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Doğru, O.C., Webb, T.L. and Norman, P. orcid.org/0000-0002-5892-0470 (2022) Can behavior change techniques be delivered via short text messages? Translational Behavioral Medicine, 12 (10). pp. 979-986. ISSN 1869-6716

https://doi.org/10.1093/tbm/ibac058

Can behavior change techniques be delivered via short text messages?

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Author version of paper accepted for publication in *Translational Behavioral Medicine* on 2 August 2022. https://doi.org/10.1093/tbm/ibac058

Abstract:

Objective. Despite significant advancements in behavioural science it is unclear whether behaviour change techniques (or BCTs) can be delivered to large numbers of people in a cost-effective and reliable way. The current study investigated whether it is possible to reliably deliver BCTs using short text messages.

Methods. Short text messages were designed to deliver each of the 93 BCTs specified in the BCT taxonomy v1. Following initial coding and refinement by the team, a Delphi study with a panel of 15 experts coded which BCT each short text message was designed to deliver and also rated whether they were likely to be understood by recipients and easily converted to target different behaviours.

Results. After two iterations, the experts correctly assigned 66 of the 93 messages to the BCT that they were designed to deliver and indicated that these messages were likely to be easy to apply to a range of behaviours and understood by recipients. Experts were not able to identify which BCT 27 of the messages were designed to deliver and it was notable that some clusters of BCTs (e.g., 'Goals and planning') were easier to deliver via short text messages than other clusters (e.g., 'Scheduled consequences').

Conclusions. The findings suggest that short text messages can be a reliable way to deliver many, but not all, BCTs. The implications of the current study are discussed with respect to the delivery of specific BCTs and clusters of the taxonomy, as well as the need to test the acceptability of interventions delivered via short messages and the impact of messages on behaviour.

Keywords:

Behaviour change techniques; Delphi method; short text messages; intervention; cycling

Can Behaviour Change Techniques Be Delivered via Short Text Messages?

Behaviour change is central to almost all societal grand challenges, including health and well-being and issues around sustainability and climate change. Addressing such challenges therefore requires the development of tools and interventions that have the potential to change behaviour(s) – e.g., promote active travel [1], help people to quit smoking [2, 3], drink less alcohol [4, 5], use contraceptives [6, 7], eat more healthily [8], or recycle [9]. Research on interventions to change behaviour has increased rapidly over recent years [10, 11, 12] and, more recently, has sought to identify the key components (i.e., the active ingredients) of effective interventions [13]. A particular focus has been the behaviour change techniques (or BCTs) that are included in interventions, i.e., the "observable, replicable, and irreducible component(s) of an intervention [that are] designed to alter or redirect causal processes that regulate behaviour" [13, p. 82].

In a seminal paper, Michie et al. [13] identified 93 BCTs organised under 16 clusters that may be used in interventions to change behaviour – this was referred to as v1 of the 'BCT taxonomy', although it was predated by a smaller taxonomy published in 2008 [14]. Subsequent research has used the BCT taxonomy v1 to test the effectiveness of specific BCTs, either in isolation or combination [2, 4], or to code previous interventions to identify specific BCTs that are associated with stronger intervention effects [11]. However, while the BCTs described by the BCT taxonomy v1 provide a basis for identifying the active ingredients of interventions, implementing them is not always straightforward or easy [15, 16]. For example, a recent study [17] used a workshop and a follow-up call to deliver the BCT 'habit formation' (defined as prompting rehearsal and repetition of the behaviour in the same context repeatedly so that the context elicits the behaviour) as part of an intervention designed to help new gym members to be more physically active. While prompting habit formation proved effective in the sense that participants in the experimental group were significantly more physically active than participants in the control condition, the mode by which the BCT was delivered was relatively labour-intensive as instructors

had to be present at each intervention workshop and a follow-up phone call had to be conducted with each workshop participant. The number of participants that can receive the intervention will therefore be limited by the availability (and cost) of instructors and spaces to run the workshops. Many interventions that deliver BCTs via face-to-face interaction are subject to these constraints [8, 11]. However, delivering intervention components digitally – e.g., via short messages pushed to devices such as mobile phones or disseminated via social media – may help to overcome these constraints so that interventions can be delivered to larger populations with ease [3, 4, 6]. Hence, the primary aim of the current study is to test if BCTs can be delivered in the form of relatively brief text messages.

Digital Modes of Intervention Delivery

Technology is increasingly used to deliver behaviour change interventions with the increase in access to and use of the internet, smartphones, and social media [18, 19, 20]. Facebook, Twitter, smartphone applications, and short message service (SMS) have all been used to deliver behaviour change interventions [e.g., 3, 21, 22, 23, 24]. Many of these methods place no character limits for the content that can be conveyed. For example, there are virtually no character limits on emails in major service providers such as Hotmail or Gmail; Facebook only limits posts to 63,206 characters and there are no limits to the messages conveyed through many smartphone applications, such as WhatsApp. However, Twitter places a 280 character limit on tweets (changed from 140 characters in 2017) and SMS limits the first text message to 160 characters, and each consecutive message to 144 characters. This means that the sender (e.g., someone delivering an intervention designed to change behaviour) pays for one SMS for the first 160 characters, two SMSs for messages between 161 and 304 characters, and so on. SMSs are therefore the shortest form of digital communication that can currently be used to deliver BCTs and so short text messages under 160 characters can be conveyed through multiple platforms.

Advantages of Delivering BCTs via Short Text Messages

There are several reasons for investigating whether short text messages can deliver BCTs with fidelity. First, lengthy interventions can be cognitively demanding, leading people to disengage [25, 26]. Indeed, a meta-analysis of internet-based interventions [27] found that interventions that require little time to understand and use (i.e., are efficient) are more likely to be effective. Second, the delivery of short text messages to deliver BCTs can be automatized, thereby making it easier to reach larger populations. For example, a recent study [28] used short text messages to deliver an intervention to promote vaccination in a large sample of over 47,000 participants. Third, short text messages can also potentially deliver BCTs to participants at timely moments, such as at planned times, or by using geolocation services to deliver messages in specific situations (e.g., at a bar or restaurant). For example, interventions designed to promote smoking cessation might deliver BCTs early in the morning [2, 29], on the basis that the time from waking to the first cigarette of the day is an important indicator of nicotine dependence [30, 31, 32].

Fourth, being able to deliver specific BCTs via short text messages provides tools that can be used to contribute to a cumulative science of behaviour change [33]. In particular, it should mean that interventions are easier to replicate, as the BCTs that are used and the text messages that are sent could be virtually identical across studies. In many intervention studies, underreporting of the intervention content, procedures, and/or BCTs is a problem [34, 35]. Indeed, a recent systematic review and meta-analysis found that approximately two thirds of the BCTs used in interventions for smoking cessation are not reported/explained in published material [34]. Delivering BCTs via short text messages would make it easier to report all the active components and therefore to replicate them in different samples and/or contexts. Being able to deliver BCTs in a brief and efficient manner to large numbers of recipients would also allow researchers to examine the efficacy of particular combinations of BCTs, potentially within factorial designs that systematically manipulate each intervention component in order to test the effectiveness of BCTs both in isolation and in

combination with other BCTs [36, 37]. For example, a study [36] examined the effectiveness of five intervention modules of an alcohol reduction app in a 2^5 factorial design, finding that the combination of the 'self-monitoring and feedback' and 'action planning' modules led to a significant reduction in AUDIT scores (i.e., harmful drinking). Similarly, another study [37] tested combinations of the three BCTs (i.e., action planning, coping planning and self-monitoring) in a 2^3 factorial randomised trial of an e- and m-health intervention to increase physical activity and reduce sedentary behaviour. The combination of all three BCTs was found to be the most effective way to increase physical activity whereas the combination of action planning and self-monitoring was the most effective way to reduce sedentary behaviour [37].

The Current Study

Given the potential benefits of delivering BCTs using short text messages, the current study aimed to develop a list of messages that can be used to deliver individual BCTs. To illustrate how short messages might be used to deliver BCTs, messages were designed to promote cycling – a behaviour with many physical and mental health benefits [38, 39]. However, the messages were written in such a way that they could be easily adapted to target other behaviours. The Delphi method [40, 41] was used to obtain expert opinion on the extent to which the short text messages (1) delivered each of the BCTs with fidelity, (2) could be converted easily to target other behaviours, and (3) were likely to be understood easily by the general public.

