

What Keeps You Going? Modelling Motivation and Lifestyle Change in Patients with Type 2 Diabetes

Karine van 't Land¹, Sietze Kai Kuilman², Simon Laub³, Jan Treur⁴

¹ Amsterdam UMC. Department of Public and Occupational Health
`karinevantland@gmail.com`

² Delft University of Technology
`S.K.Kuilman@tudelft.nl`

³ EAAA, Business Academy Aarhus (Dk)
`silaa@eaaa.dk`

⁴ Vrije Universiteit Amsterdam
`j.treur@vu.nl`

Abstract. Chronic lifestyle-related disease is one of the major health problems the world is facing in the twenty-first century. One of the ways to address the problem of chronic lifestyle-related disease is through programs which support lifestyle changes. Research shows the actual benefits of lifestyle changes for patients. However, in reality only a fraction of patients succeeds in changing their lifestyle. Their level and type of motivation appear to be important factors in shaping their chances for success. We devised a second order temporal-causal network for adoption of habit with regards to motivation, focusing on patients with type 2 diabetes who receive advice to exercise. Taking into account a variety of motivational forces, the model clearly shows the benefits of more and repeated interactions. They lead to a more long-lasting change, even though these interactions may also amplify negative emotions. These findings are in accordance with tentative findings in research.

Keywords: Diabetes, temporal-causal networks, lifestyle, motivation, exercise

1 Introduction

Chronic lifestyle-related disease is one of the major health problems the world is facing in the twenty-first century. Obesity, type 2 diabetes, hypertension and cardiovascular disease are not just problems of so-called Western countries. For instance, worldwide, 422 million people have type 2 diabetes, the majority living in low and middle-income countries⁵. The Covid-19 pandemic only stressed the severity of the problem, as it showed the vulnerability of people suffering from chronic disease. The world is in need of effective, scalable and affordable solutions

⁵ Estimates taken from the World Health Organisation

in order to prevent chronic lifestyle-related disease and support those suffering from these diseases.

One of the ways to address the problem of chronic lifestyle-related disease is formed by programs to support lifestyle change in patients. Research clearly points to the actual benefits lifestyle change has to offer to these patients. When patients with type 2 diabetes follow a suitable energy-restricted diet and exercise regularly, many of them can lower their medication or even completely stop using medication. However, in reality only a fraction of patients succeeds in successfully changing lifestyle[3].

Key factors for the adoption of new habits actually arise from self-esteem and intrinsic motivation. Especially the latter can be taken as indicative of long-term change. The question is of course: how can one boost such motivation? Next to these promoting factors, patients with type 2 diabetes encounter serious barriers to lifestyle change. It is important to take these barriers into account as well.

This paper presents a second order temporal-causal network for adoption of lifestyle habit, focusing on patients with type 2 diabetes who receive advice to exercise. Our aim is to provide caregivers of patients with type 2 diabetes with insights on the nature of promoting factors and barriers for the adoption of lifestyle change and the development of new habits. The temporal-causal network enables us to present findings from qualitative research in a new and visual manner. Furthermore, by attaching weights, speeds and adaptivity to the diverse connections, we can tentatively experiment with different types of care-giving and predict their effects. After devising our model, we compared Dutch standard care for type 2 diabetes patients with a typical blended care program. Dutch standard care is delivered by well-trained assistants of general practitioners, who see their patients in a face-to-face consultation once every three months. The blended care program has a strong digital component and consists of 100 days of daily interaction.

This paper consists of four sections: firstly, a discussion about the theoretical aspects of motivation and temporal-causal networks followed up with a general overview of our model, secondly, a few simulations that show the effectiveness of the model, thirdly a verification of the model based on findings in the literature, and lastly a discussion about how the model could be extended and a few of the possible objections.

2 Method

In this section we provide relevant theoretical notions on motivation. We present research findings on barriers and promoting factors to change in type 2 diabetes patients. Finally, we present theory on networks and explain the model we devised based on research findings.

Motivational theory Over the years many theories have been put forward to explain why we behave as we do, such as Maslow’s theory of the hierarchy of

needs[7], McClelland's Human Motivation Theory (needs for achievement, affiliation, or power) [9] and Skinner's operant conditioning theory (where response or behavior is strengthened by rewards)[15]. Sometimes we are moved by external forces such as rewards, grades or other peoples opinions, and sometimes we are moved by internal forces such as interests, curiosity and our own values. The interplay between these extrinsic forces and intrinsic motives and how they affect our ability to make choices and manage our lives is a central part of theories about self-determination[2]. Self-determination theory is the common construct nowadays to address and understand lifestyle change.

