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Interventions on Contextualized Decision Making: an Agent-Based Simulation Study

by

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"All models are wrong, but some are useful."

George Box

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Abstract

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We present an agent-based model that uses the concept of social practices to model contextualized decision making. We use simulations to show that such a model can give insight in (1) the limited success of interventions that target intentions rather than context and (2) which interventions on context might work. We end this thesis by discussing the relevance of these insights for policy makers and pointing out crucial gaps in knowledge that should be picked up in further work.

Acknowledgements

After one of my first meetings with Frank I sent him an e-mail telling him I was disillusioned by our last meeting. I had expected a thorough examination of my work and probably a pat on the back, but instead received the efficient style I now so appreciate. Interestingly enough, Frank apologized. He did not attack or defend, but explained, understood and appreciated the feedback. To be able to truly listen to a young know-it-all is a remarkable skill. Combined with his nose for what is really important it made sure I left every next meeting with a smile. Thank you, Frank. I learned a lot.

It is the same honest and human interest I found in Melbourne with Yoshi. Yoshi always gave me the feeling that I was discussing with an equal, just one that happened to know all the psychology papers published, ever. Thank you, Yoshi. For making me feel at home at the Melbourne School of Psychology.

This thesis would not have been there if it wasn't for these supervisors nor the loving support of the wonderful people around me. Thank you Mom, Charlotte, Melissa, Harry, Julia, Renate and everyone from USCKI Incognito.

Contents

Chapter 1

Introduction

Despite both governmental and scientific interventions, greenhouse gas (GHG)-emissions continue to rise, almost surely leading to more frequent extreme weather events, a rise in sea levels, an increase in widespread infectious diseases, and decreases in crop yields and water quality (Gifford, 2014). Climate change is primarily driven by GHG-emitting human behavior and could therefore be largely mitigated by interventions in human behavior. For example, a global transition to a healthy low meat-diet would have a substantial impact on lowering GHG-emissions (Stehfest et al., 2009, Jones and Kammen, 2011). However, human behavior is the least understood aspect of the climate change system and many interventions have not had the effect hoped for (Intergov. Panel Climate Change., 2014). One possible major defect in such interventions might be the focus on changing intentions rather than context (Abrahamse et al., 2005). Whether one's prior aims, i.e. intentions, actually lead to action is influenced by one's setting, i.e. context. For example, information on the environmental consequences of meat-eating might not induce behavior change (e.g. Seigerman, 2014). Firstly, because one's context might not give the opportunity to do a new action (Steg and Vlek, 2009). For example, one might have an intention to eat a vegetarian dish, but there are no nice vegetarian dishes on the menu. Secondly, one's context can trigger a *habit* opposing one's intention. Habits are learned dispositions to repeat past behavior that emerge when context co-varies with behavior (Wood and Neal, 2007). For example, one might have the intention to eat a vegetarian dish, but upon entering the pub with mates one automatically orders that good old hamburger.

This raises the main research question: how can we improve interventions given the described influence of context on decision making? This is relevant because an answer could help mitigate climate change and thus global pain and suffering. In this study we focus on the choice to eat meat or vegetarian dishes. Some results will only apply to this

domain, but the study aims to be general enough for some results to be extrapolated to other domains.

To answer the research question we first need a model that provides insight in how these influences relate to decision making. To our knowledge the current state of the field provides no such model, but there are several calls for one in different fields (Gifford, 2014, Steg and Vlek, 2009, Dignum et al., 2014a). As a minimum this model should explain the limited success of interventions that target intentions rather than context. We propose that such a model can be made using the concepts of *agents* and *social practices*. Agents represent acting individuals, e.g. robots, bacteria, or in this case, humans. A social practice is a way of (inter)acting that is shared between these agents. Social practices aim to integrate actors with their context and could thus be a good starting point to model contextualized decision making. Our first sub research question is thus: can we explain the limited success of interventions that target intentions rather than context, with a model that uses the concepts of agents and social practices? This question is relevant because it can firstly help answer our main research question and thus help mitigate climate change. In particular making a model can show gaps in knowledge and thus highlight new research questions. Secondly, this thesis answers to the wish in several fields, e.g. artificial intelligence (Dignum et al., 2014a) and environmental psychology (Gifford, 2014)) for a model that relates context to decision making and uses social practices.

