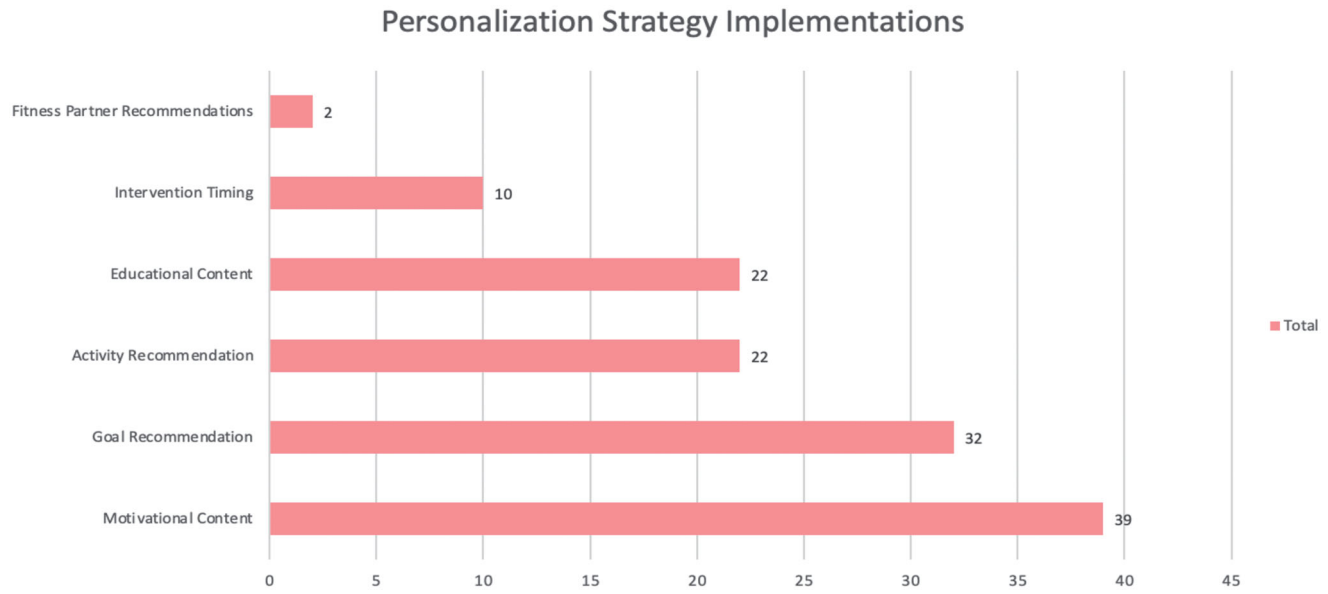

Figure 12. Personalization strategy implementations in the reviewed articles.

Table 8. Examples of personalization strategy implementations in the reviewed articles.

#	Personalization strategy implementation	Examples
1	Personalized Goal Recommendations	• The PRO-Fit application by Dharia et al. (2016) provides personalized goal recommendations as personalized PA exercises and training sessions to the users based on their target PA goal.
2	Personalized Activity Recommendations	• The On11 application by He and Agu (2014) offers activity recommendations to the users, such as personalized short walks and detours.
3	Personalized Fitness Partner Recommendations	• The PRO-Fit application by Dharia et al. (2016) recommends a personalized fitness partner to the user by tracking and identifying the user's activities and matching them when they have similar activity goals and statuses.
4	Personalized Educational Content	• The digital mobile coaching system by Dantzig et al. (2018) delivers personalized educational and context-aware coaching messages about PA to the users.
5	Personalized Motivational Content	• The StepMarton application by Foster et al. (2010) provides personalized motivational Facebook notifications to the users. • The Motivate application by Lin et al. (2011) offers personalized motivational advice on PA to the users.
6	Personalized Intervention Timing	• The Alert Me application by Fahim et al. (2017) provides timely personalized messages and allows the users to manage alerts based on their preferable time.

partners who have similar goals as the users of a system to encourage them and assist them in maintaining or increasing PA (Ghanvatkar et al., 2019). Table 8 shows examples of each personalization strategy implementation in the reviewed articles.

Our findings illustrate the effectiveness of the personalization strategy-based implementations for mobile-based PT interventions for promoting PA and reducing SB. A personalized motivational content implementation of the personalization strategy was employed in 39 studies, out of which 25 studies (64%) reported fully successful outcomes, nine studies (23%) were partially successful, three studies (8%) did not provide any evaluation of their mobile-based PT designs, one study (2.5%) did not specify their outcomes, and only one study (2.5%) was unsuccessful. Personalized goal recommendations were employed in 32 studies, out of which 17 studies (53%) were fully successful, six studies (19%) were partially successful, seven studies (22%) did not evaluate their system's design, and only two studies (6%) did not specify their outcomes.

4.4.6. Praise strategy

A praise strategy is one of the essential PSs used to motivate users to engage more in PA. Praise or compliments can be offered to users in different formats such as symbols, words, images, and sounds (Harri & Marja, 2009). Our findings show that a praise strategy came in sixth place in the most commonly employed PSs in the mobile-based PT interventions for PA and SB in the reviewed articles. Figure 4 shows that a praise strategy was employed in 61 studies (31%) of the 198 reviewed articles.

A praise strategy in the mobile-based PT interventions was implemented in many ways. Figure 13 shows the various ways a praise strategy was implemented in the PA and SB area along with a display of the most and least frequent forms of implementation. Table 9 provides examples of each implementation of a praise strategy in the reviewed articles.

Our findings show the effectiveness of praise strategy-based implementations for mobile-based PT interventions for promoting PA and reducing SB. Textual positive

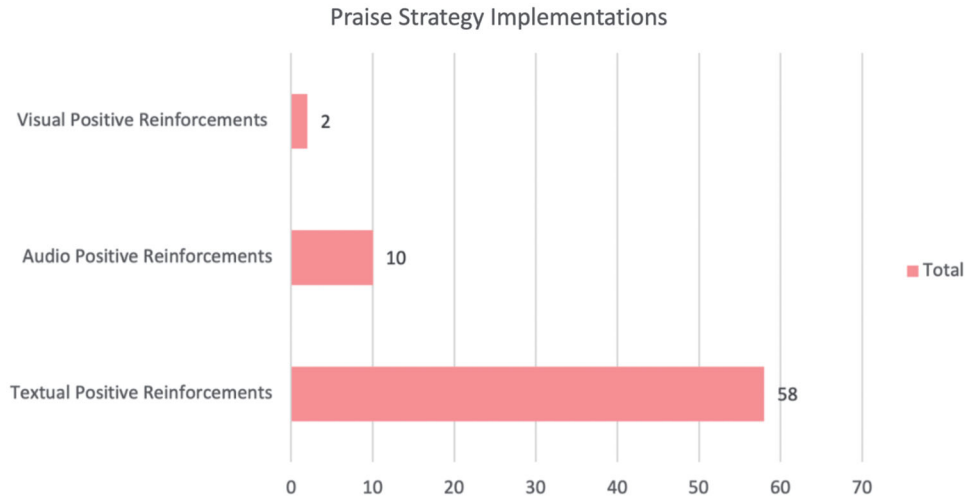

Figure 13. Praise strategy implementations in the reviewed articles.

Table 9. Examples of praise strategy implementations in the reviewed articles.

#	A praise strategy implementation		Examples
1	Textual Positive Reinforcements	Textual Pop-up or Push Messages	• The Evitapp application by Bascur et al. (2018) provides positive textual reinforcements as textual pop-up messages to praise users on their PA performance. • The MobileMen application by Newton et al. (2019) sends pop-up positive textual messages to encourage users on their PA progress by saying, for example, "Keep up the good work." • The digital smartphone coaching system by Dantzig et al. (2018) provides positive push textual messages to the users to encourage them to engage more in PA.
		Text Messages	• The iCanFit application by Hong et al. (2013) sends praise to users as congratulatory text messages to those who completed their target PA goals. The app also sends motivational messages to other users who did not achieve their PA goals.
2	Audio Positive Reinforcements		• The WalkWithMe application by Geurts et al. (2019) provides positive audio reinforcements to encourage users to walk. • The TandemTrack application by Luo et al. (2020) uses the smart speaker Alexa to provide positive audio reinforcements to users regarding their PA performance.
3	Visual Positive Reinforcements		• The mPED application by Fukuoka et al. (2011) provides daily positive messages along with positive, encouraging video clips to build and maintain the motivation of users.

reinforcements of a praise strategy were employed in 58 studies, out of which 33 studies (57%) reported fully successful outcomes, 14 studies (24%) were partially successful, two studies (3.5%) were unsuccessful, two studies (3.5%) did not specify their outcomes, and seven studies (12%) did not provide any evaluation of their mobile-based PT designs. Out of the ten studies that employed audio positive reinforcements of a praise strategy, six studies (60%) were fully successful, one study (10%) reported partially successful outcomes, and three studies (30%) had no evaluation. Implementing a visual positive reinforcement was the least employed form of praise strategy. It was employed in only two studies that showed fully successful outcomes.

4.4.7. Tailoring strategy

We found that a tailoring strategy ranked as the seventh most commonly employed PS in the mobile-based PT interventions for increasing PA and decreasing SB. Figure 4 shows that a tailoring strategy was employed in 47 studies (24%) of 198 reviewed articles. Tailoring and personalization strategies are both concerned with acknowledging the differences between users. The main difference is that tailoring is applied at a group level (e.g., adapting the system to different groups of users such as people of the same age, gender, personality type, and health condition), while personalization is at the individual level.

The tailoring strategy in the mobile-based PT interventions was implemented in many ways. Figure 14 shows how the tailoring strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation. Table 10 provides examples of each implementation of a tailoring strategy in the reviewed articles.

Our findings show the effectiveness of a tailoring strategy-based implementation for mobile-based PT interventions for promoting PA and reducing SB. Providing a set of information, tips, games, or recommendations to a particular group of people based on their age, target goal, preferences, or health conditions for motivating, educating, or increasing the awareness of users as a tailoring strategy was implemented in 27 studies, out of which 15 studies (56%) reported fully successful outcomes, seven studies (26%) were partially successful, one study (3%) did not specify their

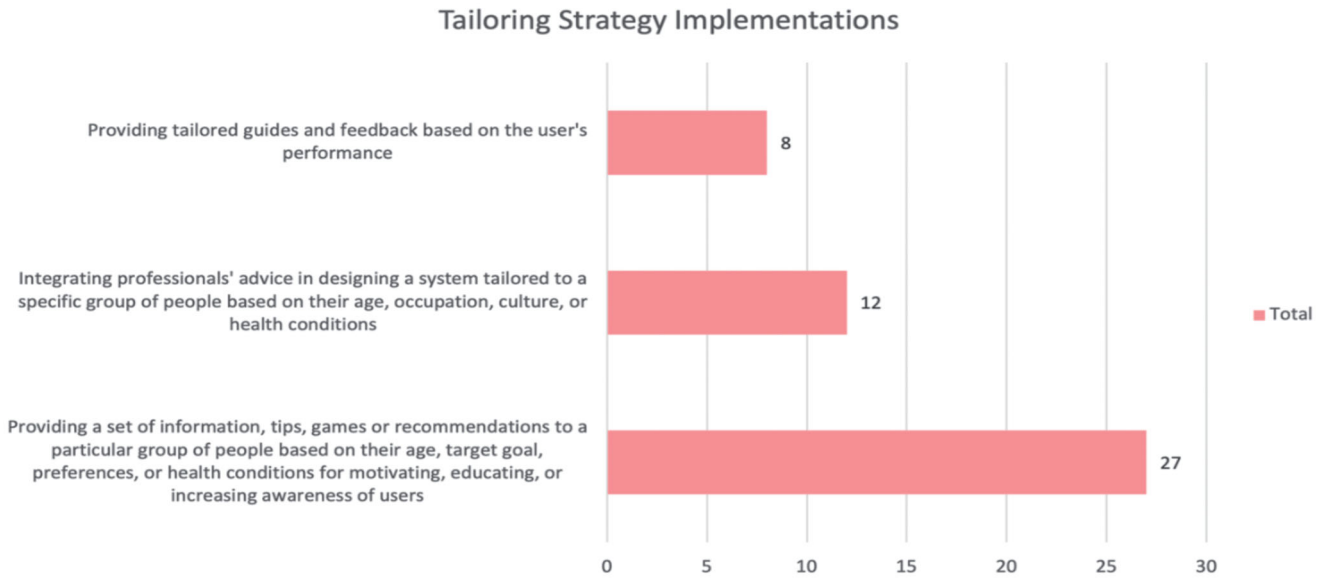

Figure 14. Tailoring strategy implementations in the reviewed articles.

Table 10. Examples of tailoring strategy implementations in the reviewed articles.

#	Tailoring strategy implementation	Examples
1	Providing a Set of Information, Tips, Games or Recommendations to a Particular Group of People Based on Their Age, Target Goal, Preferences, or Health Conditions for Motivating, Educating, or Increasing the Awareness of Users	• The On11 application by He and Agu (2014) provides personal and tailored walking activity recommendations according to the user's environmental conditions, such as the time, weather, and location. • The WargaFit application by Mohadis and Ali (2016) provides tailored and suitable health and PA information for elderly workers. • The CoviHealth application by Villasana et al. (2019) delivers educational and tailored nutrition and PA information to teenagers. • The mPED application by Fukuoka et al. (2011) offers tips on how to have a healthy diet and lifestyle tailored to physically inactive American females by providing daily messages or video clips.
2	Integrating Professionals' Advice in Designing a System Tailored to a Specific Group of People Based on Their Age, Occupation, Culture, or Health Conditions	• Oyibo et al. (2019) designed culture-tailored persuasive health applications as represented in the BEN'FIT application by designing two versions (personal and social) to meet and verify the user needs. The two versions of the BEN'FIT application were designed and tailored to African Nigerian populations. • The GaitTrack application by Cheng et al. (2013) is designed and tailored to patients with chronic obstructive pulmonary disease (COPD). • The smartphone exergame application by Francillette et al. (2018) is designed and tailored for people with severe mental health issues by providing accessible mechanics and straightforward instructions.
3	Providing Tailored Guides and Feedback Based on the User's Performance	• The Active2Gether application by Klein et al. (2017) tailors the coaching instructions and feedback to the young adult user's situation and requirements. • The iCanFit application by Hong et al. (2013) delivers tailored feedback reflecting the user's PA progress and provides tailored recommendations to change short-term PA objectives.

outcomes, and four studies (15%%) did not provide any evaluation of their mobile-based PT designs.

4.4.8. Reduction strategy

To incorporate a reduction strategy into a persuasive system, the system has to reduce the efforts and burdens that users may experience when using the system and performing their target behaviors. Figure 4 shows the employment of a reduction strategy in the mobile-based PT interventions in the reviewed articles. The reduction strategy was applied in 46 studies (23%) of the 198 articles included in our review paper in the domain of promoting PA and reducing SB.

