Persuasive system features in computer-mediated lifestyle modification interventions for physical activity

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Abstract

Objective:
Increasing physical activity has been identified as one of the most important factors in lifestyle modification. Previous studies have reported the effectiveness of using the Internet in motivating behavioural modifications of physical activities. The aim of this study is to identify the persuasive system features most frequently used in computer-mediated physical activities in the current literature.

Materials and Method
In this review, intervention studies were identified through a structured computerised search of PubMed, PsychInfo, and Web of Science. The results of the search were analysed using the Persuasive Systems Design (PSD) features identified by Oinas-Kukkonen and Harjumaa (2009).

Results
Thirty-eight articles were reviewed and the features of the physical activity interventions described were mapped to the identified facets of Persuasive Systems Design (PSD). The PSD features used most often by researchers in the studies considered in this research included: tailoring; tunnelling; reminders; trustworthiness; and expertise. The effectiveness of the interventions described in the studies was also compared. The stage of change theory was applied in several intervention studies and the importance of stage of change has been identified in effectiveness of persuasion towards physical activity.

Research highlights

- The persuasive systems design features commonly present in physical activity intervention studies were identified.
- The tailoring, tunneling, reminders, trustworthiness and expertise features were used more frequently than others in promoting health behaviour change to increase physical activity.
- The tailoring feature was frequently used in conjunction with features from the dialogue support category to encourage physical activity in online applications.
- The social support category was not discussed widely in physical activity intervention studies.
- The effectiveness of computer-mediated lifestyle modification interventions for physical activity was gauged.

Persuasive system features in computer-mediated lifestyle modification interventions for physical activity

1. Background

”Prevention of chronic disease has become a priority in the healthcare industry” (1, 2). One of the key aspects—and a dilemma—in minimising the risk factors for chronic diseases is how to motivate people to modify their lifestyle (3). Increasing physical activity has been identified as one of the most important factors in lifestyle modification; among others such as balanced nutrition, smoking cessation, and reduction in alcohol intake. Previous studies have reported on the effectiveness of online self-management in behavioural modifications (4-6) such as a self-monitoring program for people living with HIV/AIDS (7), a burns self-management education program (8), a diabetes self-management education program (9) and an asthma self-management program (10). There is evidence supporting the contention that online health information provision, education and management have both health and social benefits for health consumers (6, 11). Studies also indicate that interactive computing could change consumers’ attitudes and behaviour with regard to their healthcare management (12).

Several studies have described how behaviour change support could be implemented to improve health management (13-16). Behaviour change support systems are defined as “socio-technical information systems with psychological and behavioral outcomes designed to form, alter or reinforce attitudes, behaviours or an act of complying without using coercion or deception” (17) and such systems must be persuasive in nature; employing computer–human persuasion or computer-mediated persuasion.

As the intent of behaviour change is to influence users, it is important to identify the design features in these systems that elicit the desired outcomes. Since context always plays an important role in persuasion, each event of persuasion should be designed after identifying the problem domain as well as the attitude, behaviour motivation of the intended users, and the technology-dependent features (14, 18).

The aim of this study is to identify the persuasive features most frequently used in the design of physical activity interventions. A literature review was conducted to identify the Persuasive Systems Design (PSD) features (19).

1.1. Persuasive systems design

Over the years, models and theories of persuasion have been posited in an effort to identify its characteristics. The Elaboration Likelihood Model explains the effectiveness of persuasive communications by describing it as a dual process involving a central and peripheral "route" (20). Using this model of persuasion in a behavioural change design, text messages could be provided as the central route to assist in critical thinking, with information presentation as the peripheral route (21). Persuasive systems that mimic or extend the patient-provider communication would be likely to assist in the process of behavioural change (14). Social Support theory also indicates that social support can influence the health and well-being of individuals (22). Several researchers have studied the concept of tailoring a system according to the user's needs (8, 11, 23, 24), providing interactivity with the system for better communication (25-27), and social support (28, 29) to assist patients' behavioural change. Michie et al. (2013) identified a behaviour

change taxonomy which included a number of facets such as "scheduled consequences", "reward and threat", "repetition and substitution", "antecedents, associations", "covert learning", "natural consequences", "feedback and monitoring", "goals and planning", "information about others' approval", "self belief", "comparison of outcomes", "identity", "shaping knowledge and regulation" (30). Various studies have adopted behaviour change perspectives based on different theoretical philosophies. Of these, Social Cognitive Theory has been strongly favoured in behaviour change studies (31) with goal-setting being a key strategy for behaviour change (31). While providing information is important, including an attainable goal for behaviour change to enhance personal motivation is also regarded as an essential ingredient. Additionally, social motivation should be provided in behaviour change interventions. Goal-setting can be self-set, assigned or collaborative (32, 33). Therefore, including goal-setting, having an attainable goal, conducting self-monitoring and providing feedback have been recognised as requirements for behaviour change support (34). Fogg (2003) identified recognised that computers could act as tools, social actors and media for persuasion; leading to behaviour change (12). From this perspective, technology-assisted health behaviour change support systems need to provide behaviour change techniques such as goal-setting, self-monitoring, feedback, reinforcement (35), and social support (18). Previous studies also have reviewed behavior change techniques for different health domain (36).

The Persuasive Systems Design (PSD) model has been developed to assist in both designing and evaluating systems that influence the attitudes or behaviours of users (19) and has been validated in previous studies (37, 38). The model defines seven postulates which need to be addressed when designing or evaluating persuasive systems. These key

premises relate to the users of persuasive systems, persuasion strategies, and system features. The system features are divided into four categories: primary task support; dialogue support; system credibility support; and social support. In addition to this, the model defines twenty-eight design guidelines, which are subdivisions of the four categories. These guidelines describe system features that will improve the persuasiveness of a system. These features are presented in Table 1.

Insert Table 1 here.

2. Methodology

2.1. Search Strategy and Data Sources

In this review, intervention studies were identified through a structured computerised search of PubMed, PsychInfo, and Web of Science. The search terms used were (exercise OR motor activity OR sports OR leisure activities) OR (physical* AND active) OR (physical* AND activity) OR (physical* AND activities) OR exercis* OR walking OR cycling OR sport* OR leisure activit* AND (education OR behavior OR behavio* OR education) AND (tailored OR tailoring OR tailor* OR expert system). To identify the delivery platforms of interest, the following search terms were added: (web* OR computer* OR internet* OR online OR mobile OR mHealth OR digital OR technology). No limitations for age of participants or study design were added, however the studies considered were confined to those targeting physical activity to improve user's health.

2.2. Selection of Studies

The studies selected for this review had to examine a computer-based intervention aimed at promoting healthy physical activity as a means of preventing potentially chronic diseases. The selection criteria devised by the authors determined that the platform for the intervention could be either a static or a mobile computing device and delivery could be via an application or a browser. The search terms were used to identify potential studies in three databases: PubMed, PsychInfo and Web of Science. One of the authors searched these databases and exported the results to an Endnote file. Two authors independently assessed the suitability of the articles and discussed the results after every stage of the filtering process. The elimination process is depicted in Figure 1.

Insert Figure 1 here.

Figure 1: Flow Chart of Database Search

Inclusion and Exclusion criteria

Inclusion criteria

- Studies need to meet following criteria to be included in the review
- A peer reviewed article, written in English
- Paper focuses on lifestyle modification of physical activity.

Exclusion criteria

- Papers focused on other behavioural change activities such as smoking cessation, medication management, and alcohol consumption
- Studies on continuing medical education for health professionals
- Articles that are not consumer-centric
- Disease specific studies, which are not related to physical activities
- Intervention studies on physical activity change that do not use any form of information technology
- Reviewed articles.

2.3. Data Extraction

Detailed information was extracted only from studies that met the aforementioned criteria for inclusion and exclusion. Two authors were involved in the data extraction process. After the final 38 articles were identified, the three authors reviewed the articles and coded them on an Excel spreadsheet according to the definitions of the 28 design features identified in the PSD (19). Any differences in the coding were discussed and a second round of coding was conducted. The final mapping was based on the agreement of at least two (of the three) authors. Articles were also categorised based on the study type. Those studies that conducted a randomised controlled trial were further assessed to determine which behaviour change techniques had been utilised and what outcome or outcomes had been achieved.

