

Appendix of the Paper “Persuading to Prepare for Quitting Smoking with a Virtual Coach: Using States and User Characteristics to Predict Behavior”

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This document is the Appendix of our paper “Persuading to Prepare for Quitting Smoking with a Virtual Coach: Using States and User Characteristics to Predict Behavior.” Using the same section names as in the paper, we provide more information on the virtual coach, persuasion algorithm, data collection, optimal and worst policies computed for research questions Q3 and Q4, and the weighting of samples based on similarity for research question Q6.

METHODOLOGY

Virtual coach

Figure 1 shows the structure of the conversational sessions with the virtual coach Sam, each of which lasted about five to eight minutes. An example of the start of the second session with Sam is further given in Figure 2. Moreover, Table 1 contains examples of preparatory activities used in the study. The complete list of activities can be found in Albers et al. [3].

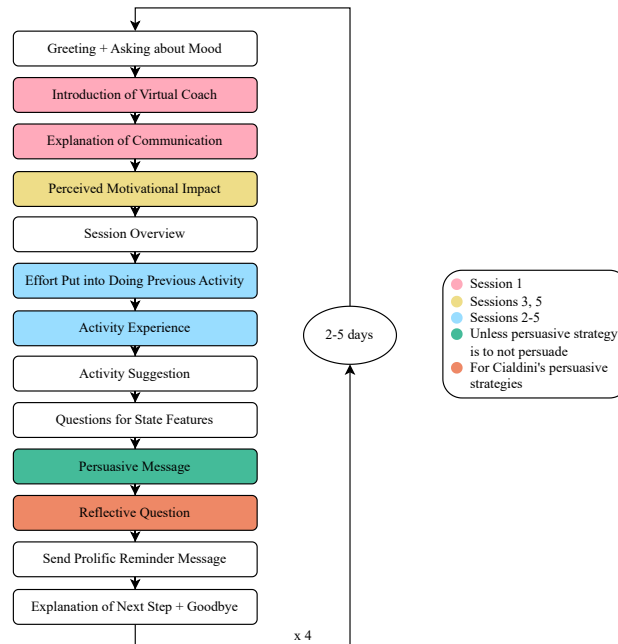


Figure 1: Structure of the conversational sessions [1]. In sessions 3 and 5, participants were asked about the perceived motivational impact of the last two conversational sessions.

Table 1: Examples of preparatory activities used in the study.

Title and Formulation	
1	Desired future self (writing). Having high aspiration to quit smoking may aid quitting successfully. Thus, before the next session, I advise you to think about the person that you would like to be once you have successfully quit smoking. For example, you might want to be a “grandfather who can play football with his grandchildren” or a “nurse who can walk up the stairs to the fourth floor without getting out of breath.” Write down everything that comes to your mind.
2	Reasons for quitting smoking. Having high aspiration to quit smoking may aid quitting successfully. So, before the next session, I advise you to identify and write down reasons why you want to stop smoking. After writing them down, think about which reasons are most important to you and order them accordingly.
3	Feared future self (writing). Having high motivation to quit smoking may aid quitting successfully. Thus, before the next session, I advise you to think about who you do NOT want to be in the future but might become if you continue to smoke. For example, you might NOT want to be a “mother who dies early of coronary heart disease like her mother did” or a “husband who is frowned upon by his wife” or a “man who is dependent on a substance.” Write down everything that comes to your mind.

Persuasion algorithm

Figure 3 illustrates the idea of our algorithm using fictitious data. Table 2 shows the eight candidate state features from which we selected three to reduce the size of the state space and the number of questions users would need to answer in practice. Examples of the persuasive messages and subsequent reflective questions are given in Table 3 and Table 4.

Table 2: Candidate state features based on the COM-B self-evaluation questionnaire [13] and measuring self-efficacy [15], mapped to the COM-B components.