Reduction strategies in the mobile-based PT interventions were implemented in many ways. Figure 15 shows the various ways reduction strategies were implemented in the PA and SB area, along with the most and least frequent forms of implementation. The following shows the reduction strategy implementations (in order from the most frequently employed implementations on the top to the least frequently employed on the bottom):

1. *Providing a List of Different Predefined Options or Choices or Suggestions:*
   Out of the 46 studies that employed a reduction strategy, 18 studies (39%) implemented a reduction strategy by providing users with a list of different predefined options. Thus, this form of reduction implementation was the most frequently employed in the reviewed studies. For example, the Non-Exercise Activity

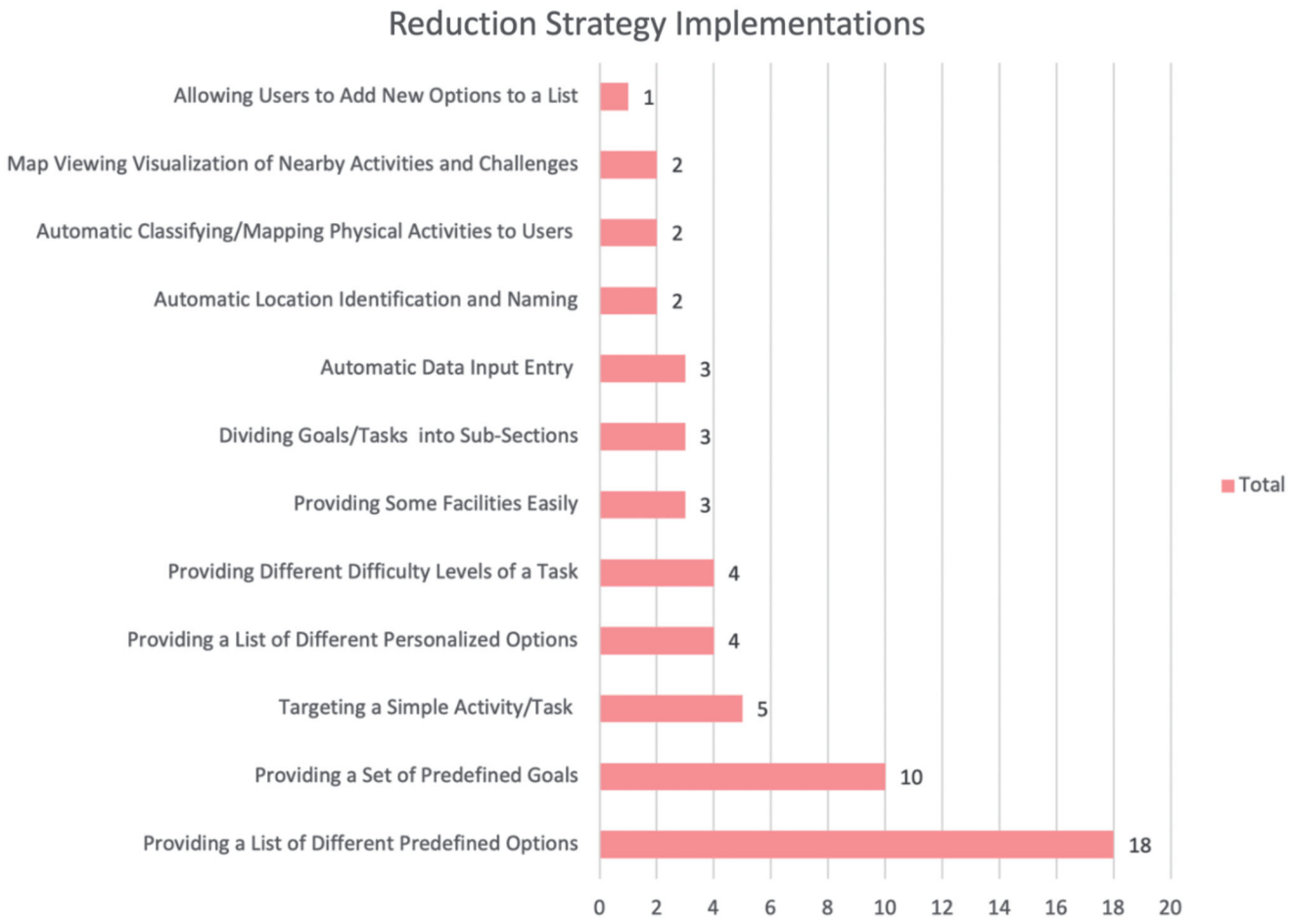

Figure 15. Reduction strategy implementations in the reviewed articles.

Thermogenesis (NEAT!) mobile application by Pellegrini et al. (2015) provides a fast and simple way to understand the reasons behind the user's adherence and commitment to the prompts in performing their target behavior of PA. The system comprehends why users adhere or not to the prompts by providing four response options to the users: Cannot Stand, Stand, Extend, and Ignore.The Motivate application by Lin et al. (2011) provides a drop-down list of a simple agenda service that allows users to choose and add activities from the list, which has the following options: "Go home," "Dinner," "Go to work," "Lunch," "Busy," and "Work." Furthermore, in the SP-Stretch mobile social game by Chen et al. (2014), the system's host returns a list of all competition pairs (stretching types and available responders). The list is generated once one of the users creates the competition. The Chick Clique system by Toscos et al. (2006) provides the user with a list of healthy food options in different fast-food restaurants. The ActiConverge and ActiSit systems by Beck et al. (2019) provide the user with a list of all available exercises. Beside each exercise name, an arrow opens a drop-down menu with all the activities.

2. *Providing a Set of Predefined Goals, Plans, or Programs:* *Providing a set of predefined goals, plans or programs* to reduce a user's effort in creating a new plan for their PA goals ranked as the second most common form of reduction strategy implemented with ten studies (22%) out of the 46 studies that employed a reduction strategy. For instance, the *On11* application by He and Agu (2014) provides three types of goals for the user to select from (1) Lose Weight, (2) Keep Healthy, or (3) Burn Calories. Thus, the system provides the user with a specific plan for each particular selection from the three predefined goals. Furthermore, the TripleBeat system by De Oliveira and Oliver (2008) provides a list of predefined workout plans to a user and displays them along with relevant information in a visual interface. Other examples are the Bounce application by Marcu et al. (2018), Active 10 application by Ciravegna et al. (2019), and *Storywell* application by Saksono et al. (2020).
3. *Targeting a Simple Activity or Task:*
Targeting a simple activity or task ranked as the third most employed form of reduction strategy with five studies (11%). For example, one of the included articles considered targeting walking or a stretching activity as a way of employing a reduction strategy as represented in the *WragaFit* application (Mohadis & Ali, 2016). This is not completely accurate according to the reduction definition in the PSD model. The Active2Gether system by Klein et al. (2017) focuses on

three specific types of PA: (1) stair walking, (2) active transport, and (3) leisure time sports activities. The *iFitQuest* mobile game application by Macvean and Robertson (2013) provides a list of eight short and simple mini-game mechanisms such as collecting objects.

4. *Providing a List of Different Personalized Options or Choices or Suggestions:*
   Providing a list of different personalized options was the fourth most common way of implementing a reduction strategy with four studies (9%). For example, the BunnyBolt game application by Keung et al. (2013) provides a list of personalized episodes. Thus, the game enables users to reperform past fitness workouts, return where they have left off in the game, or reread unlocked storylines. Furthermore, the exergame application by Francillette et al. (2018) provides personalized PA options of different difficulty levels of the game according to the user's old choices. The PersonalFit application by Oliveira et al. (2016) generates a personalized list of the user's PA exercises in the same order as shown on their gym.
5. *Providing Different Task Difficulty Levels:*
   Providing different task difficulty levels ranked as the fourth most common way of implementing a reduction strategy with four studies (9%). For example, the LocoSnake game (Chittaro & Sioni, 2012) provides the user with three difficulty levels (easy, medium, and hard). The ExerLink system by Macvean and Robertson (2013) provides users with three different intensity modes (slow, medium, and fast) when using an exercise device.
6. *Providing Some Facilities Easily:*
   Providing some facilities easily ranked as the fifth most common way of implementing a reduction strategy with three studies (7%). For example, the Ready ~ Steady application by McMahon et al. (2013) reduces users' effort by providing interface displays that are easily and simply accessible based on the user's preference and suitable times and also do not interrupt users' routines. The *TripleBeat* system (R. De Oliveira & Oliver, 2008) provides recommendations and information in an easy-to-comprehend visual interface display. The TandemTrack by Luo et al. (2020) allows users to exercise easily, as it reduces the complexity of the exercise process. The exercise shifts between push-ups and sit-ups, concentrating on the repetitions and timing. The system provides the user with the number of repetitions for push-ups/sit-ups after completing each exercise session automatically.
7. *Dividing Goals or Tasks into Sub-sections:*
   Dividing goals or tasks into sub-sections also ranked as the fifth most frequent way of implementing a reduction strategy with three studies (7%). For example, the Habito application by Gouveia et al. (2015) divides the daily walking goal into four sub-goals. For instance, a goal of 8 km will be split into three mini sub-goals of 2, 4, and 6 km. The SP-Stretch system by Chen et al. (2014) categorizes PA stretching movements into five types: hip stretches, upper extremity stretches, upper back stretches, trunk stretches, and lower extremity stretches. The *Active10* application by Ciravegna et al. (2019) divides the activities' goals of walking and brisk walking on an hourly basis as they are provided in a predefined manner to the user.
8. *Automatic Data Input Entry:*
   Automatic data input entry also ranked as the fifth most frequent way of implementing a reduction strategy with three studies (7%). The PersonA application by Ayubi and Parmanto (2012) has simple tasks to increase the user's adherence, as it provides automatic data input rather than using manual typing input or paper-pencil. The ExerLink system by Macvean and Robertson (2013) provides automatic data input entry by converting the user's PA intensities when using an exercise device into game input values. Furthermore, the TandemTrack by Luo et al. (2020) reduces the data entry burden, as it just captures and tracks the number of push-ups and sit-up repetitions per session.
9. *Automatic Location Identification and Naming:*
   Only two studies (4%) of the reviewed articles employed a reduction strategy by providing automatic location identification and naming to users, which ranked sixth. For example, the Habito application by Gouveia et al. (2015) automatically identifies locations in all subsequent visits and provides a list of suggested names. The *iCanFit* application by Hong et al. (2013) provides a locator function that allows users to easily search and locate PA resources such as parks, activity programs, and other facilities.
10. *Automatic Classifying and Mapping of Physical Activities:*
    The automatic classifying and mapping of physical activities also ranked as the sixth most common way of implementing a reduction strategy with two studies (4%). The PRO-Fit application by Dharia et al. (2016) automatically classifies the user's PA into one of the following exercises: step down, step up, sitting, running, standing, jogging, and walking. The ExerLink system by Macvean and Robertson (2013) provides a personalized and automatic mapping function for each fitness device. The system converts the different intensities received on each fitness device into game input measurements.
11. *Map-Viewing Visualization of Nearby Activities and Challenges:*
    The map-viewing visualization of nearby activities and challenges ranked as the sixth most common way of implementing a reduction strategy with two studies (4%). For example, the CrowdWalk application by Ornelas et al. (2015) provides a map-viewing visualization of nearby walking activity trails and challenges. The user is allowed to add an unlimited number of walking activities and locations. The system shows a list of different activity trails around a user's location. The *GeoFit* application by Terry et al. (2015) provides

the users with paths of the PA challenges on a map and displays a description of each PA challenge.

12. *Allowing Users to Add New Options to a List:* *Allowing users to add new options to a list* ranked as the sixth and least common way of implementing a reduction strategy in the reviewed studies with only one study (2%). For instance, the CrowdWalk application by Ornelas et al. (2015) allows the users to add unlimited walking activities with their particular locations.

Our findings present the effectiveness of reduction strategy-based implementations for mobile-based PT interventions in increasing PA and decreasing SB. The implementation of providing a list of different predefined choices or options or suggestions for a personalized reduction strategy was employed in 18 studies, out of which 11 studies (61%) reported fully successful outcomes, four studies (22%) were partially successful, and three studies (17%) did not provide any evaluation of their mobile-based PT designs. The implementation of providing a set of predefined goals or plans or programs of a reduction strategy was employed in ten studies, out of which six studies (60%) were fully successful, one study (10%) was partially successful, one study (10%) did not specify their outcomes, and two studies (20%) did not evaluate its system's design.

4.4.9. Tunneling strategy

Based on our findings from the reviewed articles, a tunneling strategy ranked as the ninth most commonly employed PS in the mobile-based PT interventions for increasing PA and decreasing SB. Figure 4 shows that a tunneling strategy was employed in 43 studies (22%) of the 198 reviewed articles.

The tunneling strategy in the mobile-based PT interventions was implemented in many ways. Figure 16 shows the various ways the tunneling strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation. Table 11 provides examples of each implementation of a tunneling strategy in the reviewed articles.

Our findings present the effectiveness of a tunneling strategy-based implementation for mobile-based PT interventions for promoting PA and reducing SB. The implementation of textual or written instructions for a tunneling strategy was employed in 18 studies (42%), out of which 13 studies (72%) reported fully successful outcomes, two studies (11%) were partially successful, and three studies (17%) had no evaluation. Out of the 13 studies that implemented a map visualization for challenges and walking routes as a tunneling strategy, seven studies (54%) were fully successful, two studies (15%) reported partially successful outcomes, one study (8%) did not specify their outcomes, and three studies (23%) had no evaluation. For the studies that implemented visual, video or animated instructions as a tunneling strategy, out of the ten studies that employed them, five studies (50%) reported fully successful outcomes, one study (10%) was partially successful, one study (10%) did not specify their outcomes, and three studies (30%) did not show any evaluation of their system's design.

4.4.10. Social competition strategy

The social competition strategy is one of the most important PSs employed to motivate users to adopt a target PA behavior. Our findings show that a social competition strategy ranked as the tenth most commonly employed PS in the mobile-based PT interventions for promoting PA and reducing SB in the reviewed articles. Figure 4 shows that 37 studies (19%) of the 198 reviewed articles employed a social competition strategy.

The social competition strategy in the mobile-based PT interventions was implemented in many ways. Figure 17 shows the various ways the social competition strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation. Table 12 provides examples of each implementation of a social competition strategy in the reviewed articles.

Our findings show the effectiveness of a social competition strategy-based implementation for mobile-based PT interventions in the PA and SB domains. The implementation of a leaderboard ranking as a social competition strategy was employed in 24 studies, out of which 14 studies (58%) reported fully successful outcomes, seven studies (29%) were partially successful, two studies (9%) were unsuccessful, and one study (4%) did not provide any evaluation of their mobile-based PT design. Out of the six studies that did not specify their way of implementing a social competition strategy, one study (17%) was fully successful, two studies (33%) reported partially successful outcomes, and three studies (50%) had no evaluation.

4.4.11. Suggestion strategy

According to our findings, a suggestion strategy ranked as the eleventh most frequently employed PS in the mobile-based PT interventions in the PA and SB domains in the reviewed articles. Figure 4 shows that a suggestion strategy was employed in 35 studies (18%) of the 198 reviewed articles.

The suggestion strategy in the mobile-based PT interventions was implemented in many ways. Figure 18 shows the various ways the suggestion strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation. Table 13 provides examples of each implementation of a suggestion strategy in the reviewed articles.

Our findings present the effectiveness of suggestion strategy-based implementations for mobile-based PT interventions for promoting PA and reducing SB. Textual recommendations as a suggestion strategy were employed in 35 studies, out of which 22 studies (63%) reported fully successful outcomes, ten studies (28.5%) were partially successful, and three studies (8.5%) did not provide any evaluation of their mobile-based PT designs. Out of the four studies that employed visual recommendations of a suggestion strategy, two studies (50%) were fully successful, one study

Figure 16. Tunneling strategy implementations in the reviewed articles.

Table 11. Examples of tunneling strategy implementations in the reviewed articles.