3. Results

3.1. Study selection

The initial cross-database search resulted in 981 articles. Titles and abstracts were reviewed further for specific eligibility criteria, resulting in 173 papers that were fully considered. Of those, thirty-eight were eventually included: 24 of those studies involved a web-based application; 5 used a combined web and SMS or app intervention approach; and 4 studies focused on an SMS intervention. The remainder of the studies used specialised equipment such as accelerometers or technology specifically designed for the intervention. Of the total, twelve papers discussed studies conducted in the USA, seven in Australia, five in the Netherlands, three in Belgium, two studies from Denmark, and one study each from Germany, Hong Kong, Iran, Korea, Norway and the UK. Two studies included international studies, which covered (i) Canada and London and (ii) Germany and the Netherlands. The participants involved in the studies varied from school aged children to adults.

Insert Table 2 here.

Insert Table 3 here.

3.2. Persuasive Systems Design

3.2.1. Primary task support

Computer-mediated persuasion has been identified by the authors of the reviewed papers as a means to motivate and assist users to perform the required tasks. As the reviewed articles were focused on motivating users to be physically active and encouraging users to continue using the system, the primary task support features of the PSD model (19) were present in many of these systems. Reduction (n=22), tunnelling (n=27), tailoring (n=33) and self-monitoring (n=24) were frequently noted in these articles. However, not all persuasive features are present in all the systems reviewed. Tailoring (n=33) was present in the majority of the systems described in the articles included in this review. The results of this review suggest that tailoring could be grouped with goal-setting, that is: allowing the users to choose from a set of options after giving them the available information or after using a questionnaire to profile the users (39, 40). Tailored activity and action plans were presented to users based on answers to the physical activity and psychosocial questionnaires assessment in one study (41). The reduction and tunnelling features are incorporated when a tailoring intervention has been provided; as tailored information or providing an activity would reduce user effort and bring them to the targeted behaviour. Dour et al. (2013) also suggested gender-tailored motivation as there are different health motivators for men and women (42). Step wise goal-setting was provided to participants in “Guide to Health Program” (43). Physical activity advice is tailored according to the patients’ stage of change in the study conducted in Australia to promote physical activity for different age groups (39).

The reduction feature was presented in physical activity interventions to assist users. The “COMPASS” study provides an Embodied Conversational Agent with which users can

interact, simply by touching the screen (44). Similarly, an interactive application such as Google Maps is made available to users to provide them with a navigational path (45).

The tunnelling feature was identified in many of the reviewed articles which described systems that provided tailored information based on the results of an assessment conducted on an individual user (46).

Kaptein et al. (2015) identified personalisation as both an explicit and implicit method (14). This would be achieved through explicit profiling, as tailored physical activities would be provided after answering a questionnaire, while implicit profiling would utilise the user's profile, behaviour and data from the user's social networking. Both these methods have been coded under tailoring in this review as they provide tailored information to the users.

There are several self-monitoring tools available to encourage lifestyle modifications by consumers. Web-based self-monitoring systems have been developed and these systems encourage consumers to be involved in their own healthcare (47). Sixty three per cent (24 out of 38) of the articles in this review included self-monitoring functions for consumers. This feature is presented in the systems in a variety of forms such as users sending weekly self-monitoring data via their mobile phone (48) which will become the basis for the tailored messages that they receive about their lifestyle management. A health promotion program provided to high school students used interactive self-monitoring logs for exercise and weight management (49). A clinically-endorsed lifestyle support program developed for perinatal women included progress tracking through an interactive website and a smart phone app for self-monitoring (50), while participants in a Cardiofit activity were asked to log their daily activity on a dedicated website (51).

3.2.2. Dialogue support

An important component in persuasive technology is the provision of an intervention similar to ‘‘human-to-human’’ interaction such as dialogue support (14, 52). Dialogue support must be designed according to the context in which it will be used. In a nutritional coach program, the dialogue support was designed to replicate the first session a client would have with a health advisor (53). Oinas-Kukkonen and Harjumaa (2009) identified seven features of dialogue support: praise, rewards, reminders, suggestion, similarity, liking and social role (19). Reminders and feedback in the form of praise and suggestion are essential components of effective healthcare management. Providing feedback has become an important aspect of online health interventions (54-56) since it is recognised that providing praise and rewards to users encourages them to continue modifying their behaviour. The articles included in this review indicated that positive feedback was provided to participants such as: badges being awarded for meeting the step goals, and paper walking shoes being presented when identified step goals were met (43). Motivational text messages were sent to participants in several studies (48, 57, 58).

Researchers have recognised that reminders for health interventions enhance health promotion and adherence to the user’s healthcare management guidelines (59, 60). Reminders prompt patients to perform the required task (61), hence they play a pivotal role in online health promotions and interventions. The studies examined in this review indicated that reminders (n=30) had been provided via SMS (57), and by phone and email (62).

The suggestion feature (n=22) encourages users to carry out the desired behaviours (4). This feature was identified in the Healthy Weight Assistant Program in which users were coached to: set useful and realistic goals, (63); reflect on their achievement; and find solutions (63).

Oinas-Kukkonen and Harjumaa (2009), in discussing computer-human persuasion, stated that a virtual personal advisor could provide support (19). This social role feature (n=7) was identifiable in some of the articles reviewed. In the "COMPASS" study, for example, a virtual advisor provided suggestions in English and Spanish about physical activity (44) and participants were encouraged to interact with the advisor on a weekly basis, or as frequently as they desired.

The similarity (n=3) feature was not utilised in most of the reviewed articles. The computer-human persuasion can be constructed as the influence of peers to the user. For example, Lau et al. (2012), used SMS messages which had been sent by a peer of the participants because studies have indicated that adolescents prefer to receive support from others in their own age group (64). Other examples of computer-human support evident in the reviewed articles were features such as: a salutation and individualised social dialogue sent to users from a virtual avatar (44); feedback on the progress of each participant's lifestyle modifications in graphical formats (43, 65) or using a multimedia format such as videos (66).

The "Liking" feature could not be identified in the articles reviewed as this feature would be more evident in a review of the actual system, rather than in the intervention studies.

3.2.3. System Credibility Support

It has been noted that reliability, credibility, accessibility, and readability of information are among the main concerns consumers have regarding online health information (67) (68). Credibility of information has the potential to critically affect health outcomes for many users (69). Efforts have been made to establish the criteria required for high quality online health information such as the Health on the Net Code of Conduct and the ongoing work of the Health Summit Working Group (47). System credibility support in the PSD model (Oinas-Kukkonen & Harjumaa, 2009) includes the facets of trustworthiness, expertise, surface credibility, real world feel, authority, third party endorsement and verifiability(19). The studies considered in this review have acknowledged that healthcare providers' advice to patients about targeted behaviour will be more effective (70) when there is obvious involvement of health professionals, so providing expert opinions will be beneficial to users of persuasive systems. The reviewed articles also indicated that trustworthiness (n=33) and expertise (n=31) had informed the design of the persuasive systems described. Most of the articles reviewed were studies of randomised controlled trials and interventions from health organisations and or based on clinical endorsement, thus, the credibility support features listed above have been covered. For example, in the "My Activity Coach" program the specific benefits of physical activity were sourced from the research findings of trusted organisations such as the World Health Organisation (40). Some systems provided expert advisers to users who were able to email an exercise specialist and ask questions about the program (41).

Other system credibility support facets, such as authority (n=7), third party endorsements (n=5) and verifiability (n=6), were not mentioned as much as the trustworthiness and expertise features in the reviewed articles. It could be, however, that the actual

application did have those features because the systems were supported by or developed and informed by a University hospital, health organisation or government-funded institution but these were not discussed in the papers this study reviewed.

Surface credibility and real world feel were also not noted as features of the systems described. This may have been because the reviewed papers were mainly focused on clinical trials, or the results of interventions, so the information architecture of the websites, or the medium used, were not discussed.

