

How Effective is Personalization in Persuasive Interventions for Reducing Sedentary Behavior and Promoting Physical Activity: A Systematic Review

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Abstract. The use of persuasive systems and devices to reduce sedentary lifestyles and encourage individuals to be more physically active is progressively gaining interest. This paper presents a 13 years review (from 2006 to 2019) of personalized persuasive technologies (PTs) for promoting physical activity (PA) and discouraging sedentary behavior (SB). Moreover, we deconstructed the various implementations and operationalizations of the personalization in these PTs and compared their effectiveness. Specifically, this paper aims to (1) shed light on the multiple ways of implementing personalization in these PTs to promote PA and reducing SB, (2) evaluate the effectiveness of personalized PTs for promoting PA and decreasing SB, (3) highlight trends and offer suggestions for research in the area of personalizing PTs.

Keywords: Persuasive technology, Physical activity, Sedentary behavior, Personalization, Goal recommendations, Activity recommendations, Motivation, Health

1 Introduction

Persuasive technologies (PTs) are interactive computing systems, apps, or devices that are purposely developed to influence users to adopt healthy behaviors and attitudes and prevent risky ones without using coercion or deception [15], [41]. PTs are mainly implemented to promote healthy behavior and prevent disease or to manage diseases or other health conditions [38], [40], but also have been used in other domains.

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Sedentary behavior (SB) is generally characterized as a long time sitting behavior – when an individual expends lower or equal to 1.5 metabolic equivalent (≤ 1.5 MET) [57], [44]. MET “*is defined as the amount of oxygen consumed while sitting at rest and is equal to 3.5 ml O₂ per kg body weight x min*” [25]. Accordingly, SB and an insufficient amount of PA are global health concerns, as they lead to obesity and morbidity, and they are the fourth leading reason for mortality globally, with an estimated 3.2 million deaths worldwide [60]. Therefore, increasing or maintaining a suitable level of moderate-intensity PA is essential for avoiding or mitigating different diseases and health complications such as obesity, cancer, diabetes, and cardiovascular diseases [12], [19].

Persuasive Technology (PT) interventions are considered powerful tools for helping people to adopt healthy behaviors such as maintaining or increasing PA levels and reducing sedentary lifestyles. PTs are often deployed using various technological platforms (e.g. fitness activity trackers and sensors, smartphones, websites, social networking sites (SNSs), games, desktop computers, and ambient displays) [1], [41]. Activity trackers, for instance, are often used to track and monitor personal data (e.g. the user’s PA level, step count, heart rate, and time spent sedentary), and these activity tracker devices are used mostly with other technology platforms (e.g. smartphones, web-based apps) to provide users feedback about their PA progress, personalized feedback, and personalized recommendations [1], [32], [26].

Research has suggested that personalizing PTs increases their effectiveness [39]. Thus, personalizing PT intervention is crucial because people are different with respect to their personal preferences, activity levels, objectives, requirements, lifestyles, and health conditions, and even personality [42], [43], [46]. As a result, there is an increasing demand for PTs to be personalized to increase their effectiveness. The personalization strategy requires a system to provide personalized content or services to increase relevance, motivation, and persuasion effects [22].

There is an increasing number of reviews of PTs for health and wellness. However, most of these reviews focused on the general area of health and wellness and their general application of various persuasive strategies, for example, see Orji and Moffat [41], and Aldenaini et al. [1]. Research has highlighted the importance of personalizing PT, and the personalization strategy is one of the most frequently employed persuasive strategies [3] used in PT designs. Hence, there is a need for in-depth research into analyzing various implementations of personalization in persuasive strategies and the effectiveness of personalized PTs.

Therefore, this paper presents a 13-years review (from 2006 to 2019) of personalized PTs for promoting PA and discouraging SB. Moreover, we deconstructed the various implementations and operationalization of the personalization in these PTs to evaluate and compare their effectiveness. Specifically, this paper aims to (1) shed light on the various implementations a personalization in PT interventions for increasing PA and reducing SB, (2) evaluate the effectiveness of personalized PTs for promoting PA and decreasing SB, (3) highlight trends and offer suggestions for research in the area of personalizing persuasive technologies.

2 Related Works

An increasing number of systematic reviews is being conducted to determine the effectiveness of PTs in various domains. Ghanvatkar et al. [19] provided a scoping review of personalization strategies employed in PA interventions. They included 49 eligible studies in their review paper. They examined personalization strategies in the form of feedback or recommendations. Furthermore, they identified six types of a personalization strategy based on different forms of implementation in their reviewed studies. These personalization types are summarized as shown in Table 1.

There are other interesting review papers on PT interventions in the area of PA and/or SB in general – not focus specifically on personalization. For example, Almutari and Orji [2] provided a systematic review of articles that focused on PT for promoting PA. They analyzed the effectiveness of PT that employed social influence strategies such as comparison, cooperation, and competition only. Their findings revealed that PTs employing social support strategies to promote PA are promising in motivating users to be physically active.

Similarly, Aldenaini et al. [1] conducted a 16-years systematic review (from 2003 to 2019) of PTs and their effectiveness for promoting PA and discouraging SB. They highlighted trends in their outcomes such as research methods, behavioral theories, persuasive strategies and different ways of implementing each strategy, system design, and employed technologies. Their findings revealed that employing PTs were effective and promising in promoting a desirable behavior change among different populations when employed with a suitable persuasive strategy. They also provided a list of interesting recommendations for advancing PTs' future research.

Furthermore, Wang et al. [58] conducted a systematic review of studies targeted at reducing SB in the work environment. They used the persuasive system design (PSD) model [22] to evaluate the effectiveness and utilization of PT in discouraging prolonged SB among office works. Their findings showed that a reminder was the most frequently employed PSD strategy. They also found that coupling a reminder strategy with education sessions was more promising than hourly reminders alone.

Our systematic review paper included studies that employed a personalization strategy in their PT design to promote PA and/or reduce SB. In contrast, many existing studies tend to focus only on either promoting PA or reducing SB, and hardly on both. We also aimed at examining various ways of implementing personalization in different PTs. Again, our review specifically focused on PTs employing a personalization strategy in the area of SB and PA.

Table 1: Types of Personalization [19].

Type of Personalization	Meaning/Definition
Goal Recommendations	Quantified goals such as step count, floor count, duration of exercise, calorie burn rate.

Activity Recommendations	Recommending a specific type of PA or behavior such as standing, walking, running, cycling.
Fitness Partner Recommendations	Matching a user of a system to other users who are similar and have the same target goals for motivating them in maintaining or increasing their PA levels.
Educational Content	Increasing users' knowledge and awareness by sending personalized feedback about the health benefits of PA or some techniques and tips for improving PA.
Motivational Content	Motivating users to improve their PA by sending personalized motivational feedback and reinforcement messages.
Intervention Timing	Finding the right and suitable time to send a recommendation or feedback to the users such as sending a notification reminder to a user at a suitable time and opportune moments

3 Methods and Coding Scheme

As this paper aims to evaluate and analyze PT interventions (e.g. systems, apps, or websites) that implemented a personalization strategy, we used quantitative content analysis to classify data into different categories and compare between different outcomes [48].

We used Google Scholar, ACM Digital Library, Springer, PubMed, Elsevier Scopus, and EBSCOHost databases to search for and select relevant studies. We searched the terms “Persuasive Technology and Physical Activity”, “Persuasive Technology and Sedentary Behavior”, “Technology and Physical Activity Interventions”, “Technology and Sedentary Behavior Interventions”, “Fitness and Persuasive Technology”, “Prolonged Sitting and Sedentary Lifestyles”, “Physical Activity Apps or Applications”, and “Sedentary Behavior Apps or Applications”. We also searched through the relevant references from the reviewed studies. We used Mendeley, a reference manager, to organize the obtained articles.

After searching through different databases, we identified 534 unique titles, of which 315 articles were excluded by title, while 219 articles were considered eligible based on title examinations. We investigated each title to check whether it falls within the scope of the review or not. We excluded those titles that targeted other health domains – domains not related to PA and/or SB (e.g. dental health, smoking cessation, unwanted pregnancy, eating habits, risky sexual behavior, alcohol drinking, etc.). After examining the abstract of the 219 remaining articles, we excluded 181 articles, and we included a total of 38 articles. The included articles: were published in English between 2006 and 2019; implemented any form of a personalization strategy, included personalized

recommendations or feedback to promote PA and/or reducing SB; and were targeted at PA or SB, or both. We summarized the search and exclusion process, as shown in Figure 1.

We coded the 38 relevant articles by adapting the coding scheme created by Orji and Moffat [41] and validated by many other researchers, including [1], [3], [2]. As shown in Table 2, the coding sheet contains the study author(s), year of publication, domains, technology platforms, duration of a study, evaluation methodology, persuasive strategies, theories, targeted outcomes, audience age demographic, number of participants, results, and country of a study. We added a new identification to the coding sheet, which is the type of personalization as we adapted from Ghanvatkar et al. [19]. The types of personalization refer to the different ways of implementing a personalization strategy throughout the PT interventions. Appendix 1 provides a comprehensive overview of our coding sheet.