#	Tunneling strategy implementation	Examples
1	Textual or Written Instructions	• The stAPP application by Arrogi et al. (2019) provides textual instructions to guide users on how to practice healthy sitting behavior.
2	Map Visualization for Challenges and Walking Routes	• The On11 application by He and Agu (2014) employs Google's Direction API to generate walking routes to guide users in performing walking activities from one location to another. • The CrowdWalk application by Ornelas et al. (2015) provides a list of different nearby walking activities and shows a map-viewing visualization for each walking venue.
3	Visual or Video or Animated Instructions	• The Bounce application by Marcu et al. (2018) provides visual instructions via a virtual trainer, which provides animated steps to show how to perform each type of PA.
4	Instructions as a Storyline	• The BunnyBolt game application by Keung et al. (2013) motivates users to perform PA through a friendly storyline. The user is guided through a set of screens that describe the following part of the story. • The Storywell application by Saksono et al. (2020) provides users with storyline scenarios to perform PA.
5	Audio or Voice Instructions	• The TripleBeat application by De Oliveira and Oliver (2008) guides the users by providing real-time musical feedback while performing PA. • The WalkWithMe application by Geurts et al. (2019) provides audio instructions and feedback to users through a virtual coach. The coach helps users perform walking activities to reach their target PA goals.
6	Vibration or Tactile Instructions	• The Pokémon GO application (Howe et al., 2016), (Pokémon Company, 2016) provides vibration instructions to inform the user about a nearby Pokémon.

(25%) did not specify its evaluated outcomes, and one study (25%) did not show any evaluation of their study.

4.4.12. Social cooperation strategy

Figure 4 shows the employment of a social cooperation strategy in the mobile-based PT interventions in the reviewed articles. The social cooperation strategy was employed in 36 studies (18%) of the 198 articles included in our review paper to promote PA and reduce SB.

The social cooperation strategy in the mobile-based PT interventions was implemented in many ways. Figure 19 shows how the social cooperation strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation. Table 14 provides examples of each implementation of a social cooperation strategy in the reviewed articles.

Our findings show the effectiveness of social cooperation strategy-based implementations for mobile-based PT interventions for promoting PA and reducing SB. The

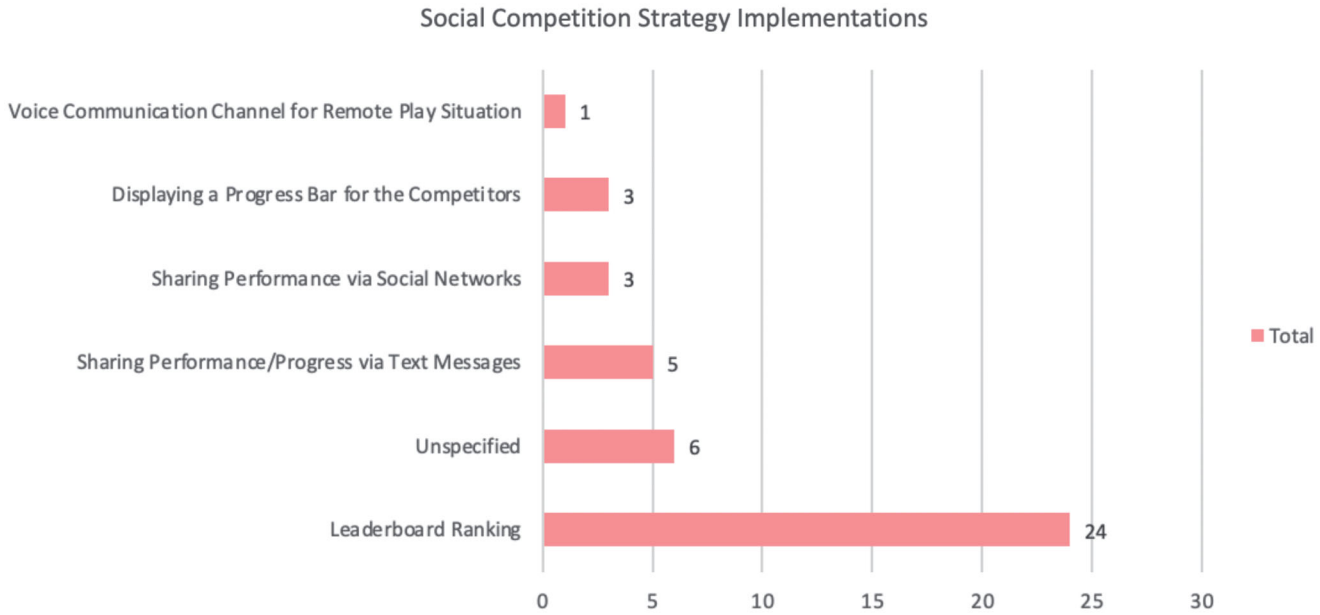

Figure 17. Social competition strategy implementations in the reviewed articles.

Table 12. Examples of social competition strategy implementations in the reviewed articles.

#	Social competition strategy implementation	Examples
1	Leaderboard Ranking	• The StepMatron application by Foster et al. (2010) provides a rankings table with competitive attributes and information for the competitors, which also offers a social interaction opportunity in step activities such as walking. • The GeoFit application by Terry et al. (2015) provides a list of the top PA performers along with displaying their PA progress. This leaderboard list is updated every time new users complete the PA challenge.
2	Unspecified	• Six articles did not specify their way of implementing a social competition strategy in their system designs, such as the mobile application by Arteaga et al. (2010), the Virtual Social Gym by Far et al. (2014), and the CoviHealth application by Villasana et al. (2019).
3	Sharing Performance/Progress via Text Messages	• The Chick Clique application by Toscos et al. (2006) creates groups of four members per group to engage in a PA competition. The system sends automated text messages to the groups to indicate their PA performance, including the PA progress of each competitor. • The NEAT-o-Games applications by Fujiki et al. (2008) sends text messages to announce the winner or the loser of the game session. • The Twitter Me system by Young (2010) sends text messages to show a group PA performance along with the each member's achievement level completed. Each competitor can notify their followers of their current PA progress and health improvement such as weight loss.
4	Sharing Performance via Social Networks	• The STEP UP application by Khalil and Abdallah (2013) allows users to share their steps with friends, which leads to peer pressure and competition to increase their step counts. • The Phone Row application by Zwinderman et al. (2012) allows users to share and compare their PA competition results via Facebook. • The Super Starfish Mania application by Schagen et al. (2015) allows users or groups to share and display their PA progress via social networks and compete.
5	Displaying a Progress Bar for the Competitors	• The PersonA application by Ayubi and Parmanto (2012) displays progress bars for competitors via social networks, increasing PA competition among users. • The HealthyTogether application by Chen and Pu (2014) presents a progress bar for each competitor, and the competitors compete to earn more badges and points.
6	Voice Communication Channel for Remote Play Situation	• The ExerLink system by Macvean and Robertson (2013) offers a voice communication channel among players to encourage social competition and interaction in a remote play location.

teamwork implementation as a social cooperation strategy was employed in 18 studies, out of which nine studies (50%) reported fully successful outcomes, six studies (33%) showed partially successful outcomes, one study (6%) was unsuccessful, and two studies (11%) had no evaluation. The implementation of sharing PA performance and progress via social networks as a social cooperation strategy was employed in 15 studies, out of which seven studies (47%) reported fully successful outcomes, five studies (33%) showed partially successful outcomes, and three studies (20%) provided no evaluation for their system design. Out of the 12 studies that implemented messages exchange as a social cooperation strategy, six studies (50%) were fully successful, three studies (25%) reported partially successful outcomes, and three studies (25%) had no evaluation.

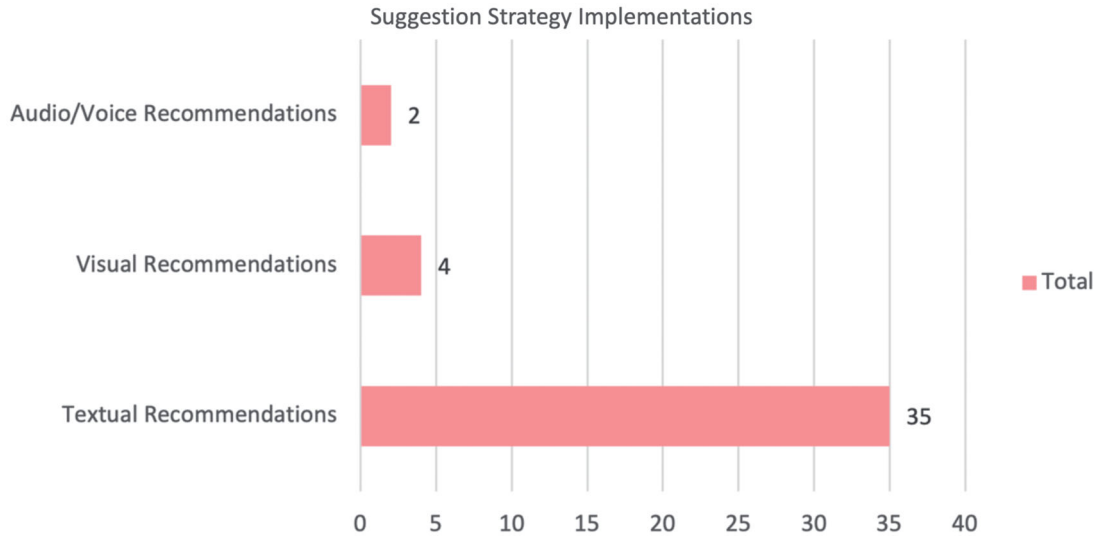

Figure 18. Suggestion strategy implementations in the reviewed articles.

Table 13. Examples of suggestion strategy implementations in the reviewed articles.

#	Suggestion strategy implementation	Examples
1	Textual Recommendations	• The iCanFit application by Hong et al. (2013) provides textual suggestions to users on changing short-term PA goals. • The mobile application of the Mining Mind project by Abbas et al. (2019) generates automated textual push notifications to users containing general PA suggestions (e.g., "stretch your arms, back, and a leg"). • The GeoFit application by Terry et al. (2015) provides textual suggestions to users as pop-up notifications. For example, when the system detects a user entering a building, the system can suggest a user to take the stairs instead of the elevator. For instance, the system can also suggest a user to perform more PA when a user is detected as remaining sitting for a long time.
2	Visual Recommendations	• The ActiConverge and ActiSit systems by Beck et al. (2019) suggest specific PA exercises to users and provide them with images of a person performing each type of physical exercise. The systems also display a brief description of each exercise. • The Pretty Pelvis application by Min et al. (2015) provides visual suggestions to the user via an interactive virtual pet that shows gestural actions to motivate users to develop healthier sitting habits.
3	Audio or Voice Recommendations	• The digital smartphone coaching system by Dantzig et al. (2018) provides textual pop-up notifications and specific audio cues to users. These notifications and cues suggest a daily step goal or performing a particular PA action.

4.4.13. Social role strategy

Figure 4 shows the employment of a social role in the mobile-based PT interventions in the reviewed articles. The social role strategy was employed in 35 studies (18%) of the 198 articles included in our review paper to promote PA and reduce SB.

The social role strategy in the mobile-based PT interventions was implemented in many ways. Figure 20 shows the various ways the social role strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation. Figure 21 shows the communication channel classifications of the social role strategy. Table 15 provides examples of each implementation of a social role strategy in the reviewed articles.

Our findings illustrate the effectiveness of social role strategy-based implementations for mobile-based PT interventions for promoting PA and reducing SB. Providing a communication channel between specialists, physicians or coaches and users or patients as a social role strategy was employed in 28 studies, out of which 21 studies (75%) reported fully successful outcomes, one study (4%) did not specify their outcomes, and six studies (21%) provided no evaluation for their system design. Out of the five studies that implemented the problem solving provided by the system to users (e.g., tips and common barriers) as a social role strategy, two studies (40%) were fully successful, one study (20%) was partially successful, and two studies (40%) had no evaluation.

4.4.14. Expertise strategy

According to the PSD model (Harri & Marja, 2009), the system will have more power of persuasion if it is seen as integrating expertise. Thus, to employ an expertise strategy in a persuasive system, the system needs to offer experience, knowledge, and qualification information. Figure 4 shows the employment of an expertise strategy in the mobile-based PT interventions in the reviewed articles. An expertise strategy was employed in 30 studies (15%) of the 198 articles included in our review paper to promote PA and reduce SB.

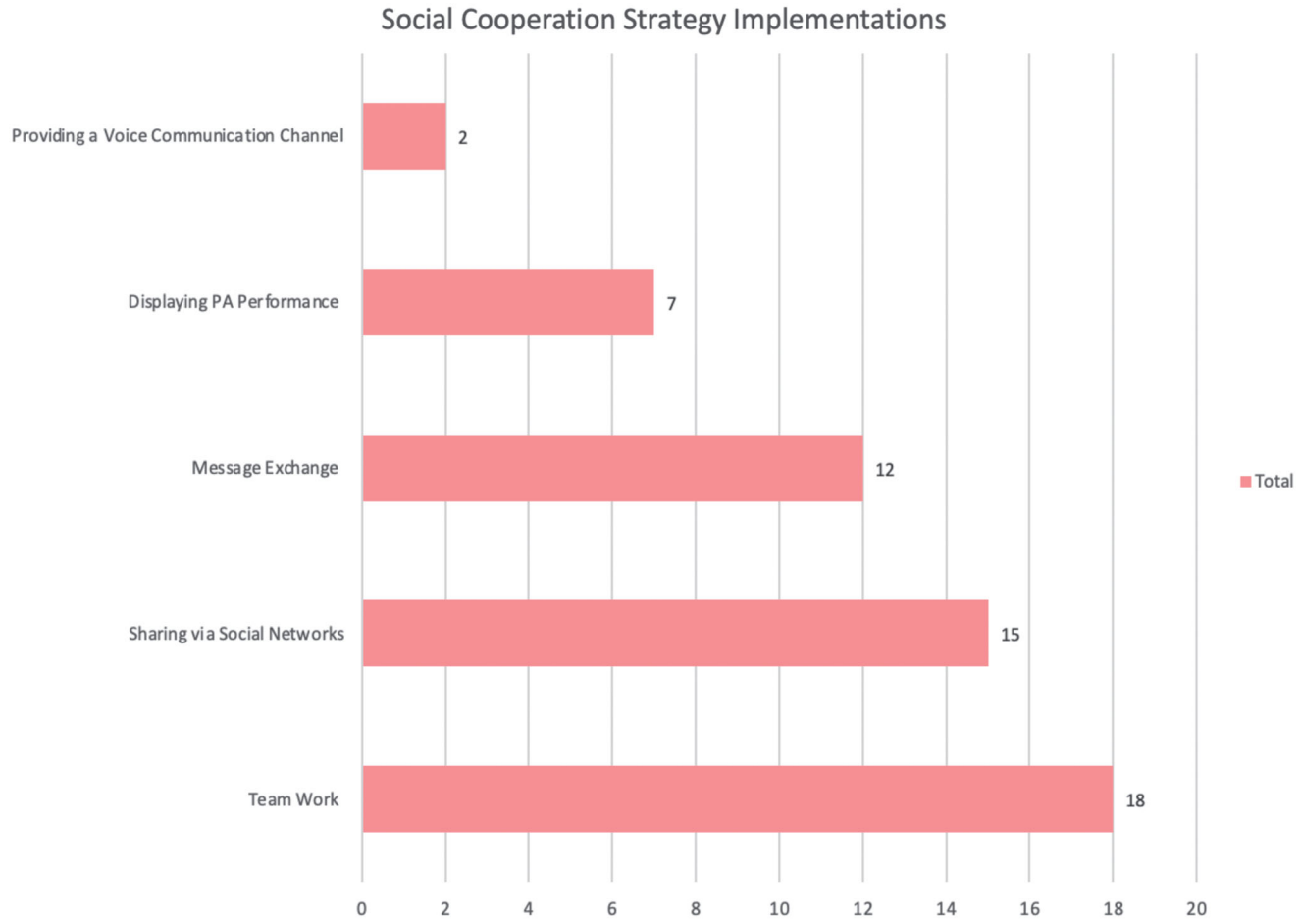

Figure 19. Social cooperation strategy implementations in the reviewed articles.