Method

Development of the messages

A list of 186 short text messages (two messages designed to deliver each of the 93 BCTs) was prepared by the first author. Each message was designed to deliver one, and only one, BCT. The second and third authors then independently coded which BCT they believed that each message was designed to deliver, using an online survey (implemented in Qualtrics) that presented each of the text messages (in a random order) followed by a question asking the respondent to identify the

BCT that the message was designed to deliver. Seventy-four of the messages (40%), covering 50 unique BCTs (54%), were coded as delivering the BCT that they were designed to convey by both authors and were taken forward to the next stage of the study. The 86 text messages designed to deliver the remaining 43 BCTs were revised by the first author and then independently coded by the second and third authors again. Thirty-eight of these 86 messages (44%), covering 30 unique BCTs (70%), were coded as delivering the BCT that they were designed to convey by both authors. Hence, by the end of the development phase, 80 of the 93 BCTs (86%) had at least one text message that was correctly assigned to the intended BCT by both authors.

The research team then considered the most appropriate text message for each BCT to take forward to the next stage of the study in which the messages would be rated by experts in a Delphi design. Where both messages designed to deliver a BCT were correctly coded by both coders (31 of the BCTs), one message was selected following discussion. Where only one of the messages designed to deliver the BCT was correctly coded by both coders (49 of the BCTs), this message was selected. Where neither message was correctly coded (13 of the BCTs), a new message was prepared.

Delphi method

The Delphi method was used as a method of achieving consensus of opinions among experts [41, 42, 43]. Specifically, independent experts were recruited to consider whether the short text messages delivered the BCTs that they were designed to deliver, could be easily converted to target other behaviours, and were likely to be understood by the general public. Ethical approval for this stage of the research was obtained from the [redacted for review].

Participants

There are no clear guidelines for the number of experts required for a Delphi study [41]; instead, the participants' level of expertise is proposed to be more important than their number [41, 42, 43]. The taxonomy of BCTs that formed the basis of the present research (i.e., the BCT

taxonomy v1) was developed in collaboration with a panel of 14 experts [13]; therefore, the current study sought to recruit a similar number of experts. Experts were required to have published at least one article in which they used the BCT taxonomy v1 [13] to code their own or others' interventions. To identify these experts, Web of Science was used to identify articles that cited the BCT taxonomy v1 and to sort these articles by number of citations. Articles were then screened to identify studies that used the BCT taxonomy v1 to explain their own or others' interventions, and the corresponding authors of the 40 articles that were most frequently cited were contacted via email. Nine positive responses were received. The articles that cited the BCT taxonomy v1 were then sorted by the date that they were published (most recent first) and the first 40 corresponding authors were contacted. A further 14 positive responses were received. Recruitment ceased at this point. In total, 42 unique experts were invited, 23 agreed to participate, and 21 started the study and 15 experts completed the study. The mean age of the experts that completed the study was 36.60 years (*SD* = 7.04), and 12 (80%) were female. Twelve had a PhD (80%), two had a master's degree (13%), and one had a bachelor's degree (7%).

Procedure

Potential participants were told that the study would have two phases; the first of which would take about four and a half to five hours, and the second of which would be shorter depending on the responses to the first survey. They were also informed that they would be given a £50 gift voucher if they completed both phases of the study. Experts who agreed to take part were sent further information, a copy of the BCT taxonomy v1, and a link to the initial survey. If the experts did not complete the first phase of the survey within a month, they were sent a reminder by email. The level of agreement between the experts in phase 1 was then calculated for each text message. Text messages with poor agreement (kappa < .60) were refined by the authors and entered into a second survey, which was sent back to the experts who completed the first phase of the survey.

Measures

The first phase of the survey consisted of informed consent, a short form to capture demographic information (age, gender, and education), and then five questions about each of the messages designed to convey each of the 93 BCTs. These questions were designed to assess:

The intended behaviour change technique: "Which BCT do you think that this message delivers?" (Participants were provided with an open-ended text box within which to enter their response to this question);

Confidence: "How confident are you?" (Participants responded on a 5-point likert scale anchored by 'not confident at all' and 'very confident');

Understandability: "To what extent do you think the message would be easy for a lay person to understand/follow?" (5-point likert scale anchored by 'very hard' and 'very easy');

Convertibility: "How easy do you think it would be to modify this message to apply to other behaviours?" (Participants responded on a 5-point likert scale anchored by 'very hard' and 'very easy')

Finally, participants were asked whether they had any suggestions to improve the message (Participants were provided with an open ended text box with which to respond).

The second phase of the survey provided a short reminder of the purpose of the research and then the same five questions with respect to each of the remaining messages.

Data Analysis

Fifteen experts completed both parts of the survey and coded an average of 87 of the 93 messages (SD = 12). As the experts were not allowed to return to questions that they had not answered, messages that were not coded as reflecting a specific BCT (e.g., because the expert did not answer the question) were considered to be coded incorrectly. The level of agreement between the experts was assessed using Cohen's kappa coefficient. Kappa scores above .60 were taken to indicate a "substantial" level of agreement as to which BCT the message delivered [45, 46]. The

formula used to compute kappa for each message was (observed agreement percentage – chance factor) / (1 – chance factor), where the chance factor was 1/93 = 0.01075.

The number of messages that had "substantial" levels of agreement (kappa > .60) after the two rounds of coding was calculated and these messages were compared to those with lower levels of agreement (kappa < .60) in the extent to which experts felt confident in identifying the intended BCT and rated the messages as understandable and easy to convert to apply to other behaviours. Finally, the proportion of messages that were correctly coded within each BCT cluster was calculated along with average levels of agreement (mean kappa scores) and ratings of confidence, understandability and convertibility.

Results

In the first phase of the Delphi study, the experts agreed on which BCT 63 of the 93 messages (68%) were designed to convey (i.e., 63 of the 93 messages had kappa scores above .60 and 30 messages had kappa scores of .60 or below; see Supplementary Table S1). In the second phase, the 30 messages with poor agreement in Phase 1 were refined by the authors, following which the experts agreed on which BCTs an additional 3 of the messages (10%) were designed to convey (i.e., 3 of the 30 revised messages had kappa scores above .60 and 27 had kappa scores of .60 or below; see Supplementary Table S2). When the messages with highest kappa scores from the two phases were combined, there were high levels of agreement with respect to 66 of the 93 messages (kappa scores above .60) and lower levels of agreement with respect to 27 of the 93 (kappa scores of .60 or below).

As shown in Table 1, the 66 messages for which the experts agreed upon which BCT they were intended to deliver had significantly higher kappa scores, $t(91) = 14.63$, $p < .001$, than the 27 messages that were not agreed upon. Experts were also significantly more confident about which BCT these 66 messages were intended to deliver, $t(91) = 7.52$, $p < .001$, were more likely to believe that they would be easily understood by lay people, $t(91) = 2.63$, $p = .01$, and were more likely to

believe that they could be easily converted to target other behaviours, $t(91) = 3.60$, $p = .001$, than the 27 messages for which they could not agree which BCT they were intended to deliver.

In order to investigate whether short messages are better suited to delivering some types of BCT than others, we compared experts' coding and ratings of text messages reflecting BCTs within each of the 16 clusters of BCTs identified within the BCT taxonomy v1 (see Table 2). Text messages designed to deliver BCTs within the 'Goals and planning' cluster had the highest level of agreement (mean kappa = .92), with all nine messages in the cluster having kappa scores above .60. All of the BCTs in three other clusters also had kappa scores above .60, indicating that they could also be reliably delivered by short messages. These clusters were 'Comparison of behaviour' (mean kappa = .75), 'Repetition and substitution' (mean kappa = .77) and 'Comparison of outcomes' (mean kappa = .80). With three exceptions, all other clusters had mean kappa scores above .60 with most, but not all, of the messages agreed by the experts, including 'Reward and threat' (mean kappa = .76; 10/11 agreed messages), 'Feedback and planning' (mean kappa = .75; 6/7 agreed messages) and 'Identity' (mean kappa = .70; 4/5 agreed messages). The three clusters of BCTs that were least reliably delivered by short text messages (i.e., had mean kappa scores < .60) were 'Associations' (mean kappa = .41; 2/8 agreed messages), 'Regulation' (mean kappa = .56; 2/4 agreed messages), and 'Scheduled consequences' (mean kappa = .51; 3/10 agreed messages).

Discussion

The present study tested if behaviour change techniques (BCTs) can be reliably delivered via short text messages. This was achieved by developing short text messages designed to deliver each of the 93 BCTs described by the BCT taxonomy v1 [13]. Experts who had worked with the taxonomy coded which BCT they believed that each message was designed to deliver and how confident they were in their judgements. The experts also rated whether they believed that the messages would be understood by members of the public and could be adapted to target other behaviours.