	State Feature	COM-B Component
1	Knowing why it is important to do an activity	Capability
2	Having sufficient time to do an activity	Opportunity
3	Having things that prompt/remind them to do an activity	Opportunity
4	Feeling part of a group that is doing these kinds of activities	Opportunity
5	Feeling like they want to do an activity	Motivation
6	Feeling like they need to do an activity	Motivation
7	Thinking that it would be a good thing to do an activity	Motivation
8	Thinking that they can do an activity	Motivation

Table 3: Examples of persuasive message templates.

Persuasive Strategy	Persuasive Message Template
Action plan- ning	Please think about the time after this and before the next session. When, where and how do you plan to do your recommended preparation activity? Please formulate a rule for completing your activity that has the form “If ⟨situation⟩, then I will ⟨do activity⟩.” For example, “If I have finished brushing my teeth tonight, then I will ⟨do activity⟩.” Type your rule into this chat. The more precise, concrete and personally you formulate your rule, the more it can help you.
Authority	Experts recommend ⟨doing activity⟩ to ⟨positive impact of activity⟩.
Commitment	You’ve committed to become somebody who has quit smoking. ⟨doing activity⟩ may help you to become this person.
Consensus	Most people think that ⟨doing activity⟩ may help to ⟨positive impact of activity⟩.

Table 4: Examples of reflective questions used for the persuasive strategies of authority, commitment, and consensus.

Persuasive Strategy	Reflective Question: “Please tell me what you think: ...
Authority	Which other experts, whose opinion you value, would agree with this?”
Commitment	In what way does doing this activity match your decision to successfully quit smoking?”
Consensus	How would people like you, in a situation like yours, agree with this?”