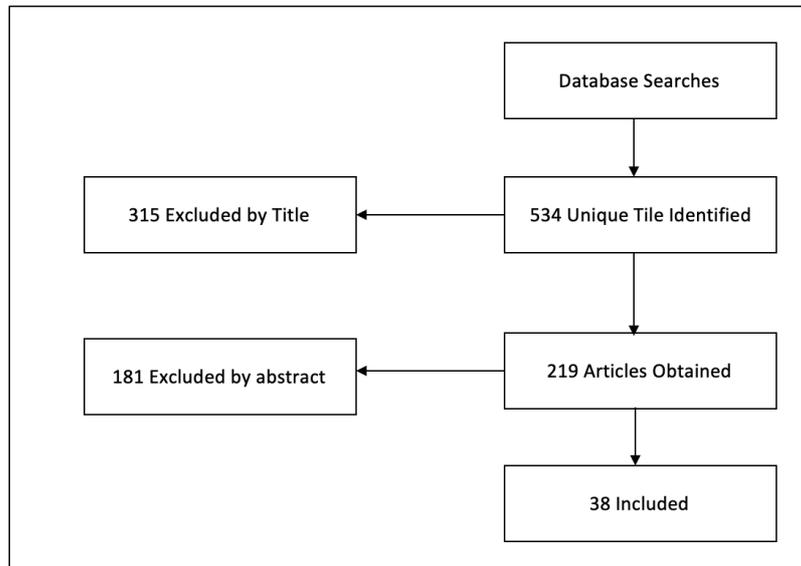


Fig. 1. The Studies Selection Workflow.

Table 2: Coding Scheme Analysis- Adapted from Orji and Moffat [41].

S/N	Identification	Example
1	Author(s)/Year	Name of author(s) and year of publication.
2	Domain	PA, SB, Mental Health, etc.
3	Technology	Mobile, Web, Computer applications, etc.
4	Evaluation Methods	Quantitative, Qualitative, and Mixed.

5	Types of Personalization (Ways of implementations)	Goal, activity, or fitness partner recommendations, educational or motivational content feedback, and intervention timing.
6	Persuasive Strategies	Motivational strategies employed.
7	Duration of Evaluation	Weeks, months, years, etc.
8	Theories	Theories implemented either on the system design of a PT or on the evaluation of a study.
9	Targeted Outcomes	Behavior, Motivation, Attitudes, Awareness, etc.
10	Audience Age Demographics	Children, Adults, Old People, etc.
11	Number of Participants	How many participants involved in the study assessment?
12	Results	Successful or not.
13	Country	Country of a study where conducted.

4 Results

Our analysis of existing PT interventions that applied personalization in their system designs for PA promotion and/or SB reduction revealed interesting outcomes. This section presents our findings from the reviewed studies in detail.

4.1 Persuasive Technology for Physical Activity and Sedentary Behavior by Year and Country

Based on our inclusion and exclusion criteria, Figure 2 shows that most of the articles were published between 2016 and 2019. Three articles (8%) were published in each of 2010, 2012, 2013, and 2014. One article (3%) was published in each of 2006, 2007, 2008, and 2011.

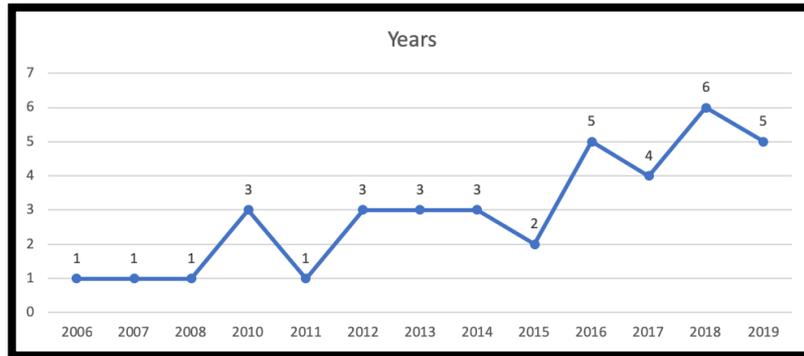


Fig. 2. Persuasive Technologies for Physical Activity Promotion and Sedentary Behavior Reduction Trends by Year.

Figure 3 shows that the reviewed studies were conducted in 16 countries. The USA had the largest number of studies with a total of 17 (45%). The UK followed the USA with a total of 4 studies (11%). Netherlands and Canada were in third place with a total of 3 studies (8%) each.

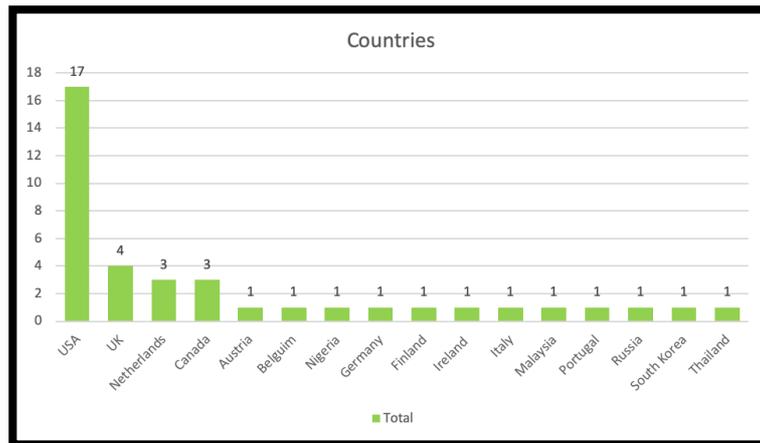


Fig. 3. Persuasive Technologies for Physical Activity Promotion and Sedentary Behavior Reduction Trends by Country.

4.2 Targeted Domains

All the studies included in this review were targeted at either promoting PA and/or discouraging SB. We categorized the targeted health domains into three groups: PA, SB, and mixed (the studies that focused on both PA promotion and SB reduction). Thirty-two studies (84%) were targeted at maintaining or increasing PA, while four studies (11%) focused on decreasing SB. Only two studies (5%) targeted both the PA and SB domains. Figure 4 presents the targeted health domains covered in this review paper.

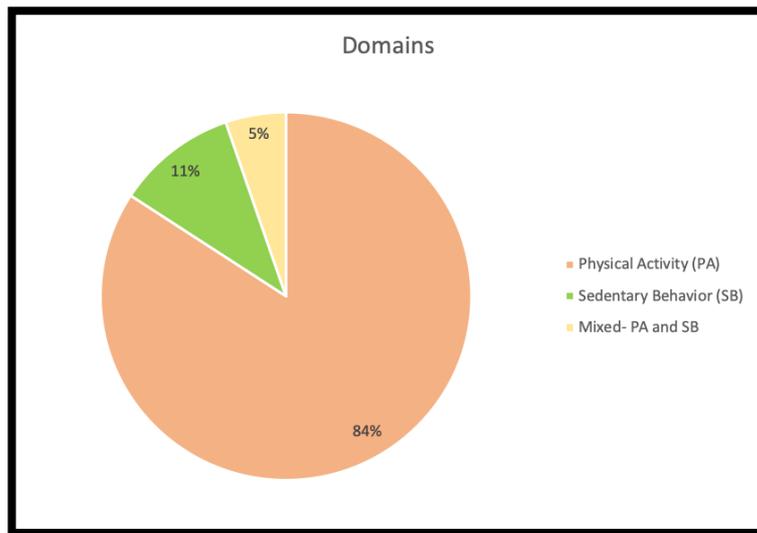


Fig. 4. Targeted Health Domains.

4.3 Evaluation Methodologies Used for Promoting Physical Activity and Reducing Sedentary Behavior

Figure 5 shows the percentage of the total number of studies employing in each evaluation methodology. The evaluation methodologies covered in the reviewed studies are categorized into three main methods: qualitative, quantitative, and mixed (methods that include both qualitative and quantitative methodologies). The evaluation approach most commonly used in the studies was mixed methods with a total of 17 studies (45%). The qualitative methodology ranked second with a total of eight studies (21%). This is followed by the quantitative methodology with a total of five studies (13%). Eight studies (21%) did not evaluate their PT designs.

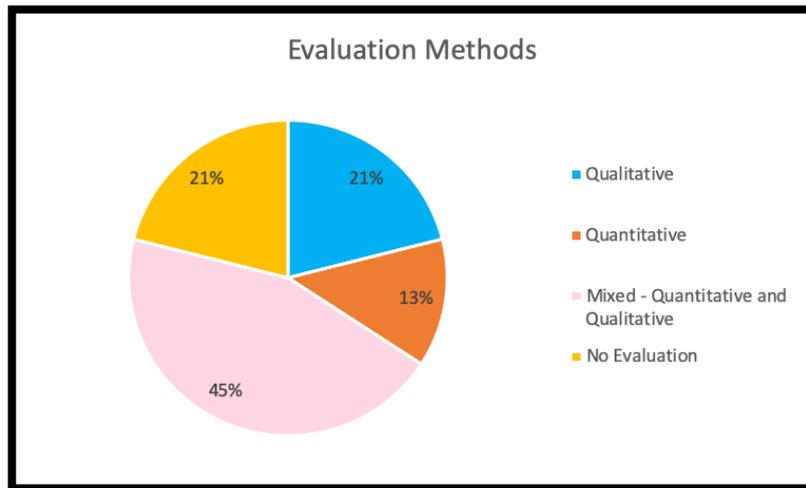


Fig. 5. Evaluation Methods Used in the Reviewed Studies.