3.2.4. Social support

Social motivation is another means by which to steer people towards the targeted behaviour (3), so the system implemented should include social support. Social comparison, social learning, normative influence and social facilitation are facets of social support that will encourage users to adopt the targeted behaviour because they can observe others with the same characteristics perform the behaviour in a similar situation (14, 71). There were a few examples of social support being facilitated between participants such as the Rural Environment and Community Health (REACH) Program which implemented online forums where participants could provide peer support through sharing experiences and information (62, 72). Participants were also encouraged to interact with each other, sharing information among others in the SMART study conducted by Patrick et al. (2014) (72). Informal support of this type was also facilitated via an online expert system used by the Kaiser Permanente Integrated Healthcare program designed for weight management (73). Social support was provided to participants in a ManUp study where participants could create a group and provide support (74) .

The social support category was one which was not frequently utilised, with facets such as cooperation (n=4), competition (n=1) and recognition (n=1) almost unused; at least when compared to the other three categories of the PSD (19). It might be expected, however, that the uptake of this feature will increase with the growing adoption of mobile technologies and social applications in healthcare.

Combined Persuasive Systems Design features

There are also instances where the tailoring feature in the primary task support category was used in conjunction with features from the dialogue support category such as praise, rewards, suggestion and reminders. The tailored feedback provided by the FATaintPHAT intervention aimed at Dutch adolescents for obesity prevention, for example, combined the provision of information targeted at their age range while encouraging them to discuss that information with their family and peers (75). Another intervention used tailored interactive text encouragements to increase the aerobic fitness of Danish adolescents (58), while a third provided tailored recommendations to manage obesity (76). Tailored reinforcement messages and personalised feedback were also provided to participants in an Internet-based weight loss program (77). Tailored messages were also provided to participants according to the self-monitoring data in an SMS maintenance treatment program for obese children (48).

These results represent how PSD features could be applied in computer-mediated physical activity interventions. Twenty of the 38 articles reported clinical trial results.

Theoretical perspectives, the behaviour change techniques applied, and the results of these studies, will be presented in the following sections.

3.3. Theoretical perspectives and the studies

The theory of Stage of Change (the Transtheoretical model) was applied in six studies (41, 57, 64, 78-80), Social Cognitive theory was used in eight (43, 44, 72, 74, 81-84), and the theory of Planned Behaviour was applied in four (62, 66, 78, 79). Other behaviour-change interventions were also used, although different theories were applied, and this information is presented in Table 4.

Insert Table 4 here.

3.3.1 Study type variations

The majority of studies (41, 43, 44, 57, 64, 72, 73, 81-85) focused on the outcome comparison with or without a specific behaviour change intervention. Some studies, however, were conducted using the same behaviour change technique but utilising different media, such as printed media compared to computerised media (45, 74), or face-to-face interactions versus a computer-based intervention (51). The intervention periods varied widely with a minimum of 8 weeks to a maximum period of up to 2 years. The characteristics of these studies, and their outcomes, are presented in Table 5.

Insert Table 5 here.

3.4. Effectiveness

Importance of stage of change

When attempting to persuade individuals to change their lifestyle and modify their behavior, not all the interventions described in the reviewed papers had significant outcomes. For example, the intervention conducted by Hansen et al. (2012) indicated that there were no significant differences in physical activity in the controlled group and the intervention group of physically inactive participants because the participants were not motivated to change. The intervention was conducted for 6 months with 12,287 physically inactive participants from 11 Municipalities in Denmark. The intervention was based on the theories of Planned Behaviour and Stage of Change. Although the intervention included tailored advice, normative feedback, a training program, a forum and general support, there was no significant difference between the control and intervention groups (79). Less than 7 per cent of participants in the study frequently visited the program's website, which demonstrated that participant's readiness to change plays an important part in changing health behaviour with regard to increasing physical activity. This was paralleled by the research of Antypas and Wangberg (2014) who found that the effectiveness of a tailored intervention is based on the patient's stage of change. Both the control group (n=38) and the intervention group (n=29) in their study could access basic web information related to the desired lifestyle modification, while the intervention group was provided with tailored feedback based on their answers to a questionnaire, such as reminders, visualized feedback, goal-setting, praise and encouragement of their activities. Only 19 participants remained to the end of the 3 month study period (57).

In contrast, a 3 month study conducted by Mutsuddi and Connelly (n=28), indicated that personal text messages customised according to the stage of change had resulted in the successful promotion of healthy physical activity. It was noted that the intervention had progressed the stage of change from "contemplation" to "action"(80).

Similarly, a one month follow up study conducted by Ammann et al. (2013) in Australia indicated that tailored messages from a dedicated website had a positive impact on the intervention they had designed (39). Both the theory of Stage of Change and the theory of Planned Behaviour were applied in the study. Personalised advice on physical activity was provided to participants, based on a psychosocial and physical activity questionnaire, and their answers were used to inform the feedback, suggestions and tailored messages they subsequently received. The study was based on self-reported physical activity improvements via a survey and, although a positive impact from the tailored intervention was noted, there were no significant differences among the participants who ranged in ages from 19 to 89 (39). Spittaels et al. (2007) reported in their study that there was a greater increase in the physical activity of participants in first four stages of TTM (Transtheoretical model) (41).

In a follow up study of Hong Kong Chinese school children, it was found that there were significant increases in their stage of motivational readiness in self-reported physical activity in the intervention group, eight weeks after the intervention (64). The intervention group (n=38) received tailored resources and self-monitoring resources, according to their stage of change, while the control group (n=40) received no intervention. (64).

High attrition was reported in studies based on the patients' stage of change, except for the one conducted by Mutsuddi and Connelly (2014) (86) with 18 to 24 year old college students in which participants were compensated up to $100 for their involvement (86) . Ammann et al. (2013) reported 395 out of 803 participants did not return after 1 week of study, although positive outcomes were seen in those who continued with the intervention (39).

Positive outcomes

A lifestyle behavior change program designed by Steinberg et al. (2013) resulted in participants losing an average of 1.27 kg in the intervention group, while the controlled arm had gained 1.14 kg, when a follow up was conducted 6 months after the intervention (85). Participants in the intervention group (n=26) received behaviour change goals based on their performance and were sent tailored messages, feedback, self-monitoring and action planning information. Videos consisting of suggestions and skill training were also sent regularly to the participants. The control group (n=24) received a group education session at baseline and after six months. They were also provided with an educational video at 3 months (85).

The study conducted by Rothert et al. (2006) of a 6 week intervention program included a comparison of the outcomes of standard online information-only activity and tailored activity. A tailored expert system provided relevant information to participants according to their psychosocial profile, family history, and tailored action plan. A supportive buddy program, emails, and suggestions were also provided. The information-only program only provided general information about lifestyle modification (73). Follow up results on

the comparative study indicated that the tailored expert system had a significant effect on participants at the 3 month and 6 month post-intervention points (73).

Reid et al. (2012) (51) also reported that the intervention group in their study that received internet coaching significantly increased their physical activity. The intervention group (n=115) logged their activity daily, received motivational feedback, watched online tutorials and followed a physical activity plan. The control group (n=108) received physical activity guidance from the doctor and an education booklet (51).

An online tailored program for adolescent school students demonstrated that an online behaviour change program is beneficial as it can anonymously provide the intervention to targeted individuals, which prevents stigmatisation (49). The program included providing knowledge, tracking activity, giving feedback according to the student's input, goal-setting by participants and providing encouragement (49). This was a non-randomised study but positive outcomes for physical activity were evident in the weight management intervention group.

Sixty eight percent of men and 63 per cent of women reported being motivated in the "Project Web Health" project, a web-based health promotion intervention program (42). In this program, the intervention group received 10 weeks of online lessons about lifestyle modification. The lessons were supplemented by goal-setting, personalised self-assessment, suggestions and forum discussions (42). Similarly, 77.8 per cent of participants in the intervention group were satisfied with the SMART study (87) in which there were statistically significant differences in weight loss in a 6 month period

(72, 87). The SMART study was almost unique in implementing all four categories of the PSD features identified by Oinas-Kukkonen and Harjumaa (2009) .