The experts correctly identified which BCT the majority of the text messages were designed to target. Indeed, by the end of the study, there was substantial agreement between the experts with respect to which BCT 66 of the 93 text messages (71%) were designed to convey. These messages were also considered easy to understand and to convert to target different behaviours. This indicates that at least 66 BCTs can be delivered with fidelity via short text messages in interventions designed to change behaviour, such as those prepared for the current study. Overall agreement rates for the 66 text messages about which the coders agreed were 'almost perfect' (mean kappa = .81; [47]). This finding suggests that delivering more than two thirds of the BCTs specified in the BCT taxonomy v1 via short text messages is both possible and viable. However, the experts were unable to agree which BCT 27 of the 93 messages (29%) were designed to convey.

Some types of BCTs were therefore better suited to delivery via short messages than others. Specifically, all of the messages reflecting BCTs in four of the clusters identified by the BCT taxonomy v1 (Goals and planning, Comparison of behaviour, Repetition and substitution, and Comparison of outcomes) had kappa scores above .60. However, for four other clusters (Shaping knowledge, Associations, Regulation, and Scheduled consequences) only half or fewer messages were deemed to reliably deliver the intended BCT. Thus, some clusters of BCTs were harder to prepare short text messages for than others. Interestingly, the 27 messages with low kappa scores sought to deliver BCTs that have been used relatively infrequently in intervention studies. For example, Black et al. [2] identified 32 unique BCTs within 113 interventions designed to cease smoking – 30 (94%) of those BCTs were among the 66 BCTs that experts agreed could be reliably delivered via short messages. Similarly, of the 46 unique BCTs identified by Cradock et al. [48] in their review of interventions targeting diet and physical activity in type 2 diabetes, 42 (91%) were among the 66 BCTs that experts agreed could be reliably delivered via short messages. Furthermore, Castillo-Eito et al. [49] identified 53 unique BCTs in their review of interventions designed to decrease adolescent aggression – 44 of these (83%) were among the 66 BCTs that

experts agreed could be reliably delivered via short messages. This observation bodes well for the idea that BCTs that are commonly used in interventions can be reliably delivered via SMS. However, it may also indicate that other BCTs are either underutilised in interventions and/or difficult to operationalise or code.

One of the reasons for the relatively low level of agreement with respect to which BCT some of the messages developed in the present study were intended to deliver is that some BCTs were commonly mistaken for each other. For instance, BCT 14.1 'Behaviour cost' and BCT 14.3 'Remove reward' were often confused with BCT 14.2 'Punishment'. Similarly, messages for BCT 4.3 'Re-attribution' and BCT 13.2 'Framing/reframing' were often confused (see Supplementary Table S3 for a list of frequently confused messages). This might be either due to the messages not being prepared well enough to distinguish the specific BCT that they were designed to deliver, or due to the BCTs being relatively similar to each other in terms of the active ingredients that they incorporate. If the latter is the case, then it may also be hard for these BCTs to be distinguished when coding from longer intervention descriptions.

These observations might suggest that some BCTs may need to be refined or, alternatively, combined. For example, while the BCT taxonomy v1 is intended to differentiate the smallest active ingredients of each intervention, a more liberal approach to categorizing the active ingredients might help when coding BCTs. For instance, is it possible to reliably differentiate between "aversive consequence contingent on the performance of the unwanted behaviour" (BCT 14.2 'Punishment') and "withdrawal of something valued if and only if an unwanted behaviour is performed" (BCT 14.1 'Behaviour cost') or between "future punishment or removal of reward will be a consequence of performance of an unwanted behaviour" (BCT 10.11 'Future punishment') and "discontinuation of contingent reward following performance of the unwanted behaviour" (BCT 14.3 'Remove reward')? Future versions of the BCT taxonomy (or the Behaviour Change Intervention Ontology [50]) may consider combining these specific BCTs.

Limitations and Future Directions

The current study has some limitations that should be noted. First, while SMS is limited to 160 characters, other modes of delivery are not limited to this number of characters and it is possible that longer messages (or more than one SMS) may convey BCTs in a clearer way. However, longer messages may also require more attention and time from the reader and so any advantages of increasing the length of messages need to be balanced against the potential costs associated with longer messages. Second, we sought to recruit experts who had experience of using the BCT taxonomy v1 to code their own or others' interventions, as inferred by their publication of highly cited or recent papers. However, we did not directly assess their level of expertise in using the BCT taxonomy v1 nor did we train the experts in using the BCT taxonomy. As a result, difficulties in identifying and coding certain BCTs could also partly reflect differing levels of expertise. Third, experts were asked whether they thought that each message would be easy for a lay person to understand/follow. However, 'understanding' the text messages and 'following' them could – and perhaps should – have been examined separately. In other words, understanding what a message suggests (termed 'delivery fidelity') may be different from being able or willing to follow this suggestion (termed 'enactment fidelity' [51]). The current study only focused on delivery fidelity and did not examine the extent to which each message resulted in the recipient enacting the message content and / or changing their behaviour accordingly.

Having shown that it is possible to deliver (at least some) BCTs via short text messages, the logical next step will be to investigate if such messages are acceptable to potential participants and therefore likely to yield engagement – something that has been shown to be important if interventions are to be effective in the sense of modifying intended outcomes [52, 53, 54]. Acceptability is defined as "a multi-faceted construct that reflects the extent to which people delivering or receiving a healthcare intervention consider it to be appropriate, based on anticipated or experienced cognitive and emotional responses to the intervention" [54, p. 4]. As this definition

covers both attitudinal aspects towards the intervention materials and intentions to engage with or continue the intervention, it is positively related to intervention effectiveness [54, 55]. Testing the acceptability of the messages would inform future interventionists about potential levels of engagement with interventions using short messages to deliver BCTs, how positive or negative participants' experience of the intervention would be, and how likely participants would be to implement the intervention material in their lives. There are reasons to expect that interventions that use short messages to deliver BCTs would be acceptable. First, the experts who considered the messages in the present research believed that they would be relatively easy for a lay person to understand/follow. Second, a systematic review of interventions for people experiencing severe mental health problems, reported that interventions delivered online and via smartphones were more acceptable than expected, especially when they used text messages [55].

Having established that participants find interventions using short messages to deliver BCTs acceptable, researchers can then move on to testing the effectiveness of the messages in promoting desired outcomes – notably, changes in behaviour and associated outcomes. However, it is worth noting two potential challenges to this endeavour. First, remotely delivered interventions using short text messages may make it harder to control for enactment fidelity of the interventions delivered compared to methods with face-to-face or online interaction that enable individual participants to be followed-up [28, 51, 56]. Second, it would be challenging to simultaneously test all 66 of the agreed BCT messages in a single study. Instead, the effectiveness of smaller numbers of BCTs, based on theory or with the aim of targeting specific mechanisms of action, could be tested in isolation or in combination. Research is also needed to test if the same BCTs yield different effect sizes when delivered via common methods (e.g., suggestions by physicians, in-person lessons) versus via short text messages.

Conclusion

The present research suggests that delivering BCTs via short text messages is possible and provides template messages for 66 of the 93 BCTs specified by the BCT taxonomy v1. The research therefore provides the basis for such messages to be integrated into interventions to address grand challenges facing society and provides a tool that can contribute to a cumulative science of behaviour change.