4.4 Effectiveness of Personalized PT based on Evaluation Methods

Figure 6 shows that out of the 17 studies that employed a mixed-methods approach, ten studies (59%) reported fully successful outcomes, and seven studies (41%) reported partially successful outcomes. Fully successful outcomes mean those studies that reported all positive outcomes with respect to achieving their design objectives, as reported by the authors in their papers. By partially successful outcomes, we mean that the results of the PT evaluation show a mixture of both positive and negative outcomes respect to achieving their design objectives. The negative outcome means studies that were totally unsuccessful at achieving their design objectives. Out of the eight studies that employed a qualitative methodology, five studies (63%) were fully successful, two studies (25%) were partially successful, and only one study (12%) did not specify its outcomes. All five studies that employed only a quantitative methodology to evaluate their PT designs reported fully successful outcomes.

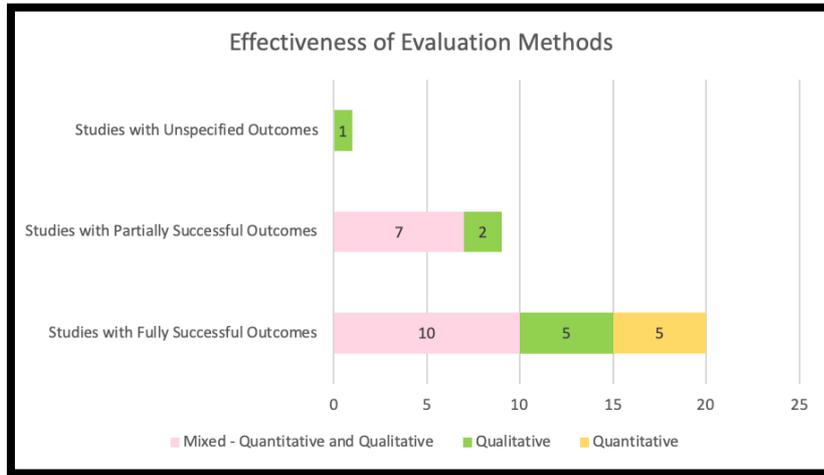


Fig. 6. Comparative Effectiveness of PTs Based on Evaluation Methods.

4.5 Target Audience of Personalized PTs

The number of participants in the evaluation of the PT interventions for promoting PA and discouraging SB varies significantly across the reviewed studies. The number of participants ranged from 4 to 129,010. For the reviewed studies that had multiple phases, we combined the number of participants from all phases.

As represented in Figure 7, sixteen studies (42%) were targeted at adults (31–54 years old), while six studies (16%) were targeted at young adults (18–30 years old). Children and elderly people were targeted in five studies (13%) for each. Four studies (11%) targeted teenagers, and only six studies (16%) did not specify their target population.

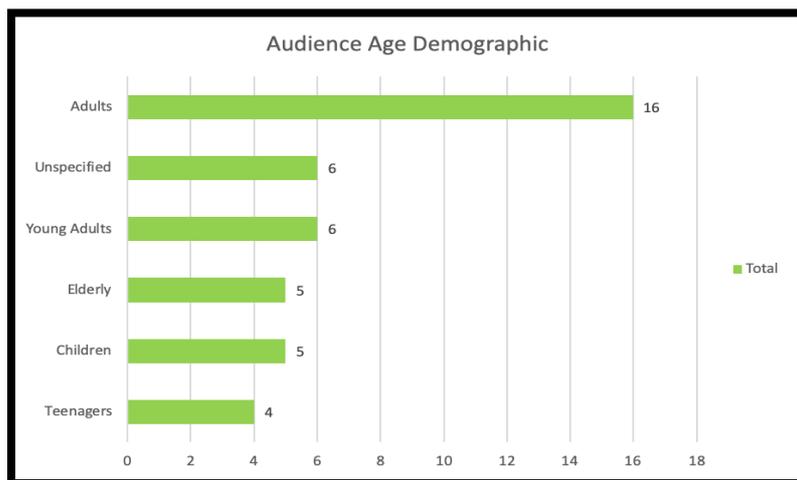


Fig. 7. Target Audience of Personalized PTs.

4.6 Effectiveness of Personalized PTs Across Various Age Groups

Figure 8 shows the effectiveness of personalized PTs based on the population age demographic. Out of the 16 studies targeted at adults, six studies (38%) reported fully successful outcomes, seven studies (44%) reported partially successful outcomes, two studies (12%) did not evaluate their PT designs, and only one study (6%) did not specify its outcomes.

All six studies that targeted at young adults reported fully successful outcomes. For children, out of the five studies targeted at them, three studies (60%) showed fully successful outcomes, one study (20%) was partially successful, and one study (20%) did not evaluate its PT design. Out of the five studies targeted at elderly people, four studies (80%) were fully successful, and only one study (20%) did not provide an evaluation for its design. Three studies (75%) targeted at teenagers reported fully successful outcomes, and only one study (25%) targeted at teenagers was partially successful. Out of the six studies that did not specify their target population, two studies (33%) were fully successful, and four studies (67%) had no evaluation.

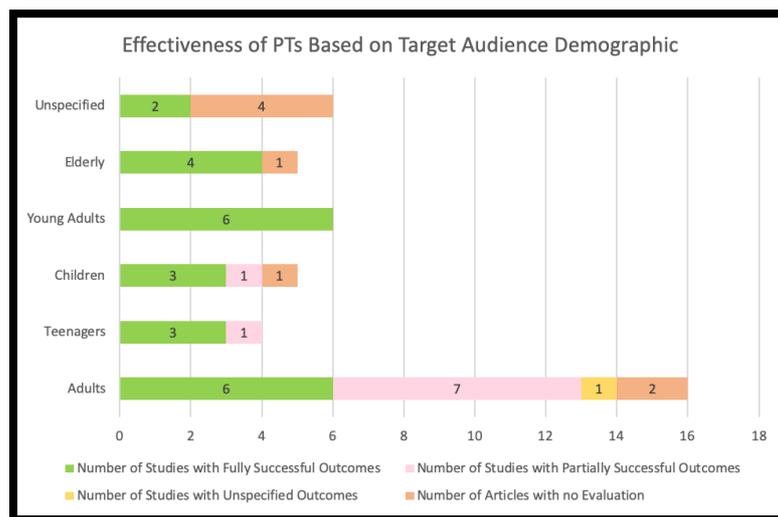


Fig. 2. Effectiveness of Personalized PTs Across Various Age Groups.

4.7 Personalization Implementations in PT for PA and SB

Most reviewed PTs implemented a personalization strategy as personalized feedback and personalized recommendations. With respect to feedback, the personalization strategy was mostly employed as personalized educational or personalized motivational content. However, for the recommendations, personalization was employed as personalized activity recommendations, personalized goal recommendations, or personalized fitness partner recommendations in line with Ghanvatkar et al. [19].

According to Ghanvatkar et al. [19], there are six types of a personalization strategy, as shown in Table 1. Thus, we adapted their categorizations of personalization and used it

in analyzing the personalization approaches employed in the reviewed studies. The comprehensive details about each type/category of personalization and their definitions can be found in Ghanvatkar et al. [19].

Figure 9 shows that out of the 38 reviewed studies, twenty-three studies (61%) implemented personalization strategy as personalized motivational feedback to users. Nineteen (50%) of the total studies implemented the personalization strategy as personalized goal recommendations. Personalized activity recommendations and personalized intervention timing ranked third with a total of ten studies (26%) for each. Just five studies (13%) implemented a personalization strategy as personalized educational feedback. Intervention timing is a type of personalization that uses the context of the feedback or recommendation to find the right and suitable time to deliver it to the user [19]. Only one study (3%) implemented a personalization strategy as a personalized fitness partner recommendation.

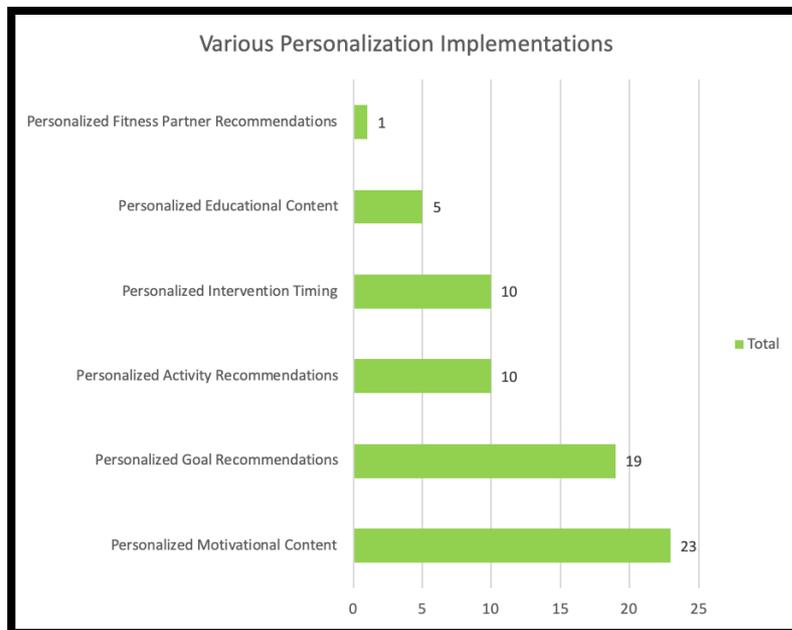


Fig.3. Personalization Implementations in Persuasive Technologies for PA and SB.

Besides the above personalization approaches, other implementations of a personalization strategy were identified in the reviewed studies. For instance, Dantzing et al.[10] implemented personalization in the form of context-aware coaching, as users got a daily personalized step goal, and they were coached through a custom-design smartphone application to achieve their targeted goal by receiving personalized messages in real-time. Thus, the work of Dantzing et al.[10] provided an example of three types of personalization: goal recommendations, educational content, and motivational content.