A study conducted by King et al. (2013) noted that there were significant differences compared to the control group in a 4 month period. Applying Social Cognitive theory, the study utilized the behaviour change perspectives of goal setting, self-monitoring and social support. The health promotion intervention provided a virtual advisor to fulfil the social role (44).

No significant differences

In some studies, however, there were no significant differences between the control group and the intervention group (79). Hansen et al, (2012) (79) reported that some participants did not log in to the website and, despite being in the intervention group, they did not participate in the intervention. Studies conducted by Patrick et al., 2011 (83) indicated that there was a significant increase in physical activity but not a significant difference in weight loss in their control group.

Although the effectiveness of studies has been reported, the potential for study bias needs to be taken into consideration. Attrition bias can be seen in some of the studies (51, 83) as the analysis undertaken is only based on those who persisted. Participant numbers were very low in some studies (44, 57, 62) and a confidence interval for the intervention could not be conducted. In some studies assessor blinding had not been undertaken (79) and the authors contended that because participants had submitted their results online,

blinding was not necessary. Selection bias can also be seen in some studies (41) as participants were voluntarily involved in the physical activity intervention study.

Despite the culling process, some of the reviewed articles - which had indicated that an intervention had been conducted - were found to be discussions about a system that was still in the proposed stage of intervention (40) or the design and implementation stage (88) or the study details were presented but not the outcome (46, 65).

4. Discussion

Some features of persuasive systems have appeared frequently in previous research on computer-mediated lifestyle modification interventions. Tailoring, for example, was one of the most common features utilised (33 out of 38). This took varying forms such as: tailoring according to user groups and introducing activities; providing tailored feedback to users; and tailored interventions after participating in social networking activities. Tailoring also often appeared in conjunction with the dialogue support features as it can enhance the personalised experience of users. It should be noted, however, that there can be some discrepancies between the use of the terms “tailoring” and “personalisation” in the reviewed articles, and the definition of personalisation made by Oinas-Kukkonen and Harjumaa (19, 88). They differentiated between tailoring and personalisation by defining tailoring as being at the level of the user group while personalisation is at the level of the individual experience or whether the individual could change the system’s user interface,

the timing of message delivery, and other features of the system. The differentiation made by Oinas-Kukkonen and Harjumaa (2009) between these two features demonstrates that there is a fine line between tailoring and personalisation as system features, and this needs further exploration. Additionally, personalisation can be implemented by including implicit profiling which will involve identifying users' habits, activities and features of their social interactions. This type of profiling could, however, present some dilemmas regarding privacy and ethical responsibilities. As indicated by Oinas-Kukkonen and Harjumaa (2008) a persuasive system should be unobtrusive and provide information at an appropriate time (4).

A key finding made by this review is that, in most cases, the lifestyle modification applications and technologies were driven by technological opportunities and analysing consumer needs rather than any identified set of persuasive features. This is not surprising, however, as those involved in the development of a behaviour change support system may choose not to incorporate all the persuasive features identified (18, 88).

In fact, some of the articles describing behaviour change support systems did not use the term 'persuasive technology' but stated that the system had been designed to modify the current behaviour of users. The authors of one article (Alley et al., 2014) claimed that "no [previous] web-based physical activity interventions have provided both computer-tailored advice and online coaching simultaneously". As a result of their findings the "My Activity Coach" system they had designed (40) provided persuasive system features in all four of the categories identified by Oinas-Kukkonen and Harjumaa (2009) (19).

Behaviour change support systems would be more effective if they provide effective communication to specific age groups, as this is likely to result in better healthcare

outcomes and empower participants. This was demonstrated in the reviewed articles which described systems facilitating effective health behaviour change in groups of teens, adolescents, school aged children (64), college students (42), adults and older individuals (39), showing that age does not have to be a barrier when providing computer-mediated physical activity interventions and promoting healthy lifestyles.

Nevertheless, high attrition in intervention programs was noted in some of the reviewed articles. Health behaviour change studies indicated that tactics such as contract monitoring and providing rewards for adherence were used in behaviour modification programs (89). Although 63 per cent of the reviewed articles indicated that computer tailored monitoring was provided, giving rewards for adherence was barely mentioned (2 out of the 38 articles reviewed). In contrast, the praise feature was present in 45 per cent of the reviewed papers. Using praise and rewards as features of a persuasive system may have reduced this attrition and improved the level of behaviour modification. Adherence to a physical activity intervention has been explored in exergaming activities and these options will need to be studied further regarding physical activity behaviour change (90).

Health behavioural change studies in psychology and healthcare indicate that patients' behavioural change can be divided into five stages, according to the Transtheoretical Model (91). In this model Prochaska et al. (2008) indicate that the maintenance stage is the most difficult to sustain. Current literature, however, (48) indicates that providing tailored messages to users would optimise the maintenance stage. This implies that providing tailored messages to engage users who have reached this stage would be beneficial in helping them to maintain the achieved health behavioural change. In contrast, results from Spittaels and de Bourdeaudhuij (2006) (92) indicated that there

were notable changes in outcome in the earlier stages, compared to the maintenance stage. Persuasive Systems Design features (19) presented in these systems are similar, however, to the de Niet et al. (2012) study which was only focused on participants in the maintenance stage (46). Antypas & Wangberg (2014) also found that patients' stage of change plays an important part in the effectiveness of the intervention (53).

Behavioural change would also be dependent on the values of the audience, their cultural norms and living patterns and these aspects need to be taken into consideration when designing a persuasive system (88). In the PSD model (Oinas-Kukkonen & Harjumaa, 2009), these are addressed in the Persuasion Context analysis. Consequently, developers of health behavioural change support systems need to have a comprehensive understanding of the problems that can be inherent in the context of behaviour change.

For example, the problem of participants of an intervention not regularly visiting the dedicated website (79) could be addressed by mobile technology such as a smart phone running a health app, as the proliferation of smart devices has made this more feasible in recent years (18). As older mobile technologies are supplanted by smart phones, and more applications are designed to provide lifestyle interventions, it is possible to envisage that further enhancements to communication, interaction, self-monitoring etc., will be possible. (93).

The importance of recognising a person's stage of change was also strengthened by one of the studies as the intervention participants were in different stages yet demonstrated significant increases in their physical activity (79). Behaviour change techniques such as goal-setting, action planning, self-monitoring and social support were utilised in the study. This indicated that designers and developers need to consider people's stage of

change and ensure their materials are tailored accordingly, to suit the needs of different cohorts.

Systems providing personal experiences of attainment to users through step-wise achievable goal-setting were identified in the papers on computer-mediated behaviour change support for physical activity. Users of the system described by Spittaels et al. (2007) can select action plans that were provided to them (41) while in the "COMPASS" study users can simply touch the screen to interact and select their desired plan (44). These features assist autonomy by providing support for participants' behavioural change. Additionally, Winett et al. (2007) enabled goal contracting by allowing users to select from a list of goal and action options (43). Therefore, features in the primary task support category such as tailoring, reduction and tunnelling have enabled behavioural change with regard to increasing physical activity. A tailored program for high school students (49) was designed with consideration given to the psychological needs of adolescents by maintaining their anonymity and, thus, preventing stigmatisation.

Goal-setting and self-monitoring have been identified as important aspects of exercise adherence behaviour (94) and these are supported by features in the primary task support category and this is reinforced by the results of this review.

Not only can individual features of the PSD (19) assist behaviour change, but, taken together, categories of features can also contribute to positive outcomes. The dialogue support category facets, in conjunction with those in the primary task support category, have assisted in improving the behaviour change perspectives of users in regard to undertaking physical activity. By providing tailored reinforcement messages, suggesting useful and realistic goals, providing a virtual trophy and rewards, and sending reminders

according to their action plans, persuasive technology assisted in reinforcing, encouraging physical activity changes, and adherence to a routine.

Social facilitation, social comparison, social learning and cooperation were identified in the reviewed articles as providing effective behavioural modification approaches to increasing physical activity.