References

1. Bird, E. L., Baker, G., Mutrie, N., Ogilvie, D., Sahlqvist, S., & Powell, J. (2013). Behaviour change techniques used to promote walking and cycling: A systematic review. *Health Psychology, 32*, 829-838. doi:10.1037/a0032078
2. Black, N., Johnston, M., Michie, S., Hartmann-Boyce, J., West, R., Viechtbauer, W., ... & de Bruin, M. (2020). Behaviour change techniques associated with smoking cessation in intervention and comparator groups of randomized controlled trials: A systematic review and meta-regression. *Addiction*, *115*(11), 2008-2020. doi:10.1111/add.15056
3. Michie, S., Free, C., & West, R. (2012). Characterising the 'Txt2Stop'smoking cessation text messaging intervention in terms of behaviour change techniques. *Journal of Smoking Cessation*, *7*(1), 55-60. doi:10.1017/jsc.2012.12
4. Black, N., Mullan, B., & Sharpe, L. (2016). Computer-delivered interventions for reducing alcohol consumption: Meta-analysis and meta-regression using behaviour change techniques and theory. *Health Psychology Review*, *10*(3), 341-357. doi:10.1080/17437199.2016.1168268
5. Michie, S., Whittington, C., Hamoudi, Z., Zarnani, F., Tober, G., & West, R. (2012). Identification of behaviour change techniques to reduce excessive alcohol consumption. *Addiction*, *107*, 1431-1440. doi:10.1111/j.1360-0443.2012.03845.x
6. Berendes, S., Gubijev, A., McCarthy, O. L., Palmer, M. J., Wilson, E., & Free, C. (2021). Sexual health interventions delivered to participants by mobile technology: A systematic review and meta-analysis of randomised controlled trials. *Sexually Transmitted Infections*. doi:10.1136/sextrans-2020-054853
7. Johnson, B. T., Michie, S., & Snyder, L. B. (2014). Effects of behavioural intervention content on HIV prevention outcomes: A meta-review of meta-analyses. *Journal of Acquired Immune Deficiency Syndromes (1999)*, *66*(Suppl 3), S259.

doi:10.1097/QAI.0000000000000235

8. McDermott, M. S., Oliver, M., Iverson, D., & Sharma, R. (2016). Effective techniques for changing physical activity and healthy eating intentions and behaviour: A systematic review and meta-analysis. *British Journal of Health Psychology*, *21*(4), 827-841. doi:10.1111/bjhp.12199
9. Greenwood, S. C., Walker, S., Baird, H. M., Parsons, R., Mehl, S., Webb, T. L., ... & Rothman, R. H. (2021). Many Happy Returns: Combining insights from the environmental and behavioural sciences to understand what is required to make reusable packaging mainstream. *Sustainable Production and Consumption*, *27*, 1688-1702. doi:10.1016/j.spc.2021.03.022
10. Fitzgibbon, M. L., Kong, A., & Tussing-Humphreys, L. (2014). Understanding population health from multi-level and community-based models. *The Handbook of Health Behaviour Change*, *4*, 22-41.
11. Michie, S., West, R., Sheals, K., & Godinho, C. A. (2018). Evaluating the effectiveness of behaviour change techniques in health-related behaviour: A scoping review of methods used. *Translational Behavioural Medicine*, *8*, 212-224. doi:10.1093/tbm/ibx019
12. Riekert, K. A., Ockene, J. K., & Pbert, L. (Eds.). (2013). *The Handbook of Health Behaviour Change*. Springer Publishing Company.
13. Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., … & Wood, C. E. (2013). The behaviour change technique taxonomy (v1) of 93 hierarchically clustered techniques: Building an international consensus for the reporting of behaviour change interventions. *Annals of Behavioural Medicine, 46*, 81-95. doi:10.1007/s12160-013-9486-6
14. Abraham, C., & Michie, S. (2008). A taxonomy of behavior change techniques used in interventions. *Health Psychology, 27*, 379-387. doi:10.1037/0278-6133.27.3.379

15. Atkins, L., Francis, J., Islam, R., O'Connor, D., Patey, A., Ivers, N., ... & Michie, S. (2017). A guide to using the Theoretical Domains Framework of behaviour change to investigate implementation problems. *Implementation Science*, *12*(1), 1-18. doi:10.1186/s13012-017-0605-9

16. Carey, R. N., Connell, L. E., Johnston, M., Rothman, A. J., De Bruin, M., Kelly, M. P., & Michie, S. (2019). Behavior change techniques and their mechanisms of action: A synthesis of links described in published intervention literature. *Annals of Behavioral Medicine*, *53*(8), 693-707. doi:10.1093/abm/kay078

17. Kaushal, N., Rhodes, R. E., Spence, J. C., & Meldrum, J. T. (2017). Increasing physical activity through principles of habit formation in new gym members: A randomized controlled trial. *Annals of Behavioral Medicine*, *51*(4), 578-586. doi:10.1007/s12160-017-9881-5

18. Alkhaldi, G., Hamilton, F. L., Lau, R., Webster, R., Michie, S., & Murray, E. (2016). The effectiveness of prompts to promote engagement with digital interventions: A systematic review. *Journal of Medical Internet Research*, *18*(1), e6. doi:10.2196/jmir.4790

19. Hekler, E. B., Michie, S., Pavel, M., Rivera, D. E., Collins, L. M., Jimison, H. B., ... & Spruijt-Metz, D. (2016). Advancing models and theories for digital behaviour change interventions. *American Journal of Preventive Medicine*, *51*, 825-832. doi:10.1016/j.amepre.2016.06.013

20. Moller, A. C., Merchant, G., Conroy, D. E., West, R., Hekler, E., Kugler, K. C., & Michie, S. (2017). Applying and advancing behaviour change theories and techniques in the context of a digital health revolution: Proposals for more effectively realizing untapped potential. *Journal of Behavioural Medicine*, *40*, 85-98. doi:10.1007/s10865-016-9818-7

21. Alkhaldi, G., Modrow, K., Hamilton, F., Pal, K., Ross, J., & Murray, E. (2017). Promoting engagement with a digital health intervention (HeLP-Diabetes) using email and text

message prompts: Mixed-methods study. *Interactive Journal of Medical Research*, *6*(2), e6952. doi:10.2196/ijmr.6952

22. Comber, R., Thieme, A., Rafiev, A., Taylor, N., Krämer, N., & Olivier, P. (2013, September). BinCam: Designing for engagement with Facebook for behaviour change. In *IFIP Conference on Human-Computer Interaction* (pp. 99-115). Springer, Berlin, Heidelberg. doi:10.1007/978-3-642-40480-1_7
23. Fedele, D. A., Cushing, C. C., Fritz, A., Amaro, C. M., & Ortega, A. (2017). Mobile health interventions for improving health outcomes in youth: A meta-analysis. *JAMA Pediatrics*, *171*(5), 461-469. doi:10.1001/jamapediatrics.2017.0042
24. Sinnenberg, L., Buttenheim, A. M., Padrez, K., Mancheno, C., Ungar, L., & Merchant, R. M. (2017). Twitter as a tool for health research: A systematic review. *American Journal of Public Health*, *107*, e1-e8. doi:10.2105/AJPH.2016.303512
25. Jackson, J. D., & Balota, D. A. (2012). Mind-wandering in younger and older adults: Converging evidence from the sustained attention to response task and reading for comprehension. *Psychology and Aging*, *27*(1), 106. doi:10.1037/a0023933
26. Subramanian, K. R. (2018). Myth and mystery of shrinking attention span. *International Journal of Trend in Research and Development*, *5*(1).
27. Van Genugten, L., Dusseldorp, E., Webb, T. L., & Van Empelen, P. (2016). Which combinations of techniques and modes of delivery in internet-based interventions effectively change health behavior? A meta-analysis. *Journal of Medical Internet Research*, *18*(6), e4218. doi:10.2196/jmir.4218
28. Milkman, K. L., Patel, M. S., Gandhi, L., Graci, H. N., Gromet, D. M., Ho, H., ... & Duckworth, A. L. (2021). A megastudy of text-based nudges encouraging patients to get vaccinated at an upcoming doctor's appointment. *Proceedings of the National Academy of Sciences*, *118*(20). doi:10.1073/pnas.2101165118

29. Bartlett, Y. K., Sheeran, P., & Hawley, M. S. (2014). Effective behaviour change techniques in smoking cessation interventions for people with chronic obstructive pulmonary disease: A meta-analysis. *British Journal of Health Psychology*, *19*(1), 181-203. doi:10.1111/bjhp.12071

30. Baker, T. B., Piper, M. E., McCarthy, D. E., Bolt, D. M., Smith, S. S., Kim, S. Y., ... & Toll, B. A. (2007). Time to first cigarette in the morning as an index of ability to quit smoking: Implications for nicotine dependence. *Nicotine & Tobacco Research*, *9*, 555-570. doi:0.1080/14622200701673480

31. Hymowitz, N., Cummings, K. M., Hyland, A., Lynn, W. R., Pechacek, T. F., & Hartwell, T. D. (1997). Predictors of smoking cessation in a cohort of adult smokers followed for five years. *Tobacco Control*, *6*, 57-62. doi:10.1136/tc.6.suppl_2.S57

32. Tait, R. J., Hulse, G. K., Waterreus, A., Flicker, L., Lautenschlager, N. T., Jamrozik, K., & Almeida, O. P. (2007). Effectiveness of a smoking cessation intervention in older adults. *Addiction*, *102*(1), 148-155. doi:10.1111/j.1360-0443.2006.01647.x