Another example implementation of the personalization as goal recommendations and motivational content was found in Bounce [31], a smartphone app for breast cancer

survivors that encourages them to engage in more PA. The Bounce app reminds users of their PA goals. It also provides personalized and customizable reinforcements and virtual rewards such as badges and trophies once users achieve progress towards accomplishing their goals and sends pop-up messages to congratulate users on their PA progress.

Schafer et al. [50] delivered personalization as personalized motivational content. They provided personalized gamified feedback through a smartphone application. This feedback was delivered by providing a simple visualization of the activity level through a personalized animated avatar and represented them based on the gender of children.

Francillette et al. [17] showed an example of implementing personalization as personalized goal recommendations and intervention timing. They designed a smartphone exergame app to motivate individuals with severe mental health conditions to integrate PA into their daily lives. The app enables players to plan and set their PA goals based on the players' profiles, which allows the system to generate different PA choices with different difficulty levels according to the players' predetermined choices as personalized goal recommendations. These PA choices were delivered to the players at suitable times as personalized intervention timing.

The PRO-Fit application [11] showed an example of implementing personalization as personalized fitness partner recommendations, goal recommendations, activity recommendations, and intervention timing. PRO-Fit is a personalized smartphone fitness application that recommends personalized PA sessions based on the user's calendar and availability, fitness goals, and preferences. Furthermore, the app integrates with the user's social networks, and, based on them, the app suggests "fitness buddies/partners" that have similar fitness goals, preferences, and availability.

Table 3 provides a summary of different ways of implementing a personalization strategy in our reviewed studies based on the types of personalization that have been classified, defined, and validated by Ghanvatkar et al. [19] in their scoping review study.

Table 3: Implementation of A Personalization Strategy.

Personalization Strategy Categories	Implementation
<u><i>Personalized Goal Recommendations</i></u>	Sending personalized messages and notifications to remind users about their target quantified goals (e.g. personalized context-aware coaching, generating different PA choices and sessions based on the users' goals and preferences). For example of implementations, see [31], [10], [11], and [17], etc.
<u><i>Personalized Activity Recommendations</i></u>	Sending personalized suggestions of suitable type of physical activities to users (e.g. biking, running, aerobic, yoga, cycling, stretching, walking). For example, see [11], and [23], etc.

<u><i>Personalized Fitness Partner Recommendations</i></u>	Matching users of a PT system to a similar partner who have the same target goals to increase their motivations (e.g. suggesting “fitness buddies/partners” that have similar fitness goals, preferences, and availability). For example, see [11].
<u><i>Personalized Motivational Content</i></u>	Sending personalized feedback or messages that aim to motivate users to change their behavior of engaging in more PA (e.g. context-aware coaching that encourages users to continue maintaining a good levels of practicing PA, personalized gamified and visual feedback of the user’s activity level through a personalized animated avatar). For example, see [10], [31], and [50], etc.
<u><i>Personalized Educational Content</i></u>	A personalized feedback that targeted at increasing the awareness and knowledge of the users by providing them with different tips and instructions (e.g. context-aware coaching that educate users in how to specific type of PA). For example, see [10], and [14], etc.
<u><i>Personalized Intervention Timing</i></u>	Intervention timing is a type of personalization that uses the context of the feedback or recommendation and finds the right and suitable time to deliver it to the user (e.g. recommending PA choices PA to be delivered to the players at their suitable times and availability). For instance, see [11], and [17], etc.

4.8 Effectiveness of Personalization in Physical Activity and Sedentary Behavior Domains

Figure 10 summarizes the effectiveness of the reviewed studies, all of which employed some form of personalization in their persuasive intervention design. Out of the total 38 reviewed studies, twenty studies (52%) reported fully successful outcomes, nine studies (24%) were partially successful, eight studies (21%) did not evaluate their PT designs, and only one study (3%) did not specify its evaluation outcomes. Overall, forty-seven (76%) of the total reviewed studies reported successful outcomes, whether fully or partially successful.

Figure 11 shows the effectiveness of various implementations of a personalization strategy. Out of the 23 studies that employed motivational feedback, 16 studies (69%) reported fully successful outcomes, five studies (22%) reported partially successful outcomes, and only two studies (9%) had no evaluation of their PT designs. Out of the 19 studies that implemented a personalization strategy as goal recommendations, eight studies (42%) were fully successful, four studies (21%) were partially successful, six studies (32%) did not evaluate their system, and only one study (5%) did not specify its outcomes.

Out of the ten studies that applied activity recommendations, six studies (60%) showed fully successful outcomes, two studies (20%) reported partially successful outcomes, and two studies (20%) had no evaluation.

Of the ten studies that employed the personalized intervention timing as an implementation of persuasive strategy, five studies (50%) reported fully successful outcomes, three studies (30%) were partially successful, and just two studies (20%) were not evaluated. Finally, out of the five studies that implemented educational feedback as a form of personalization, three studies (60%) were fully successful, one study (20%) was partially successful, and one study (20%) had no evaluation. Only one study employed a fitness partner recommendation as a form of personalization, and this study did not evaluate its PT design.

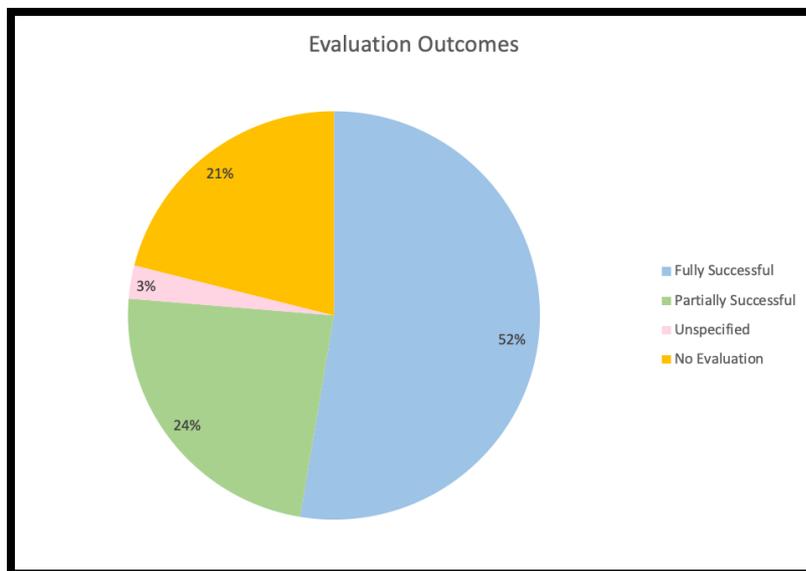


Fig.4. Overall Effectiveness of Personalized PT for PA and SB.

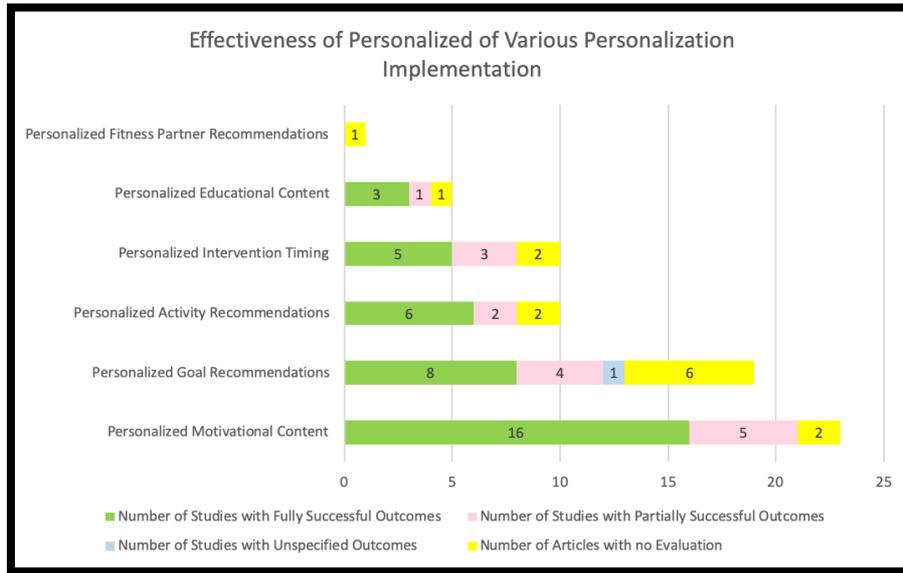


Fig. 5. Effectiveness of Personalized PT Based on How a Personalization Strategy was Implemented.

5 Discussion

We found that many of the reviewed studies (45%) employed a mixed-methods evaluation, which is a combination of qualitative and quantitative evaluation methodologies. We highly recommend researchers to apply the mixed evaluation methodology to fully reveal the comprehensive impact of their PT design and its effectiveness rather than employing either the qualitative method alone or a quantitative method alone.

The majority of the reviewed studies targeted adults and young adults with a total of 22 studies (58%). Thus, we recommend that researchers design more PT for promoting PA and discouraging SB targeting other populations such as the elderly, teenagers, and children. Our findings showed that the studies targeted at adults and young adults reported the largest number of successful outcomes, whether fully or partially successful. This is perhaps because adults and young adults are at an active age, and they can practice moderate-intensity PA easily more than older populations. Similarly, adults and young adults are more aware of the benefits of PA and the consequences of a sedentary lifestyle than teenagers and children [1], [2].

Based on the reviewed studies, we found that personalizing PT for promoting PA and discourage SB among users is an effective and promising approach of increasing the effectiveness of PTs, with a total of 29 (76%) of the entire reviewed studies (38) reporting successful outcomes, both fully and partially successful outcomes.