Ryan and Deci have suggested that types of motivation can be arranged according to the extent to which the motivation emanates from one's self [13]. Self-determination theory posits that more autonomous forms of motivation are associated with more sustainable behavior change[8]. Therefore, we arrive at a continuum of motivations from extrinsic to intrinsic. Concepts such as introjected motivation, identified motivation and integrated motivation are often used to explain different parts of the middle ground that sit between both extremes.

We have been guided by the need to include as many motivational concepts as necessary, in order to make the model relevant. At the same time, we felt the need to keep the model as simple as possible. Balancing these needs, we have included extrinsic, intrinsic motivation and identified motivation in a first version of the motivational part of our model.

According to research, the level and type of motivation of type 2 diabetes patients appear to be central factors in shaping their chances to successfully change their lifestyle. Extrinsic motivation leads them to work on lifestyle change in order to either avoid punishment or to receive praise, for instance in the interaction with caregivers who advised the lifestyle change. Qualitative research shows that patients for whom this type of motivation is predominant, only make slow progress in implementing lifestyle advice into their daily routine. Identified motivation makes patients feel responsible to follow the program, since it aligns with their own expectations to do so. After a period of changed behavior, some people develop intrinsic motivation to sustain their new lifestyle, actually enjoying their new routines and valuing them in themselves. Intrinsic motivation enables patients to more easily integrate new behavior with their daily routines and it sustains long-term lifestyle change and habit formation [14, 6, 16, 18].

Barriers and resistance Patients with type 2 diabetes suffer from real barriers in adopting and implementing lifestyle change. Many of them have a lower social-economic status, implying that they received lower education and/or have lowly paid jobs. This heightens their chance of being functionally illiterate and of possessing only low health literacy. Their social and physical surroundings may not support lifestyle change. They may experience financial difficulties. In our model, we have little assumptions about the social and physical environment or educational level of the patient, though considering the target group we can generally perceive them to be lowly educated, possess low health literacy and to

be not particularly supported in changing their lifestyle by the people they live with⁶.

Lifestyle related type 2 diabetes arises from diet and lack of exercise. Qualitative research shows that many patients positively value their diet and their lack of exercise, perceiving them as comfortable and a luxury. If they are advised to give up these comforts and to exchange them for a more moderate diet and regular exercise, they may experience resistance. When actually going through the advised lifestyle changes, patients may feel grief and experience a sense of loss[16]. Many patients appear to be unaware of the gravity of the health complications associated with type 2 diabetes. When they lack a full comprehension of their disease, this forms a strong barrier towards taking action for lifestyle change[4].

Barriers to exercise also arise from the disease itself, the associated physical states and co-morbidities. Type 2 diabetes patients tend to be overweight or obese. These conditions in themselves can pose barriers to exercise. People with these conditions are prone to suffer from muscle or joint pain, and exercise might easily exacerbate these complaints. General tiredness is a common problem in patients with type 2 diabetes. Approximately twenty percent of type 2 diabetes patients also suffers from depression[11].

In our model, we presented the barriers as ‘negative emotional states’ and ‘negative physical states’. Negative emotional states comprise emotions as guilt, grief, a sense of failure and feeling pressured. Extrinsic motivation tends to enhance these emotions, as does receiving a caregiver’s advice to exercise. Negative physical states comprise tiredness, muscle and joint pain, obesity and depression. These states are taken to be enhanced by starting exercise, while they also function as a barrier to exercise. Yet, when patients persist in exercising, these negative physical states will go down [5, 16]. When patients do not perceive their disease as threatening their future health, this is taken as a strong barrier.

3 The Adaptive Network Model

In order to illustrate, how advice given to the patient first causes action, and eventually forms a habit (to exercise), a temporal-causal network model was constructed. Such a type of network provides a type of dynamic modelling that was apt to simulate the kind of repeated interactions a patient may have over time with their caregiver.