The expertise strategy in the mobile-based PT interventions was implemented in many ways. Figure 22 shows how the expertise strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation. Table 16 provides examples of each implementation of an expertise strategy in the reviewed articles.

Our findings show the effectiveness of expertise strategy-based implementations for mobile-based PT interventions in promoting PA and reducing SB. The implementation of the health, fitness and software experts' aid in developing the system and a study intervention as an expertise strategy was employed in ten studies, out of which seven studies (70%) reported fully successful outcomes, one study (10%) showed partially successful outcomes, and two studies (20%) provided no evaluation for their system design. Out of the six studies that implemented knowledgeable and certified information (e.g., facts or healthy tips or plans by certified medical or fitness experts) as an expertise strategy, five studies (83%) were fully successful, and one study (17%) had no evaluation.

4.4.15. Social comparison strategy

We found that a social comparison strategy ranked as the fifteenth most commonly employed PS in the mobile-based PT interventions for promoting PA and decreasing SB. Figure 4 shows that 25 studies (13%) of the 198 reviewed articles employed a social comparison strategy.

The social comparison strategy in the mobile-based PT interventions was implemented in many ways. Figure 23 shows the various ways the social comparison strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation. Table 17 provides examples of each implementation of a social comparison strategy in the reviewed articles.

Figure 23 provides general classifications of the social comparison strategy implementations in the reviewed articles on promoting PA and reducing SB. Sharing PA performance and progress via social networks or text messages, or screens was the most frequently employed form of social comparison strategy, with 12 studies (48%) of the 25 studies that employed a social comparison strategy. Employing a comparison table or list (ranking and others) ranked as the second most frequently used way to employ a social comparison strategy in the reviewed studies with 11 studies (44%). Providing a visual or graphical comparison (e.g., a bar chart, line chart, ranking) ranked as the third and least common way to employ a social comparison strategy with nine studies (36%).

Our findings show the effectiveness of social comparison strategy implementations in their general classification for mobile-based PT interventions for promoting PA and reducing SB. Sharing PA performance and progress via social

Table 14. Examples of social cooperation strategy implementations in the reviewed articles.

#	Social cooperation strategy implementation	Implementations	Examples
1	Message Exchange	Message exchange as encouraging feedback/chatting/comments/or planning for contributing to a fitness exercise.	• The social version of the BEN'FIT application by Oyibo et al. (2019) provides a comment/chat icon, allowing users to chat with each other and discuss their PA plans.
2	Sharing via Social Networks	Sharing each other's experiences/ activities/performance results via social networks	• The Bounce application by Marcu et al. (2018) provides a social interaction feature that allows users to share PA tips and their experience and follow the same PA plan.
		Sending likes	• The PersonA application by Ayubi and Parmanto (2012) provides social cooperation as peer-support features that enable users to support each other in practicing PA exercises by sending likes, encouraging feedback (e.g., greetings or rewards), and sharing experiences.
		Following other users	• The *WeRun* application by Gui et al. (2017) allows users to cooperate by sending likes, exchanging messages, sharing experiences, and following each other.
3	Providing a Voice Communication Channel	Voice Communication Channel	• The ExerLink system by Park et al. (2012) offers a voice communication channel between players remotely for social interaction and cooperation.
4	Displaying PA Performance	Displaying performance as a bar chart	• The Twitter Me system by Young (2010) displays a group performance as a bar chart to encourage users to walk together instead of individually.
		Displaying performance as a progress bar	• The HealthyTogether application by Chen and Pu (2014) displays the users' performance as progress bars, which show 50% of both users' step counts and points collected.
		Displaying performance as a wearable e-textile screen on the back of each user's shirt.	• The Social Fabric Fitness system by Mauriello et al. (2014) allows users to cooperate and run together by presenting their PA progress on the wearable and glanceable e-textile screen on the back of each runner's shirt.
		Displaying performance on a separate device.	• The Super Starfish Mania application by Schagen et al. (2015) allows users to cooperate by working together toward their cooperative PA goals, and their points collections will be displayed on a separate device.
		Displaying group progress along with each user's progress (Unspecified)	• The IM system in the UP Health application by Sohn and Lee (2007) displays each group's PA progress, along with each user's PA performance. The developers of the UP Health application did not specify the way they displayed the PA progress.
5	Teamwork	Allowing users to work together as a team (by sending invitations)	• The FitPlay application by Skriloff et al. (2016) enables users to cooperate and work together as a team toward their cooperative PA goal by sending invitations that allow other users to join a team.
		Allowing users to work together as a team (Unspecified)	• The HybridPLAY system by Boj et al. (2018) enables two or more people to cooperate and work together as a team toward their PA goal without specifying how the team members established their group connection.
		Providing different real social walking or running programs	• The Vitality Active Rewards application by Patel et al. (2018) employs a cooperation strategy by offering several cooperative social running or walking activities.
		Providing a co-exercise mode that enables several participants to perform PA along with a number of flows with their friends.	• The FLOW Pillow system by Ren et al. (2016) allows users to exercise remotely from their homes or co-located exercises in the care center by providing a co-exercise mode for users to exercise together with several PA flows.
		Each participant's step counts are multiplied by 50% to obtain the total performance results for the two cooperative participants	• The HealthyTogether application by Chen and Pu (2014) multiplies each participant's step counts by 50% to get the two cooperative participants' total progress results.

networks or text messages or screens as a social comparison strategy was employed in 12 studies, out of which five studies (42%) reported fully successful outcomes, four studies (33%) were partially successful, one study (8%) was unsuccessful, and two studies (17%) did not provide any evaluation of their mobile-based PT designs. Out of the 11 studies that employed a comparison table or list (e.g., ranking or others) as a social comparison strategy, five studies (46%) were fully successful, four studies (36%) were partially successful, one study (9%) was unsuccessful, and one study (9%) had no evaluation.

4.4.16. Self-report strategy

A self-report strategy was shown in the reviewed articles as delivering feedback from users to a system (Aldenaini et al., 2020). Although the self-report strategy is not part of the PSD model strategies, we included it because it is employed in 25 studies in the considered articles. Figure 4 shows the employment of a self-report strategy in the mobile-based PT interventions in the reviewed articles. A self-report strategy was employed in 25 studies (13%) of the 198 articles included in our review paper to promote PA and reduce SB.

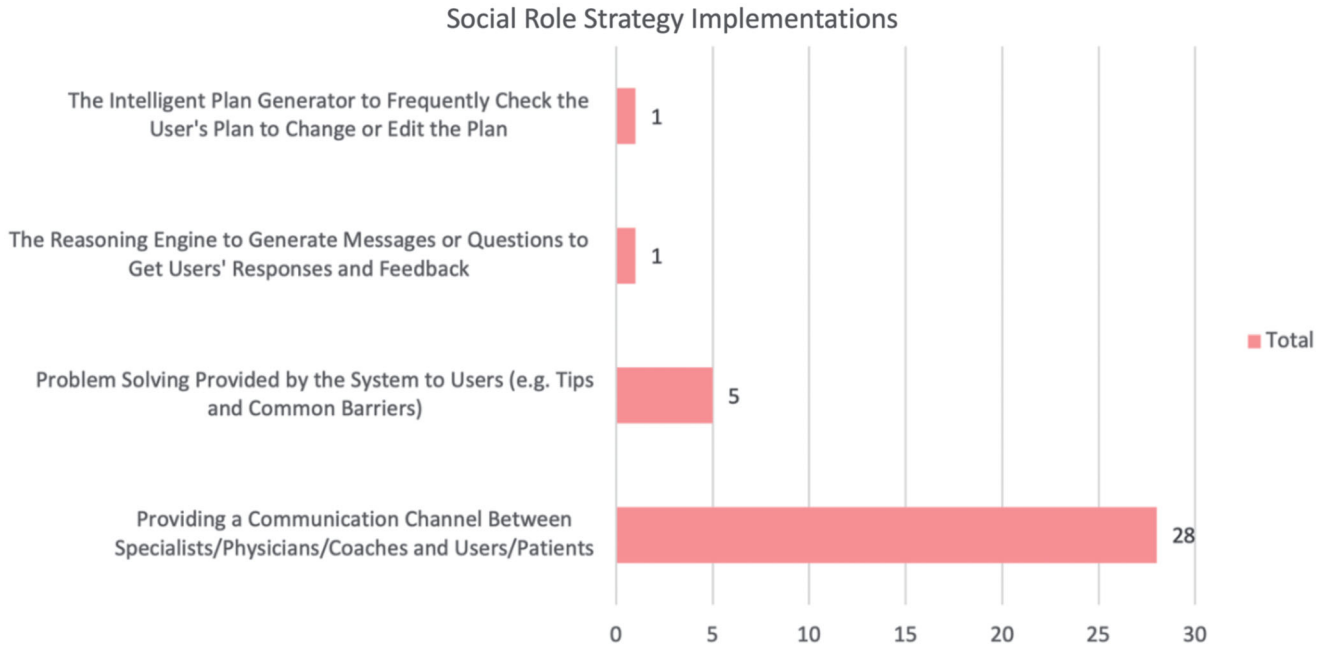

Figure 20. Social role strategy implementations in the reviewed articles.

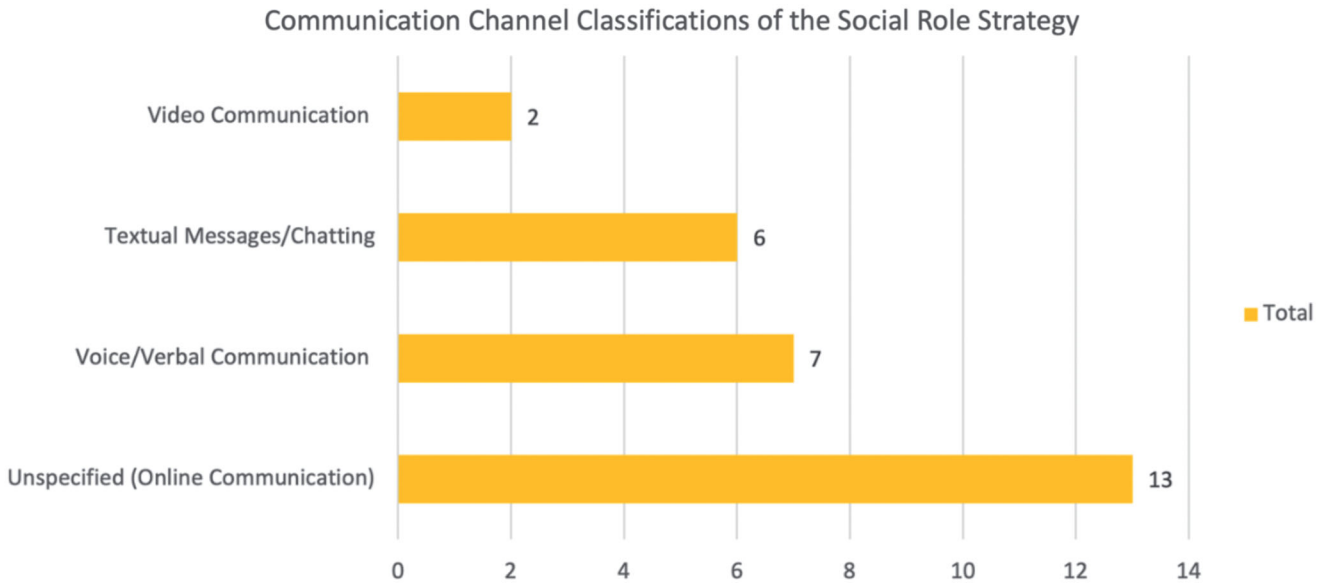

Figure 21. Communication channel classifications of the social role strategy.

The self-report strategy in the mobile-based PT interventions was implemented in many ways. Our findings show the various ways the self-report strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation and their effectiveness. The self-report strategy implementations are as follows:

1. *Entering Feedback and Responses Manually by Users:* Entering feedback and responses manually by users as a self-report strategy was employed in 24 studies (96%) out of 25 articles that employed a self-report strategy. Out of the 24 studies that employed entering feedback and responses manually by users, 15 studies (63%) reported fully successful outcomes, five studies (21%) were partially successful, two studies (8%) did not specify their outcomes, and two studies (8%) had no evaluation. For example, in the ohmage system by Ramanathan et al. (2012), users can manually enter their experience samples (e.g., location and time) as self-report feedback from users to the system. Furthermore, in the Social Coaching application by Simoski et al. (2019), users can respond to the system request by manually entering additional PA exercises (e.g., swimming, squats). As another example, in the TandemTrack application by Luo et al. (2020), the user can respond to the textual pop-up notifications by typing the numbers manually or through a user's voice as input. Moreover, in the mobile application by

Table 15. Examples of social role strategy implementations in the reviewed articles.

#	Social role implementation		Examples
1	Providing a Communication Channel Between Specialists/ Physicians/Coaches and Users/Patients	Unspecified (Online Communication)	• In the CoviHealth application by Villasana et al. (2019), the users can communicate with doctors through the web. • The Teenpower project by Carvalho et al. (2018) provides online communication between teachers and health professionals and between adolescents and health professionals.
		Voice/Verbal Communication	• The TandemTrack application by Luo et al. (2020) provides interactive voice communication between the smart speaker and the users.
		Video Communication	• The Virtual Social Gym system by Far et al. (2014) provides simultaneous video communication between the coach and the user.
2	Problem Solving Provided by the System to Users (e.g., Tips and Common Barriers)	• The BeWell24 application by Buman et al. (2016) employed problem-solving mechanisms through an interactive exercise tips tool.	
3	The Reasoning Engine to Generate Messages or Questions to Get Users' Responses and Feedback	• The Active2Gether application by Klein et al. (2017) generates messages or questions and sends them to the users through the reasoning engine. The reasoning engine collects users' answers and feedback.	
4	The Intelligent Plan Generator to Frequently Check the User's Plan to Change or Edit the Plan	• The PersonalFit application by Oliveira et al. (2016) provides an intelligent plan generator to frequently check the user's plan and determine whether the plan needs to be changed or edited.	

Figure 22. Expertise strategy implementations in the reviewed articles.

Stephenson et al. (2020), the users can enter the time they spent sitting by manually moving a slider of minutes on the time slider.

2. *Manually Posting a Short Description of the Current Status and Exercise Performance on the Social Network "Twitter" by Users:*
Manually posting a short description of the current status and exercise performance on the social network "Twitter" by users as a self-report strategy in the reviewed articles was employed in one study, which reported fully successful outcomes, as shown in the *Twitter Me system* by Young (2010).

4.4.17. Surface credibility strategy

Users can evaluate the system's credibility based on a first-hand assessment. Our findings show that a surface credibility strategy ranked as the seventeenth most commonly employed PS in the mobile-based PT interventions for promoting PA and decreasing SB. Figure 4 shows that 24 studies (12%) of the 198 reviewed articles employed a surface credibility strategy.

The surface credibility strategy in the mobile-based PT interventions was implemented in many ways. Figure 24 shows the various ways the surface credibility strategy was implemented in the PA and SB area, along with the most

Table 16. Examples of expertise strategy implementations in the reviewed articles.

