AI in biomedical informatics

Project: Using simulation to assess trigger-generating mechanisms for digital health interventions

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1 Introduction

The objectives of this project are as follows:

1. Getting familiar with the experimental environment, based on OpenAI Gym and described in [1], which allows to simulate patient behavior according to the Fogg model [2] and evaluate the operation of stimulus-generating models.
2. Modeling of the considered patient profiles (in general, users of the system offering digital health interventions) identified in the study [3], simulation of the behavior of patients representing these profiles and assessment of the quality of selected models generating triggers.

1.1 Fogg behavior model

The Fogg behavior model indicates the following factors that must occur at the same time and at an appropriate intensity for a behavior (and a subsequent long-term change) to occur:

- Motivation (M),
- Ability (A),
- Trigger or prompt (T/P).

Fogg's model is presented in Figure 1. Despite its simplicity, it is often considered in the context of digital health interventions and patient behavior modification [4].

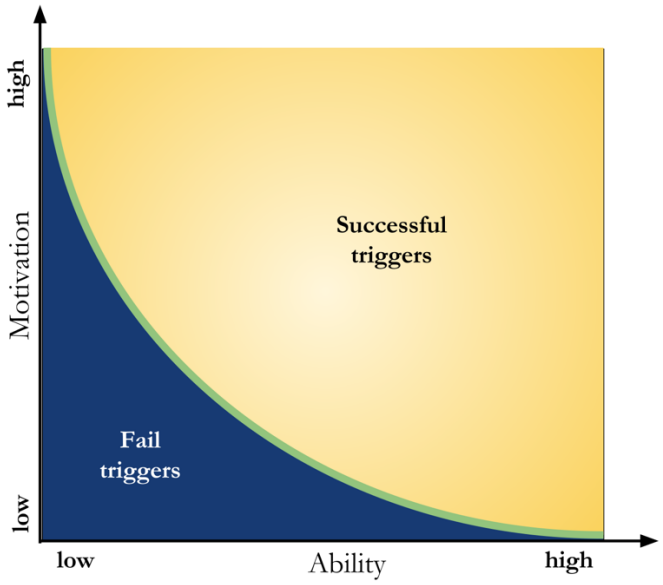

Figure 1. Fogg behavior model (source: Wikipedia)

1.2 Experimental environment

The simulation environment presented in [1] is based on Gymnasium[1] (previously known as OpenAI Gym). It assumes that the patient's condition is characterized using variables presented in Fig. 2. The figure also shows their exemplary values, and a detailed description of the variables and the method of encoding their values can be found in Table 1 in the paper [1].

variable	value
time of day	midday
day	weekday
benefit	yes
location	home
awake state	awake
valence	negative
arousal	low
cognitive load	high
motion	stationary
sufficient sleep	no
no. notified	0
no. activity performed	0

Figure 2. Variables describing the patient state

These variables are used to check whether a behavior (in this case, physical activity – walking) is "activated". For this purpose, the following (simple) formula (based on the Fogg's model) is used:

$$Behavior = \begin{cases} 1 & if\ (Motivation \times Ability \times Trigger) > action\ threshold \\ 0 & otherwise \end{cases}$$

The variables in the above formula are defined as follows (see paper [1] for details):

$$Motivation = Positive\_Valence + Has\_Family + Perceived\_Benefit + Sufficient\_Sleep$$

$$Ability = Low\_Cognitive\_Load + Self\_Efficacy + Unstrained\ (\text{not tired/not bored})$$

$$Trigger = Mid\_Arousal + Day + Time + Location + No\_Motion$$

1.3 Patient profiles

The paper [3] presents the results of a survey aimed (among others) at identification of patient profiles that should be included in the simulation. Based on the analysis of the answers to the questions related to Fogg's model and concerning motivation, ability and trigger, four profiles were identified and described by answering 5 questions (indicated as relevant as a result of the analysis). These profiles are displayed in Figure 3, which presents the distribution of responses

[1] https://github.com/Farama-Foundation/Gymnasium

to each question. In addition, Table 1 summarizes the most common answers to each question for the profiles considered.