To better illustrate and analyze the network, we should view the model in the following way. A patient gets advice to exercise from their caregiver. To actually undertake such an action is dependent on a variety of factors as we have seen in the previous sections. Both stimulants and barriers to exercise exist in the case of patients with type 2 diabetes. Each connection between nodes can be seen as a directional influence. These connections can suppress or amplify the state,

⁶ Rodriguez-Saldana, Joel. The Diabetes Textbook Clinical Principles, Patient Management and Public Health Issues . 1st ed. 2019. Cham: Springer International Publishing, 2019. Web.

thus providing barriers or stimulants. Whereas the caregivers’ advice to start exercising is given on one point in time, the patients’ actual predictions of the effects of action, the preparations for action and adaptations or learning effects take place over a period of time, comprising complicated interactions with one another. A temporal-causal network provides a type of dynamic modelling that is apt to simulate the repeated interactions patients may have over time with their caregivers.

The Network-Oriented Modeling approach used here is based on ideas presented in Treur’s book [17]. This gives us both a conceptual framework and a numerical representation. The former is the one we can see in figure 1. It involves the representation between certain factors found in the literature. The states have activation levels that may vary over time. Yet not all connections are created equally, thus also introducing a notion of strength. Furthermore whenever multiple relations affect a state, we require some way to aggregate these impacts. Lastly, a notion of speed is used to represent the malleability of a node. This gives us three important factors.

Connectivity: The strength of a connection between state X and Y is represented by some *connection weight* $\omega_{X,Y}$

Aggregation: Each state Y is also passed along some *combination function* $\mathbf{c}_Y$ which combine the impacts from other states via (multiple) incoming connections on Y .

Timing: Each state Y also takes along a *speed factor* η_Y which represents the speed by which state Y changes upon impact.

Using the notion of *self-modeling network* (also called *reified network*) introduced in (Treur, 2020), every network characteristic can be made adaptive by adding a (self-model) state to the network that represents the value of this characteristic. This will be applied here to obtain a second-order adaptive network in which for some states X and Y : (1) first-order self-model states $\mathbf{W}_{X,Y}$ are included in the network that represent the value of connection weight $\omega_{X,Y}$, and (2) second-order self-model states $\mathbf{H}_{\mathbf{W}_{X,Y}}$ are included in the network that represent the value of the speed factor of $\mathbf{W}_{X,Y}$ (learning rate).

In the model a number of links between states are assumed to be adaptive, meaning that they are learned over time. They are depicted as red arrows in Fig. 1. However to better represent the variety and adaptivity that takes place in habit formation we required a first- and second-order self-model (depicted in different planes) to describe the adaptive relations. In the full model, as shown by Fig. 2, some connection strengths are learned over time through Hebbian learning. The second-order self-model states represent the speed of said adaptation, following the second-order adaptation principle ‘adaptation accelerates with increasing exposure’ formulated in [12]. More details of the design of the model can be found in Linked Data at URL <https://www.researchgate.net/publication/353654589>.