33. Michie, S., & Johnston, M. (2012). Theories and techniques of behaviour change: Developing a cumulative science of behaviour change. *Health Psychology Review*, *6*(1), 1-6, doi: 10.1080/17437199.2012.654964

34. De Bruin, M., Black, N., Javornik, N., Viechtbauer, W., Eisma, M. C., …, & Johnston, M. (2021). Underreporting of the active content of behavioural interventions: A systematic review and meta-analysis of randomized trials of smoking cessation interventions. *Health Psychology Review, 15*(2), 195-213. doi:10.1080/17437199.2019.1709098

35. Lorencatto, F., West, R., Stavri, Z., & Michie, S. (2012). How well is intervention content described in published reports of smoking cessation interventions? *Nicotine & Tobacco Research, 15*(7), 1273–1282. doi:10.1093/ntr/nts266

36. Crane, D., Garnett, C., Michie, S., West, R., & Brown, J. (2018). A smartphone app to

reduce excessive alcohol consumption: Identifying the effectiveness of intervention components in a factorial randomised control trial. *Scientific Reports*, *8*(1), 1-11. doi:10.1038/s41598-018-22420-8

37. Schroé, H., Van Dyck, D., De Paepe, A., Poppe, L., Loh, W. W., Verloigne, M., ... & Crombez, G. (2020). Which behaviour change techniques are effective to promote physical activity and reduce sedentary behaviour in adults: A factorial randomized trial of an e-and m-health intervention. *International Journal of Behavioral Nutrition and Physical Activity*, *17*(1), 1-16. doi:10.1186/s12966-020-01001-x
38. Bos, I., Jacobs, L., Nawrot, T. S., Geus, D. B., Torfs, R., Panis, L. I., …, & Meeusen, R. (2011). No exercise-induced increase in serum BDNF after cycling near a major traffic road. *Neuroscience Letters, 500*, 129-132. doi:10.1016/j.neulet.2011.06.019
39. Warburton, D. E. R., Nicol, C. W., & Bredin, S. S. D. (2006). Health benefits of physical activity: The evidence. *Canadian Medical School Journal, 174*, 801-809. doi:10.1503/cmaj.051351
40. Linstone, H. A., & Turoff, M. (Eds.). (1975). *The Delphi Method*. Reading, MA: Addison-Wesley.
41. Pill, J. (1971). The Delphi method: Substance, context, a critique and an annotated bibliography. *Socio-economic Planning Sciences*, *5*(1), 57-71. doi:10.1016/0038-0121(71)90041-3
42. Akins, R. B., Tolson, H., & Cole, B. R. (2005). Stability of response characteristics of a Delphi panel: Application of bootstrap data expansion. *BMC Medical Research Methodology, 5*, 37. doi:10.1186/1471-2288-5-37
43. Ogbeifun, E., Agwa-Ejon, J., Mbohwa, C., & Pretorius, J. H. C. (2016). The Delphi technique: A credible research methodology. Presented at Proceedings of the 2016 International Conference on Industrial Engineering and Operations Management, Kuala

Lumpur, Malaysia, March 8-10, 2016.

44. Williams, P. L., & Webb, C. (1994). The Delphi technique: A methodological discussion. *Journal of Advanced Nursing, 19*, 180-186. doi:10.1111/j.1365-2648.1994.tb01066.x
45. Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics, 33*(1), 159-174. doi:10.2307/2529310
46. Michie, S., & Prestwich, A. (2010). Are interventions theory-based? Development of a theory coding scheme. *Health Psychology, 29*, 1-8. doi:10.1037/a0016939
47. Holey, E. A., Feeley, J. L., Dixon, J., & Whittaker, V. J. (2007). An exploration of the use of simple statistics to measure consensus and stability in Delphi studies. *BMC Medical Research Methodology, 7*, 1-10. doi:10.1186/1471-2288-7-52
48. Cradock, K. A., ÓLaighin, G., Finucane, F. M., Gainforth, H. L., Quinlan, L. R., & Ginis, K. A. M. (2017). Behaviour change techniques targeting both diet and physical activity in type 2 diabetes: A systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 1-17. doi:10.1186/s12966-016-0436-0
49. Castillo-Eito, L., Armitage, C. J., Norman, P., Day, M. R., Doğru, O. C., & Rowe, R. (2020). How can adolescent aggression be reduced? A multi-level meta-analysis. *Clinical Psychology Review, 78*, e101853. doi:10.1016/j.cpr.2020.101853
50. West, R., Finnerty, A., Norris, E., Wright, A., Marques, M. M., Johnston, M., ... & Michie, S. (2021). A new tool for specifying behavioural interventions: The behaviour change intervention ontology. *International Journal of Behavioral Medicine, 28*, S33-S33. doi:10.1007/s12529-021-09997-7
51. Toomey, E., Hardeman, W., Hankonen, N., Byrne, M., McSharry, J., Matvienko-Sikar, K., & Lorencatto, F. (2020). Focusing on fidelity: Narrative review and recommendations for improving intervention fidelity within trials of health behaviour change interventions. *Health Psychology and Behavioral Medicine*, *8*(1), 132-151.

doi:10.1080/21642850.2020.1738935

52. Perski, O., Blandford, A., West, R., & Michie, S. (2017). Conceptualising engagement with digital behaviour change interventions: A systematic review using principles from critical interpretive synthesis. *Translational Behavioral Medicine, 7*, 254-267. doi:10.1007/s13142-016-0453-1
53. Perski, O., & Short, C. E. (2021). Acceptability of digital health interventions: Embracing the complexity. *Translational Behavioral Medicine, 11*, 1473-1480. doi:10.1093/tbm/ibab048
54. Sekhon, M., Cartwright, M., & Francis, J. J. (2017). Acceptability of healthcare interventions: An overview of reviews and development of a theoretical framework. *BMC Health Services Research*, *17*(1), 1-13. doi:10.1186/s12913-017-2031-8
55. Berry, N., Lobban, F., Emsley, R., & Bucci, S. (2016). Acceptability of interventions delivered online and through mobile phones for people who experience severe mental health problems: A systematic review. *Journal of Medical Internet Research*, *18*(5), e5250. doi:10.2196/jmir.5250
56. Hemmingsson, E., Udden, J., Neovius, M., Ekelund, U., & Rössner, S. (2009). Increased physical activity in abdominally obese women through support for changed commuting habits: A randomized clinical trial. *International Journal of Obesity, 33*, 645–652. doi:10.1038/ijo.2009.77.

Table 1

Descriptive statistics reflecting the experts' assessment of the final list of short messages

	Correctly coded (*n* = 66)	Incorrectly coded (*n* = 27)
Agreement (Kappa)	0.81 (0.10)	0.41 (0.16)
Confidence	4.09 (0.45)	3.36 (0.44)
Understandability	4.33 (0.35)	4.12 (0.36)
Convertibility	4.22 (0.32)	3.92 (0.47)

Note. Values are means (standard deviations).

Table 2

Kappa scores, and confidence, understandability, and convertibility scores by BCT clusters

BCT messages for clusters:	Messages correctly coded	Mean Kappa	Mean (SD) confidence	Mean (SD) understandability	Mean (SD) convertibility
1. Goals and planning	9/9	.92	4.49 (0.26)	4.34 (0.30)	4.48 (0.15)
2. Feedback and monitoring	6/7	.75	4.22 (0.59)	4.46 (0.23)	3.96 (0.21)
3. Social support	2/3	.73	3.91 (0.34)	4.38 (0.30)	4.40 (0.31)
4. Shaping knowledge	2/4	.65	3.61 (0.43)	4.10 (0.42)	3.86 (0.58)
5. Natural consequences	4/6	.79	4.01 (0.79)	4.36 (0.27)	4.16 (0.25)
6. Comparison of behaviour	3/3	.75	4.33 (0.13)	4.46 (0.06)	4.31 (0.20)
7. Associations	2/8	.41	3.45 (0.41)	4.10 (0.39)	3.91 (0.37)
8. Repetition and substitution	7/7	.77	3.86 (0.45)	4.49 (0.15)	4.21 (0.21)
9. Comparison of outcomes	3/3	.80	3.88 (0.69)	4.39 (0.25)	4.35 (0.28)
10. Reward and threat	10/11	.76	4.05 (0.32)	4.30 (0.55)	4.43 (0.28)
11. Regulation	2/4	.56	3.11 (0.66)	3.81 (0.22)	3.57 (0.60)
12. Antecedents	4/6	.69	3.75 (0.53)	4.25 (0.35)	3.83 (0.35)
13. Identity	4/5	.70	3.75 (0.64)	3.89 (0.45)	3.86 (0.50)

14. Scheduled consequences	3/10	.51	3.49 (0.35)	4.21 (0.30)	4.07 (0.23)
15. Self-belief	3/4	.75	4.23 (0.39)	4.55 (0.12)	4.60 (0.14)
16. Covert learning	2/3	.71	3.78 (0.24)	4.12 (0.18)	4.02 (0.10)
Note. For the calculation of scores for clusters, the message with highest kappa score was selected from each phase.					