Results from the reviews demonstrated that applying persuasive technology could assist in increasing physical activity and enhancing health behavioural change attitudes. The effectiveness of interventions has been reported in several studies, as presented in Table 3. Intervention groups demonstrated increases in physical activity in most of the studies (62, 64, 74, 82, 86). This shows that encouraging physical activity behaviour change via a persuasive system is comparable to behaviour change support provided in person. This review focused on the Persuasive System Design features of computer mediated physical activity changes, and the effectiveness of those interventions. Previous systemic literature reviews either focused on the effectiveness of an intervention (95), without considering the system design features, or only concentrated on the design perspectives (96) for physical activity intervention.

5. Limitations

This literature review was conducted to determine the current state of health promotion and intervention activities involving physical activity that used persuasive technology. The features discussed were extracted from academic articles. The limitation of the study is that features present in the actual system were not categorised or discussed in the reviewed articles. This review used the Web of Science, PubMed, and PsychInfo

databases as these collect health sciences articles. Despite Web of Science being one which covers a broad collection of publications, it is possible that relevant articles were missed in the review. Initial search on Cochrane library only returned 2 protocols and 1 review and they were also a duplicate with the search result from other databases so Cochrane library was not included. This study focused on physical activity interventions via a computer, the web or using mobile phones, so studies using smart devices such as RFID, Nintendo Wii, XBox or other gaming applications were not included. Additionally, as the focus of the study was the identification of commonly utilised persuasive system features in computer-mediated physical activities, the articles reviewed were not only from clinical trials but also from pilot studies and studies of the design and implementation of computerised or online physical activity interventions. Although there are twenty studies containing intervention results, some studies have a very smaller sample size (n=20) and the type of study varies considerably. Consequently, meta-analysis was not conducted.

6. Conclusion

This study systematically reviewed the literature on computer-mediated lifestyle modification, as it pertains to encouraging users to increase their physical activity, using the Oinas-Kukkonen and Harjumaa (2009) identified features of Persuasive Systems Design (PSD) (34). This review demonstrated that those features are relevant to physical

activity intervention and highlighted the importance of an information system's actual use in lifestyle modification. Motivating behaviour change for physical activity is a complex task. Context plays an important role in persuasion and the reviewed articles demonstrated that the designers had identified the appropriate strategy to motivate their target segment of participants. The Behaviour Change Techniques, the theory used and the effectiveness of the intervention discussed in the studies were also analysed in this review. The importance of stage of change in behavioural intervention is noted and system designers need to design appropriately according to the stages .

This review also noted that the application of the PSD model varies from study to study. For example, the social support category was present in only 13 out of the 38 articles reviewed. With the increasing popularity of social media and burgeoning creation and use of mobile applications, it is highly likely that the landscape will change.

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Figure 1: Literature review screening process

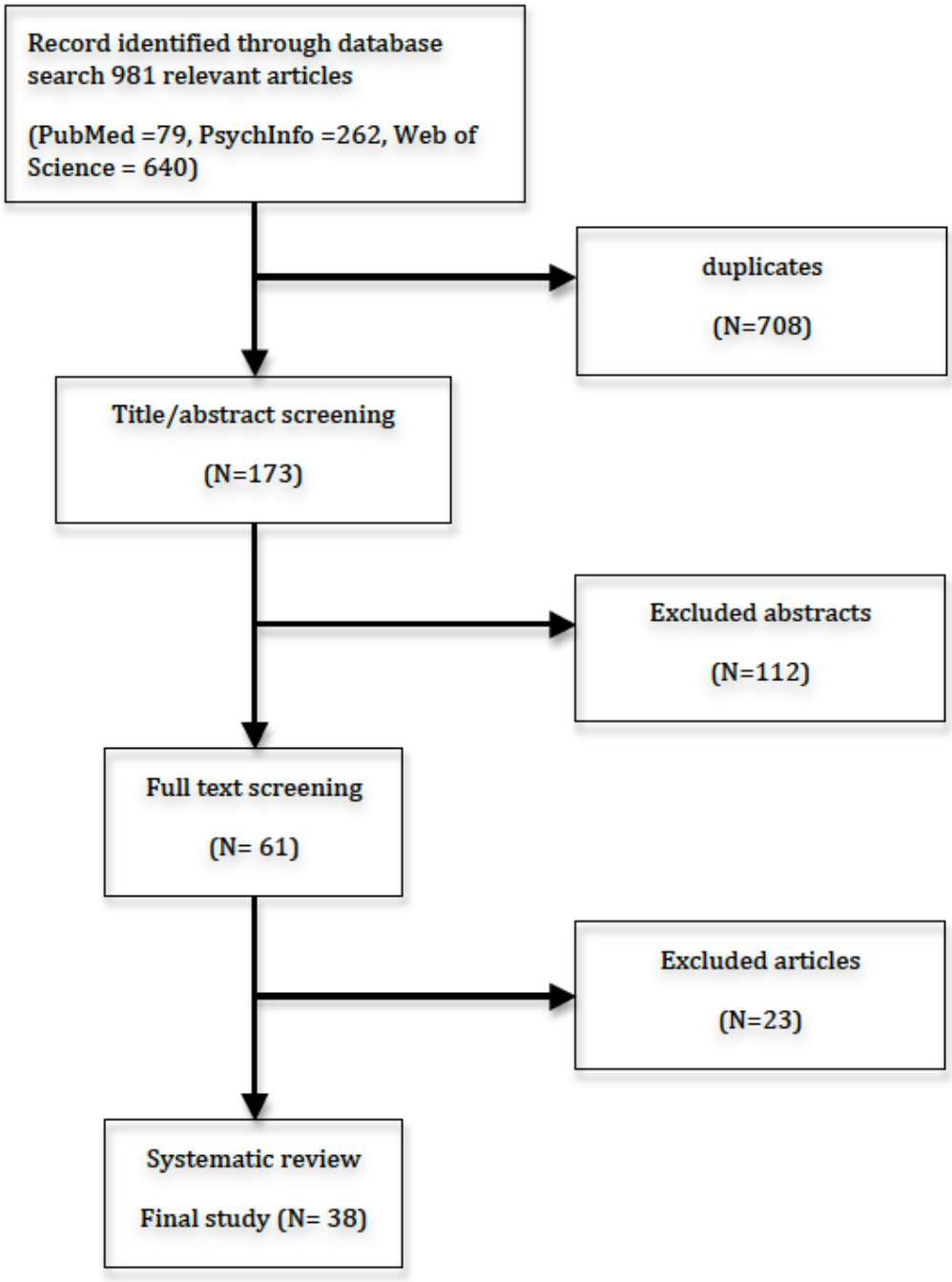

Table 1: Persuasive system design feature categories and features presented in the PSD model(Oinas-Kukkonen & Harjumaa, 2009)

Primary Task Support	
Reduction	System should reduce effort users expend when performing target behaviour
Tunnelling	System should guide users in attitude change process by providing means for action that brings them closer to target behaviour
Tailoring	System should provide tailored info for user groups
Personalization	System should offer personalized content and services for users
Self-monitoring	System should provide means for users to track their performance or status
Simulation	System should provide means for observing link between cause & effect with regard to users' behaviour
Rehearsal	System should provide means for rehearsing target behaviour
Dialogue Support	
Praise	System should use praise via words, images, symbols, sounds to provide user feedback based on behaviours
Rewards	System should provide virtual rewards for users to give credit for performing target behaviour
Reminders	System should remind users of their target behaviour or steps towards it while using the system
Suggestion	System should suggest users carry out behaviours while using the system
Similarity	System should imitate its users in some specific way
Liking	System should have a look & feel that appeals to users
Social Role	System should adopt a social role
Credibility Support	
Trustworthiness	System should provide info that is truthful, fair & unbiased
Expertise	System should provide info showing knowledge, experience & competence
Surface Credibility	System should have competent look & feel
Real-World Feel	System should provide info of the organization/actual people behind its content & services
Authority	System should refer to people in the role of authority
Third-Party Endorsements	System should provide endorsements from respected sources
Verifiability	System should provide means to verify accuracy of site content via outside sources
Social Support	
Social Learning	System should provide means to observe others performing their target behaviours to see outcome of their behaviour
Social Comparison	System should provide means for comparing performance with the performance of others
Normative Influence	System should provide means for gathering people who have same goal & make them feel norms
Social Facilitation	System should provide means for discerning others who are performing the behaviour
Cooperation	System should provide means for co-operation
Competition	System should provide means for competing with others
Recognition	System should provide public recognition for users who perform their target behaviour