We included studies that implemented any form of personalization in the PT design for PA and SB domains. The results of our analysis revealed that personalization was delivered and implemented differently from one study to another based on the user's *profile, preferences, predetermined goals, and availability*. We found that the most common and effective way of implementing a personalization strategy based on the reviewed studies emerged to be personalized motivational content. We believe this is because motivation is one of the most crucial factors for persuading users to achieve a particular objective [37], such as, in our case, increasing PA levels and reducing SB. Thus, personalized feedback that aims to motivate users to change their behavior of engaging in more PA and reducing SB plays an essential role in improving users' motivation and commitment.

The second most frequently employed and effective type of personalization implementation is the goal recommendations. Personalized goal recommendations were delivered to users based on the PA goals they set on the PT system. It is important to mention that goal recommendations describe quantified goals such as step counts, calories burned, and duration of activity [19]. Users appreciated systems that reminded them of their personal goals and objectives.

Based on our findings, personalized activity recommendations and intervention timing ranked as the third most commonly employed and effective implementation of personalization in PTs for promoting PA and decreasing SB. Activity recommendation entails prescribing different types of activities for achieving a set goal such as running, walking, or cycling. Intervention timing focuses on sending feedback or recommendations to users at a suitable and available time for them because users may ignore or forget feedback sent when they are busy with other primary tasks that take greater priority [19].

Although educational content and fitness partner recommendations seem to be the least commonly employed types of personalization implementation, they are considered effective tools to increase the awareness of the users about the benefits of PA for health and general well-being and the consequences of SB and to provide external motivations through matching users with partners who have similar goals and objectives to assist them in maintaining their PA level [19]. Therefore, we recommend researchers to employ a personalization strategy and deliver it to users using different types of implementation based on the users' needs and combine it with other complementary persuasive strategies to achieve a desired behavior change objective.

Since most of the reviewed studies employ more than one persuasive strategy, this makes it challenging to know which of the employed persuasive strategies contributed to the effectiveness of a PT and lead to the observed behavior change, such as increasing PA levels and reducing SB. Therefore, we cannot attribute the observed results on the effectiveness of the PTs to their use of a personalization strategy only.

6 Conclusion

This paper presented some interesting trends on various implementations of a personalization strategy and provided a general overview of personalized PT interventions for promoting PA and discouraging SB. We uncovered various ways of implementing personalization in different PTs and compared their effectiveness, including *personalized motivational and educational content feedback*, *personalized goal and activity recommendations*, *personalized intervention timing*, and *personalized fitness partner recommendations*. Finally, our findings revealed that PT interventions for promoting PA and decreasing SB are effective and promising when they are personalized.

REFERENCES

1. Noora Aldenaini, Felwah Alqahtani, Rita Orji, and Sampalli Srinivas. 2020. Trends in Persuasive Technologies for Physical Activity and Sedentary Behavior: A Systematic Review. *Frontiers in Artificial Intelligence Journal for Human Learning and Behavior Change*, 21 February 2020: 85.
2. Najla Almutari and Rita Orji. 2019. How Effective Are Social Influence Strategies in Persuasive Apps for Promoting Physical Activity?: A Systematic Review. 167–172. <https://doi.org/10.1145/3314183.3323855>
3. Felwah Alqahtani, Ghazayil Al Khalifah, Oladapo Oyeboode, and Rita Orji. 2019. Apps for Mental Health: An Evaluation of Behavior Change Strategies and Recommendations for Future Development. *Frontiers in Artificial Intelligence*. <https://doi.org/10.3389/frai.2019.00030>
4. Maximilian Altmeyer, Pascal Lessel, Tobias Sander, and Antonio Krüger. 2018. Extending a Gamified Mobile App with a Public Display to Encourage Walking. <https://doi.org/10.1145/3275116.3275135>
5. Sonia M. Arteaga, Mo Kudeki, Adrienne Woodworth, and Sri Kurniawan. 2010. Mobile system to motivate teenagers' physical activity. 1. <https://doi.org/10.1145/1810543.1810545>
6. Dale S. Bond, J. Graham Thomas, Hollie A. Raynor, Jon Moon, Jared Sieling, Jennifer Trautvetter, Tiffany Leblond, and Rena R. Wing. 2014. B-MOBILE - A smartphone-based intervention to reduce sedentary time in overweight/obese individuals: A within-subjects experimental trial. *PLoS ONE* 9, 6. <https://doi.org/10.1371/journal.pone.0100821>
7. Scott A Cambo, Daniel Avrahami, and Matthew L Lee. 2017. BreakSense: Combining Physiological and Location Sensing to Promote Mobility during Work-Breaks. *Proceedings of the 2017 Acm Sigchi Conference on Human Factors in Computing Systems (Chi'17)*. <https://doi.org/10.1016/j.engappai.2016.10.012>
8. Luca Chittaro and Riccardo Sioni. 2012. Turning the classic snake mobile game into a location-based exergame that encourages walking. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 7284 LNCS: 43–54. https://doi.org/10.1007/978-3-642-31037-9_4
9. Fabio Ciravegna, Jie Gao, Neil Ireson, Robert Copeland, Joe Walsh, and Vitaveska Lanfranchi. 2019. Active 10- Brisk Walking to Support Regular Physical Activity. *Proceedings Paper in PervasiveHealth2019*. <https://doi.org/10.1145/3329189.3329208>
10. Saskia van Dantzig, Murtaza Bulut, Martijn Krans, Anouk van der Lans, and Boris de Ruyter. 2018. Enhancing physical activity through context-aware coaching. <https://doi.org/10.1145/3240925.3240928>
11. Saumil Dharia, Vijesh Jain, Jvalant Patel, Jainikkumar Vora, Rizen Yamauchi,

- Magdalini Eirinaki, and Iraklis Varlamis. 2016. PRO-Fit: Exercise with friends. *Proceedings of the 2016 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining, ASONAM 2016*: 1430–1433. <https://doi.org/10.1109/ASONAM.2016.7752437>
12. David W. Dunstan, Alicia A. Thorp, and Genevieve N. Healy. 2011. Prolonged sitting: Is it a distinct coronary heart disease risk factor? *Current Opinion in Cardiology*. <https://doi.org/10.1097/HCO.0b013e3283496605>
 13. Daphne Economou, Miriam Dwek, Claire Roberston, Bradley Elliott, Thanos Kounenis, Tayebeh Azimi, Mohammad Ramezani, and Nathan Bell. 2017. PhytoCloud: A Gamified Mobile Web Application to Modulate Diet and Physical Activity of Women with Breast Cancer. In *Proceedings - IEEE Symposium on Computer-Based Medical Systems*. <https://doi.org/10.1109/CBMS.2017.164>
 14. Muhammad Fahim, Thar Baker, Asad Masood Khattak, and Omar Alfandi. 2017. Alert me: Enhancing active lifestyle via observing sedentary behavior using mobile sensing systems. *2017 IEEE 19th International Conference on e-Health Networking, Applications and Services, Healthcom 2017* 2017-Decem: 1–4. <https://doi.org/10.1109/HealthCom.2017.8210838>
 15. B J Fogg. 1998. *Persuasive Computers: Perspectives and Research Directions*. Retrieved March 14, 2019 from www.captology.org
 16. Derek Foster, Conor Linehan, Ben Kirman, Shaun Lawson, and Gary James. 2010. Motivating physical activity at work: Using persuasive social media for competitive step counting. *Proceedings of the 14th International Academic MindTrek Conference on Envisioning Future Media Environments - MindTrek '10*: 111. <https://doi.org/10.1145/1930488.1930510>
 17. Yannick Francillette, Bruno Bouchard, Eric Boucher, Sébastien Gaboury, Paquito Bernard, Ahmed Jérôme Romain, and Kévin Bouchard. 2018. Development of an Exergame on Mobile Phones to Increase Physical Activity for Adults with Severe Mental Illness. <https://doi.org/10.1145/3197768.3201521>
 18. Eva Geurts, Fanny Van Geel, Peter Feys, and Karin Coninx. 2019. WalkWithMe-Personalized Goal Setting and Coaching for Walking in People with Multiple Sclerosis. In *Proceedings of the 27th ACM Conference on User Modeling, Adaptation and Personalization - UMAP '19*, 51–60. <https://doi.org/10.1145/3320435.3320459>
 19. Suparna Ghanvatkar, Atreyi Kankanhalli, and Vaibhav Rajan. 2019. User models for personalized physical activity interventions: Scoping review. *Journal of Medical Internet Research*. <https://doi.org/10.2196/11098>
 20. Liam G. Glynn, Patrick S. Hayes, Monica Casey, Fergus Glynn, Alberto Alvarez-Iglesias, John Newell, Gearóid ÓLaighin, David Heaney, and Andrew W. Murphy. 2013. SMART MOVE - a smartphone-based intervention to promote physical activity in primary care: Study protocol for a randomized controlled trial. *Trials*. <https://doi.org/10.1186/1745-6215-14-157>
 21. Md Sanaul Haque, Wali Mohammad Abdullah, Sadiqur Rahaman, Maarit Kangas, and Timo Jämsä. 2016. Persuasive health and wellbeing application: A theory-driven design in promoting physical activity. *1st International Conference on Medical Engineering, Health Informatics and Technology, MediTec 2016*. <https://doi.org/10.1109/MEDITEC.2016.7835369>
 22. Oinas-Kukkonen Harri and Harjumaa Marja. 2009. Persuasive Systems Design: Key Issues, Process Model, and System Features. *Communications of the Association for Information Systems* 24, 1: 96. <https://doi.org/10.17705/1CAIS.02428>
 23. Qian He and Emmanuel Agu. 2014. On11: An Activity Recommendation Application to Mitigate Sedentary Lifestyle. *Proceedings of the 2014 Workshop on Physical Analytics*: 3–8. <https://doi.org/10.1145/2611264.2611268>
 24. Yan Hong, Deborah Vollmer Dahlke, Marcia Ory, Angela Hochhalter, Jana Reynolds,