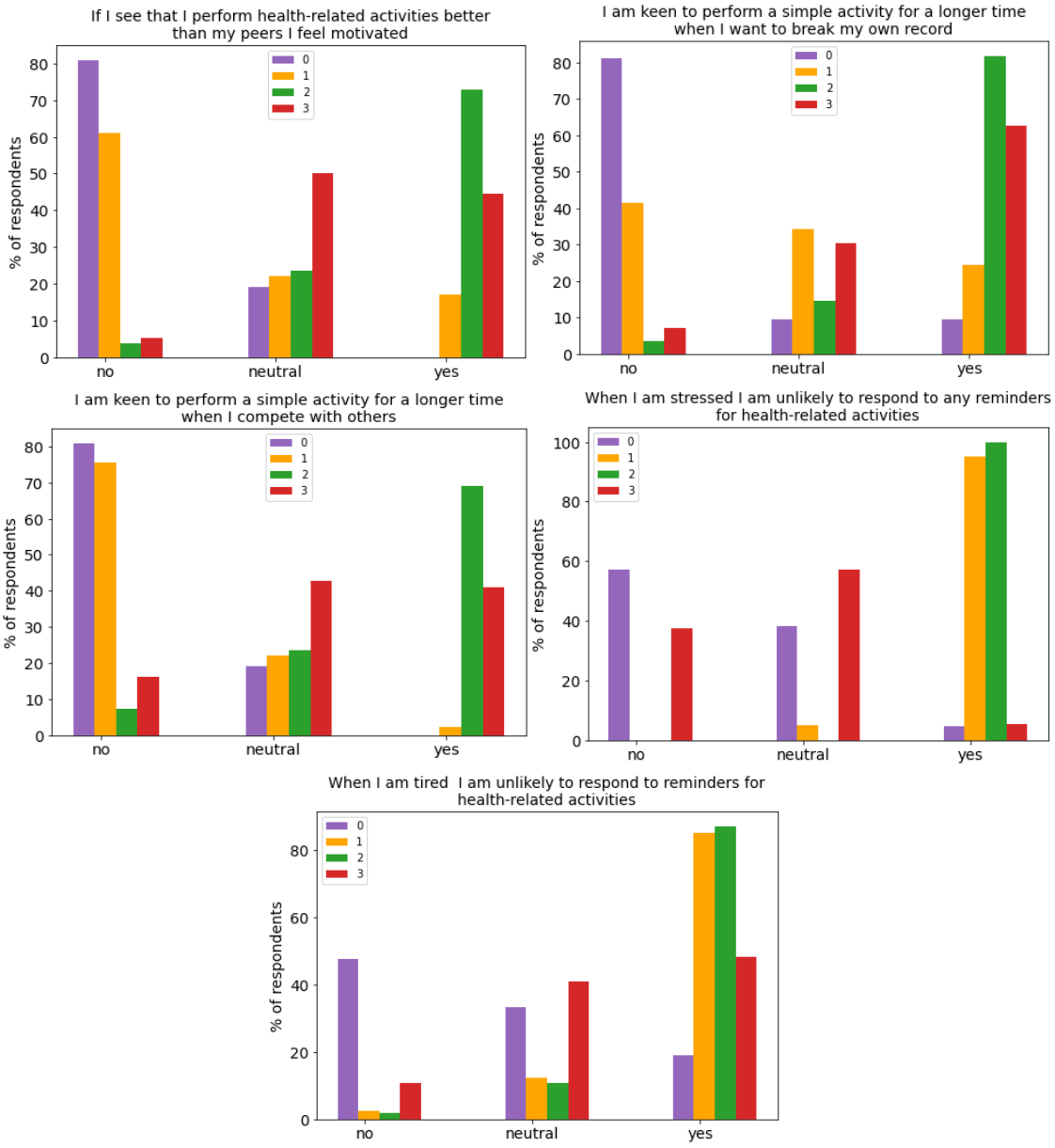

Figure 3. Distribution of responses for specific questions related to the Fogg's model