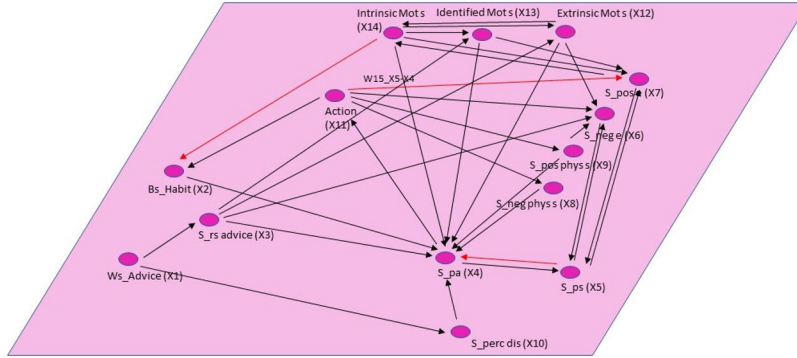


Fig. 1: Base level of model

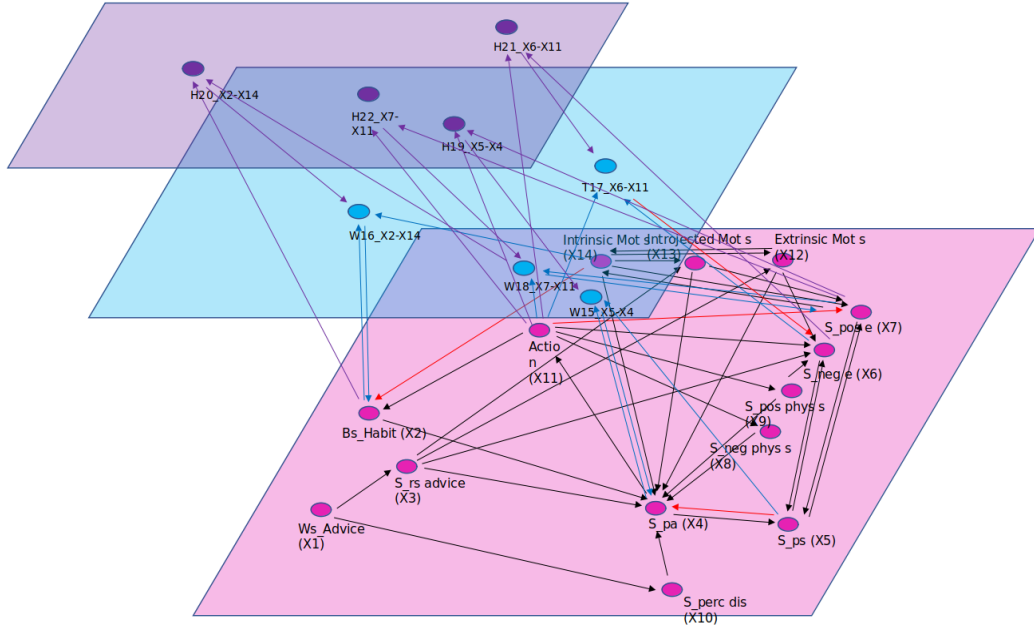


Fig. 2: Complete adaptive network model for formation of habits in patients with Diabetes

4 Simulation Results

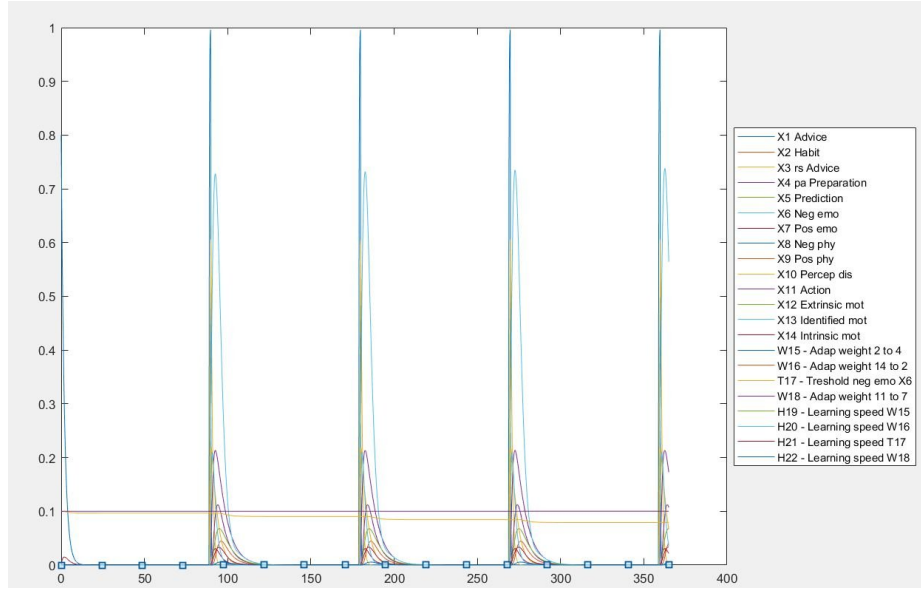
While individuals may vary, we found that a significant impediment in habit formation arises when patients have infrequent interaction with their caregivers. By contrast, when running our model with the input frequency of advice every

other day for a period of 100 days, we found that the patient does develop a habit to exercise (Fig. 6b). In order to comprehend this difference in outcomes, we need to focus on the complex interaction between advice given, physical body states, emotions and motivational drives.