Table 2: Mapping of persuasive features mentioned and discussed in the reviewed papers

Principles																															Total	Coded Paper
Reduction	Tunneling	Tailoring	Personalization	Self-monitoring	Simulation	Rehearsal	Praise	Rewards	Reminders	Suggestion	Similarity	Liking	Social Role	Trustworthiness	Expertise	Surface Credibility	Real-World Feel	Authority	Third-Party Endorsements	Verifiability	Social Learning	Social Comparison	Normative	Social Facilitation	Cooperation	Competition	Recognition		
Primary Task Support							Dialogue Support							System Credibility Support							Social Support									
	✓	✓					✓		✓					✓								✓							6	A1
✓	✓	✓												✓	✓			✓	✓	✓									8	A2
		✓		✓			✓		✓					✓	✓			✓	✓	✓				✓					10	A3
✓	✓	✓				✓			✓	✓				✓	✓														8	A4
		✓		✓			✓		✓	✓				✓	✓			✓	✓	✓									10	A5
	✓	✓		✓			✓		✓	✓				✓	✓														8	A6
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		✓		✓	✓		✓		✓	✓				✓	✓														8	A36
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✓	✓	✓		✓	✓		✓	✓	✓					✓	✓						✓	✓	✓	✓	✓				15	A38
22	27	33	3	24	11	1	18	2	30	22	3	0	7	33	31	0	0	7	5	6	9	14	10	11	4	1	1					

	Article	Country	PSD Features Present
A1	(Alley, Jennings, Plotnikoff, & Vandelanotte, 2014)	Australia	Tunnelling, Tailoring Praise, Reminders, Trustworthiness, Social Comparison
A2	(Ammann, Vandelanotte, de Vries, & Mummery, 2013)	Australia	Reduction, Tunnelling, Tailoring Trustworthiness, Expertise, Authority, Third Party Endorsement, Verifiability
A3	(Antypas & Wangberg, 2014)	Norway	Tailoring, Self-Monitoring, Praise, Reminders, Trustworthiness, Expertise, Authority, Third Party Endorsement, Verifiability
A4	(Camerini, Giacobazzi, Boneschi, Schulz, & Rubinelli, 2011)	Switzerland	Reduction, Tunnelling, Tailoring, Rehearsal Reminders, Suggestion, Trustworthiness, Expertise
A5	(De Cocker, Spittaels, Cardon, De Bourdeaudhuij, & Vandelanotte, 2012)	Belgium	Tailoring, Self-Monitoring, Praise, Reminders, Suggestion, Trustworthiness, Expertise, Authority, Third Party Endorsement, Verifiability
A6	(de Niet et al., 2012)	Netherlands	Tunnelling, Tailoring, Self-monitoring Praise, Reminders, Suggestion, Trustworthiness, Expertise
A7	(Dour et al., 2013)	USA	Reduction, Tunnelling, Tailoring, Self-Monitoring, Simulation, Trustworthiness, Expertise, Social Comparison, Normative Influence, Social Facilitation
A8	Duncan et al.	Australia	Reduction, self-monitoring, social role, trust worthiness, expertise
A9	(Ezendam, Noordegraaf, Kroeze, Brug, & Oenema, 2013)	Netherlands	Reduction, Tunnelling, Tailoring Praise, Reminders, Suggestion, Trustworthiness, Social Comparison
A10	(Funk et al., 2011)	USA	Reduction, Tunnelling, Tailoring, Self-Monitoring, Praise, Reminders, Trustworthiness
A11	(Hansen et al., 2012)	Denmark	Reduction, Tunnelling, Tailoring, Suggestion, Social Role, Trustworthiness, Expertise,

			Social Learning, Social Comparison, Normative Influence
A12	(Hearn, Miller, & Fletcher, 2013)	Australia	Tunnelling, Tailoring, Reminders, Expertise, Verifiability
A13	(Hurling et al., 2007)	UK	Reduction, Tunnelling, Tailoring, Self-Monitoring, Praise, Reminders, Suggestion, Social Learning, Social Comparison, Social Facilitation
A14	(Jahangiry et al., 2014)	Iran	Reduction, Tunnelling, Tailoring, Self-Monitoring, Trustworthiness, Expertise
A15	(Jones et al., 2014)	USA	Self-Monitoring, Simulation, Social Learning, Social Comparison, Normative Influence, Social Facilitation
A16	(Kelders, van Gemert-Pijnen, Werkman, & Seydel, 2010)	Netherlands	Tunnelling, Tailoring, Self-Monitoring, Reminders Trustworthiness, Expertise
A17	(Kim, Park, Min, & Jeon, 2013)	Korea	Tunnelling, Tailoring, Self-Monitoring, Reminders, Trustworthiness, Expertise
A18	(King, Bickmore, Campero, Pruitt, & Yin, 2013)	USA	Tailoring, Simulation, Reminders, Similarity, Social Role, Trustworthiness, Expertise
A19	(Klausen et al., 2012)	Denmark	Tailoring, Self-Monitoring, Reminders, Suggestion, Trustworthiness, Expertise
A20	(Lau, Lau, Chung, Ransdell, & Archer, 2012)	Hong Kong	Tunnelling, Tailoring, Reminders, Suggestion, Similarity, Social Role, Trustworthiness, Expertise, Social Learning, Social Comparison, Normative Influence, Social Facilitation
A21	(Migneault et al., 2012)	USA	Tailoring, Reminders, Suggestion, Similarity, Trustworthiness, Expertise
A22	(Mitchell et al., 2014)	Australia	Tailoring, Self-Monitoring, Trustworthiness, Expertise, Social Learning, Social Comparison, Normative Influence, Social Facilitation
A23	(Morgan et al., 2013)	Australia	Tailoring, Personalisation, Self-Monitoring, Trustworthiness, Expertise
A24	(Mutsuddi, 2012)	USA	Tailoring, Self-Monitoring, Praise, Reminders, Suggestion, Social Role, Social Comparison, Normative Influence, Social Facilitation, Cooperation
A25	(Patrick et al., 2011)	USA	Tunnelling, Tailoring, Personalisation, Self-Monitoring, Simulation, Reminders, Suggestion, Trustworthiness, Expertise
A26	(Patrick et al., 2014)	USA	Tunnelling, Tailoring, Self-Monitoring, Rewards, Reminders, Suggestion, Social Role, Trustworthiness, Expertise, Authority, Third Party Endorsements, Verifiability, Social Learning, Social Comparison, Normative Influence, Social Facilitation, Cooperation, Competition, Recognition