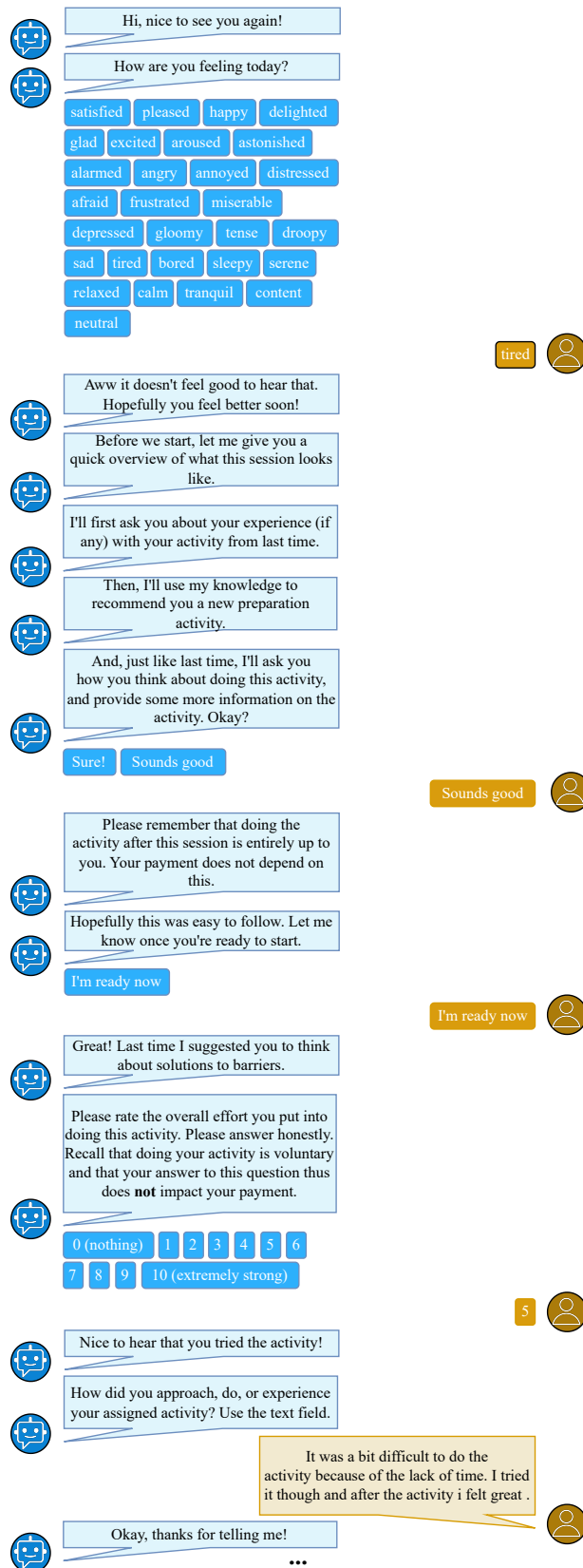


Figure 2: Example of the start of the second conversational session with Sam, including responses given by a participant.

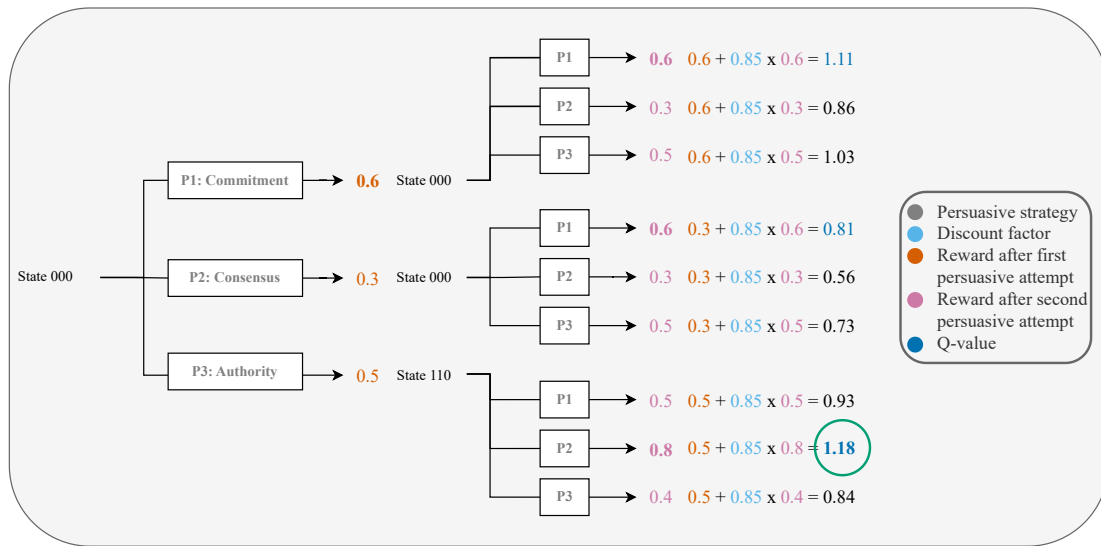


Figure 3: Algorithm illustration [1] with fictitious data. Using a persuasive strategy in a certain state results in a reward and a next state. To assess the overall effectiveness of using a persuasive strategy, we compute the discounted sum of rewards over time. Discounted thereby means that future rewards are discounted with a discount factor. Using persuasive strategy P_3 in state 000 and subsequently persuasive strategy P_2 in state 110 leads to the highest discounted sum of rewards. This means that it is optimal to use P_3 in state 000.

Data collection

Study. Figure 4 depicts the participant flow through the study components. Table 5 further shows the policies based on which people were persuaded in the study after session 2. Participant characteristics are given in Table 6.