We aim to answer this question by firstly describing some of the background literature (chapter 2) on social practices and related agent models. We will also describe some of the social psychology literature on two modes of action a context-aware agent uses: habitual and intentional actions. This is important because for our model to give insight it needs to correspond to some extend to known intuitions and literature. Note that we do not claim our model is supported by all the literature on social psychology, just that the model has explanatory power as it is supported by some of the state-of-the-art. In chapter 3 we will describe the model. We will highlight how an agent uses social practices, habits, intentions and evaluates its actions to make context-dependent decisions. We will use agent-based simulations to support the construction of our model. Agent-based simulations are a new analytical method in the (social) sciences where a computer is used to test the (macro) implications of (micro) agent interactions (Gilbert, 2008). An agent-based simulations study helps constructing a model by (1) forcing the model to be exact as it must be implemented and (2) testing the implications of modeling choices on the macrolevel. In chapter 3 and 4 we will use these simulations to validate the model against proposed model requirements. This concludes our first aim: to make a model that (1) explains the limited success of interventions focusing on intentions instead of context (2) represents contextualized decision making, (3) uses agents

and social practices as a parsimonious framework and (4) is grounded in intuition and literature.

Our second sub research question is: what happens if we aim interventions at the context? We thus aim to show that our model is not only helpful in explaining why interventions on intentions *might not* work, but also in which context interventions *might* work. In chapter 5 we show several experiments showing that some interventions might work where others do not. In particular we show that an intervention that uses the intention to motivate people to go to a new context, where they do not have the opportunity to fall back in to their old habit, and stay for a short period of time with like minded agents, can be surprisingly effective. Lastly, we aim to describe some of the insights we obtained concerning our main research question. We discuss the relevance and the generalization (outside the domain of meat-eating) of these insights and make suggestions for further work in chapter 6.

Chapter 2

Background

In this chapter we will describe some of the background literature necessary to construct a model that can explain the limited success of interventions focusing on intentions over context. Central to our model is the concept of social practices. Social practice theory seeks to determine the link between practice and context within social situations (Smolka, 2001). We will describe social practices in the first section. Dignum and Dignum (2015) use the concept of social practice to make an agent model. In section 2.2 we will describe current agent models and how this led to the social agent framework they propose. According to Dignum and Dignum agents have two important modes of action in contextualized decision making: intentional and habitual. We end this chapter by describing some of the literature in social psychology on these two modes of action (section 2.3 and 2.4). We do this so that in the next chapter (chapter 3) we can argue that the model is supported by some of the literature.

2.1 Social Practice Theory

A practice is a nexus of doings and sayings (Schatzki, 1996, p. 89). A practice refers to an aggregate of actions, abstracting over time, space and actors. For example, where a psychologist might look at what influenced a participant to choose a vegetarian meal over a meat meal a practice theorist looks at the practice of (vegetarian) eating: how it has evolved, how it has recruited and lost carriers and how it is influenced by its environment. In social practice theory a practice is seen as a distinct epistemological entity consisting of three elements: materials (covering physical aspects), competences (skills and knowledge needed to carry out a practice) and meanings (referring to the mental and social associations of carrying out practices) (Shove et al., 2012). The social practice of eating for example can be divided in its materials - tableware, cutlery and

food - its required competences - etiquette and usage of cutlery - and its meaning - pleasure, health or the achievement of a necessary chore (Halkier, 2009). On enactment one combines these distinct elements into the single practice of eating.

The focus of the social practice theorist on the practice instead of the actor brings a few interesting points in focus. Firstly, and most importantly in this thesis, social practices aim to integrate the individual in his or her surrounding environment, assessing how context (e.g. the relevant materials) relate to common experience, culture and capabilities of the individual.

Secondly, elements influence the enactment of the practice, but the enactment feeds back changing (or 'monitoring') the elements. For example, nowadays the practice of car driving can be decomposed in the material car, the competence to drive it, and its meaning as a means of transport. In the past though, car driving was constituted by a petroleum engine, the competence to maintain this and the meaning of adventure or burgundy. The continuous enactment with the wish to use the car as a means of transport influenced an advance in car technology and reduced the need for maintaining. In this process elements are created, transformed or left behind like driving goggles or the competence of starting a car.