Table 1. The most frequent responses for specific profiles

	Profile			
Question	0	1	2	3
If I see that I perform health-related activities better than my peers I feel motivated	No	No	Yes	Neutral
I am keen to perform a simple activity for a longer time when I want to break my own record	No	No	Yes	Yes
I am keen to perform a simple activity for a longer time when I compete with others	No	No	Yes	Neutral
When I am stressed I am unlikely to respond to any reminders for health-related activities	No	Yes	Yes	Neutral
When I am tired I am unlikely to respond to any reminders for health-related activities	No	Yes	Yes	Yes

2 Tasks

2.1 Getting familiar with the experimental environment

Familiarize yourself with the computing environment provided for this project[2]. When installing the necessary packages, use the `pip` tool (you can also use Docker):

```
pip install -r requirements.txt
pip install jupyter
```

After preparing the environment, run some example experiments defined in the `experiments` notebook (this notebook implements the calculations the results of which are presented in the paper [1]). Due to the long computation time, it is recommended to limit the number of repetitions (`runs`) to 100 (however, this may reduce the stability of the obtained models compared to those from the publication) and to omit the experiment with static random tree learning, defined in the `supervised_after_three_weeks` function. An experiment using the adaptive (incremental) learning implemented in `supervised_adaptive_after_three_weeks` takes a little longer but allows for more interesting results.)

[2] https://github.com/sysmon37/aibi-dhi-simulator

2.2 Modification of the patient profiie

Part 1

Prepare a new class based on `fogg_behavioural_model.Patient`, which will represent one of the patient (user) profiles presented in the paper [3] and identified on the basis of the analysis of the survey results. Suggest and briefly explain how the characteristics of the profile can be "implemented" (considered) in the simulation environment. Pay attention to the limitations of the current version of the environment (the ability to simulate only a single patient at a time), which may require some simplifications, e.g. when comparing a given patient with a group (*peers*) – the behavior of the group must be simulated.

Part 2

Perform a computational experiment verifying the behavior of the simulated patient (modeled in Part 1 of the task) and evaluating the quality of the selected stimulus generation models. Perform a computational experiment and visualize the results using a sample notebook using the following suggestions:

1. Perform the calculation for 500 repetitions (`runs = 500`).
2. Assume the patient's characteristics and initial state as described in the paper [1] (m.in., acceptance of up to 3 reminders per day).
3. Assume that the patient's preference and activity threshold do not change during the simulation.
4. Perform experiments for the following stimulus generation techniques:
    a. random (`random_notification`),
    b. Incremental machine learning (`supervised_adaptive_after_three_weeks`)
    c. reinforcement learning (DQN, PPO, A2C).
5. As part of the visualization of the results, present graphs illustrating the percentage of stimuli resulting in an action and the average number of reminders.

After completing the simulation experiments, prepare a notebook describing how the patient profile was modeled and the results obtained during the simulation. **It is recommended to perform the project in groups of 4 people, in which each person is involved in modeling one profile and conducting simulations for this profile**. It is worth considering modifications common to the group (e.g. additional variables) that will allow for differentiation of patient profiles.

3 References

1. A. Lisowska, Sz. Wilk, M. Peleg, From Personalized Timely Notification to Healthy Habit Formation: A Feasibility Study of Reinforcement Learning Approaches on Synthetic Data,

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2. B.J. Fogg, Tiny Habits: The Small Changes That Change Everything. 2019.
3. A. Lisowska, S. Lavy, Sz. Wilk, M. Peleg, Personality and Habit Formation: Is There a Link? in: SMARTERCARE 2021. Workshop Proceedings, CEUR-WS, vol. 360, CEUR, 2021, pp. 42-47. http://ceur-ws.org/Vol-3060/paper-5.pdf
4. Crutzen R. The behavioral intervention technology model and intervention mapping: the best of both worlds. J Med Internet Res. 2014;16(8):e188. Published 2014 Aug 5. https://dx.doi.org/10.2196%2Fjmir.3620