A27	(Peels et al., 2013)	Netherlands	Tunnelling, Tailoring, Self-Monitoring, Simulation, Praise, Reminders, Suggestion, Trustworthiness, Expertise, Authority, Third Party Endorsements, Verifiability
A28	(Pollak et al., 2014)	USA	Tunnelling, Tailoring, Self-Monitoring, Praise, Reminders, Suggestion, Trustworthiness, Expertise
A29	(Postrach et al., 2013)	Germany	Tunnelling, Tailoring, Self-Monitoring, Praise, Reminders, Suggestion, Social Role, Authority, Social Learning, Social Comparison, Normative Influence, Social Facilitation, Cooperation
A30	(Reid et al., 2012)	Canada and UK	Tunnelling, Tailoring, Personalisation, Self-Monitoring, Simulation, Praise, Reminders, Suggestion, Trustworthiness, Expertise
A31	(Reinwand, Kuhlmann, Wienert, de Vries, & Lippke, 2013)	Germany and Netherlands	Tunnelling, Reminders, Trustworthiness, Expertise
A32	(Rothert et al., 2006)	US	Tunnelling, Tailoring, Self-Monitoring, Simulation, Reminders, Suggestion, Trustworthiness, Expertise
A33	(Schulz et al., 2014)	Netherlands	Tunnelling, Self-Monitoring, Simulation, Praise, Reminders, Trustworthiness, Expertise, Social Comparison
A34	(Spittaels & de Bourdeaudhuij, 2006)	Belgium	Tunnelling, Tailoring, Praise, Reminders, Suggestion, Trustworthiness, Expertise, Authority
A35	(Spittaels, De Bourdeaudhuij, Brug, & Vandelanotte, 2007)	Belgium	Tunnelling, Tailoring, Praise, Reminders, Suggestion, Trustworthiness, Expertise
A36	(Steinberg, Levine, Askew, Foley, & Bennett, 2013)	USA	Tailoring, Self-Monitoring, Simulation, Praise, Reminders, Suggestion, Trustworthiness, Expertise
A37	(Vandelanotte, Duncan, Plotnikoff, & Mummery, 2012)	Australia	Tunnelling, Simulation, Reminders, Suggestion, Trustworthiness, Expertise
A38	(Winett, Anderson, Wojcik, Winett, & Bowden, 2007)	USA	Tunnelling, Tailoring, Self-Monitoring, Simulation, Praise, Rewards, Reminders, Trustworthiness, Expertise Social learning, Social comparison, Normative influence, Social facilitation, Cooperation

Table: 3: Persuasive features

		Article	Behaviour Change Technique	Goal setting	Action planning	Self-monitoring of behaviour	Self-monitoring of outcomes of	Social support (unspecified)	Behaviour performance	Behaviour demonstration	Credible source
1	A3	Antypas & Wangberg, 2014	TTM	X		X	X	X			X
2	A5	De Cocker et al., 2012	TPB, TTM		X	X	X	X	X	X	X
3	A8	Duncan et al., 2014	SCT	X	X	X	X				X
4	A10	Funk et al., 2011		X	X	X	X	X			X
5	A11	Hansen et al., 2012	TTM, TPB	X	X	X		X			X
6	A13	Hurling et al., 2007	TPB	X	X	X	X		X	X	X
7	A18	King et al., 2013	SCT	X		X	X	X			X
8	A20	Lau et al., 2012	TTM	X		X	X				X
9	A21	Migneault et al., 2012	SCT, TTM		X	X	X	X			X
10	A23	Morgan et al., 2013	SCT	X		X	X				X
11	A24	Mutsuddi & Connelly, 2012	TTM			X	X	X			X
12	A25	Patrick et al., 2011	SCT, SDT			X	X				X
13	A26	Patrick et al., 2014	SCT	X	X	X	X	X			X
14	A27	Peels et al., 2013	Social Modelling		X	X	X				X
15	A30	Reid et al., 2012		X	X	X	X				X
16	A32	Rothert et al., 2006		X	X	X	X				X
17	A33	Schulz et al., 2014	SCT	X	X	X	X				X
18	A35	Spittaels et al., 2007	TTM	X		X	X	X			X
19	A36	Steinberg et al., 2013		X	X	X	X				X
20	A38	Winett et al., 2007	SCT	X	X	X	X	X			X

TTM = Transtheoretical model (Theory of Stage of Change), SCT = Social Cognitive Theory, TPB = Theory of Planned Behaviour,

SDT = Self Determinant Theory

Table 4: Theories and behaviour change techniques

		Article	Study Type	techniques for intervention group	Intervention duration, frequency	PSD Features Present	Effectiveness	Control group	Method
1	A3	(Antypas & Wangberg, 2014)	Randomised controlled trial (2 arms) Adults (33-75 years) N=67 (control=38 ,,tailored=29)	Monitoring of physical activity, social support	Generic content, online forum and tailored intervention, IPAQ questionnaire at 1 month & 3 months	Tailoring, Self-Monitoring, Praise, Reminders, Trustworthiness, Expertise, Authority, Third Party Endorsement, Verifiability	Effectiveness based on patients' stage of change. Significant level of walking, reason: did not need help)	Generic version of website and online forum/Tailored intervention	Assessors blinded to the group assignment (high attrition rate in the intervention group) Small sample size, non-parametric test
2	A5	(De Cocker, Spittaels, Cardon, De Bourdeaudhuij, & Vandelanotte, 2012)	Randomised controlled trail (2 arms) (18-65 years) N=92 (control= 47, intervention =45)	Tailored advice, feedback about participants' intentions, attitudes, self-efficacy, social support, knowledge, benefits, and barriers related to physical activity	Daily with feedback and follow up at 1 month for 3 months	Tailoring, Self-Monitoring, Praise, Reminders, Suggestion, Trustworthiness, Expertise, Authority, Third Party Endorsement, Verifiability	No superior effect compared to self-reported and pedometer-based physical activity	Pedometer + Computer/ Pedometer only	Descriptive statistics Small sample 13 out of 45 drop out in intervention group.
3	A8	Duncan et al.	Randomised controlled trial 35-54 years old male N=301, IT based arm = 205, printed arm = 96	Self-monitoring, goal setting, social interaction, social support,	Mobile phone based, 9 Month study baseline, 3 months and 9 months measure, walking, cycling, swimming, running, sport and recreation,	Reduction, self-monitoring, social role, trust worthiness, expertise	Significant improvement in physical activity, however, not significant difference between IT and printed arm	Printed based intervention	Outcome measured but usage of the material in the controlled arm is no assessed.

					strengthening				
4	A10	(Funk et al., 2011)	Randomized trial testing long-term efficacy of different strategies (3 arms) Patients who lost 4 kg or more in 6 months study in phase 1 are continued in this study as phase Internet intervention =348 Total participant - 1032	record weight, physical activity, social support, self-monitoring, reliable information, supportive tools for change, accountability, tailored reinforcement messages, tailored action plan, individualised summary report	Internet based maintenance	Reduction, Tunnelling, Tailoring, Self-Monitoring, Praise, Reminders, Trustworthiness	Tool development for the study was described but not its effectiveness	One self-directed group and one personal contact group	Assessment is related to the times that user use the site
5	A11	(Hansen et al., 2012)	Randomised controlled trial on physical activity promotion (2 arms) adults (18+ years) N=12287 (intervention =6055, control = 6232)	Tailored feedback, self-efficacy, goal setting, social support, knowledge, recommendation	3 months and 6 months study Monitoring of everyday activity, total activity time, strength training, physio therapist answered question	Reduction, Tunnelling, Tailoring, Suggestion, Social Role, Trustworthiness, Expertise, Social Learning, Social Comparison, Normative Influence	No significant difference in physical activity between intervention and controlled group	Non-intervention - control	No blinding Active users – subsample of the intervention group results were assessed.

6	A13	(Hurling et al., 2007)	Randomised controlled trial (2 arms) Healthy adults (30-55 years) N=77 (control=30, intervention=47)	Goal-setting, planning, constructive feedback, monitoring, habit forming, reward	Bluetooth activated watch Offered solution to perceived barriers, advice, Weekly multimedia content, dialogue, goal setting or planning, message board, motivational tips, self-assessment, skills and knowledge questionnaire	Reduction, Tunnelling, Tailoring, Self-Monitoring, Praise, Reminders, Suggestion, Social Learning, Social Comparison, Social Facilitation	Increases in physical activity and increased weight loss were seen in the intervention group. There is a significant different between the 2 groups	Waitlist controlled arm	Small sample size
7	A18	(King, 2013)	Randomized controlled trial (2 arms) Inactive adults older, low income, N=40 (control=20, intervention=20)	Problem solving around barriers, monitoring, establish personalised goal, understanding the risk of physical inactivity, committing oneself, substituting more active alternate,	4 month study Virtual advisor Track daily steps, tailored feedback, action plan based on the pedometer input, social dialogue	Tailoring, Simulation, Reminders, Similarity, Social Role, Trustworthiness, Expertise	Increased walking in virtual advisor intervention. 130-135 minutes per week walking difference between groups	Health education control	19 item computer credibility skill Small sample size