Thirdly, practices are interconnected by sharing elements. They form bundles, complexes and hierarchies. For example, the practice of car-driving shares its meaning of masculinity with repairing (see figure 2.3). Interestingly, practices might become entangled because they were often enacted in the same context. Practices thus do not only feed back on their own elements, but also on each other. (In Shove et al. (2012)'s terminology: cross-referencing.) Driving and repairing collaborate but other practices compete, like eating vegetarian or eating meat.

In sum, social practices provide a perspective that focus on the practices' context, evolvement and connection with other practices. In this thesis we will focus on the first aspect, but the latter two are important to keep in mind to understand the implication of an agent framework using social practices. For example, the practice of dining - the focus of this thesis - is influenced by the practice of doing groceries or the practice of eating with friends. In further work it is important to explore how these practices formally relate to each other.

2.2 A Social Agent Framework

In this thesis we use the concept of agents, i.e. acting entities, to model contextualized decision making. In recent years various agent framework have emerged (for an

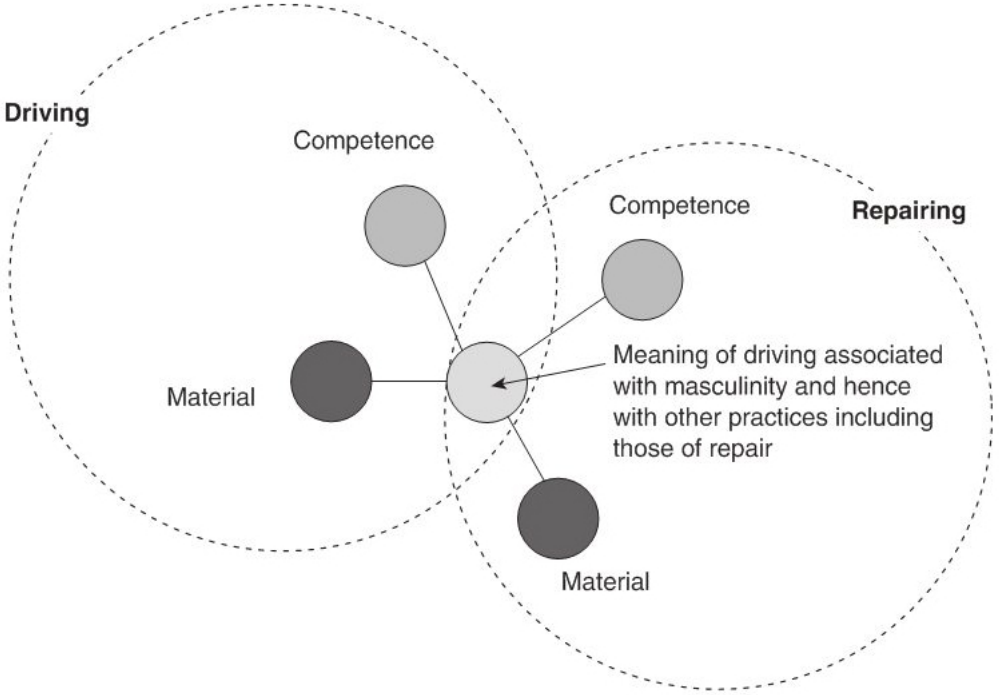


FIGURE 2.1: Practices are interconnected and influence each other. (Shove et al., 2012, p. 37)

overview see (Gilbert and Balke, 2014)). In agent-based simulations the state-of-the-art is to take relatively simple, e.g. vector-based, agents and study if in large populations complex phenomena might emerge. One downside of this approach is that such a limited agent framework does not allow for complex cognitive mechanisms. To gain insight in how *humans* make decisions a more cognitive plausible agent is needed. The BDI-agent is the most popular of such cognitive plausible approaches. It is based on the work of Bratman and the agent uses its beliefs to filter its desires in prioritized intentions. Dignum and Dignum (2015) argue that this approach firstly does not mimic the humans social nature and secondly leads to inefficient planning in dynamic context. As a first step towards a solution they propose a social agent framework based on the concept of *social practices* (Dignum et al., 2014a, Dignum and Dignum, 2015, Dignum et al., 2014b).