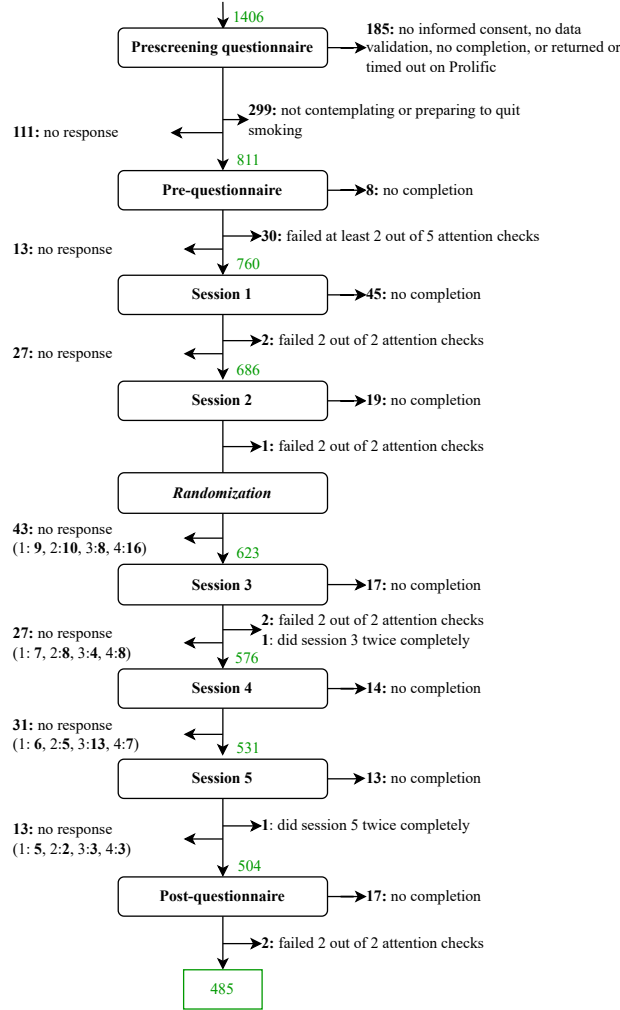


Figure 4: Participant flow through the study components [1]. The numbers next to the downward arrows denote how many people started the study components. We show the distribution across the four groups for the participants who did not respond to the invitation to a study component after the randomization. Note that participants can return their submission on Prolific to withdraw from a study.

Data. Besides $\langle s, a, r, s' \rangle$ -samples, we collected data on 32 user characteristics. This includes data on demographics (age, gender, household size, personal and household income, education level, socioeconomic status), smoking (smoking and quit smoking status, smoking frequency, Transtheoretical Model (TTM)-stage for quitting smoking [9]¹, quitter (Cronbach's $\alpha = 0.76$, $N = 715$ ²), smoker ($\alpha = 0.74$), and non-smoker ($\alpha = 0.68$) self-identity based on Meijer et al. [12], smoker ($\alpha = 0.78$) and non-smoker ($\alpha = 0.78$) group identity based on five items each from the "Ingroup Ties"-subscale of the Group Identification Scale by Cameron [6], quitting self-efficacy ($\alpha = 0.82$), existence and number of quit attempts in the last year [9], time since the last quit attempt), physical activity (weekly exercise amount, number of hours spent sitting on week and weekend days [8], TTM-stage for becoming physically active based on adapting the question by Norman et al. [14]³ to physical activity, physical activity identity ($\alpha = 0.89$) based on adapting the Exercise Identity Scale by Anderson and Cychosz [4] to physical activity),

¹<https://web.uri.edu/cprc/measures/smoking/adult-stage-of-change-short-form/>

²We use for the Cronbach's α computation the data from all 715 people with data on at least one state.

³<https://web.uri.edu/cprc/measures/exercise/stages-of-change-short-form/>

Table 5: Policies used after session 2 in the study. All policies were trained on the data gathered in sessions 1 and 2 for the first batch of people ($N = 516$) who successfully completed session 2.