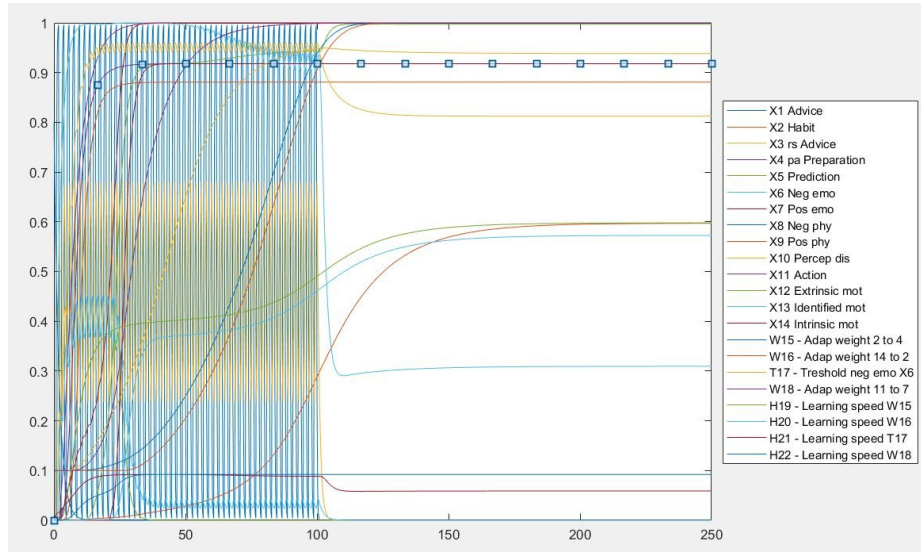
Comparing the graphs arising from our model, we see that when patients receive advice every other three months, they do start to exercise right after the encounter with the caregiver. The action arises despite the barriers of negative emotions, negative physical states and sub-optimal motivational state we placed in the model. Yet, after exercise patients experience pain, tiredness and negative emotions, while they lack repeated stimulus for action. Their attempts to exercise therefore quickly fade away. Patients show no signs of habit formation⁷.

We found that frequent advice prevents the attempts to exercise from fading away so quickly. Patients start exercising after receiving advice (Fig 3b). This causes them to experience negative physical states and emotions, such as muscle pain and a sense of loss. Yet, because of the repetition of the advice, patients repeat their attempts to exercise. Pain and negative emotions gradually drop off with more exercise (Fig 4a). After exercising for some time, positive effects start to emerge, such as more stamina, better physical shape, actual enjoyment of the exercise and a sense of well-being (Fig 4b). These effects lead to fewer negative emotions (Fig 5a). In time, the threshold for negative emotions goes up, making the new lower state for negative emotions more stable (Fig 5b). As the intrinsic motivation to exercise picks up, this increases the adaptive weight to the habit (Fig 6a) that will later cause the habit to form (Fig 6b).

⁷ This of course depends on the state of the individual, their basic intrinsic motivation, their perception of the disease and many of the other factors we modelled.

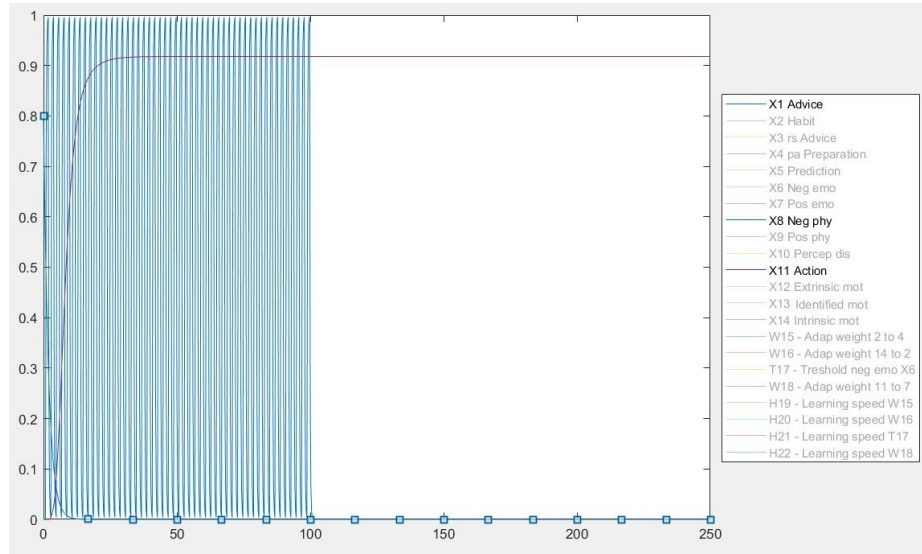


(a) When the advice (X1) is only given every 90 days, a habit (X2) for exercise is not formed.