Appendix 1

Table S1

Agreement between coders with respect to the BCT that the text message was intended to deliver (kappa), ratings of confidence in identifying intended BCT, understandability and convertibility of the message (phase 1)

Target BCT	Text message	Kappa	Confidence	Understandability	Convertibility
Goals and planning					
1.1 Goal setting (behaviour)	Set yourself the goal to cycle in the next two days.	1.00	4.67 (0.52)	4.67 (0.62)	4.80 (0.56)
1.2 Problem solving	Think about what stops you from using your bike and think of ways to overcome these problems.	.80	4.07 (1.07)	4.40 (0.74)	4.53 (0.64)
1.3 Goal setting (outcome)	Set yourself the goal of losing weight by cycling.	.80	4.47 (0.64)	4.36 (0.63)	4.23 (0.83)
1.4 Action planning	Make a plan detailing when and where you will cycle – e.g. next Wednesday to get to work.	1.00	4.60 (0.51)	4.60 (0.63)	4.60 (0.63)
1.5 Review behaviour goal(s)	Have you achieved your goal of cycling a certain number of times each week? Do you need to set a new goal or keep the same goal?	1.00	4.36 (0.63)	4.43 (0.76)	4.43 (0.76)
1.6 Discrepancy between current behaviour and goal	Is there a discrepancy between the amount that you currently cycle and your cycling goals?	.93	4.60 (0.51)	4.00 (1.07)	4.27 (0.96)

1.7 Review outcome goal(s)	Have you achieved your goal of being fitter by riding your bicycle? Do you need to set a new goal or keep the same goal?	.73	4.07 (0.62)	4.36 (0.84))	4.62 (0.65)
1.8 Behavioural contract	Make and sign a behavioural contract (witnessed by someone else) to cycle a certain number of days each week.	1.00	4.80 (0.41)	3.71 (1.33)	4.47 (0.74)
1.9 Commitment	Reaffirm your commitment to riding your bicycle. Say “I am strongly committed to riding my bicycle”.	1.00	4.53 (0.52)	4.53 (0.74)	4.53 (0.64)
Feedback and monitoring					
2.1 Monitoring of behaviour by others without feedback	We are measuring the amount that you cycle.	.93	4.20 (0.86)	4.29 (0.83)	3.86 (1.03)
2.2 Feedback on behaviour	You have cycled for … minutes in the last week.	.73	4.57 (0.65)	4.79 (0.43)	4.29 (0.99)
2.3 Self-monitoring of behaviour	You can keep track of your cycling using a smartphone app to see how often or how far you cycle.	.93	4.27 (0.70)	4.57 (0.65)	4.07 (1.03)
2.4 Self-monitoring of outcome(s) of behaviour	If you want to lose weight by cycling, then weigh yourself each week to see how you are doing.	.87	4.53 (0.64)	4.57 (0.76)	4.07 (0.96)
2.5 Monitoring outcome(s) of behaviour by others without feedback	There are apps that keep track of your daily progress towards your goals, even without letting you know.	.12	2.93 (1.39)	4.08 (1.04)	3.85 (0.99)

2.6 Biofeedback	Your current heart rate is ...	.87	4.64 (0.63)	4.36 (0.75)	3.64 (1.22)
2.7 Feedback on outcome(s) of behaviour	You have lost ... kilograms since you have started cycling.	.80	4.40 (0.83)	4.53 (0.64)	3.93 (1.00)
Social support					
3.1 Social support (unspecified)	Ask a close friend to support you to cycle.	.93	4.20 (0.68)	4.07 (0.88)	4.47 (0.83)
3.2 Social support (practical)	Think about what practical help you could get to cycle more. For example, you could ask someone to help you to fix your bike or show you good routes.	.80	4.00 (1.31)	4.40 (0.83)	4.07 (0.96)
3.3 Social support (emotional)	Inviting friends to cycle with you would make it more fun and encouraging for you to cycle more!	.46	3.53 (0.83)	4.67 (0.62)	4.47 (0.64)
Shaping knowledge					
4.1 Instruction on how to perform a behaviour	When going uphill, change gear, so that it is easier to pedal.	.80	3.64 (0.93)	4.47 (0.74)	3.07 (1.28)
4.2 Information about antecedents	Keep a record of what makes you feel like cycling or not cycling on different days, so that you know what determines your behaviour.	.53	3.80 (1.15)	4.14 (0.77)	4.29 (0.83)
4.3 Re-attribution	Try attributing your tiredness to inactivity due to NOT cycling regularly rather than cycling.	.53	4.07 (1.03)	3.57 (1.45)	3.71 (1.27)
4.4 Behavioural	Try cycling at different time of the day or for	.46	2.85 (1.28)	4.08 (0.95)	4.00 (1.00)

experiments	different amounts of time, so that you can identify when and how you like to cycle.				
Natural consequences					
5.1 Information about health consequences	Cycling has lots of health benefits such as improved cardiovascular and mental health, and better weight management.	1.00	4.73 (0.59)	4.53 (0.74)	4.07 (1.28)
5.2 Salience of consequences	Keep the benefits of regularly cycling in your mind.	.33	1.92 (0.86)	3.92 (1.04)	4.08 (1.04)
5.3 Information about social and environmental consequences	Cycling can reduce traffic congestion – everyone can get around easier and the air is cleaner as a result!	.93	4.53 (0.64)	4.43 (0.76)	3.73 (1.34)
5.4 Monitoring of emotional consequences	How do you feel after you cycle for half an hour?	.60	3.14 (1.35)	4.29 (0.83)	4.21 (0.89)
5.5 Anticipated regret	Imagine the regret that you would feel if you used a vehicle, instead of your bike to go to work / school today.	.87	4.40 (1.12)	4.27 (0.96)	4.47 (0.83)
5.6 Information about emotional consequences	Cycling decreases the likelihood of depression, improves your mood, and can make you happier!	.87	4.40 (0.63)	4.73 (0.59)	4.27 (0.88)
Comparison of behaviour					
6.1 Demonstration of the behaviour	Watch videos that demonstrate how to cycle safely.	.66	4.20 (0.78)	4.43 (0.85)	4.14 (0.95)

6.2 Social comparison	Do you know anyone else who cycles? Do they cycle more or less frequently than you?	.87	4.46 (0.52)	4.42 (0.79)	4.25 (1.06)
6.3 Information about others' approval	Your colleagues and friends will approve of you cycling more.	.73	4.33 (0.72)	4.53 (0.64)	4.53 (0.64)
Associations					
7.1 Prompts/cues	If your bike is kept in a shed, then put a picture or model of a bike somewhere where you will see it before you leave your house to prompt you to cycle.	.87	3.86 (0.95)	4.29 (0.73)	4.21 (0.70)
7.2 Cue signalling reward	You will be given a £2 reward for cycling to work when it's raining, but not when it's dry.	.06	4.07 (0.92)	4.38 (0.77)	3.85 (0.69)
7.3 Reduce prompts/cues	We will send you less frequent reminders to cycle over time.	.87	4.07 (1.03)	4.67 (0.62)	4.33 (0.90)
7.4 Remove access to the reward	To make yourself cycle more, let's agree that if you don't cycle, the cupboard of snacks is locked for you that day!	.26	3.60 (0.83)	4.20 (0.78)	4.13 (0.74)
7.5 Remove aversive stimulus	Set an alarm to go off every half an hour and only dismiss it when you cycle that day.	.39	3.00 (1.20)	4.21 (0.70)	4.21 (0.89)
7.6 Satiation	Avoid any form of exercise - you will soon get fed up of it!	.00	3.23 (1.24)	3.33 (1.30)	3.08 (1.31)
7.7 Exposure	If you are not used to cycling when it is dark, cycle your route in the daytime first.	.00	2.43 (1.02)	4.50 (0.76)	3.79 (0.98)
7.8 Associative learning	Put a picture of yourself cycling next to something else you like, like pictures of your	.53	2.43 (1.16)	4.31 (0.86)	3.85 (1.07)