In contrast with social practice theory Dignum et al. look at a social practice from the individual perspective, bridging the micro and macrolevel. The entity of the social practice thus contains information that guides the deliberation process of the agent. A first attempt by Dignum et al. to capture all the information needed is depicted in figure 2.2. To transpose social practices to the domain of individual deliberation Dignum needs to connect it with context and other concepts that are used in deliberation like motives, values and identity. The relation between these concepts as posed by Dignum et al. is depicted in figure 2.3.

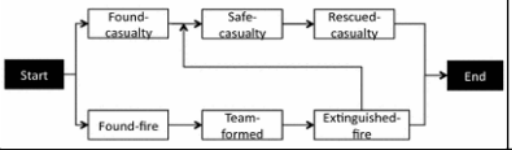
Abstract Social Practice	**Combat Fire**	**Going to work**
Physical Context		
Resources	inflammable objects, water, barriers...	Vehicles, money, ...
Places	locations of fire, actors and resources,...	Stations, roads,...
Actors	Victims, bystanders, colleagues,...	Drivers, co-passengers, ...
Social Context		
Social interpretation	Dangerous places, safe places, rescue equipment	Bus driver, train driver...
Roles	police, medics, ...	
Norms	own safety; public safety	
Activities	Identify type of fire; Extinguish fire; Removal victims; Clear area; ensure own/team safety; ...	Choose transport type; buy ticket; drive car; ...
Plan patterns		
Meaning	braveness, leadership, ...	Environmental conscientiousness, comfort, social status, ...
Competences	• Fire combat knowledge and skills • Coordination skills	• driving skills, • cycling skills, • knowledge of public transport routes

FIGURE 2.2: A social practice as by Dignum et al. specified for the scenario of fire fighting (Dignum and Dignum, 2015, unpublished)

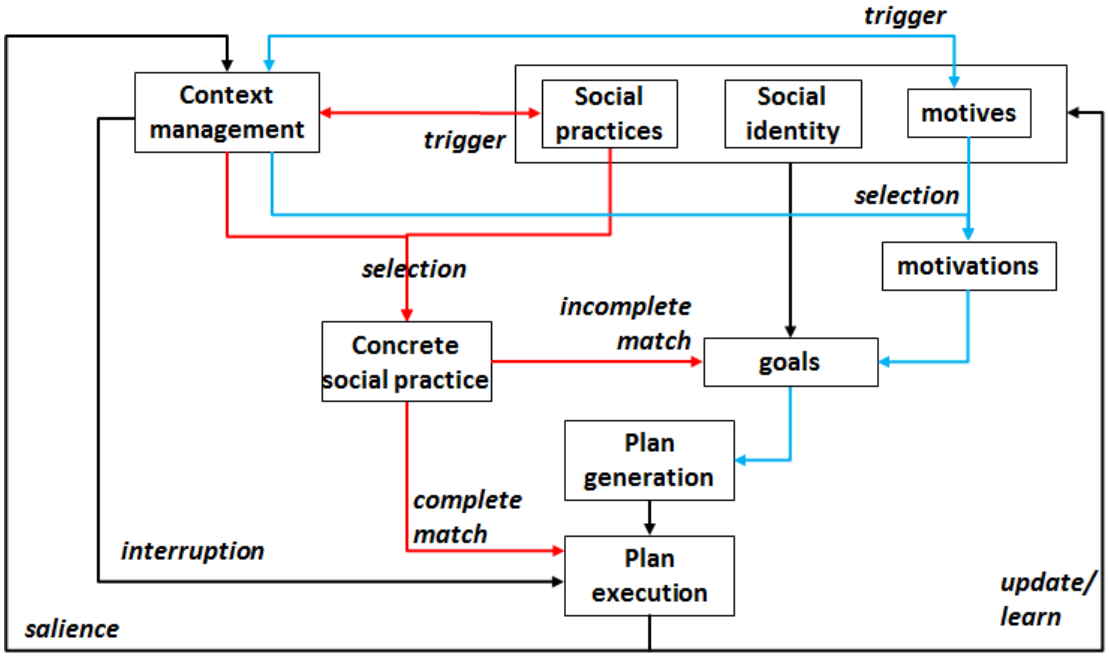


FIGURE 2.3: The deliberation of an agent using social practices. The blue arrows show a slow-thinking intentional path and the red arrows a fast-thinking habitual path (Dignum and Dignum, 2015, unpublished) .