- Ninfa Pena Purcell, Divya Talwar, and Nola Eugene. 2013. Designing icanfit: A mobile-enabled web application to promote physical activity for older cancer survivors. *Journal of Medical Internet Research*. <https://doi.org/10.2196/resprot.2440>
25. M. Jetté, K. Sidney, and G. Blümchen. 1990. Metabolic equivalents (METs) in exercise testing, exercise prescription, and evaluation of functional capacity. *Clinical Cardiology* 13, 8: 555–565. <https://doi.org/10.1002/clc.4960130809>
26. Michel C.A. Klein, Adnan Manzoor, and Julia S. Mollee. 2017. Active2Gether: A personalized m-health intervention to encourage physical activity. *Sensors (Switzerland)* 17, 6: 1–16. <https://doi.org/10.3390/s17061436>
27. Nicholas D. Lane, Mu Lin, Mashfiqui Mohammad, Xiaochao Yang, Hong Lu, Giuseppe Cardone, Shahid Ali, Afsaneh Doryab, Ethan Berke, Andrew T. Campbell, and Tanzeem Choudhury. 2014. BeWell: Sensing sleep, physical activities and social interactions to promote wellbeing. *Mobile Networks and Applications*. <https://doi.org/10.1007/s11036-013-0484-5>
28. Daehyoung Lee, Georgia Frey, Alison Cheng, and Patrick C. Shih. 2018. Puzzle walk: A gamified mobile app to increase physical activity in adults with autism spectrum disorder. In *2018 10th International Conference on Virtual Worlds and Games for Serious Applications, VS-Games 2018 - Proceedings*. <https://doi.org/10.1109/VS-Games.2018.8493439>
29. Yuzhong Lin, Joran Jessurun, Bauke de Vries, and Harry Timmermans. 2011. Motivate: towards Context-Aware Recommendation Mobile System for Healthy Living. 250–253. <https://doi.org/10.4108/icst.pervasivehealth.2011.246030>
30. Chiraphrueet Mansart, Siriluck Sukitphittayanon, Panitan Pantongkhum, and Supphachai Thaicharoen. 2015. Go Run Go: An Android Game-Story Application for Aiding Motivation to Exercise. *Proceedings - 2015 IEEE International Symposium on Multimedia, ISM 2015*: 407–410. <https://doi.org/10.1109/ISM.2015.49>
31. Gabriela Marcu, Anjali Misra, Karina Caro, Meghan Plank, Amy Leader, and Andrea Barsevick. 2018. Bounce: Designing a Physical Activity Intervention for Breast Cancer Survivors. <https://doi.org/10.1145/nnnnnnn.nnnnnnn>
32. Corby K Martin, L Anne Gilmore, John W Apolzan, Candice A Myers, Diana M Thomas, and Leanne M Redman. 2016. Smartloss: A Personalized Mobile Health Intervention for Weight Management and Health Promotion. *JMIR mHealth and uHealth*. <https://doi.org/10.2196/mhealth.5027>
33. Siobhan McMahon, Mithra Vankipuram, and Julie Fleury. 2013. Mobile Computer Application for Promoting Physical Activity. *Journal of Gerontological Nursing*. <https://doi.org/10.3928/00989134-20130226-01>
34. Hazwani Mohd Mohadis and Nazlena Mohamad Ali. 2016. Designing persuasive application to encourage physical activity at workplace among older workers. In *2016 6th International Conference on Digital Information and Communication Technology and Its Applications, DICTAP 2016*. <https://doi.org/10.1109/DICTAP.2016.7544013>
35. Adity Mutsuddi and Kay Connelly. 2012. Text Messages for Encouraging Physical Activity Are they effective after the novelty effect wears off? *2012 6th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth) and Workshops*: 33–40. <https://doi.org/10.4108/icst.pervasivehealth.2012.248715>
36. T. Oliveira, D. Leite, and G. Marreiros. 2016. PersonalFit - Fitness App with intelligent plan generator. In *ACM International Conference Proceeding Series*. <https://doi.org/10.1145/2948992.2949014>
37. Rita Orji. 2017. Why are persuasive strategies effective? Exploring the strengths and weaknesses of socially-oriented persuasive strategies. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. https://doi.org/10.1007/978-3-319-55134-0_20
38. Rita Orji and Regan L. Mandryk. 2014. Developing culturally relevant design guidelines

- for encouraging healthy eating behavior. *International Journal of Human Computer Studies*. <https://doi.org/10.1016/j.ijhcs.2013.08.012>
39. Rita Orji, Regan L. Mandryk, and Julita Vassileva. 2017. Improving the efficacy of games for change using personalization models. *ACM Transactions on Computer-Human Interaction*. <https://doi.org/10.1145/3119929>
 40. Rita Orji, Regan L. Mandryk, Julita Vassileva, and Kathrin M. Gerling. 2013. Tailoring persuasive health games to gamer type. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*. <https://doi.org/10.1145/2470654.2481341>
 41. Rita Orji and Karyn Moffatt. 2018. Persuasive technology for health and wellness: State-of-the-art and emerging trends. *Health Informatics Journal* 24, 1: 66–91. <https://doi.org/10.1177/1460458216650979>
 42. Rita Orji, Lennart E. Nacke, and Chrysanne Di Marco. 2017. Towards personality-driven persuasive health games and gamified systems. In *Conference on Human Factors in Computing Systems - Proceedings*. <https://doi.org/10.1145/3025453.3025577>
 43. Rita Orji, Gustavo F. Tondello, and Lennart E. Nacke. 2018. Personalizing persuasive strategies in gameful systems to gamification user types. In *Conference on Human Factors in Computing Systems - Proceedings*. <https://doi.org/10.1145/3173574.3174009>
 44. N. Owen, A. Bauman, and W. Brown. 2009. Too much sitting: A novel and important predictor of chronic disease risk? *British Journal of Sports Medicine*. <https://doi.org/10.1136/bjsm.2008.055269>
 45. Kiemute Oyibo, Abdul-Hamid Olagunju, Babatunde Olabenjo, Ifeoma Adaji, Ralph Deters, and Julita Vassileva. 2019. BEN³FIT: Design, Implementation and Evaluation of a Culture-Tailored Fitness App. <https://doi.org/10.1145/3314183.3323854>
 46. Kiemute Oyibo, Rita Orji, and Julita Vassileva. 2017. The influence of culture in the effect of age and gender on social influence in persuasive technology. In *UMAP 2017 - Adjunct Publication of the 25th Conference on User Modeling, Adaptation and Personalization*. <https://doi.org/10.1145/3099023.3099071>
 47. Nithya Ramanathan, Faisal Alquaddoomi, Hossein Falaki, Dony George, Cheng-Kang Hsieh, John Jenkins, Cameron Ketcham, Brent Longstaff, Jeroen Ooms, Joshua Selsky, Hongsuda Tangmunarunkit, and Deborah Estrin. 2012. ohmage: An open Mobile System for Activity and Experience Sampling. <https://doi.org/10.4108/icst.pervasivehealth.2012.248705>
 48. Daniel Riffe, Stephen Lacy, and Frederick G. Fico. 1997. *Analyzing Media Messages: Using Quantitative Content Analysis in Research*. <https://doi.org/10.2307/358412>
 49. Ankita Samariya, Anud Sharma, Margiawan Fitriani, Tucker Ferguson, Jerry Alan Fails, and Jerry Alan. 2019. KidLED: A colorful approach to children’s activity awareness. <https://doi.org/10.1145/3311927.3326594>
 50. Hanna Schäfer, Joachim Bachner, Sebastian Pretscher, Georg Groh, and Yolanda Demetriou. 2018. Study on Motivating Physical Activity in Children with Personalized Gamified Feedback. <https://doi.org/10.1145/3213586.3225227>
 51. Sarah Justine Guy Skriloff, Dario C Gonzalez, Kurtis C Christensen, Logan J Bentley, and Cody V Mortensen. 2016. FitPlay Games: Increasing Exercise Motivation Through Asynchronous Social Gaming. *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. <https://doi.org/10.1145/2851581.2890367>
 52. M Sohn and Jeunwoo Lee. 2007. UP health: Ubiquitously Persuasive Health Promotion with an Instant Messaging System. *25th SIGCHI Conference on Human Factors in Computing Systems 2007, CHI 2007: 2663–2668*. <https://doi.org/10.1145/1240866.1241059>
 53. P. Spiesberger, F. Jungwirth, C. Wöss, S. Bachl, J. Harms, and T. Grechenig. 2015.