#	Expertise strategy implementation	Examples
1	Health, Fitness, and Software Experts' Aid in Developing the System and a Study Intervention	• In the interactive sensory office chair system with a mobile app (Van Almkerk et al., 2015), four experts were involved in providing feedback and creating the concept: a physiotherapist, a design expert, a chiropractor, and a university professor in rehabilitation sciences. • In the Active 10 application by Ciravegna et al. (2019), a group of experts and stakeholders from Exercise Medicine in Sheffield and the National Centre for Sport were cooperatively involved in designing the PA app intervention.
2	Knowledgeable and Certified Information (e.g., Facts or Healthy Tips or Plans by Certified Medical or Fitness Experts)	• In the CoviHealth application by Villasana et al. (2019), healthcare professionals were involved in setting diet and PA training plans. • The ExSed application by Vasankari et al. (2019) enables a physiotherapist to monitor a user's PA progress and then set PA and SB plans online for a user.
3	Health Experts' Aid in Determining and Customizing PA Exercises and Goals	• All the PA exercises and goals in the Bounce application by Marcu et al. (2018) were determined by medical and behavioral specialists in breast cancer.
4	Health Experts' Participation in a Research Study	• COPD patients from the Hospital and Health Sciences System at the University of Illinois in Chicago participated in a research study for evaluating the GaitTrack system by Cheng et al. (2013).
5	Communication Channel Between Users and Health Experts	• The Teenpower application by Carvalho et al. (2018) employed a communication channel between users and health professionals through a web service.

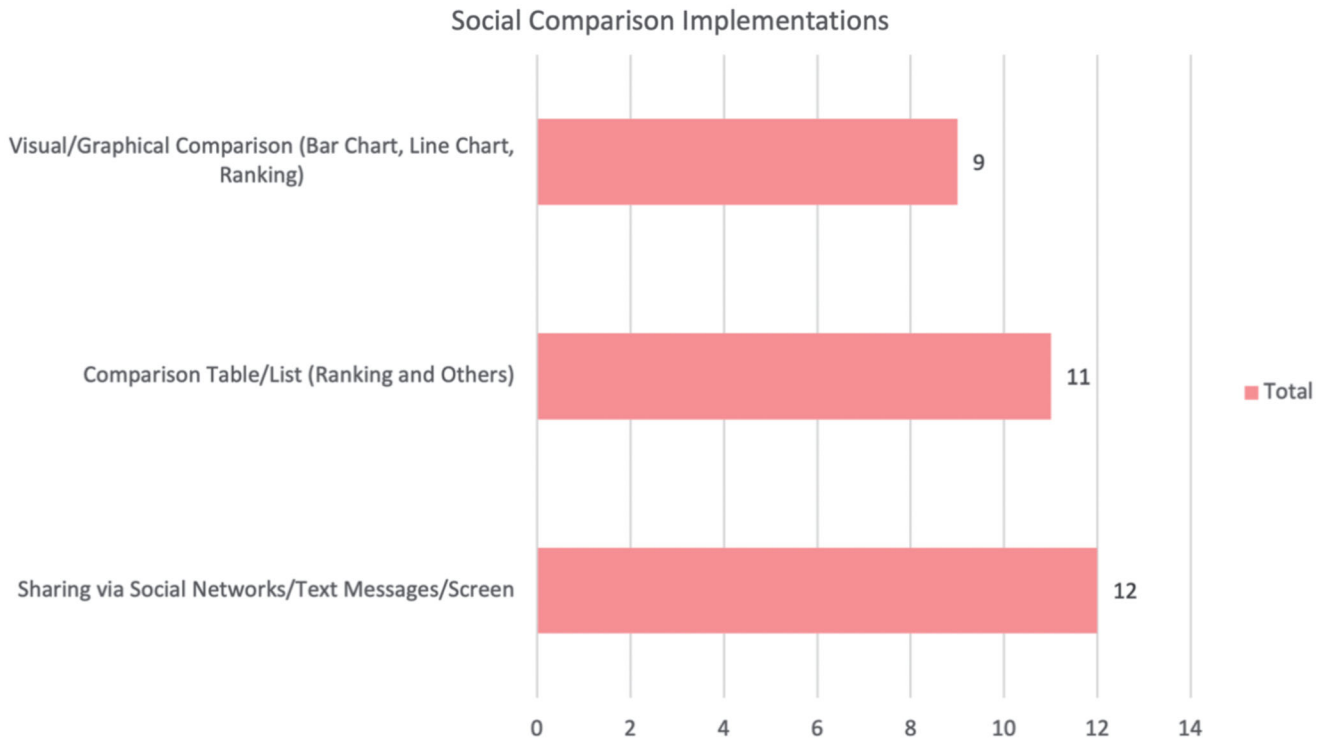

Figure 23. Social comparison strategy implementations in the reviewed articles.

and least frequent forms of implementation. Table 18 provides examples of each implementation of a surface credibility strategy in the reviewed articles.

Our findings show the effectiveness of a surface credibility strategy-based implementation for mobile-based PT interventions for promoting PA and reducing SB. The implementation of providing security norms as a surface credibility strategy was employed in 15 studies, out of which five studies (33%) reported fully successful outcomes, three studies (20%) showed partially successful outcomes, one study (7%) was unsuccessful, and six studies (40%) provided no evaluation for their system design. Out of the 14 studies that provided privacy norms as a surface credibility strategy, six studies (43%) were fully successful, three studies (21%) reported partially successful outcomes, and five studies (36%) had no evaluation.

4.4.18. Simulation strategy

Regarding our findings in this review paper, Figure 4 shows the employment of a simulation strategy in the mobile-based PT interventions in the reviewed articles. The simulation strategy was employed in 26 studies (13%) of the 198 articles included in our review paper to promote PA and reduce SB.

The simulation strategy in the mobile-based PT interventions was implemented in many ways. Figure 25 shows the various ways the simulation strategy was implemented in

Table 17. Examples of social comparison strategy implementations in the reviewed articles.

#	General classification of a social comparison strategy	Social comparison strategy implementations	Examples
1	Sharing via Social Networks/Text Messages/Screen	Sharing via Social Networks	• The SitCoach application by Dantzig et al. (2013) allows users to share their PA performance with peer users and compare their progress with other users' progress.
		Sharing via Text Messages	• The Chick Clique application by Toscos et al. (2006) allows the users to share their PA performance and progress and make a walking activity plan via text message exchanges.
		Sharing via Displaying on a Shirt's Screen	• The Social Fabric Fitness system by Mauriello et al. (2014) introduces a wearable and glanceable e-textile shared screen on the back of the wearer's shirt. The system provides this methodology of sharing PA performance and progress to motivate users and increase their awareness.
2	Comparison Table/List (Ranking and Others)	Comparison Table as a Leaderboard Ranking	• The StepByStep application by Zuckerman and Gal-Oz (2014) provides a real-time comparison table in the form of a leaderboard ranking of users' performance to employ a social comparison element.
		Comparison Table	• The BEN'FIT application by Oyibo et al. (2019) enables users to see each other's PA performance by displaying a comparison table that includes users' goals, PA levels, calories burned, step counts, and number of activities.
		Comparison List	• The Evitapp application by Bascur et al. (2018) provides a comparison list that includes all users' personal information, including their names, personal images, and occupations. Once a particular user is chosen from the comparison list, the system will display their picture and PA progress.
		Comparison List as a Leaderboard Ranking	• The Phone Row application by Zwinderman et al. (2012) provides a comparison list of the users' racing results as a leaderboard ranking, combining two persuasion strategies: competition and comparison.
3	Visual/Graphical Comparison (Bar Chart, Line Chart, Ranking)	Visual/Graphical Comparison (as a Bar Chart)	• The Shakra application by Anderson et al. (2007) provides a visualized comparison of users' daily activity levels as bar charts.
		Visual/Graphical Comparison (as a Line Chart)	• The gamified fitness mobile application by Altmeyer et al. (2018) provides a visualized graphical comparison of the users' PA performance by a line chart. The users can view each other's nicknames, step counts, and duration of performing PA.
		Visual/Graphical Comparison (a Bar Chart as a Leaderboard Ranking)	• The Active2Gether application by Klein et al. (2017) allows users to see and compare each other's PA performance on two levels: as a group and as an individual. The application provides a bar chart comparison as a leaderboard ranking.

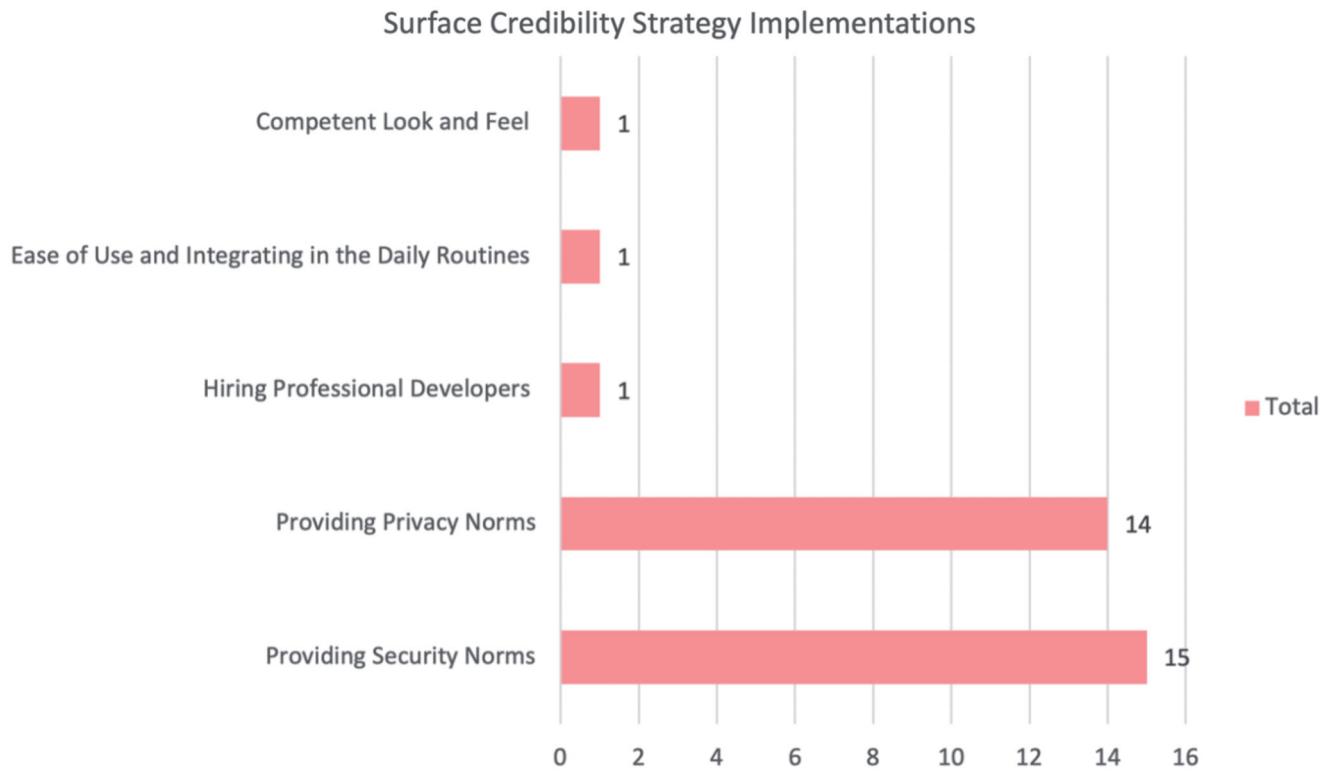

Figure 24. Surface credibility strategy implementations in the reviewed articles.

Table 18. Examples of surface credibility strategy implementations in the reviewed articles.

#	Surface credibility strategy implementation	Examples
1	Providing Security Norms	• The phone row system by Zwinderman et al. (2012) generates a secure QR-code and AppID (a new identifier) every time the user visits the websites for security and verification purposes. • The WEIGHTBIT application by Guida et al. (2017) offers a Rest API to let the medical institutions obtain data easily and provide security and privacy while sharing data. • The PhytoCloud system by Economou et al. (2017) encrypts data files and other related account information for security purposes.
2	Providing Privacy Norms	• The Virtual Social Gym system by Far et al. (2014) represents the user anonymously via visualization of an animated human avatar in a virtual gym environment. • The WEIGHTBIT application by Guida et al. (2017) provides a Rest API to let the medical institutions get data easily and offers security and anonymity for users who share data.
3	Hiring Professional Developers	• Klein et al. (2017) hired professional developers to design the Active2Gether application to increase the system's credibility and give it a good look and feel.
4	Ease of Use and Integration into the Daily Routines	• The Backtive system (Van Almkerk et al., 2015) uses a credibility and expectancy questionnaire (CEQ) to provide an ease of use design of the system that can be integrated into the user's daily routines.
5	Competent Look and Feel	• The BunnyBolt game application by Keung et al. (2013) has a competent look and feel, as it provides well-designed storyline scenarios on a set of screens.

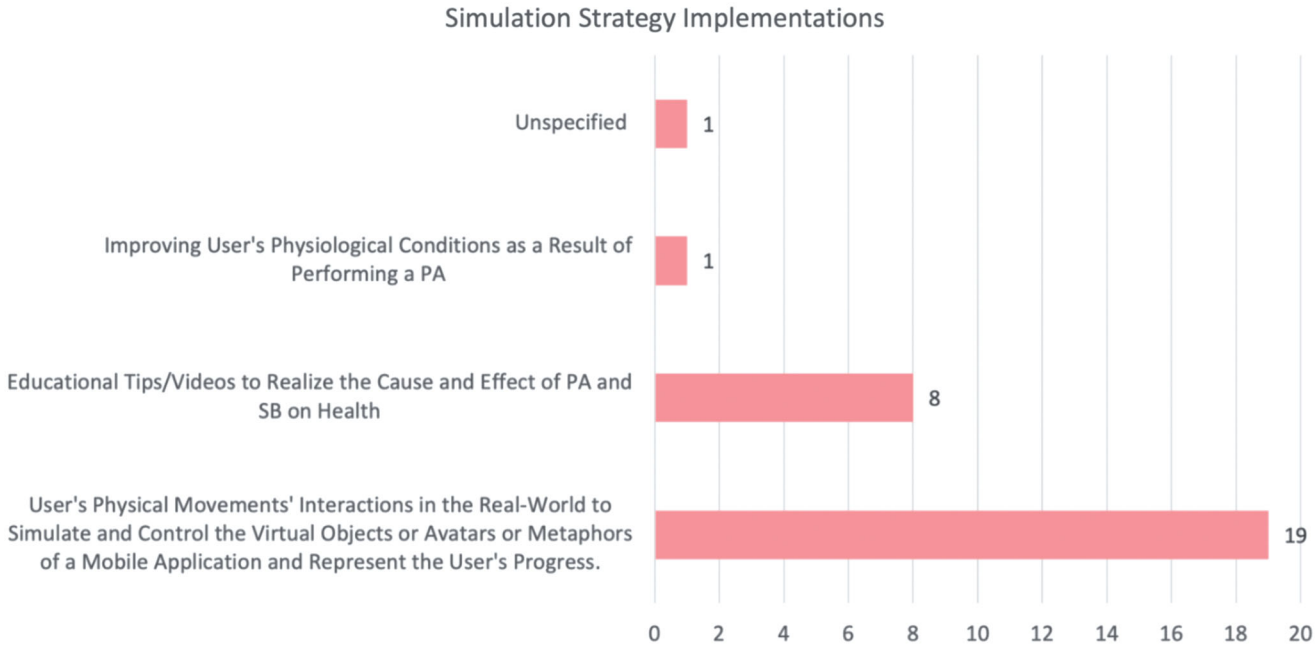

Figure 25. Simulation strategy implementations in the reviewed articles.

the PA and SB area, along with the most and least frequent forms of implementation. Table 19 provides examples of each implementation of a simulation strategy in the reviewed articles.