Dignum et al.'s framework highlights a few important aspects of social practices. Firstly, social practice are similar for all agents. Some element might completely coincide, e.g. the meaning of eating meat as masculine, and others might differ per individual, e.g. the association of the competence of using chopsticks or cutlery with eating. In other words, agents seem to adhere to a similar prototype of a practice, sharing some of the elements. Secondly, this similarity in practices provides an easy way to learn from each other. For example, after being exposed to several masculine meat eating barbecues one might adapt its meaning of eating meat to the meaning others associate with eating. Note that given the aim of this thesis we do not focus on working out these two aspects, but they are used in a simplified way in the model (chapter 3) and discussed for further work (chapter 6).

In this thesis we will focus on the relation of context and deliberation. Dignum et al. define context as the immediate physical and social setting in which something happens or develops (see figure 2.2). The physical context describes elements like resources, places and actors that can be sensed. The social context describes a high-level interpretation of the social setting including roles and norms. Note that there are many definitions of context (see Zimmermann et al., 2007) including a simpler one often used in psychology: the relevant people, location and behavior (Wood and Neal, 2007, Black et al., 1985). Dignum et al. state that context plays an important part in deliberation. The social practice guides the agent in the process of both sensing and acting upon the context. For Dignum et al. these two are intertwined: the sensing of the context is an active process where one searches for information that one needs at that point in the deliberation.

Dignum et al. seperate between two modes of action in which context plays a role: fast (habitual) actions (the red path in figure 2.3) and slow (intentional) action (the blue path in figure 2.3). The first mode of action happens when the context completely matches certain information in the social practice; the agent does not need complex deliberation and reacts automatically to the context . This is what Wood and Neal (2007) call a habit and we will further explore this topic in the next section. The second mode of action happens when the social practice guides the agent in searching for more information in the context and deliberate about the goals (motives, needs, etc.) of the agent to choose an action. In social psychology this is often referred to as an intentional action (Danner et al., 2008, O'Brien and Kashima, 2015) and, as both Dignum et al. and Steg and Vlek (2009) recognize, this is subject to context as well. Context can limit the control one has over the intentional action or be a necessary precondition to enact the intention. For example, without the necessary infrastructure and services it is impossible to enact the intention to use the public transport instead of a car (e.g. as in Bamberg and Schmidt, 1999, Fujii and Kitamura, 2003). In social psychology the

Reasoned Action Approach is the dominant way to understand intentional actions and we will further explore this approach in section 2.4.

To summarize, Dignum et al. provide a framework for contextualized decision making that uses social practices. In this framework an agent uses two modes of action that play an important role in modeling the relation of actors and context: habitual actions and intentional actions. As Dignum et al. state though the social practice framework needs to be more precise on this manner in order to serve as a basis for implementation. In this thesis we take up the task of using this high-level framework to construct an implementable model that can explain the limited success of interventions that focus on intention rather than context. To make sure our model has explanatory power we will relate it to some of social psychology literature on habitual and intentional actions. In the next section we will discuss some of the literature on habitual actions and in section 2.4 some of the literature on intentional actions.

2.3 Habitual Actions

In Dignum et al.'s framework in some cases the context matches completey with information in the social practice. In this case an agent reacts automatically to the context. This is what Wood and Neal (2007) call a habit. They explain habits as learned dispositions to repeat past responses. They emerge when behavior co-varies with context. The two main determent of habit strength are past frequency and context stability. For example, when one repeatedly eats pizza at home one forms and strengthens a habit. Once a habit is formed, perception of context, e.g. home, triggers the habit.

Lally et al. (2010) aimed to research how habits are acquired in the real world. They asked participants to carry out a healthy eating (drinking or exercise) action one's per day at the same time and place. The self-reported increase in habit strength is depicted in figure 2.4. They found that automaticity scores fitted an asymptotic curve. Furthermore, it took 66 days to reach 95% of the maximum of this curve (with a standard deviation of 52). The height of the maximum habit strength differs per person, where a higher maximum takes longer to reach.