Group	Policy
1	The persuasive strategy with the overall highest average reward, which was <i>Commitment</i> .
2	The persuasive strategy with the highest average reward in a user’s state. Three state features were chosen in a way that was inspired by the G-algorithm [7] based on average rewards. The chosen features were whether users felt like they wanted to do an activity, whether they felt like being part of a group that was doing these kinds of activities, and whether they thought they could do an activity. The policy for the resulting eight states was as follows: 000: <i>Action planning</i> , 001: <i>Action planning</i> , 010: <i>Consensus</i> , 011: <i>No persuasion</i> , 100: <i>Consensus</i> , 101: <i>No persuasion</i> , 110: <i>No persuasion</i> , 111: <i>Commitment</i> .
3	The persuasive strategy with the highest Q-value in a user’s state. Three state features were chosen in a way that was inspired by the G-algorithm [7] based on Q-values. The chosen features were whether users thought that it would be a good thing to do an activity, whether they thought they could do an activity, and whether they knew why it was important to do an activity. The policy for the resulting eight states was as follows: 000: <i>Consensus</i> , 001: <i>Consensus</i> , 010: <i>Commitment</i> , 011: <i>No persuasion</i> , 100: <i>Authority</i> , 101: <i>Commitment</i> , 110: <i>Consensus</i> , 111: <i>Commitment</i> .
4	The persuasive strategy with the highest similarity-weighted Q-value in a user’s state. Similarity was determined through users’ Big-Five personality [10] and Transtheoretical Model (TTM)-stage for becoming physically active based on adapting the question by Norman et al. [14] to physical activity. The same three state features as for group 3 were used. There was a separate policy for each user.

Big-Five personality [10], and need for cognition ($\alpha = 0.76$) based on the three items from Cacioppo et al. [5] used by Steward et al. [16]. We refer to these characteristics measured before any persuasive attempts as pre-characteristics. In addition, we measured users’ overall involvement in their assigned activities after the five sessions ($\alpha = 0.89$). For this, we used three items that were based on Maheswaran and Meyers-Levy [11] and answered on a scale from -5 (Disagree strongly) to 5 (Agree strongly). Due to dropout, we obtained involvement data only for 500 participants. All collected data underlying our paper can be found in the online repository accompanying our article [2]. This repository also contains more information on each measure.

Table 6: Characteristics of the 671 participants with at least one transition sample.

Characteristic	Value
AGE	
- 18 – 20, n (%)	47 (7.00%)
- 21 – 30, n (%)	268 (39.94%)
- 31 – 40, n (%)	168 (25.04%)
- 41 – 50, n (%)	100 (14.90%)
- 51 – 60, n (%)	70 (10.43%)
- 61 – 70, n (%)	16 (2.38%)
- 71 – 74, n (%)	2 (0.30%)
GENDER	
- Female, n (%)	349 (52.01%)
- Male, n (%)	310 (46.20%)
- Other, n (%)	11 (1.64%)
- <i>No data</i> , n (%)	1 (0.15%)
HIGHEST COMPLETED EDUCATION LEVEL	
- No formal qualifications, n (%)	5 (0.75%)
- Secondary education (e.g. GED/GCSE), n (%)	76 (11.33%)
- High school diploma/A-levels, n (%)	170 (25.34%)
- Technical/community college, n (%)	103 (15.35%)
- Undergraduate degree (BA/BSc/other), n (%)	211 (31.45%)
- Graduate degree (MA/MSc/MPhil/other), n (%)	95 (14.16%)
- Doctorate degree (PhD/other), n (%)	7 (1.04%)
- <i>No data</i> , n (%)	4 (0.60%)
PERSONAL INCOME	
- Less than £10,000, n (%)	212 (31.59%)
- £10,000 – £19,999, n (%)	164 (24.44%)
- £20,000 – £29,999, n (%)	110 (16.39%)
- £30,000 – £39,999, n (%)	55 (8.20%)
- £40,000 – £49,999, n (%)	27 (4.02%)
- £50,000 – £59,999, n (%)	13 (1.94%)
- £60,000 – £69,999, n (%)	10 (1.49%)
- £70,000 – £79,999, n (%)	1 (0.15%)
- £90,000 – £99,999, n (%)	3 (0.45%)
- £100,000 – £149,999, n (%)	3 (0.45%)
- More than £150,000, n (%)	1 (0.15%)
- <i>No data</i> , n (%)	72 (10.73%)
TTM-STAGE FOR BECOMING PHYSICALLY ACTIVE	
- Precontemplation, n (%)	44 (6.56%)
- Contemplation, n (%)	188 (28.02%)
- Preparation, n (%)	159 (23.70%)
- Action, n (%)	83 (12.37%)
- Maintenance, n (%)	197 (29.36%)