Our findings present the effectiveness of simulation strategy-based implementations for mobile-based PT interventions in promoting PA and reducing SB. The implementation of the user's physical movement interactions in the real world to simulate and control the virtual objects, avatars or metaphors of a mobile application and represent the user's progress as a simulation strategy was employed in 19 studies, out of which ten studies (53%) reported fully successful outcomes, four studies (21%) showed partially successful outcomes, one study (5%) was unsuccessful, one study (5%) did not specify their outcomes, and three studies (16%) provided no evaluation for their system design.

4.4.19. Social recognition strategy

Figure 4 shows the employment of a social recognition strategy in the mobile-based PT interventions in the reviewed articles. The social recognition strategy was employed in 17 studies (9%) of the 198 articles included in our review paper to promote PA and reduce SB.

The social recognition strategy in the mobile-based PT interventions was implemented in many ways. Figure 26 shows the various ways the social recognition strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation. Table 20 provides examples of each implementation of a social recognition strategy in the reviewed articles.

Our findings show the effectiveness of social recognition strategy-based implementations for mobile-based PT interventions in promoting PA and reducing SB. Implementing a

Table 19. Examples of simulation strategy implementations in the reviewed articles.

#	Simulation strategy implementation	Examples
1	User's Physical Movement Interactions in the Real World to Simulate and Control the Virtual Objects, Avatars or Metaphors of a Mobile Application and Represent the User's Progress.	• The LocoSnake mobile game by *Chittaro and Sioni (2012)* enables the user to control a virtual snake's movements in the game through the user's walking activity in the real world. • In the Phone Row mobile game by *Zwinderman* et al. *(2012)*, the users can control a virtual boat's movements through their actual PA performance. • The Walk2Build application by *Hamilton* et al. *(2012)* represents and simulates the user's walking progress through the visualization of a virtual town. Thus, the more steps achieved by the user, the taller and more prominent the buildings.
2	Educational Tips or Videos to Realize the Cause and Effect of PA and SB on Health	• The BeWell24 application by Buman et al. (2016) provides educational tips to show the link between the cause and effect (e.g., excessive sitting and chronic disease).
3	Improving the User's Physiological Conditions as a Result of Performing a PA	• In the WargaFit application by Mohadis and Ali (2016), the user can notice the cause and effect relationship between practicing PA and improving their physiological health.
4	Unspecified	• The Active2Gether application by Klein et al. (2017) indicates the employment of a simulation strategy without specifying exactly how it has been employed.

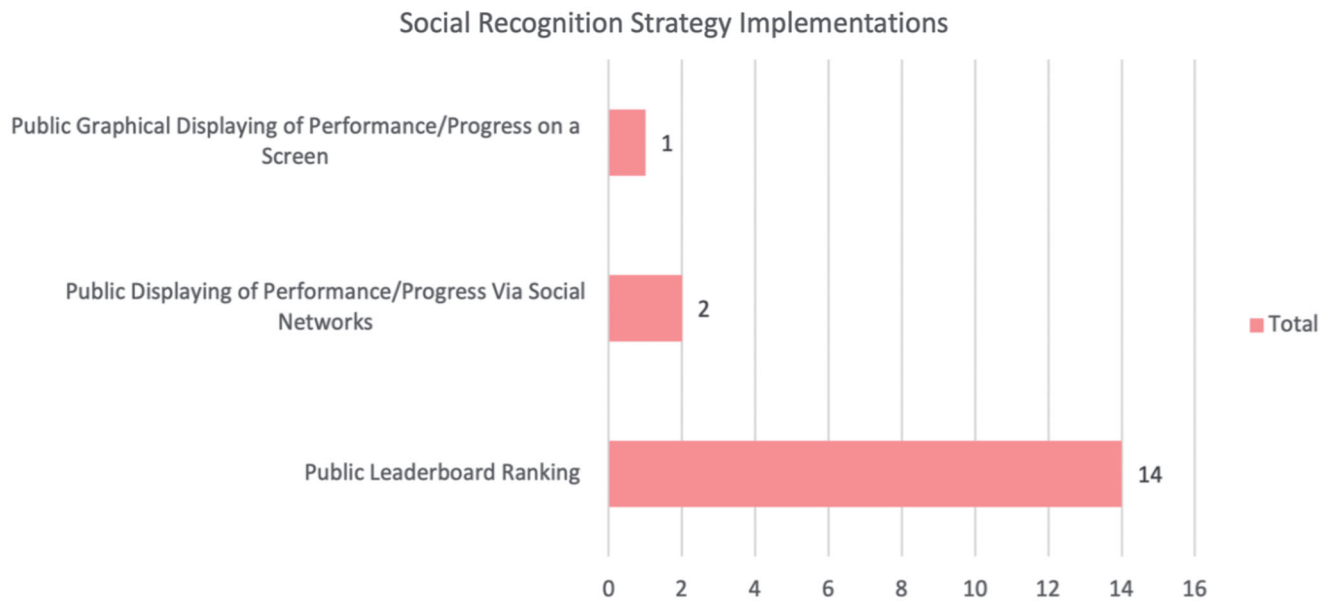

Figure 26. Social recognition strategy implementations in the reviewed articles.

Table 20. Examples of social recognition strategy implementations in the reviewed articles.

#	Social recognition strategy implementation	Examples
1	Public Leaderboard Ranking	• The GeoFit application by Terry et al. (2015) provides a ranking list of the top PA performers with displays of their progress. • The WeRun application by Gui et al. (2017) ranks the users' daily steps and the step counts of their contacts automatically.
2	Public Display of Performance/Progress Via Social Networks	• The Super Starfish Mania application by Schagen et al. (2015) displays users' collections publicly to other users or groups online. • The iCanFit application by Hong et al. (2013) displays the PA performance of users who achieved their PA goals online.
3	Public Graphical Display of Performance/Progress on a Screen	• The gamified mobile application by Altmeyer et al. (2018) provides a public graphical display of the users' step counts from the last week on a screen.

public leaderboard ranking as a social recognition strategy was employed in 14 studies, out of which eight studies (57%) reported fully successful outcomes, four studies (29%) were partially successful, one study (7%) was unsuccessful, and one study (7%) provided no evaluation of their system design. Out of the two studies that implemented a public display of performance/progress via social networks as a social recognition strategy, one study (50%) was fully successful, and one study (50%) had no evaluation.

4.4.20. Liking Strategy

Figure 4 shows the employment of a liking strategy in the mobile-based PT interventions in the reviewed articles. A liking strategy was employed in 15 studies (8%) of the 198 articles included in our review paper to promote PA and reduce SB.

The liking strategy in the mobile-based PT interventions was implemented in many ways. Figure 27 shows the various ways the liking strategy was implemented in the PA and

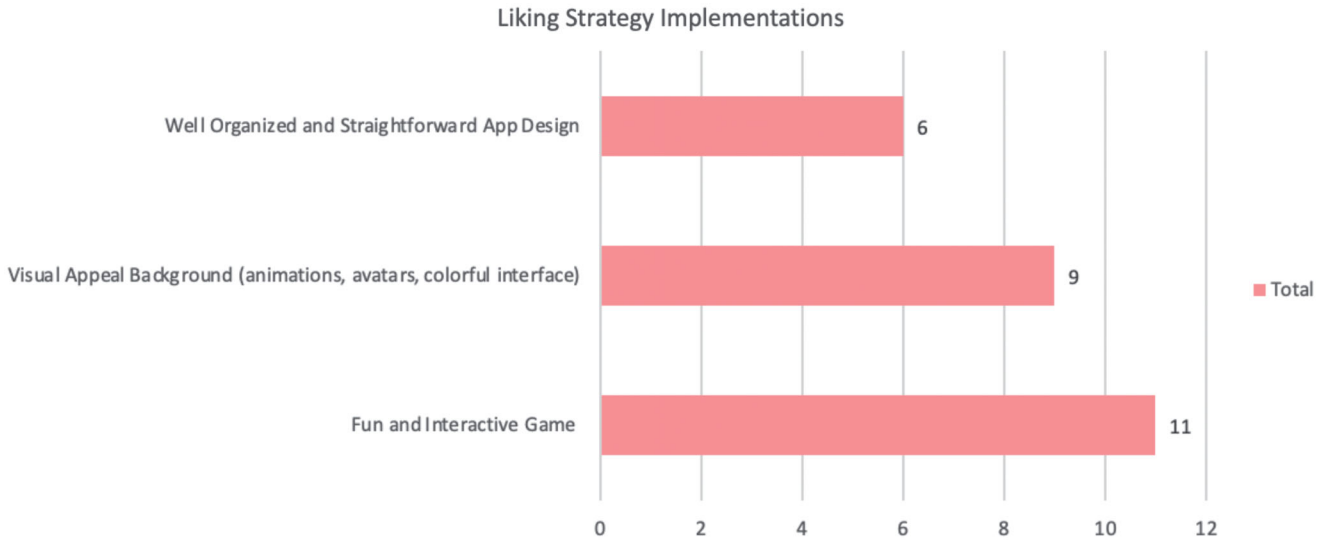

Figure 27. Liking strategy implementations in the reviewed articles.

Table 21. Examples of liking strategy implementations in the reviewed articles.

#	Liking strategy implementation	Examples
1	Visual Appeal Background (animations, avatars, colorful interface)	• The Puzzle Walk application by Lee et al. (2018) provides a visually attractive look and appealing user interface. • The BeWell + application by Lane et al. (2014) provides a visually appealing fish animation ambient display on the background screen.
2	Fun and Interactive Game	• The Storywell application by Saksono et al. (2020) provides fun and interactive game elements; for example, spinning the magic needle will open the next chapter of the story. The application also has appealing interfaces. • The Pokémon GO application (Howe et al., 2016), (Pokémon Company, 2016) shows users a fun and interactive game.
3	Well-Organized and Straightforward App Design	• The design of the On11 application by He and Agu (2014) is straightforward and well-organized, and the background is visually appealing to the users.

SB area, along with the most and least frequent forms of implementation. Table 21 provides examples of each implementation of a liking strategy in the reviewed articles.

Our findings show the effectiveness of a liking strategy-based implementation for mobile-based PT interventions in promoting PA and reducing SB. Out of the 11 studies that implemented fun and interactive games as a liking strategy, five studies (46%) were fully successful, three studies (27%) were partially successful, one study (9%) was unsuccessful, and two studies (18%) had no evaluation. Implementing a visually appealing background (e.g., animations, avatars, colorful interface) as a liking strategy was employed in nine studies, out of which three studies (33%) reported fully successful outcomes, four studies (45%) were partially successful, one study (11%) was unsuccessful, and one study (11%) provided no evaluation for their system design.

4.4.21. Normative influence strategy

Figure 4 shows the employment of a normative influence strategy in the mobile-based PT interventions in the reviewed articles. The normative influence strategy was employed in 13 studies (7%) of the 198 articles included in our review paper to promote PA and reduce SB.

The normative influence strategy in the mobile-based PT interventions was implemented in many ways. Figure 28 shows the various ways the normative influence strategy was implemented in the PA and SB area, along with displaying the most and least frequent forms of implementation. Table 22 provides examples of each implementation of a normative influence strategy in the reviewed articles. The normative influence strategy implementations are as follows:

1. *Joining or creating a group to share and observe each other's experiences:*
   Joining or creating a group to share and observe each other's experiences was implemented in eight studies (62%) as a normative influence strategy, out of which six studies (74%) reported fully successful outcomes, one study (13%) did not specify their outcomes, and one study (13%) had no evaluation.
2. *Connecting and the public display of each other's performance (Numerical, Visual, Graphical Feedback):*
   The implementation of connecting and the public display of each other's performance (as numerical, visual, or graphical feedback) as a normative influence strategy was employed in two studies (15%) out of 13 articles that employed a normative influence strategy. Out of

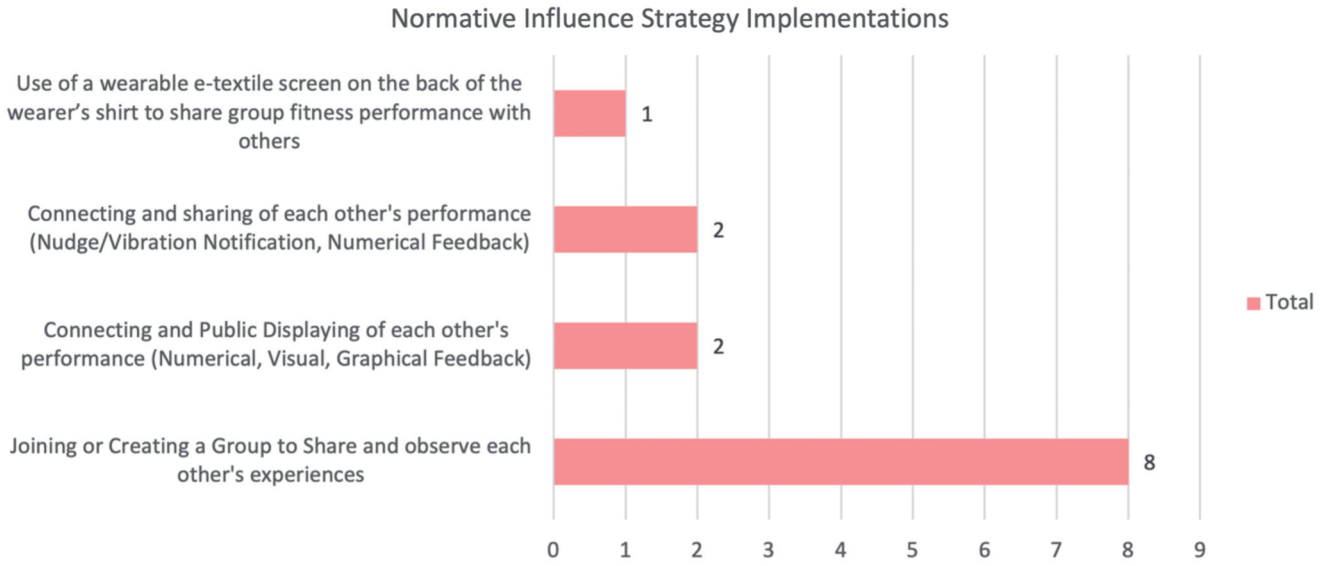

Figure 28. Normative influence strategy implementations in the reviewed articles.

Table 22. Examples of normative influence strategy implementations in the reviewed articles.

#	Normative influence strategy implementation	Examples
1	Connecting and public display of each other's performance (Numerical, Visual, Graphical Feedback)	• The gamified mobile application by Altmeyer et al. (2018) allows users to share experiences and observe others' performance by searching through a list of members who have similar profiles.
2	Connecting and sharing each other's performance (Nudge/Vibration Notification, Numerical Feedback)	• The PhytoCloud application by Economou et al. (2017) allows users to share experiences and observe others' performance by searching through a list of members who have similar profiles.
3	Joining or creating a group to share and observe each other's experiences	• The Bounce application by Marcu et al. (2018) allows users who have some common points or goals (e.g., the same activity level, the same age group, or similar surgeries or treatments) to connect with each other remotely and share their experiences by joining or creating a group.
4	Using a wearable e-textile screen on the back of the wearer's shirt to share the group's fitness performance with others	• The Social Fabric Fitness application by Mauriello et al. (2014) provides a shared screen as a wearable e-textile display on the back of a runner's shirt to leverage peer pressure, motivation, and awareness of all runners' performance.

these, one study (50%) reported fully successful outcomes, and one study (50%) was partially successful.