Habits interface with intentions, but exactly how is research in progress. Wood and Neal (2007) take a quite dichotomous model of habits and intentions. Once a habit is formed a cue automatically triggers a response. In a few cases one can override this response with self-control, but in all other cases the response is activated *without a mediating goal.*

This differs from the viewpoint of habits of Danner et al. (2008) which can be traced back to Triandis (1980) who first hypothesized that habit strength moderates the intention behavior relation. Wood et al. acknowledge that this can happen, but would classify it as automatic goal pursuit, a case where in absence of the goal (i.e. intention) the behavior might not be executed. The cue might thus (partly) be linked with the goal and not the action. Habits as defined by Wood et al. are, once activated, completely independent of goals, or for that matter, rewards, perception of control, self-concept as actor and attitude accessibility.

Note that Wood et al. do acknowledge that habits interface with goals. Habits are often the residue of past goal pursuit. One might infer goals from their habits; these goals can provide a tool for evaluation of the action. And in pursuit of a goal one might try to place itself in a certain context to activate a habit.

2.4 Intentional Actions

In Dignum et al's framework sometimes a social practice guides the agent in searching for more information in the context and deliberate about its goals (values, motives, needs, etc.) to choose an action. In social psychology this is often referred to as an intentional action (Danner et al., 2008, O'Brien and Kashima, 2015). The dominant way of understanding intentional behavior in social psychology is with the Reasoned Action Approach (RAA) (Fishbein and Azjen, 2011). The reasoned action approach is the latest installment in a series of Fishbein and Azjen models where the key belief is that (measurable) intentions are the main determinant of behavior. Intentions are influenced by the person's attitude towards the behavior, perceived norm and perceived behavioral control (see figure 2.5).

Attitude is often the strongest determinant of intentions and, given that outcome beliefs are fairly stable, it can be understood as the evaluation of the outcome on the basis of *values* (Schwartz, 2012). The function of values is notoriously hard to capture (van der Weide, 2011, Dechesne et al., 2012). Firstly, as mentioned, they can be used as post-action standards or criteria to evaluate behavior. For example, if we value stimulation highly and attribute little importance to security values we are likely to have a positive evaluation of bungee jumping. Secondly, Schwartz (2012) also sees values as pre-action triggers that motivate an action. For example, security values might trigger the action to buy locks. Thirdly, Tosto and Dignum (2013) use them as criteria to navigate the deliberation of an agent. For example, an agent with higher openness values is more likely to make an explorative plan.