	family or friends.				
Repetition and substitution					
8.1 Behavioural practice/rehearsal	Practice cycling to improve your skills and confidence.	.73	3.80 (0.86)	4.53 (0.64)	4.40 (0.74)
8.2 Behaviour substitution	Identify something you could stop doing (like watching TV) to go cycling instead.	.80	3.80 (1.27)	4.43 (0.85)	4.21 (0.89)
8.3 Habit formation	Try to cycle at the same times and for the same reasons (e.g., to meet friends or go shopping) so that cycling becomes a habit.	.87	4.43 (0.76)	4.71 (0.61)	4.43 (0.76)
8.4 Habit reversal	Try to break your bad habits. Instead of always driving to the shop near your home, ride your bike instead.	.73	4.07 (0.70)	4.60 (0.74)	4.33 (0.82)
8.5 Overcorrection	If you haven't cycled as much as you wanted to one week, then make up for it by cycling more than usual the following week.	.73	3.00 (1.24)	4.36 (0.84)	4.14 (0.77)
8.6 Generalization of a target behaviour	Do you cycle on weekends? How about cyclıng to work as well?	.66	3.79 (1.25)	4.27 (1.22)	3.80 (1.21)
8.7 Graded tasks	Take small steps – for example, start cycling a short distance or just one day a week and then build up.	.87	4.13 (0.83)	4.50 (0.86)	4.14 (0.86)
Comparison of outcomes					
9.1 Credible source	Doctors are quick to point out the health benefits of cycling.	.73	3.57 (0.94)	4.31 (1.03)	4.23 (0.93)

9.2 Pros and cons	List and compare the advantages and disadvantages of cycling.	.93	4.67 (1.05)	4.47 (0.92)	4.67 (0.62)
9.3 Comparative imagining of future outcomes	Would you feel better tomorrow if you cycled today or if you did not cycle today?	.73	3.40 (1.35)	4.20 (1.01)	4.14 (0.77)
Reward and threat					
10.1 Material incentive (behaviour)	We will give you a £2 voucher for every day that you cycle for at least 30 minutes.	.80	3.87 (0.74)	4.53 (0.64)	4.40 (0.74)
10.2 Material reward (behaviour)	You have earned a £2 voucher for cycling today.	.80	4.50 (0.52)	4.73 (0.59)	4.60 (0.74)
10.3 Non-specific reward	You have just earned a reward for cycling today!	.66	3.93 (0.96)	4.57 (0.65)	4.64 (0.63)
10.4 Social reward	Congratulations for cycling today!	.73	3.50 (1.02)	4.50 (0.76)	4.50 (0.76)
10.5 Social incentive	If you cycle to work everyday next week, your work colleagues will congratulate you.	.46	4.27 (0.70)	4.67 (0.62)	4.36 (0.84)
10.6 Non-specific incentive	You will gain a reward if you cycle tomorrow.	.73	4.27 (0.70)	4.50 (0.65)	4.57 (0.65)
10.7 Self-incentive	Reward yourself if you cycle next week.	.39	4.00 (0.93)	4.60 (0.63)	4.60 (0.63)
10.8 Incentive (outcome)	You will receive a £10 voucher for every kilogram of weight that you lose by cycling.	.66	4.33 (0.72)	4.53 (0.74)	4.60 (0.63)
10.9 Self-reward	Have you been using your bike? If so, why not give yourself a little reward to say well done!	.93	4.33 (0.72)	4.29 (0.73)	4.64 (0.63)

10.10 Reward (outcome)	You have been awarded a £30 voucher for losing 3 kilograms of weight by cycling.	.93	4.27 (0.46)	4.67 (0.62)	4.53 (0.74)
10.11 Future punishment	If you do not cycle next week, then your membership to the cycling club will be cancelled.	.60	3.47 (1.13)	4.43 (1.09)	3.77 (0.83)
Regulation					
11.1 Pharmacological support	Caffeine tricks your body into feeling less tired and can improve cycling. Have a cup of coffee before you head out on your bike.	.33	2.87 (1.41)	4.00 (1.18)	2.79 (1.12)
11.2 Reduce negative emotions	Find a way to deal with your stress – that way you can get on with the things that you want to do – like cycling more!	.66	3.47 (1.25)	3.57 (1.09)	4.00 (1.04)
11.3 Conserving mental resources	Do not try to change too many things at the same time. Concentrate your mental resources on trying to cycle more.	.87	3.80 (1.47)	4.00 (0.85)	4.07 (0.80)
11.4 Paradoxical instructions	Try not doing any form of exercise until you feel like you really want to cycle.	.39	2.31 (1.44)	3.67 (1.16)	3.42 (1.00)
Antecedents					
12.1 Restructuring the physical environment	Place your bicycle in a convenient place to grab and go on your way out.	.87	4.07 (0.70)	4.73 (0.59)	4.13 (1.25)
12.2 Restructuring the social environment	Spend less time with your friends who do not cycle.	.73	4.21 (0.89)	4.15 (0.99)	4.23 (1.01)
12.3 Avoidance/reducing	Hide your car keys or bus pass to avoid cues to use other models of transport.	.66	3.53 (1.13)	4.14 (0.95)	3.92 (1.04)

exposure to cues for the behaviour					
12.4 Distraction	If you find yourself thinking about other modes of transport, then distract yourself so you can refocus on cycling.	.73	4.27 (0.88)	3.71 (0.91)	3.86 (0.95)
12.5 Adding objects to the environment	Get yourself new cycling gear.	.60	2.93 (1.22)	4.29 (0.83)	3.29 (1.33)
12.6 Body changes	Hit the gym or do squats at home to strengthen the muscles you use for cycling.	.53	3.47 (1.30)	4.50 (0.76)	3.57 (1.02)
Identity					
13.1 Identification of self as role model	You can be the one starting cycling a trend among your friends!	.80	3.60 (1.40)	4.07 (0.80)	3.87 (0.99)
13.2 Framing/reframing	Let’s call your bike the “life cycle” So that it reminds you why you are cycling.	.39	2.73 (1.53)	3.14 (1.17)	3.00 (1.24)
13.3 Incompatible beliefs	There’s a discrepancy between your view of yourself as a cyclist and how often you’ve actually cycled in the past year.	.66	4.21 (0.80)	3.92 (0.86)	4.08 (0.95)
13.4 Valued self-identity	What are your 5 most important strengths? Think about them and elaborate them to yourself. These could help you to cycle more.	.80	3.87 (0.99)	4.00 (0.96)	4.07 (0.92)
13.5 Identity associated with changed behaviour	From now on, think of yourself as a cyclist.	.87	4.33 (0.72)	4.33 (0.72)	4.27 (0.88)
Scheduled consequences					

14.1 Behaviour cost	£2 has been subtracted from your account as you did not cycle today.	.53	3.87 (0.92)	4.73 (0.59)	4.60 (0.74)
14.2 Punishment	Because you have not cycled over the last week, your phone's alarm will go off twice at random hours today.	.73	3.07 (1.16)	3.64 (1.08)	3.71 (1.07)
14.3 Remove reward	Because you have not cycled over the last week, you have lost your chance to earn a £2 voucher the next time you cycle.	.66	3.20 (0.78)	4.29 (0.83)	4.14 (0.86)
14.4 Reward approximation	You have earned a £2 voucher for cycling 15 minutes today. You will need to cycle for 30 minutes next time to earn the voucher.	.12	3.13 (1.06)	4.40 (0.83)	4.30 (0.72)
14.5 Rewarding completion	You have earned a £2 voucher for cycling today. To get this reward next time you will also need to wear a helmet.	.26	3.29 (1.14)	4.38 (0.65)	3.62 (1.26)
14.6 Situation-specific reward	You have earned a £5 voucher for cycling during the rush hour but you will not get these vouchers if you cycle at other times.	.80	3.53 (1.46)	4.29 (0.83)	3.71 (1.20)
14.7 Reward incompatible behaviour	You have received a reward for not driving your car to the shops.	.33	3.67 (0.82)	4.20 (0.94)	4.07 (0.80)
14.8 Reward alternative behaviour	We have arranged for you to be rewarded every time that you find an alternative to using the car.	.26	3.80 (0.86)	4.00 (0.88)	4.00 (0.88)
14.9 Reduce reward frequency	For cycling today you have earned a voucher but you will need to cycle two days in a row to earn your next voucher.	.33	3.80 (0.68)	4.36 (0.75)	4.14 (0.86)