3. *Connecting and sharing of each other's performance (Nudge/Vibration Notification, Numerical Feedback):* Two studies (15%) employed the connecting and sharing of each other's performance (nudge/vibration notification, numerical feedback) as a normative influence strategy. Out of these two studies, one study (50%) was partially successful, and one study (50%) had no evaluation.
4. *Using a wearable e-textile screen on the back of the wearer's shirt to share group fitness performance with others:*

Only one study (8%) implemented a wearable e-textile screen on the back of the wearer's shirt to share group fitness performance with others as a normative influence strategy, which reported fully successful outcomes.

4.4.22. Social learning strategy

When individuals can observe other users performing a target behavior, they will be more influenced to do the intended behavior. Figure 4 shows the employment of a social learning strategy in the mobile-based PT interventions in the reviewed articles. The social learning strategy was employed in 12 studies (6%) of the 198 articles included in our review paper to promote PA and reduce SB.

The social learning strategy in the mobile-based PT interventions was implemented in many ways. Figure 29 shows the general classifications of the social learning strategy implemented in the PA and SB area, along with the most and least frequent forms of implementation. Table 23 provides examples of each implementation of a social learning strategy in the reviewed articles. We present the most and least frequently employed implementation examples in the following:

1. *Visual and Numerical Feedback:* The implementation of displaying the PA progress of other users as visual and numerical feedback as a social learning strategy was employed in ten studies (83%) out of 12 articles that employed a social learning strategy. Out of these, five studies (50%) reported fully successful outcomes, three studies (30%) were partially successful, and two studies (20%) had no evaluation.
2. *Textual Feedback:* The implementation of displaying the PA progress of other users as textual feedback as a social learning

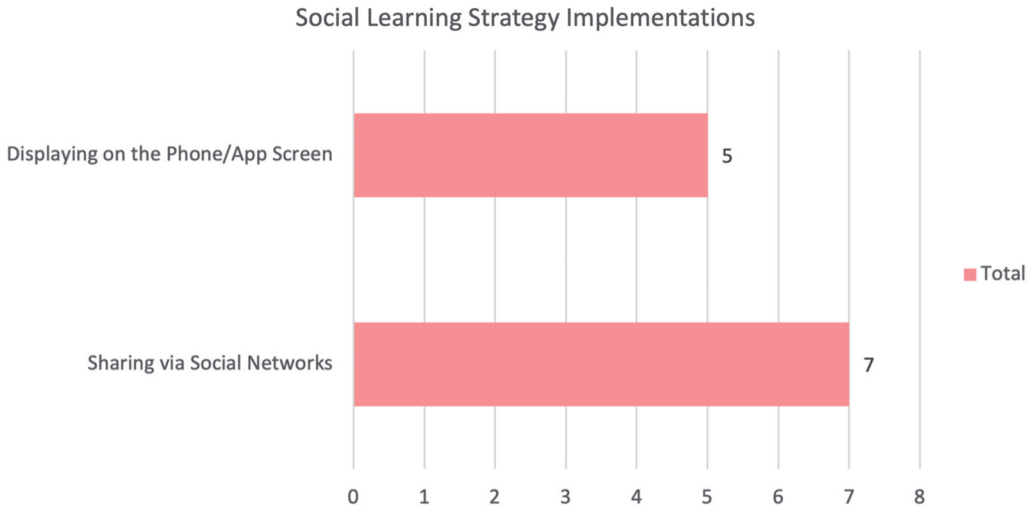

Figure 29. Social learning strategy implementations in the reviewed articles.

Table 23. Examples of social learning strategy implementations in the reviewed articles.

#	Social learning strategy implementation		Examples
1	Displaying the PA Progress of Other Users through Sharing on Social Networks	Visual and Numerical Feedback	• The BEN'FIT application by Oyibo et al. (2019) displays a user's PA performance (e.g., step count, calories burned, number of activities, PA level), allowing users to view each other's performance.
		Textual Feedback (Textual Message Notifications)	• The StepMatron application by Foster et al. (2010) allows users to share their PA performance via textual messages on Facebook, enabling them to view each other's step counts and their PA progress.
		Colored Light Feedback	• The KidLED application by Samariya et al. (2019) allows children to share their PA as a simple colored light, and their performance can be viewed by other children.
2	Displaying the PA Progress of Other Users on the Screen	Visual and Numerical Feedback	• The mobile application by Gasser et al. (2006) enables users to view other team members' PA performance by displaying their progress on the screen as visual and numerical feedback.

strategy was employed in only one study (8%) out of 12 studies that employed a social learning strategy. This study reported fully successful outcomes.

3. *Colored Light Feedback:*
   The implementation of displaying the PA progress of other users as colored light feedback as a social learning strategy was employed in only one study (8%) out of 12 studies that employed a social learning strategy. This study provided no evaluation for its system design.

Our findings show the effectiveness of social learning strategy-based implementations for mobile-based PT interventions for promoting PA and reducing SB. Displaying the PA progress of other users through sharing on social networks as a social learning strategy was employed in seven studies, out of which three studies (42%) reported fully successful outcomes, two studies (29%) were partially successful, and two studies (29%) provided no evaluation for their system design. Out of the five studies that implemented the display of the PA progress of other users on a screen as a social learning strategy, three studies (60%) were fully successful, one study (20%) was partially successful, and one study (20%) had no evaluation.

4.4.23. Verifiability strategy

Figure 4 shows the employment of a verifiability strategy in the mobile-based PT interventions in the reviewed articles. A verifiability strategy was employed in seven studies (4%) of the 198 articles included in our review paper to increase PA and decrease SB.

The verifiability strategy in the mobile-based PT interventions was implemented in one way. Our findings show how the verifiability strategy was implemented in the PA and SB areas and their effectiveness. The verifiability strategy implementation is as follows:

1. *Providing External Links to Sources:*
   Providing external links to sources as a verifiability strategy was employed in seven studies (100%) out of seven articles that employed a verifiability strategy. Out of the seven studies that employed a verifiability strategy, five studies (71%) reported fully successful outcomes, and two studies (29%) had no evaluation; these were the WargaFit application by Mohadis and Ali (2016), the iCanFit application by Hong et al. (2013), and the Teenpower application by Carvalho et al. (2018).

4.4.24. Authority strategy

A system can gain enhanced persuasion power if it leverages the role of authority (Harri & Marja, 2009). Figure 4 shows that 3% of the studies employed an authority strategy in the mobile-based PT interventions. The authority strategy was employed in five studies (3%) of the 198 articles included in our review paper to promote PA and reduce SB.

The authority strategy in the mobile-based PT interventions was implemented in different ways. Our findings show the various ways the authority strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation. Furthermore, the findings also show the effectiveness of authority strategy-based implementations for mobile-based PT interventions in promoting PA and reducing SB. The authority strategy implementations (in order from the most frequently employed implementations on the top to the least frequently employed on the bottom) are as follows:

1. *Use of the OAuth 2.0 Protocol:*
   An OAuth 2.0 protocol as an authority strategy was the most employed form of implementation, with two studies (40%) out of five articles that employed an authority strategy. The two studies that employed an OAuth 2.0 protocol provided no evaluation for their system design. For example, the PRO-Fit application by Dharia et al. (2016) and the Teenpower application by Carvalho et al. (2018) employed authorization and authentication using the OAuth 2.0 protocol. The applications support the integration of different service providers (e.g., Hotmail, Google, and Yahoo), and the OAuth 2.0 access token validates the identification of an API consumer.The OAuth application is an industry-standard protocol. It provides specific authorization flows for web applications, desktop applications, mobile phones, and living room devices for authorization that supports the integration of different service providers (e.g., Google,). So, employing the OAuth 2.0 protocol refers to the authorization of the service providers, which are the "people or organizations in the role of authority."
2. *A Medical Oncology Specialist that Provides Trusted Verbal Persuasion:*
   A medical oncology specialist that provides trusted verbal persuasion as an authority strategy in the reviewed articles was employed in one study, which reported fully successful outcomes. For example, the Bounce application by Marcu et al. (2018) provides trusted and authorized verbal persuasion from a medical oncology specialist.
3. *Allowing Users to Access Authoritative Health Information via a 'Library' Function:*
   Allowing users to access authoritative health information via a "library" function as an authority strategy was implemented in one study, which was fully successful. The iCanFit application by Hong et al. (2013) provides a "Library" function to enable users to access authoritative health information and connections to the main health and cancer survivor administrations.
4. *Using Government Guidelines Informed by Scientific Literature:*
   The employment of government guidelines informed by scientific literature as an authority strategy was implemented in one study, which had no evaluation for its system design. The PhytoCloud application by Economou et al. (2017) helps women track their diets and general lifestyle and provides them with advice based on government guidelines verified by scientific literature.

4.4.25. Third-Party endorsement strategy

Figure 4 shows the employment of a third-party endorsement strategy in the mobile-based PT interventions in the reviewed articles. The third-party endorsement strategy was employed in five studies (3%) of the 198 articles included in our review paper to promote PA and reduce SB.

The third-party endorsement strategy in the mobile-based PT interventions was implemented in different ways. Our findings reveal the various ways the third-party endorsement strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation and their effectiveness. The third-party endorsement strategy implementations are as follows:

1. *Determining PA goals based on Ministry of Health guidelines:*
   Determining PA goals based on Ministry of Health guidelines as a third-party endorsement strategy was employed in one study (20%) out of five articles that employed a third-party endorsement strategy; this was the WargaFit application by Mohadis and Ali (2016), which reported fully successful outcomes.
2. *Providing access to authoritative health information via a "Library" function and providing links to major senior health and cancer survivor organizations:*
   One study employed a third-party endorsement strategy to provide access to authoritative health information via a "library" function and links to major senior health and cancer survivor organizations as a third-party endorsement strategy in the reviewed articles. This study reported fully successful outcomes, as shown in the iCanFit application by Hong et al. (2013).
3. *Patients have direct and automatic communication with a doctor, and they perform the exercises specified by the doctor:*
   Allowing patients to have direct and automatic communication with a doctor and performing the exercises specified by the doctor as a third-party endorsement strategy was implemented in one study, which provided no evaluation for its system design, as shown in the WEIGHTBIT application by Guida et al. (2017).
4. *Providing a connection to an extended version of an existing data source, including data analysis on phytoestrogens:*
   Providing a connection to an extended version of an existing data source, including data analysis on phytoestrogens as a third-party endorsement strategy, was

implemented in one study, which had no evaluation for its system design, as shown in the PhytoCloud application by Economou et al. (2017).

5. *Providing educational resources as showcase content such as videos, suggestions, manuals, links, interactive content, and challenges:*
   Providing educational resources as showcase content such as videos, suggestions, manuals, links, interactive content, and challenges as a third-party endorsement strategy was implemented in one study, which had no evaluation for its system design, as shown in the Teenpower application by Carvalho et al. (2018).

4.4.26. Trustworthiness strategy

Figure 4 shows the employment of a trustworthiness strategy in the mobile-based PT interventions in the reviewed articles. The trustworthiness strategy was employed in five studies (3%) of the 198 articles included in our review paper to promote PA and reduce SB.

The trustworthiness strategy in the mobile-based PT interventions was implemented in different ways. Our findings show the various ways the trustworthiness strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation and their effectiveness. The trustworthiness strategy implementations are as follows:

1. *Trustworthy Source of Information (e.g., Healthy Tips from Physicians and Health Specialists):*
   Implementing a trustworthy source of information (e.g., healthy tips from physicians and health specialists) as a trustworthiness strategy was employed in three studies (60%) out of five articles that employed a trustworthiness strategy, as shown in the *CoviHealth* application by Villasana et al. (2019), stAPP application by Arrogi et al. (2019), and iCanFit application by Hong et al. (2013). Out of the three studies that employed a trustworthy source of information, two studies (67%) reported fully successful outcomes, and one study (33%) was partially successful.
2. *Frequently Asked Questions (FAQs) Tab and Cautionary Warnings by Medical Professionals:*
   The implementation of a frequently asked questions (FAQs) tab and cautionary warnings by medical professionals as a trustworthiness strategy was employed in one study, which reported fully successful outcomes, as shown in the Bounce application by Marcu et al. (2018).
3. *Health and Computer Scientists' Assistance for Developing Systems and Technologies:*
   Using health and computer scientists' assistance for developing systems and technologies as a trustworthiness strategy was implemented in one study, which reported partially successful outcomes, as shown in the PhytoCloud application by Economou et al. (2017).

4.4.27. Real-world feel strategy

Figure 4 shows the employment of a real-world feel strategy in the mobile-based PT interventions in the reviewed articles. The real-world feel strategy was employed in four studies (2%) of the 198 articles included in our review paper to promote PA and reduce SB.

The real-world feel strategy in the mobile-based PT interventions was implemented in some studies. Our findings show how the real-world feel strategy was implemented in the PA and SB area and its effectiveness. The real-world feel strategy implementation is as follows:

1. *Highlighting the Organizations or People Behind the System Services or Content by Asking Questions/Inquiries or Sending Feedback:*
   Highlighting the organizations or people behind the system services or content by asking questions/inquiries or sending feedback by users as a real-world feel strategy was employed in four studies (100%) out of four articles that employed a real-world feel strategy. Out of the four studies that employed a real-world feel strategy, three studies (75%) reported fully successful outcomes, and one study (25%) was partially successful. Our findings show some examples of the organizations and people behind a system's content and services to employ a real-world feel strategy in the reviewed articles. These examples include the Senior Health and Cancer Survivor organizations, as shown in the *iCanFit* application by Hong et al. (2013); the National Centre for Sport and Exercise Medicine in Sheffield, as shown in the Active 10 application by Ciravegna et al. (2019); the Veterans Health Administration, as shown in the BeWell24 application by Buman et al. (2016); and the News Feed Journal, as shown in the WargaFit application by Mohadis and Ali (2016).

4.4.28. Similarity strategy

Figure 4 shows the employment of a similarity strategy in the mobile-based PT interventions in the reviewed articles. A similarity strategy was employed in only two studies (1%) of the 198 articles included in our review paper to increase PA and decrease SB.

A similarity strategy in the mobile-based PT interventions was implemented in different ways. Our findings show the various ways the similarity strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation and their effectiveness. The similarity strategy implementations are as follows:

1. *Allowing users to identify themselves by choosing nicknames and colors:*
   Allowing users to identify themselves by choosing nicknames and colors as a similarity strategy was employed in one study (50%) out of the two articles that employed a similarity strategy; this study reported partially successful outcomes, as shown in the gamified mobile application by Altmeyer et al. (2018).
2. *Using images to make older office workers feel familiar:*
   Using images to make older office workers feel familiar as a similarity strategy in the reviewed articles was employed in one study, which reported fully successful outcomes, as shown in the WargaFit application by Mohadis and Ali (2016).

4.4.29. Social facilitation strategy

Figure 4 shows the employment of a social facilitation strategy in the mobile-based PT interventions in the reviewed articles. The social facilitation strategy was employed in only two studies (1%) of the 198 articles included in our review paper to increase PA and decrease SB.