				rewarding, reminding					
8	A20	(Lau, et al, 2012)	Quasi experimental study, non-randomised N=78 12- 15 years old, school children non-randomly assigned (intervention =38, control =40)	Stage-matched information, behaviour skill training, reinforcement, reward, goal-setting	Daily tailored SMS and stage-matched internet physical activity program twice a week for 8 weeks	Tunnelling, Tailoring, Reminders, Suggestion, Similarity, Social Role, Trustworthiness, Expertise, Social Learning, Social Comparison, Normative Influence, Social Facilitation	Significant improvement in Stage of Motivational Readiness group	Stage-matched program/no treatment	Non-randomised Descriptive statstics
9	A21	(Migneault et al., 2012)	Randomised controlled trial of multi-behaviour intervention (2 arms) urban African–American adults N=337	Multi-behaviour intervention	Automated telephone calls over 8 months, assessments every 4 months for 1 year	Tailoring, Reminders, Suggestion, Similarity, Trustworthiness, Expertise	Improvement in results noted	Education only control	Multivariate analysis
10	A23	(Morgan et al., 2013)	Randomised, controlled trial (multi arm) Overweight & Obese men	Goal setting, self-monitoring	3 month intervention duration with 6 month assessment One arm Gender-	Tailoring, Personalisation, Self-Monitoring, Trustworthiness, Expertise	Significant improvement noted , lower BMI, waist circumference	Control =Waitlist	

			N=159 Resources (n=54), online (n=53), waitlist (52)		tailored weight loss materials (DVD, handbooks, pedometer, tape measure Another arm, resources, online, feedback				
11	A24	(Mutsuddi, 2012)	Persuasive power of text messages study College students N= 42	Reminder, self-monitoring	Text messages for 2 months Source of messages (automated, fitness specialist, family/friends) tailoring (tailored /non tailored) Followed by interview	Tailoring, Self-Monitoring, Praise, Reminders, Suggestion, Social Role, Social Comparison, Normative Influence, Social Facilitation, Cooperation	Positive impact noted	none	There was no controlled arm 2 x 3 research design
12	A25	(Patrick et al., 2011)	Randomised controlled trial (2 arms) Overweight or obese men N=441	Goal setting, social support, self efficacy Web-based assessment of diet and physical activity behaviour	Modules to be completed weekly addressing weight-related behaviours with 6 and 12 month assessments	Tunnelling, Tailoring, Personalisation, Self-Monitoring, Simulation, Reminders, Suggestion, Trustworthiness, Expertise	increase in walking activity in intervention group but no significant differences between groups, however, 35% of men in highest tertile of goal setting has poitive outcome, lost at	Intervention/ delayed treatment	ANOVA attrition

							least 5% of body weight, increase in understanding		
13	A26	(Patrick et al., 2014)	Randomised controlled trial (2 arms) Overweight or obese college students N=404 Intervention n= 202) control (n=202)	Self-monitoring, intention formation, goal setting, feedback, self efficacy, social support, tailoring	Daily contact with one or more web or phone-based Utilises multiple touchpoints: Facebook, text messaging, apps, blogs and email after 2 years	Tunnelling, Tailoring, Self-Monitoring, Rewards, Reminders, Suggestion, Social Role, Trustworthiness, Expertise, Authority, Third Party Endorsements, Verifiability, Social Learning, Social Comparison, Normative Influence, Social Facilitation, Cooperation, Competition, Recognition	Differences were significant in 6 months and 12 months but not significant in 18 months and 24 months.	information	Large sample, ethinically diverse ,retention- high
14	A27	(Peels et al., 2013)	Randomised intervention Dutch adults (50+ years) N=1729 (basic printed, basic web based, printed environmen	Same behaviour change principle delivered in different medium Tailored information, feedback Motivation, awareness, active learning, action plan	3 interventions via tailored communication in 4 months with assessment 3, 6 & 12 months after baseline was established	Tunnelling, Tailoring, Self-Monitoring, Simulation, Praise, Reminders, Suggestion, Trustworthiness, Expertise, Authority, Third Party Endorsements, Verifiability	Printed and wb-based intervention equally effective	Printed information for control group	Intervention component used measures ANOVA $P<0.008$ Recall bias

			tal printed web based intervention ,						
15	A30	(Reid et al., 2012)	Randomised controlled trial (2 arms) Adults (20-80 years) N=223 (control =108, intervention =115)	self-control ,planning, goal-setting, monitoring and self-regulation	6 month intervention with personally tailored program and access to a website, 5 online tutorials, 2, 4, 8, 14 weeks	Tunnelling, Tailoring, Personalisation, Self-Monitoring, Simulation, Praise, Reminders, Suggestion, Trustworthiness, Expertise	Significantly increased physical activity resulted in intervention group	received information from the physician and the booklet, email contact	High attrition
16	A32	(Rothert et al., 2006)	Randomised controlled trial (2 arms) N=2862 Intervention Overweight and obese people with a BMI between 27 to 40 kg/m2 (N= 1475), control	Action planning, Social support, self-monitoring	Expert system 6 weeks with follow up at 6 & 12 months Online tailored advice, email reminders to complete questionnaires about progress and achievements	Tunnelling, Tailoring, Self-Monitoring, Simulation, Reminders, Suggestion, Trustworthiness, Expertise	Participants using the tailored behavioural weight management program experienced significant weight loss	Information only	ANOVA method Missing data considered Reliance of self-reported data
17	A33	(Schulz et al., 2014)	Randomised controlled trial 18-65 years with computer	Planning, monitoring, normative feedback	Sequential, simultaneous and controlled tailoring,	Tunnelling, Self-Monitoring, Simulation, Praise,	Five lifestyle behaviours were targeted and changed over time. Physical	Control group receive feedback on	

			and internet access Sequential N= 1736, simultaneous = 1638, control =1681		Follow up at 12 months and 24 months	Reminders, Trustworthiness, Expertise, Social Comparison	activity is one of them,	initial health assessment	
18	A35	(Spittaels, De Bourdeaudhuij, Brug, & Vandelanotte, 2007)	Randomised controlled trial (3 arms) Healthy adults (25-55 years) N=526 Email group (n=174), tailored group = 175, non-tailored advice = 177	Self monitoring,	8 weeks with 6 month follow up Online tailored physical activity advice, reinforcement emails	Tunnelling, Tailoring, Praise, Reminders, Suggestion, Trustworthiness, Expertise	All 3 groups reported increase in physical activity. No significant difference between tailored advice and standard advice	Non tailored advice	Large sample Randomised study. ANOVA Self-selection bias
19	A36	(Steinberg, Levine, Askew, Foley, & Bennett, 2013)	Randomised controlled trial (2 arms) Racial and ethnically minor women (25-50 years) with BMI greater than or equal to 25 kg/m²	Goal setting, self-monitoring of behavioural goals, regular feedback	6 months follow up study Monitor goal daily for 12 weeks, walking goal	Tailoring, Self-Monitoring, Simulation, Praise, Reminders, Suggestion, Trustworthiness, Expertise	Greater adherence to text messaging associated with greater weight loss	Education control	Pilot study, small sample size

			N=50 (control=24 , intervention =26)						
20	A38	(Winett, Anderson, Wojcik, Winett, & Bowden, 2007)	Group randomised controlled trial (3 arms) 14 churches N=1071 Control 4 church (N=343), GTH only 5 church (N=209), GTH plus intervention 5 churches (n=364)	Goal setting, Monitoring, social support,	Weekly for 12 weeks with 6 month follow up Web-based video-delivered information & self-regulation strategies with weekly goal-setting & future planning followed by positive feedback	Tunnelling, Tailoring, Self-Monitoring, Simulation, Praise, Rewards, Reminders, Trustworthiness, Expertise Social learning, Social comparison, Normative influence, Social facilitation, Cooperation	Internet based intervention together with the environmental social support may improve outcomes for participants	wait list	Large sample size, >80% follow up

Table: 5: Studies and their effectiveness