14.10 Remove punishment	To make yourself cycle more, arrange removal of a chore you don't like doing. If you cycle, you don't do the chore!	.60	3.14 (1.10)	3.86 (0.95)	4.14 (1.03)
Self-belief					
15.1 Verbal persuasion about capability	You can cycle today! Even though it seems far, you can do it!	.87	4.33 (0.72)	4.57 (0.64)	4.60 (0.63)
15.2 Mental rehearsal of successful performance	Close your eyes and imagine cycling successfully somewhere.	.60	3.67 (1.59)	4.47 (0.73)	4.47 (0.83)
15.3 Focus on past success	Think of all the times in the past that you didn't want to cycle but you did it anyway.	.66	4.36 (0.63)	4.46 (0.66)	4.54 (0.66)
15.4 Self-talk	Tell yourself (aloud or silently) that cycling today will be enjoyable.	.87	4.57 (1.09)	4.71 (0.47)	4.79 (0.43)
Covert learning					
16.1 Imaginary punishment	To convince yourself to cycle more, imagine yourself suffering because of not cycling.	.80	3.53 (0.92)	3.93 (0.73)	3.93 (0.83)
16.2 Imaginary reward	Imagine cycling regularly and getting compliments on your looks from your significant other or someone attractive to you.	.80	4.00 (0.56)	4.29 (0.73)	4.00 (0.78)
16.3 Vicarious consequences	Observe the benefits that other people who cycle regularly get, such as being fitter or receiving compliments.	.53	3.80 (1.32)	4.13 (0.83)	4.13 (0.83)

Note. Standard deviations are in parentheses.

Appendix 2

Table S2

Agreement between coders with respect to the BCT that the text message was intended to deliver (kappa), ratings of confidence in identifying the intended BCT, understandability and convertibility of the message (phase 2)

Target BCT	Text message	Kappa	Confidence	Understandability	Convertibility
2.5 Monitoring outcome(s) of behaviour by others without feedback	Your saddle has a sensor that automatically records your weight.	.06	4.20 (0.94)	4.53 (0.52)	4.67 (0.62)
3.3 Social support (emotional)	Asking a friend to cycle with you would be much more enjoyable!	.39	3.47 (0.83)	4.33 (0.82)	4.13 (0.92)
4.2 Information about antecedents	You typically go cycling in the morning.	.00	3.50 (0.86)	4.08 (0.76)	4.23 (0.73)
4.3 Re-attribution	Try to attribute your tiredness to inactivity rather than cycling too much.	.53	4.00 (0.76)	3.73 (0.96)	3.80 (0.86)
4.4 Behavioural experiments	Experiment with cycling at different times of the day to work out when works best for you.	.73	3.00 (1.24)	3.86 (1.10)	4.29 (0.91)
5.2 Salience of consequences	Keep the image of a healthy heart in your mind to remind yourself of the benefits of cycling.	.46	2.87 (1.19)	3.93 (1.07)	4.00 (1.11)
5.4 Monitoring of emotional consequences	Keep a record of how you feel after cycling - what emotions do you experience?	.00	4.00 (0.96)	4.21 (0.89)	4.29 (0.83)
7.2 Cue signalling reward	The weather will be used to decide if you will get	.06	3.47 (1.13)	3.47 (1.41)	3.33 (1.29)

	a reward - If the weather is bad when you are cycling, then you will be more likely to get the reward.				
7.4 Remove access to the reward	Your free gym membership will be removed because you did not cycle twice in the past week.	.06	3.87 (0.74)	4.53 (0.52)	4.13 (0.92)
7.5 Remove aversive stimulus	We will stop sending you nagging texts if you cycle twice this week, in order to encourage you to cycle more.	.19	2.79 (1.31)	3.77 (1.24)	3.92 (1.24)
7.6 Satiation	Don't cycle for a month - you'll soon want to start again.	.06	3.13 (0.92)	3.67 (1.18)	3.93 (1.10)
7.7 Exposure	If you're frightened about cycling to work, then cycle the route on the weekend to reduce your fear.	.26	3.53 (1.06)	4.33 (0.72)	3.60 (1.12)
7.8 Associative learning	Tape a picture of something that you really like on to your bike, so that you come to love cycling more!	.53	2.93 (1.39)	3.93 (0.88)	3.53 (0.99)
10.5 Social incentive	Your friends will congratulate you if you cycle more - this is your incentive!	.60	3.80 (0.86)	4.40 (0.91)	4.47 (0.74)
10.7 Self-incentive	Incentivise yourself to cycle more!	.73	3.67 (1.29)	2.87 (0.92)	3.73 (1.28)
10.11 Future punishment	If you do not cycle now, then you will be punished for it later.	.80	4.07 (0.80)	3.67 (1.11)	4.07 (1.10)
11.1 Pharmacological support	Caffeine and vitamin supplements can make it easier to cycle.	.00	3.20 (1.15)	3.93 (0.96)	3.93 (0.96)
11.4 Paradoxical	Try not doing any exercise until you feel like you	.00	3.73 (1.16)	4.47 (0.64)	4.13 (0.83)

instructions	really want to cycle.				
12.5 Adding objects to the environment	Get yourself cycling gear appropriate for different weather conditions (or even a new bike)!	.06	3.20 (1.21)	4.20 (0.68)	4.13 (0.92)
12.6 Body changes	Do some squats or lunges at home - this will strengthen the muscles that you use for cycling.	.00	3.33 (1.29)	4.27 (0.88)	3.71 (1.27)
13.2 Framing/reframing	Think of cycling to work as an easy way to stay fit rather than as a mode of transport.	.00	3.47 (1.30)	4.20 (1.01)	4.40 (0.83)
14.1 Behaviour cost	£2 has been subtracted from your account as you did not cycle today.	.60	4.13 (0.99)	4.67 (0.49)	4.27 (0.96)
14.4 Reward approximation	You have earned a £2 voucher for cycling 15 minutes today (as part of your 30 minute target).	.33	3.20 (0.94)	4.40 (0.74)	4.29 (0.73)
14.5 Rewarding completion	You will receive a reward for completing your goal of cycling safely - that means cycling AND wearing a helmet.	.33	3.47 (1.13)	4.40 (0.63)	3.93 (0.96)
14.7 Reward incompatible behaviour	You will receive a reward when you do not drive your car to work.	.19	3.79 (1.19)	4.23 (0.73)	4.08 (1.19)
14.8 Reward alternative behaviour	You will receive a reward if you find an alternative to using the car.	.33	3.60 (1.06)	4.00 (1.00)	4.07 (0.96)
14.9 Reduce reward frequency	This week you will receive a voucher if you cycle to work every day. You will receive the next voucher when you have done this every day for a month.	.46	3.87 (0.92)	4.33 (0.62)	4.40 (0.83)
14.10 Remove punishment	Arrange for someone else to do a chore that you	.33	3.57 (0.94)	3.92 (1.04)	4.00 (1.29)

	don’t like doing, if you cycle to work.				
15.2 Mental rehearsal of successful performance	Close your eyes and imagine cycling somewhere and enjoying the experience.	.39	3.57 (1.09)	4.29 (0.73)	4.21 (0.80)
16.3 Vicarious consequences	See what other people seem to get out of cycling regularly.	.39	2.73 (1.16)	3.47 (1.13)	3.73 (1.28)

Note. Standard deviations are in parentheses.

Appendix 3

Table S3

BCTs that were confused two or more times

4.3 Re-attribution	13.2 Framing/reframing
7.1 Prompts/cues	7.3 Reduce prompts/cues
7.1 Prompts/cues	12.3 Avoidance/reducing exposure to cues for the behaviour
7.3 Reduce prompts/cues	12.3 Avoidance/reducing exposure to cues for the behaviour
7.4 Remove access to the reward	14.3 Remove reward
7.5 Remove aversive stimulus	14.10 Remove punishment
7.6 Satiation	11.4 Paradoxical instructions
7.7 Exposure	8.7 Graded tasks
8.1 Behavioural practice/rehearsal	8.7 Graded tasks
8.2 Behaviour substitution	8.4 Habit reversal
9.3 Comparative imagining of future outcomes	16.2 Imaginary reward
10.11 Future punishment	14.2 Punishment
14.1 Behaviour cost	14.2 Punishment
14.1 Behaviour cost	14.3 Remove reward
14.7. Reward incompatible behaviour	14.7. Reward alternative behaviour