The social facilitation strategy in the mobile-based PT interventions was implemented in different ways. Our findings show the various ways the social facilitation strategy was implemented in the PA and SB area, along with the most and least frequent forms of implementation and their effectiveness. The social facilitation strategy implementations are as follows:

1. *Newsfeed displaying other users performing PA at the same time:*
   Implementing a newsfeed displaying other users performing PA at the same time as a social facilitation strategy was employed in one study (50%) out of the two articles that employed a social facilitation strategy; these studies reported fully successful outcomes, as shown in the WargaFit application by Mohadis and Ali (2016).
2. *The success of each member of the team is visible to the team, and the success of the whole team is visible to the team and other teams:*
   One study employed making the success of each member of the team visible to the team and the success of the whole team visible to the team and other teams as a social facilitation strategy; this study reported fully successful outcomes, as shown in the mobile application by Gasser et al. (2006).

4.4.30. Rehearsal strategy

Figure 4 shows the employment of a rehearsal strategy in the mobile-based PT interventions in the reviewed articles. The rehearsal strategy was employed in only one study (1%) of the 198 articles included in our review paper to increase PA and decrease SB.

The rehearsal strategy in the mobile-based PT interventions was implemented in one way. Our findings show the way the rehearsal strategy was implemented in the PA and SB area and its effectiveness. The rehearsal strategy implementation is as follows:

1. *Video Tutorial on How to Do Stretching at Work:*
   A video tutorial on how to do stretching at work as a rehearsal strategy was employed in one study, which reported fully successful outcomes, as shown in the WargaFit application by Mohadis and Ali (2016).

4.5. Comparative effectiveness of PTs by PS

Figure 30 compares the effectiveness of the PSs implemented in mobile-based PT interventions in the reviewed articles to increase PA and reduce SB. We noticed that some PSs were employed more frequently than others. However, some strategies influenced users' behavior to adopt the desired behavior change, such as increasing PA levels, more than others. A tracking or self-monitoring strategy was implemented in 192 studies (97%) out of the 198 reviewed articles, out of which 107 studies (56%) were fully successful, 50 studies (26%) were partially successful, three studies (2%) reported unsuccessful outcomes, seven studies (4%) did not specify their outcomes, and 25 studies (13%) did not evaluate their PT systems.

We categorize the most frequently employed PSs in the reviewed articles based on the total number of successful studies (whether fully or partially successful) to evaluate the effectiveness of each PS. As illustrated in Figure 30, out of the total number of articles that applied each PS (refer to Section 4.2), the tracking/self-monitoring strategy was the most effective PS, with 157 studies (82%) that reported successful outcomes. The reminder strategy ranked second with 73 successful studies (84%). The goal-setting strategy ranked third with 71 successful studies (79%). The reward strategy ranked fourth with 65 successful studies (79%). The personalization strategy came in fifth place with 59 studies (77%) that reported successful outcomes, followed by praise, tailoring, reduction, and tunneling strategies with a total of 48 successful studies (79%), 39 successful studies (83%), 35 successful studies (76%), and 34 successful studies (79%), respectively. Social competition, suggestion, and social cooperation strategies ranked eleventh with 30 successful studies (81%), (86%), and (83%), respectively. This is followed by social role, expertise, self-report, social comparison, and simulation strategies with 26 successful studies (74%), 22 successful studies (73%), 21 successful studies (84%), 20 successful studies (80%), and 20 successful studies (77%), respectively. The social recognition strategy ranked seventeenth with 14 successful studies (82%), followed by the liking strategy with 13 successful studies (87%). We followed the same methodology to evaluate the effectiveness of the remaining PSs.

Briefly, we observed that the twelve most effective PSs implemented in the mobile-based PT interventions in the reviewed articles were tracking/self-monitoring, reminder, goal setting, reward, personalization, praise, tailoring reduction, tunneling, social competition, suggestion, and social cooperation strategies.

5. Discussion

This paper focuses on delivering a comprehensive systematic review of the PSs used in mobile-based PT interventions for supporting PA and decreasing SB. This study aims to (1) evaluate the effectiveness of different ways of implementing PSs on mobile-based PT interventions that aim to motivate users to increase their PA and reduce their time spent sedentary, (2) show the different classification-based implementations for each PS, (3) show the weaknesses and strengths of the intervention-based strategies and implementations, (4) provide a comparison of the different ways of implementing each PS, (5) highlight the limitations and pitfalls of the existing research and PT interventions, and (6) give recommendations and directions for future research.

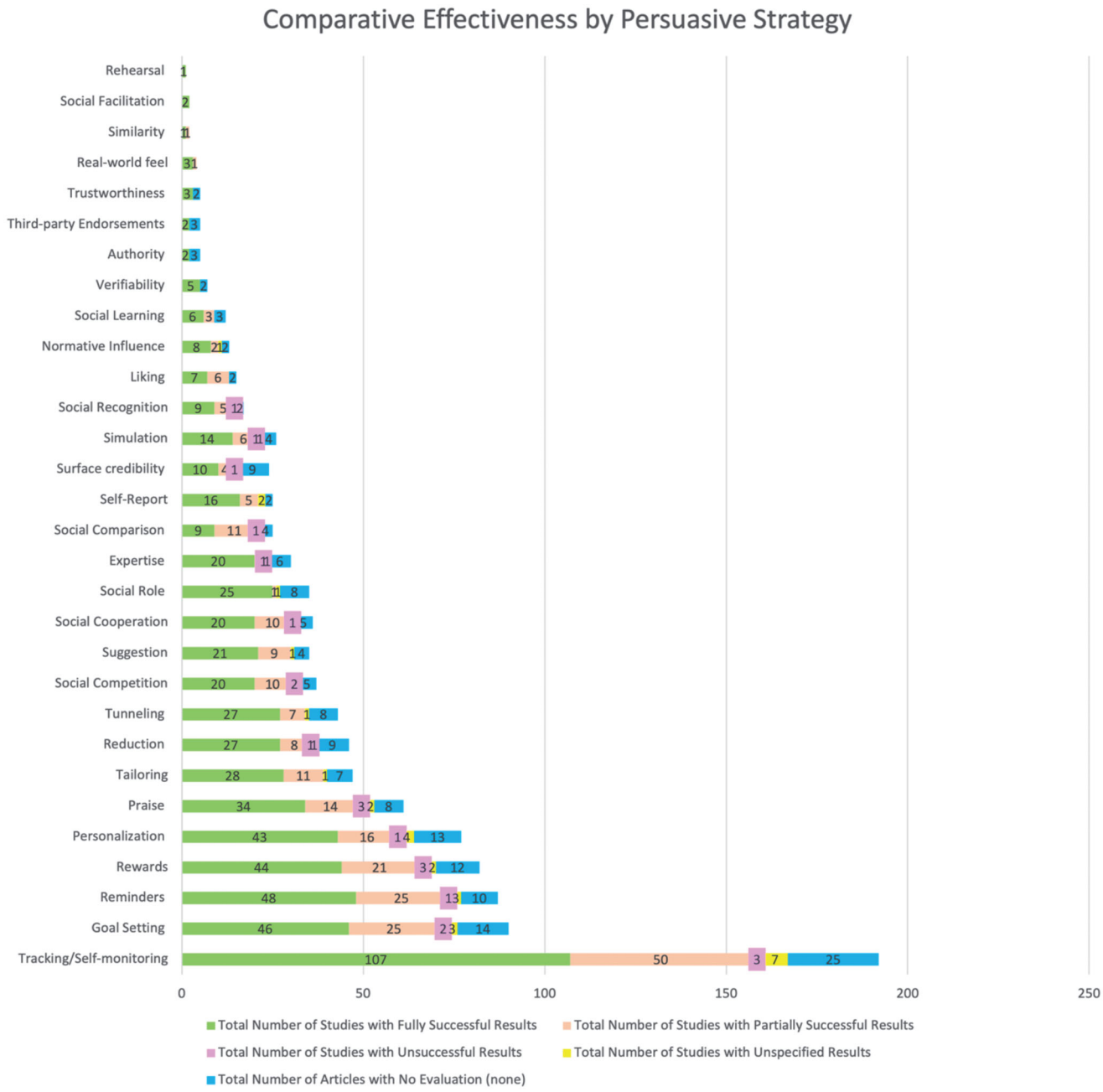

Figure 30. Comparative effectiveness by persuasive strategy.

5.1. PSs and their implementations

This section aims to answer RQ1 (What PSs were used in designing mobile-based PTs for PA and SB?) and RQ2 (What are the various ways that PSs were implemented in mobile-based PTs for PA and SB?). Our findings (presented in Section 4.2) show that the 15 most frequently employed PSs on mobile-based PTs for PA and SB domains, ordered from the most to the least frequently employed, were tracking/self-monitoring, goal-setting, reminder, reward, personalization, praise, tailoring, reduction, tunneling, social competition, suggestion, social cooperation, social role, expertise, and social comparison. On the other hand, the least frequently used strategy is rehearsal, followed by social facilitation and similarity. Figure 4 summarizes these results. The results presented in Section 4.3 indicate that the Primary Task Support Category is the most frequently employed category in the articles based on the PSD model. All the papers employed strategies belonging to this category, and the total number of times strategies were employed was 427. On the other hand, strategies belonging to the System Credibility Support category were the least employed.

In regard to the implementation of each PS, we found that most of the reviewed studies employed more than one strategy in their mobile-based PT designs to realize the targeted PA behavioral change goal. Each strategy is implemented in multiple ways across the literature. For example, the cooperation strategy was implemented in five different

ways, and the reduction strategy was implemented in 12 different ways. Section 4.4 shows the complete results regarding the different forms of implementation.

5.2. The relationship between the PS implementation type and effectiveness of mobile-based PTs

This section answers RQ3 (What is the relationship between the PSs' implementation type and their effectiveness?). This paper sheds light on the different ways of implementing each PS, provides examples of each type of implementation from the reviewed studies, and compares the effectiveness of each implementation based on the total number of successful studies that employed each form of implementation. This way of measuring is not precisely accurate, as the effectiveness of each study is often related to various factors and aspects such as the target population (e.g., age, health condition, occupation, gender, sample size, etc.), the objective of the study, domain, environment (e.g., weather, location), technology platforms, and PSs employed. It is worth noting that it is not easy to accurately state and measure the effectiveness of each PS and its implementation because most of the reviewed studies employed more than one PS, and each strategy might be implemented in different ways. Thus, it is almost impossible to measure the effectiveness of each PS and its implementations. The following are the most important observations and findings from this study:

1. The majority of the reviewed studies employ more than one PS, and each PS was employed in one or more different ways.
2. A single type of implementation can be considered a way of implementing multiple strategies. For example, delivering textual messages in the "*Alert Me*" application by Fahim et al. (2017) to the user regarding their PA performance and sedentary behavior can be considered a self-monitoring, personalization, and reminder strategy.
3. It is impossible to know exactly the most and least effective PSs and ways of implementing each PS by comparing the available studies because most of the articles employed more than one PS, and each PS can be implemented in different ways. Thus, we invite researchers to explore this direction by conducting lab or field studies and comparing participants' responses to different strategies. For example, thematic analysis can be used to get more detailed insights into the effectiveness of each strategy. Beyond just reporting on the overall performance of the app with respect to promoting the target behavior, researchers could dig deeper (through qualitative studies, for example) to determine what made the app work or not.
4. We classified some PSs based on how they are delivered to users (e.g., textual, visual), and we classified other PSs as system-based or user-driven strategies.
5. It was not easy to extract, name, and classify the different PSs employed in the reviewed studies, and we needed to study each article in-depth (read, extract, sort, analyze).
6. We recommend that each article describe the PSs they employed and link each strategy with an existing example from their system design (What, How, Where) in a table or list.
7. Some articles did not specify exactly how to implement each PS, while others provided examples (the form of implementation) without mentioning the PS itself.
8. It was also difficult to find the different types of each PS implementation. It was not easy to classify them into groups, name them, or differentiate between the general classification and the examples (they were confusing).
9. Giving brief names as titles for each PS implementation was sometimes extremely difficult.
10. Some examples of the implementations were provided only once as an example, so we could not categorize them clearly.
11. The ways of implementing, naming, and classifying the PSs were mostly based on the authors' points of view.
12. We used the PSD model to classify the PSs employed in the reviewed articles; however, this model was not comprehensive enough as we found other strategies that do not belong to the PSD (e.g., goal setting, self-reporting).
13. The definitions of PSs in the PSD model were sometimes overlapping and confusing, especially for the social support strategies (e.g., learning, comparison, recognition, and competition).
14. Most of the reviewed articles provide some figures showing the PSs employed while ignoring others or not informing the readers about how they employed other PSs. Therefore, more organized tables and figures would be helpful (visualization if applicable).
15. We need to know more about users' reviews, feedback, comments, and opinions regarding the PS they like the most and the least, as well as their views regarding the form of implementation they like or dislike the most and the least.

5.3. Observations and recommendations for future research

In regard to RQ4 (What are the gaps, pitfalls, and limitations in the present literature on mobile-based PTs for PA and SB?) and RQ5 (What are the directions and recommendations for future research in the area of mobile-based PTs for PA and SB?), this section addresses some observations and limitations of the reviewed studies. It also provides some recommendations to inform future research. These observations are supported by other reviewed articles such as (Aldenaini et al., 2020; Orji & Moffatt, 2018):

1. There is a lack of a comparison between the effectiveness of mobile-based PTs applying a single PS and those applying multiple PSs.
2. There is no clear guideline for evaluating the effectiveness of PSs and their implementations.
3. There is a need to provide an inclusive PT design framework that considers all the essential aspects such

as target populations, technology platforms, PSs employed and their implementations, domain, and other aspects.

4. It is essential to consider publishing studies that have both positive and negative outcomes so they can help other researchers avoid ineffective approaches and only follow correct and verifiable ones.
5. There is a need to precisely name the PSs employed in the PT interventions along with their forms of implementation and examples. This could be shown in a table, list, or figure. The reviewed articles showed that most of the reviewed studies did not clearly specify the PSs employed in their PT design and did not show how exactly they employed each strategy in their designs. The reader needs to read the whole article and sometimes dig in depth to extract the PSs employed and their implementations. Thus, we recommend that future researchers provide a clear way of displaying each strategy and how it is employed in their PT system design (e.g., by providing a table showing the PSs employed, the type of implementation, an example of each implementation in the PTs design, an image or a diagram of the implementation (such as a user interface, icon, prototype, or avatar).

6. Conclusion and future work

This paper introduces a rich, comprehensive, and valuable systematic review of mobile-based PTs in the PA and SB domains. Based on our analysis of 198 articles, this paper sheds light on the PSs used in designing mobile-based PTs for PA and SB while showing how PSs were implemented differently in designing mobile-based PTs for PA and SB; highlights the gaps, pitfalls, and limitations in the present literature on mobile-based PTs for PA and SB; and provides directions and recommendations for the future of mobile-based PT research.

Future research should clearly describe the PSs employed and their implementations. There is also a need for more review papers that address different implementations of each PS in the PA and SB domains and other domains (e.g., healthy diet, smoking cessation, mental health, etc.). Future systematic reviews should also address the PSs' implementations based on different technology platforms, not only for mobile-based PTs. It is important to provide a standard measurement for the effectiveness of each PS and each implementation. We also suggest that future research provide clear and unified classifications for each PS's implementation with possible examples. Thus, our systematic review paper can be considered a reference source of knowledge for such a purpose in the PA and SB domains for mobile-based PTs. Finally, we noticed that PSs were implemented in multiple ways. However, the literature still lacks a clear view of the most effective strategies or combination of strategies that will yield the best results. Thus, future work should investigate this direction to fill this gap.

Disclosure statement

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