- Woody: A location-based smartphone game to increase children's outdoor activities in urban environments. In *ACM International Conference Proceeding Series*. <https://doi.org/10.1145/2836041.2841210>
54. K G Stanley, I Livingston, A Bandurka, R Kapiszka, and R L Mandryk. 2010. PiNiZoRo: A GPS-based exercise game for families. *International Academic Conference on the Future of Game Design and Technology, Future Play 2010*: 243–246. <https://doi.org/10.1145/1920778.1920817>
 55. Tammy Toscos, Anne Faber, Shunying An, and Mona Praful Gandhi. 2006. Chick Clique- Persuasive Technology to Motivate Teenage Girls to Exercise. <https://doi.org/10.1145/1125451.1125805>
 56. Tammy Toscos, Anne Faber, Kay Connelly, and Adity Mutsuddi Upoma. 2008. Encouraging physical activity in teens can technology help reduce barriers to physical activity in adolescent girls? In *Proceedings of the 2nd International Conference on Pervasive Computing Technologies for Healthcare 2008, PervasiveHealth*. <https://doi.org/10.1109/PCTHEALTH.2008.4571073>
 57. Mark S. Tremblay, Salomé Aubert, Joel D. Barnes, Travis J. Saunders, Valerie Carson, Amy E. Latimer-Cheung, Sebastien F.M. Chastin, Teatske M. Altenburg, and Mai J.M. Chinapaw. 2017. Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. *International Journal of Behavioral Nutrition and Physical Activity* 14, 1: 75. <https://doi.org/10.1186/s12966-017-0525-8>
 58. Yunlong Wang, Lingdan Wu, Jan Philipp Lange, Ahmed Fadhil, and Harald Reiterer. 2018. Persuasive technology in reducing prolonged sedentary behavior at work: A systematic review. *Smart Health*. <https://doi.org/10.1016/j.smhl.2018.05.002>
 59. Jingwen Zhang and John B. Jemmott III. 2019. Mobile App-Based Small-Group Physical Activity Intervention for Young African American Women: a Pilot Randomized Controlled Trial. *Prevention Science*: 1–10. <https://doi.org/10.1007/s11121-019-01006-4>
 60. Physical activity. Retrieved February 7, 2020 from <https://www.who.int/health-topics/physical-activity>

APPENDIX 1

Appendix 1. A Comprehensive Overview of PT for Physical Activity and/or Sedentary Behavior

#	Authors of Articles, Year, Reference	Domain	Technology	Application / Project Name	Persuasive Strategies /Affordances	Theories	Evaluation Method	Types of Personalization (Ways of implementation)	Duration	Targeted Outcomes	Audience Age Group	No. of Participants	Results	Country of Study
1	Foster et al.(2010), [16]	PA	Smartphone mobile, Computer, Pedometer	StepMatron	Tracking, Personalization, Goal Setting, Self-Monitoring, Social Support (Social Learning, Comparisons, Competition, Rankings Recognition, Giving Comments)	none	Mixed	motivational content and goal recommendation	3 Weeks	Behavior	Adults	10	Fully Successful	UK
2	He and Agu (2014), [23]	SB	Smartphone mobile	On11	Tracking, Reduction, Tunneling, Tailoring, Personalization, Goal Setting, Self-Monitoring (Self-Reflection), Reminder, Suggestion, Liking	none	Qualitative	activity recommendations, and intervention timing	2 Weeks	Behavior, Awareness	Adults	8	Partially Successful	USA
3	Fahim et al.(2017) , [14]	SB	Smartphone mobile	Alert Me	Tracking, Personalization, Self-Monitoring, Reminder	none	Quantitative	educational content, activity recommendation, intervention timing	Unspecified	Behavior, Awareness	Unspecified	0	Fully Successful	Russia
4	Mohadis and Ali (2016), [34]	PA	Smartphone mobile	WargaFit	Tracking, Reduction, Tunneling, Tailoring, Personalization, Self-Monitoring, Simulation, Rehearsal, Praise, Reminders, Suggestions, Similarity, Expertise, Real world feel, Third-Party Endorsement, Verifiability, Social Support (Social Learning, Social Comparison, Normative influence, Social facilitation, Competition, Recognition)	none	Mixed	goal recommendations, and activity recommendation	Unspecified	Behavior	Elderly	8	Fully Successful	Malaysia

Appendix 1. (continued)

#	Authors of Articles, Year, Reference	Domain	Technology	Application / Project Name	Persuasive Strategies / Affordances	Theories	Evaluation Method	Types of Personalization (Ways of implementations)	Duration	Targeted Outcomes	Audience Age Group	No. of Participants	Results	Country of Study
5	Cambo et al.(2017), [7]	SB	Smartphone mobile, Smartwatch	BreakSense	Tracking, Personalization, Self-Monitoring, Rewards, Reminder	none	Mixed	intervention timing, and activity recommendation	8 Days	Behavior	Adults	6	Partially Successful	USA
6	Mansart et al.(2015), [30]	PA and SB	Smartphone-based mobile exergame	Go Run Go	Tracking, Tunneling, Personalization, Self-Monitoring, Rewards, Social Support (Sharing)	none	Mixed	motivational content	Unspecified	Behavior	Adults	10	Fully Successful	Thailand
7	Lin et al.(2011), [29]	PA	Smartphone mobile application, web application	Motivate	Tracking, Reduction, Personalization, Feedback from users (Self-Report), Reminder, Suggestion	none	Mixed	motivational content, intervention timing, activity recommendations	5 Weeks	Behavior, Awareness	Adults	6	Fully Successful	Netherlands
8	Dharia et al.(2016), [11]	PA	Smartphone mobile applications	PRO-Fit	Tracking, Reduction, Personalization, Self-Monitoring, Reminder, Suggestion, Authorization, Social Support	none	none	goal recommendations, activity recommendations, fitness partner recommendations, intervention timing	none	Behavior	Unspecified	0	none	USA
9	Klein et al.(2017), [26]	PA	Smartphone mobile application, Web page, Facebook, Wearable activity tracker (Fitbit)	Active2Gether	Tracking, Reduction, Tailoring, Personalization, Goal Setting, Self-Monitoring, Simulation, Reminder, Suggestion, Liking, Social Role, Surface Credibility, Social Support (Social Comparison)	MBR, TTM, DCM, SCT, SRT, HAPA	Qualitative	motivational content, intervention timing, activity recommendations	3 Months	Behavior, Awareness	Young Adults	100	Fully Successful	Netherlands

Appendix 1. (continued)

#	Authors of Articles, Year, Reference	Domain	Technology	Application / Project Name	Persuasive Strategies / Affordances	Theories	Evaluation Method	Types of Personalization (Ways of implementations)	Duration	Targeted Outcomes	Audience Age Group	No. of Participants	Results	Country of Study
10	Arteaga et al.(2010) , [5]	PA	Smartphone mobile game application	Mobile App	Tracking, Reduction, Personalization, Self-Monitoring, Reward, Social Support (Competition)	TPB, TMB, PRT	Qualitative	activity recommendations, motivational content	1 Month	Behavior Motivation	Teenagers	5	Fully Successful	USA
11	Luca Chittaro and Riccardo Sioni (2012), [8]	PA	Smartphone mobile exergame	LocoSnake game	Tracking, Reduction, Personalization, Self-monitoring, Simulation, Rewards	none	Mixed	motivational content	5 Minutes	Attitude	Young Adults	15	Fully Successful	Italy
12	Haque et al.(2016) , [21]	PA	Mobile to web application (Android)	iGO	Personalization, Self-Monitoring, Rewards, Reminder, Social Support (Competition, Recognition)	SDT	Qualitative	motivational content	1 Week	Behavior	Young Adults	26	Fully Successful	Finland
13	Bond et al.(2014) , [6]	SB	Smartphone application, Wearable sensor	B-MOBILE	Tracking, Personalization, Goal Setting, Self-Monitoring, Praise, Rewards, Reminder	none	Quantitative	goal recommendations, intervention timing	16 Months	Behavior, Motivation	adults	30	Fully Successful	USA

Appendix 1. (continued)

#	Authors of Articles, Year, Reference	Domain	Technology	Application / Project Name	Persuasive Strategies /Affordances	Theories	Evaluation Method	Types of Personalization (Ways of implementations)	Duration	Targeted Outcomes	Audience Age Group	No. of Participants	Results	Country of Study
14	Skriloff et al.(2016), [51]	PA	Smartphone mobile application (Android), Wearable activity tracker (Fitbit)	FitPlay Games platform	Tracking, Personalization, Social Support (Cooperation, Competition)	none	none	intervention timing, and activity recommendation	none	Behavior, Motivation	Unspecified	0	none	USA
15	McMahon et al.(2013), [33]	PA	Smartphone mobile application	Ready~Steady	Reduction, Personalization, Goal Setting, Self-Monitoring, Simulation, Praise, Rewards, Social Role	WMT, USS, TDP	none	goal recommendations	none	Behavior	Elderly	0	none	USA
16	Ramanathan et al.(2012), [47]	PA and Experience Sampling	Mobile to web platform	ohmage	Tracking, Personalization, Self-Monitoring, Feedback from users (Self-Report), Praise, Surface Credibility, Social Support	none	none	goal recommendations, motivational content	none	Behavior	Unspecified	0	none	USA
17	Stanley et al.(2010), [54]	PA and Obesity	Smartphone mobile game application	PiNiZoRo	Tracking, Reduction, Personalization, Simulation	none	Qualitative	activity recommendations	Unspecified	Behavior, Awareness	Children	4	Fully Successful	Canada

18	Toscos et al.(2008), [56]	PA	Mobile phone application, Pedometer	Mobile App	Tracking, Personalization, Goal Setting, Self-Monitoring, Praise, Reminder, Social Support (Comparison, Competition, Sharing)	none	Mixed	motivational content	3 Weeks	Behavior	Teenagers	8	Partially Successful	USA
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Appendix 1. (continued)