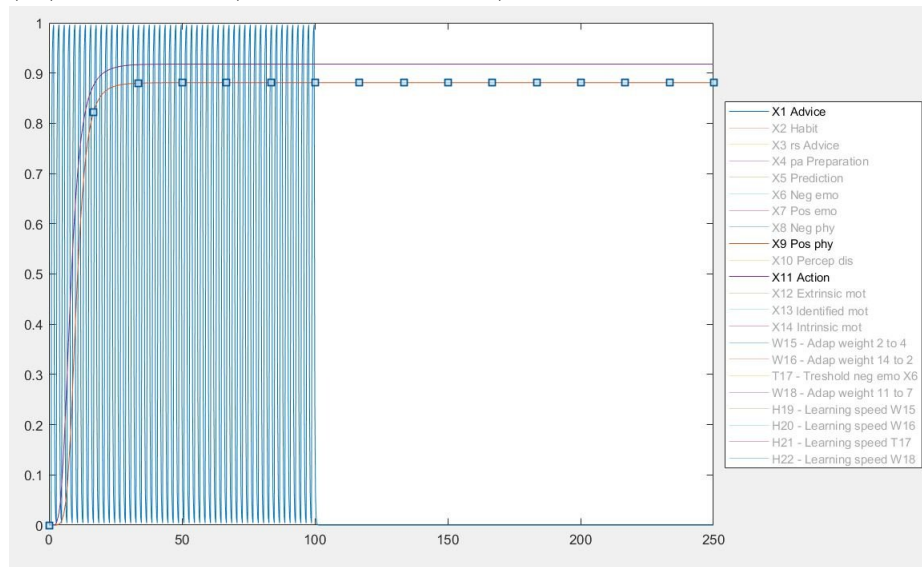


(b) Given frequent advice, until time step 100, the patient begins to exercise (X11 Action)

Fig. 3: Difference in advice

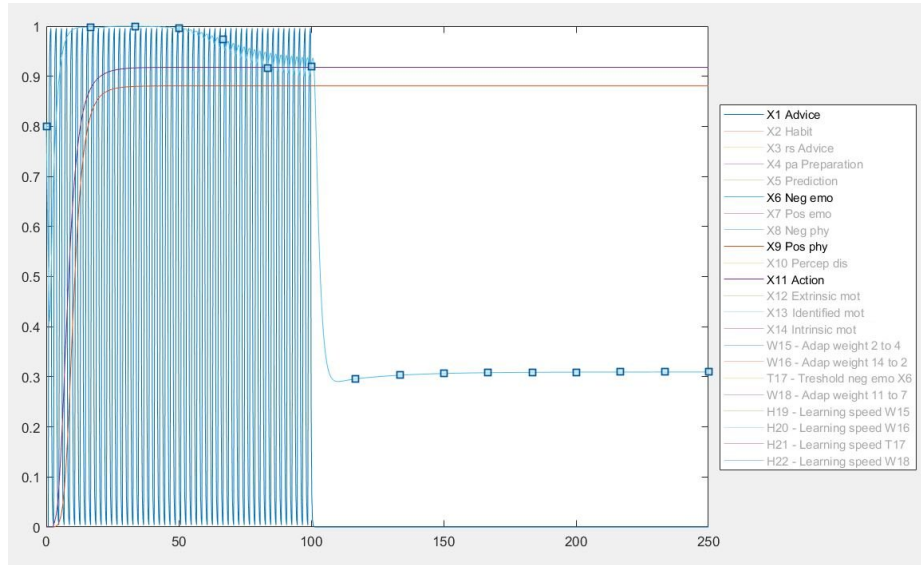


(a) As the patient begins to exercise (X11 Action), the negative physical body state (X8) begins to drop (from an initial 0.8 value)