Abbreviations: SD, Standard deviation; GED, General educational development; GCSE, General certificate of secondary education; BA, Bachelor of Arts; BSc, Bachelor of Science; MA, Master of Arts; MSc, Master of Science; MPhil, Master of Philosophy; PhD, Doctor of Philosophy; TTM, Transtheoretical model.

RESULTS

Optimal and worst policies

Table 7 shows the optimal policy π^* and the worst policy π^- calculated via value iteration based on all gathered samples for research questions Q3 and Q4.

Table 7: Optimal policy π^* and worst policy π^- calculated via value iteration based on all gathered samples.

State	π^*	π^-
000	Commitment	Consensus
001	Consensus	Commitment
010	No persuasion	Action planning
011	Consensus	Action planning
100	Commitment	Action planning
101	Commitment	Consensus
110	No persuasion	Authority
111	Commitment	Action planning

Weighting of samples based on similarity

For research question Q6, we considered four ways of choosing user characteristics for measuring the similarity of people: 1) the three user pre-characteristics most correlated with the effort people spent on their activities, 2) the three user pre-characteristics that were among the two most correlated for any of the three state features, 3) the union of the characteristics from 1) and 2), and 4) people’s involvement in their activities. We excluded binary pre-characteristics and used Spearman correlations. The user pre-characteristics most correlated with the effort were physical activity identity, personal income, and the Big-5 personality dimension of conscientiousness; those most correlated with the state features were quitter self-identity, physical activity identity, and nonsmoker self-identity. The similarity of people was then calculated based on the Euclidean distances of the user variable vectors, whereby each user characteristic had been scaled to the interval $[0, 1]$ and missing values had been filled with the median⁴. We mapped Euclidean distances to similarities so that the similarity for the smallest Euclidean distance was 1, and the similarity for the highest Euclidean distance was 0.

For each of these four settings, we tested two approaches for weighting observed samples based on this similarity. In the first approach, all samples were weighted based on people’s similarity. More precisely, we computed the weight w_{ij} of a sample from person j for person i as follows:

$$w_j = \max\left(\frac{s_{ij}}{\sum_k s_{ik}}, 0.0001\right), \quad (1)$$

where s_{ij} is the similarity of i and j , and the addition of 0.0001 was to ensure that no sample was given a weight of 0. In the second approach, the samples from the $k \in \{0.05, 0.1, 0.25, 0.5\}$ most similar people were copied $c \in \{2, 5, 10, 50\}$ times. This means that overall, we tried 17 different configurations for weighting samples based on similarity for each setting, for a total of 68 configurations.

The configuration with the lowest mean L_1 -error for predicting the reward was using people’s involvement in their activities as a measure of similarity and setting $k = 0.1$ and $c = 10$ when weighting samples based on similarity. This is the configuration for which we report the mean L_1 -error as part of Figure 6 in the paper.

⁴There is missing data for 10 user characteristics that we extracted from participants’ Prolific profiles. This includes the gender ($N = 1$), education level ($N = 4$), socioeconomic status ($N = 2$), household size ($N = 7$), household income ($N = 66$), personal income ($N = 72$), weekly exercise amount ($N = 5$), smoking frequency ($N = 3$), quit smoking status ($N = 4$), and smoking status ($N = 3$). In addition, we obtained involvement data for only 500 of the 671 participants due to dropout.

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