#	Authors of Articles, Year, Reference	Domain	Technology	Application / Project Name	Persuasive Strategies /Affordances	Theories	Evaluation Method	Types of Personalization (Ways of implementation)	Duration	Targeted Outcomes	Audience Age Group	No. of Participants	Results	Country of Study
19	Mutsudi and Connelly (2012), [35]	PA	Mobile text messaging app, Pedometer	Mobile phone text messaging app	Tailoring, Personalization, Goal Setting, Self-Monitoring, Praise, Reward, Reminder, Suggestion, Social Support (Sharing)	TTM	Mixed	goal recommendations, motivational content	3 Months	Behavior	Young Adults	30	Fully Successful	USA
20	Toscos et al.(2006), [55]	Eating and PA	Cell-phone application, Pedometer	Chick Clique	Tracking, Reduction, Personalization, Self-Monitoring, Praise, Social Support (Cooperation, Competition, Sharing)	none	Mixed	motivational content	6 Days	Behavior, Awareness	Female Teenagers	10	Fully Successful	USA
21	Sohn and Lee (2007), [52]	PA and Smoking	PDA text messaging, Instant Messaging (IM) system, Mobile device	UP Health	Tracking, Personalization, Goal Setting, Self-Monitoring, Reward or Punishment, Reminder, Social Support (Cooperation, Competition)	none	Qualitative	goal recommendations	1 week	Behavior, Awareness	Adults	5	Partially Successful	South Korea
22	Glynn et al.(2013), [20]	PA	smartphone, Pedometer	Accupedo	Tracking, Personalization, Goal Setting, Self-Monitoring, Social Support (Sharing)	none	Qualitative	goal recommendations	2 Months	Behavior	Adults	80	Unspecified	Ireland

23	Marcu et al. (2018), [31]	PA	Smartphone mobile	Bounce	Reduction, Tunneling, Personalization, Goal Setting, Self-Monitoring, Praise, Rewards, Reminders, Social Role, Trustworthiness, Expertise, Authority, Social Support (Normative Influence, Cooperation, Social Interaction)	TTM, SCT	Qualitative	motivational content , goal recommendations	3 Weeks	Behavior, Attitude, Awareness, Motivation	Adults	4	Fully Successful	USA
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Appendix 1. (continued)

#	Authors of Articles, Year, Reference	Domain	Technology	Application / Project Name	Persuasive Strategies /Affordances	Theories	Evaluation Method	Types of Personalization (Ways of implementations)	Duration	Targeted Outcomes	Audience Age Group	No. of Participants	Results	Country of Study
24	Zhang and Jemmot t (2019), [59]	PA	Mobile application, Activity Tracker (Fitbit)	PennFit	Tracking, Personalization, Self-Monitoring, Reminder, Social Support (Comparison, Social Interaction (messages with chatting tool))	SCT	Quantitative	motivational content, intervention timing	3 Months	Behavior, Awareness	Young Adults	91	Fully Successful	USA
25	Lee et al. (2018), [28]	PA and SB	Smartphone application	Puzzle Walk	Tunneling, Personalization, Goal Setting, Self-Monitoring, Praise, Rewards, Reminder, Liking	unspecified	none	goal recommendations	none	Behavior, Motivation	Adults	34	none	USA
26	Lane et al.(2014), [27]	PA, Sleep, Social Interaction	Smartphone application, and ambient display on the smartphone wallpaper	BeWell+	Tracking, Personalization, Self-Monitoring, Simulation, Rewards, Liking, Social Support (Social Interaction)	none	Quantitative	motivational content	19 Days	Behavior, Social Interaction	Unspecified (General)	27	Fully Successful	UK

27	Hong et al.(2013), [24]	PA	A mobile to web application (desktop version as a web, iPhone version)	iCanFit	Tracking, Reduction, Tunneling, Tailoring, Personalization, Goal Setting, Self-Monitoring, Suggestion, Praise, Trustworthiness, Expertise, Surface Credibility, Real-world Feel, Authority, Third-party Endorsements, Verifiability, Social Support (Normative Influence, Social Interaction)	none	Mixed	goal recommendations, motivational content, educational content	11 months	Behavior, Motivation	Elderly	112	Fully Successful	USA
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Appendix 1. (continued)

#	Authors of Articles, Year, Reference	Domain	Technology	Application / Project Name	Persuasive Strategies /Affordances	Theories	Evaluation Method	Types of Personalization (Ways of implementations)	Duration	Targeted Outcomes	Audience Age Group	No. of Participants	Results	Country of Study
28	Francillette et al.(2018), [17]	PA	A smartphone exergame application	An smartphone exergame app	Reduction, Tailoring, Personalization, Goal Setting, Self-Monitoring, Rewards, Reminder, Liking	none	Mixed	goal recommendations, intervention timing	30 minutes	Behavior, Motivation	Adults	15	Partially Successful	Canada
29	Dantzig et al.(2018), [10]	PA	A smartphone application, wearable activity tracker device	A digital smartphone coaching system	Tracking, Personalization, Self-monitoring, Praise, Reminder, Suggestion	none	Mixed	goal recommendations, educational content, motivational content	1 Month	Behavior, Motivation	Adults	70	Partially Successful	Netherlands
30	Altmeyer et al.(2018), [4]	PA	A gamified system includes fitness tracker, mobile app, website as a	A gamified mobile app	Tracking, Personalization, Self-Monitoring, Rewards, Reminder, Similarity, Social Support (Comparison, Normative Influence)	SDT	Mixed	motivational content	1 Month	Behavior, Motivation, Usability	Adults	12	Partially Successful	Germany

			public display											
31	Schafer et al.(2018), [50]	PA	A gamified smartphone app	A gamified smartphone app	Tracking, Personalization, Self-Monitoring, Praise, Rewards, Liking	none	Mixed	motivational content	1 Month	Behavior, Awareness, Motivation, Acceptance, Attitude	Children	61	Partially Successful	Germany
32	Ciravegna et al.(2019), [9]	PA	Mobile phone application	Active 10	Tracking, Reduction, Personalization, Self-monitoring, Goal-Setting, Praise, Rewards, Reminders, Expertise, Real-world feel	unspecified	Quantitative	goal recommendations and motivational content	1 year and 11 months	Behavior, Adherence	Unspecified	749,010	Fully Successful	UK

Appendix 1. (continued)

#	Authors of Articles, Year, Reference	Domain	Technology	Application / Project Name	Persuasive Strategies /Affordances	Theories	Evaluation Method	Types of Personalization (Ways of implementations)	Duration	Targeted Outcomes	Audience Age Group	No. of Participants	Results	Country of Study
33	Oyibo et al.(2019), [45]	PA	Mobile phone application	BEN'FIT	Tailoring, Personalization, Goal-Setting, Self-Monitoring, Rewards, Social Support (Social Learning, Social Comparison, Cooperation)	SCT	Mixed	goal recommendations, motivational content	1 Months	Behavior, Motivation	Adults	120	Partially Successful	Canada, USA, and Nigeria
34	Samaruya et al.(2019), [49]	PA	Mobile application, Wearable LED Color Light Display, Activity Tracker	KidLED mobile application	Tracking, Personalization, Goal-Setting, Self-Monitoring, Social Support (Social Learning, Social Comparison)	none	none	goal recommendations	none	Motivation, Awareness	Children	none	none	USA

35	Oliveira et al.(2016), [36]	PA	Mobile application	PersonalFit	Tracking, Reduction, Personalization, Social Role	none	none	goal recommendations	none	Self-management	Unspecified	none	none	Portugal
36	Economou et al.(2017), [13]	PA and Eating (Diet)	Gamified Mobile Web App	PhytoCloud	Tracking, Tailoring, Personalization, Goal-Setting, Self-Monitoring, Suggestions, Trustworthiness, Expertise, Surface Credibility, Authority, Third-Party Endorsement, Social Support (Social Learning, Normative Influence, Recognition (Ranking), Sharing)	none	none	educational content , motivational content	none	Behavior	Adults	none	none	UK

Appendix 1. (continued)

#	Authors of Articles, Year, Reference	Domain	Technology	Application / Project Name	Persuasive Strategies /Affordances	Theories	Evaluation Method	Types of Personalization (Ways of implementation)	Duration	Targeted Outcomes	Audience Age Group	No. of Participants	Results	Country of Study
37	Geurts et al.(2019), [18]	PA	Mobile application	Walk-WithMe	Tracking, Tunneling, Tailoring, Personalization, Goal-Setting, Self-Monitoring, Praise, Expertise, Social Support (Sharing)	GST	Mixed	goal recommendations, educational content, motivational content	10 Weeks	Behavior, Motivation	Elderly	13	Fully Successful	Belgium

38	Spies-berger et al.(2015), [53]	PA	A gamified smartphone app	Woody	Tracking, Personalization, Simulation, Reminder, Rewards, Liking, Expertise	none	Mixed	motivational content	12 Days	Behavior, Awareness, Motivation	Children	38	Fully Successful	Austria
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ABBREVIATIONS

MBR: Model-Based Reasoning

TTM: Transtheoretical Model

DCM: Dynamic Computational Model

SCT: Social Cognitive Theory

SRT: Self-Regulation Theory

HAPA: Health Action Process Approach

TPB: Theory of Planned Behavior

TMB: Theory of Meaning Behavior

PRT: Personality Theory

SDT: Self-Determination Theory

WMT: Wellness Motivation Theory

USS: User-Specific Strategies

TDP: Theoretical Design Principles

GST: Goal-Setting