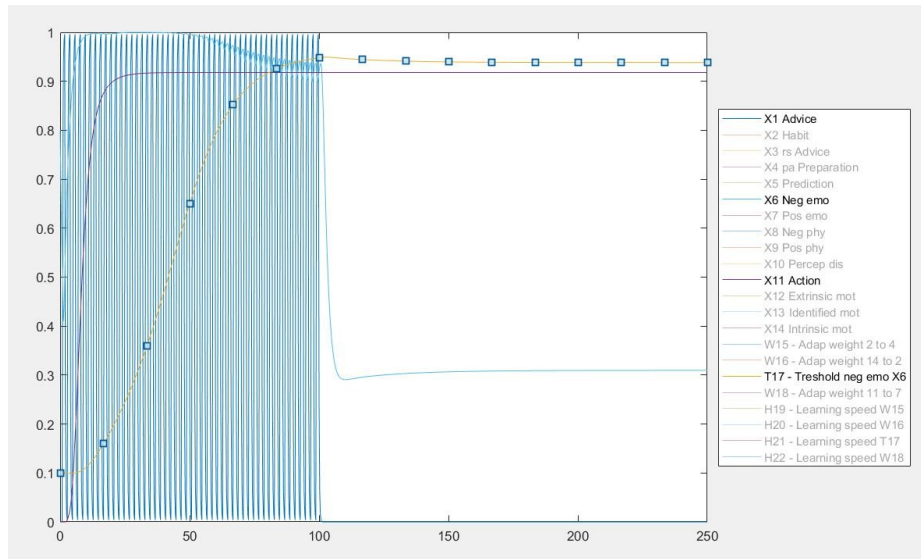


(b) The positive physical state (X9) begins to improve with more exercise

Fig. 4: Negative and positive physical states

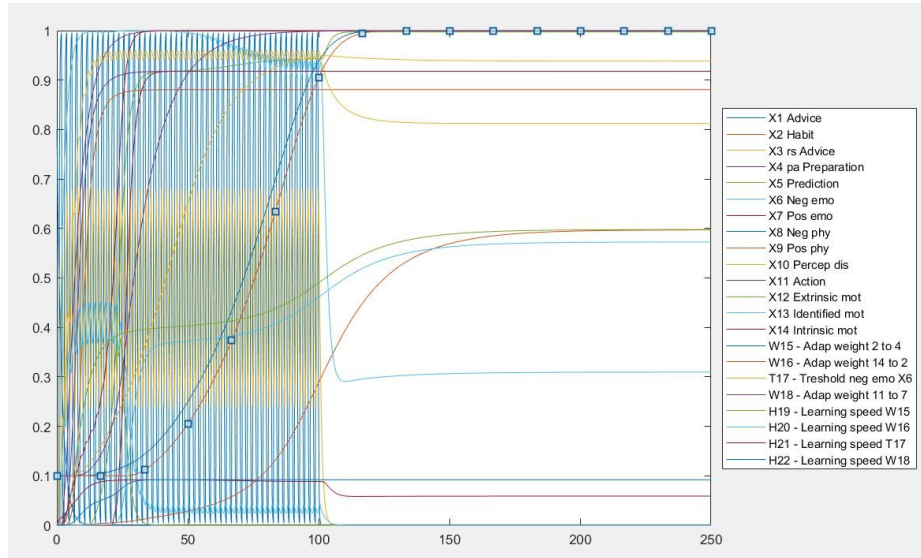


(a) As the positive physical body state (X9) improves and stays high, negative emotions (X6) goes down

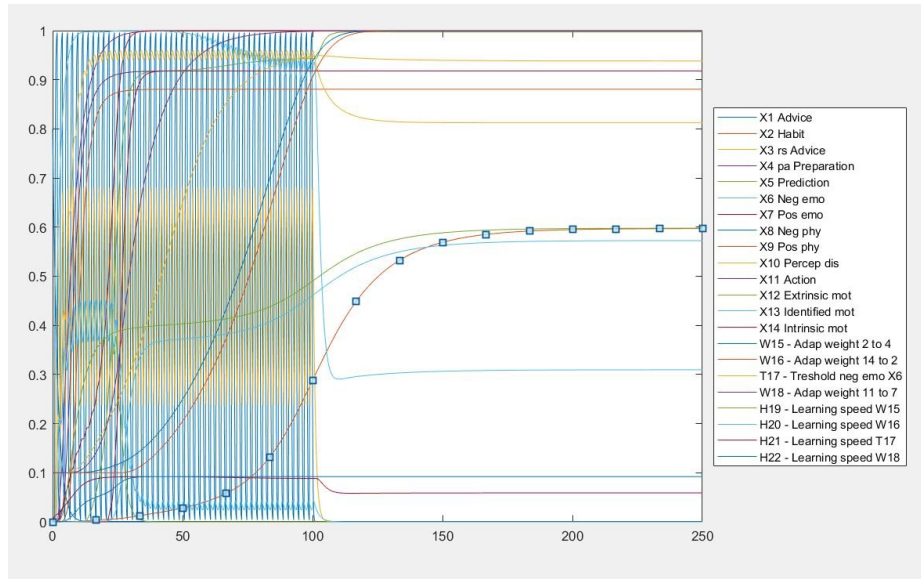


(b) As threshold (T17 neg emo) for changing the negative emotions goes up, the emotional state become more stable, and it becomes more difficult to push it (X6 negative emotions) upwards again

Fig. 5: Negative emotion and its threshold



(a) As the intrinsic motivation (X14) picks up, this adjusts the adaptive weight (W16) to the habit, that will later cause the habit to form.



(b) As the strength of the W16 weight increases this then leads to the formation of the habit (X2)

Fig. 6: Habit formation

Discussion

In reality, more interaction will not easily and not always lead to habit formation. To put it bluntly: there are more factors at work here. We have not modeled all the personal and interpersonal factors which might be influential in shaping the caregiver-patient relation, for instance. The way one receives advice and from whom matters. The effect of advice might depend on personality of both patient and caregiver. The content and tone of the advice are important. Is the advice concrete or vague, tailored or general, fitting for the patient or wildly astray? Is the tone warm or cold, relaxed or hasty, understanding or accusatory, emphatic with the real problems or overly positive?

Furthermore, we only used three types of motivation, whereas other types may influence the effectiveness of advice and consequently habit formation as well. Literature on motivation theory points to a relation between habit formation and identified motivation[19]. However, in the case of type 2 diabetes the self-identification with say being an exercising person, does take ample amount of time. Moreover, literature[16] on type 2 diabetes specifically points to intrinsic motivation as a key factor to persevering in exercising. Identified motivation is presented as sustaining the difficult first phase of habit formation for exercise. We would advocate further research into the relation between identified motivation and habit formation for exercise.

Possibly even more importantly, the model has neglected the physical and social environment of patients. Modern societies created a highly obesogenic and therefore diabetogenic environment. Our built environment is often solely car-oriented, our main hobbies comprise various forms of screen-watching, and many cities resemble food swamps, flooded with unhealthy options of highly processed and lowly nutritious food, which we have learnt to perceive as ‘yummy’ from our toddler days onward. It is tough to change your lifestyle when you live in an environment filled with cues to sit and to eat[10]. It is even tougher to change your lifestyle when you share this environment and the lifestyle it promotes with many others. Their aggregated social influence might be stronger than that of the most convincing caregiver, blended or otherwise. Furthermore, we should take into account that, as stated above, many patients with type 2 diabetes have a lower socioeconomic position, which makes them prone to struggle with other problems than their diabetes, such as poverty, unsafe neighborhoods, unemployment and chronic stress. Those patients who encounter such problems may well find it hard to direct their mental and financial resources towards lifestyle change[1].

Thus, chronic lifestyle-related disease such as type 2 diabetes presents itself as a complex and wicked problem in real life, not as a complicated yet neat model. Why did we endeavour to create such a model in the first place, and how do we think it can prove useful? Our aim in building and running the model was to provide caregivers with insights on the nature of promoting factors and barriers for lifestyle change for type 2 diabetes patients. Our model, we feel, might prove useful to enhance caregivers’ understanding of their patients’ difficult position and the barriers they encounter. Our results stress the limitations of standard

care for inducing lifestyle change, and they could raise the awareness of blended care's potential.

We would advise to expand this first model. In next versions, we would advocate to consider the nature and content of the relation between caregiver and patient in more detail, possibly focusing on finding the right balance between face-to-face and digital contact in blended care. Other types of motivation could be taken into account. Barriers in the physical and social environment could be modeled, as well as pervasive problems such as poverty. We believe that step by step, next versions of the model will show opportunities to overcome barriers and to achieve better results for more people.

Conclusion

We constructed a second order temporal-causal network model on type 2 diabetes patients receiving caregivers' advice to exercise, taking into account motivational forces, emotions, physical states and habit formation. We based ourselves on qualitative research findings when we consciously constructed a model filled with many barriers. We found that the advice frequency of Dutch standard care of once every other three months did lead to attempts to exercise, which quickly faded away. According to our model, this advice frequency did not lead to habit formation or to lasting lifestyle change. When we increased the advice frequency to every other day, as can be achieved through blended care with a strong digital component, we found that the attempts to exercise were no longer extinguished by the barriers of physical pain and negative emotions. These barriers still rose after starting exercise. Yet, through the repetition of the advice and the ensuing repetition of attempts, negative effects of exercise went down and positive effects, such as stamina and well-being, started to emerge. Eventually, these positive changes sustained habit formation. We would advise to expand our model later on, adding relational factors, motivational states, barriers in the physical and social environment and socioeconomic problems.

As is well known, intrinsic motivation is crucial for lifestyle adaptation. In order to successfully treat chronic lifestyle-related disease like type 2 diabetes, caregivers require a good understanding of boosting this motivational state. The motivational model represented in this paper provides suggestions on how to improve adoption rate. Frequent and consistent interactions, while also garnering more negative emotions, showed to have a positive effect on the patient's lifestyle in the long run. With the established severity and pervasiveness of type 2 diabetes we should ensure that people are getting the best care that they can get and that most likely means better guidance for those in need.

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