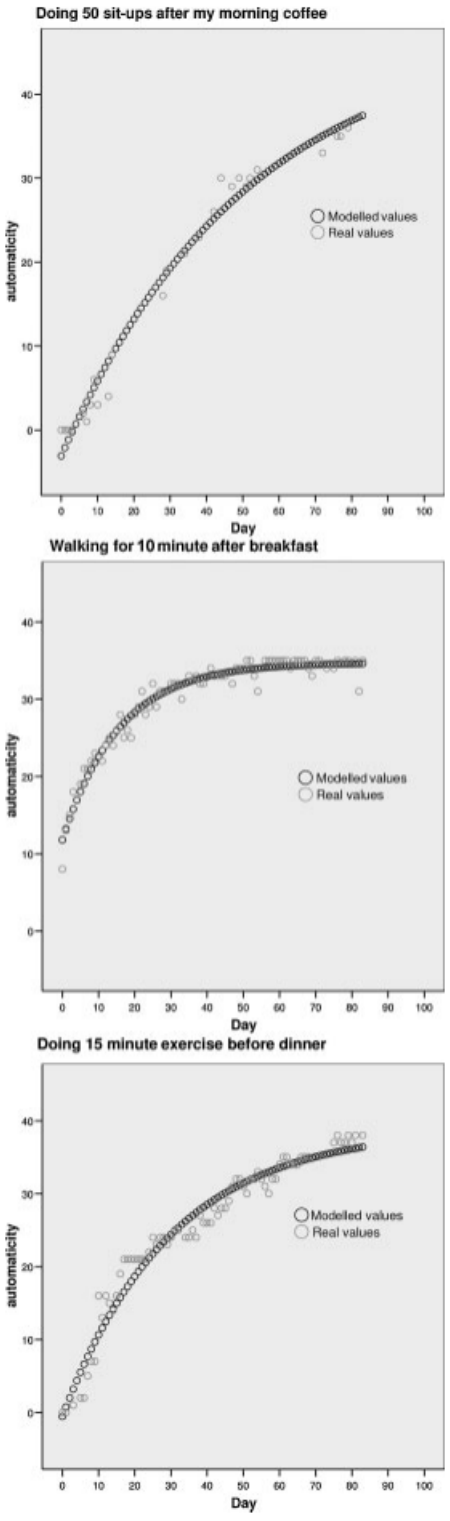


FIGURE 2.4: Three examples of increases in automaticity scores during the 84 days of the study showing the scores entered and the curve modelled using nonlinear regressions. (Lally et al., 2010, p. 1005)

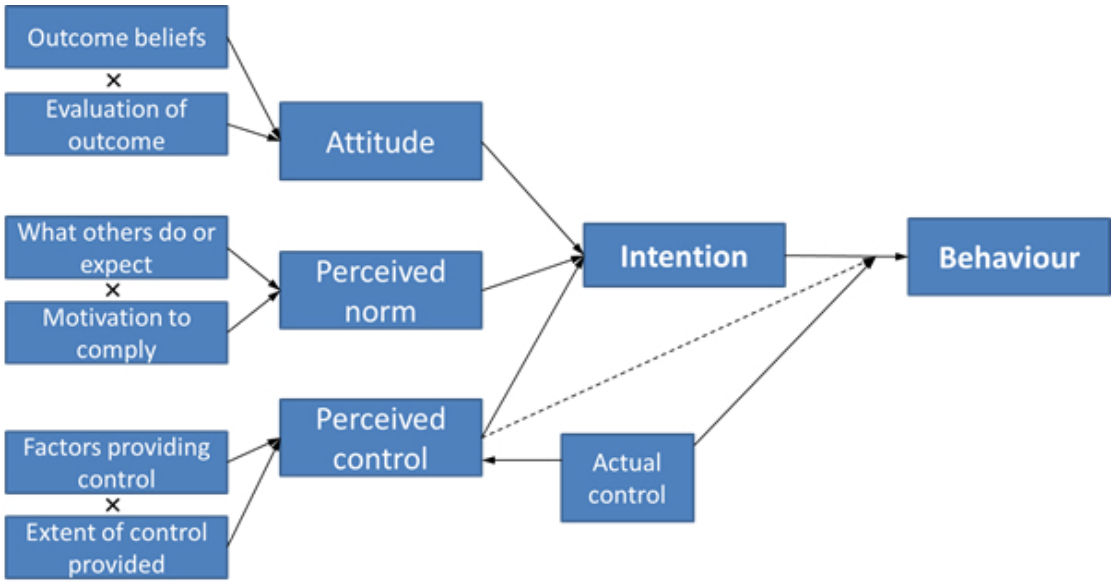


FIGURE 2.5: A simplified diagram of the Reasoned Action Approach (O'Brien and Kashima, 2015, p. 13).

By empirical research Schwartz (2012) has divided values in to four distinct categories: self-enhancement, self-transcendence, openness to change and conservation. Self-enhancement values seem to result in less environmental concern, while self-transcendence values like altruistic, pro-social and biospheric values favor environmental preservation (De Groot and Steg, 2010, Kaiser and Byrka, 2011, Milfont and Gouveia, 2006, Nilsson et al., 2004, Nordlund and Garvill, 2002). This effect is consistent across cultures (Schultz, 2005), but weak (Nordlund and Garvill, 2003). In conclusion, values seem to have a primary role in decision making, but more research needs to be done to correctly integrate it in an adequate model (of intentional actions).

As O'Brien and Kashima (2015) suggest there are some problems with using the RAA as a basis for modeling contextualized decision making. The RAA does include an 'actual control' component that should account for the variety of contextual factors that will limit a person's ability to act on its intention. However, the RAA does not provide a theoretical specification of when and why this will occur or how context relates to the other variables. For example, there is no theoretical specification of how and when context leads to habitual behavior. This under-specification is often argued to be one of the reasons that, especially in the domain of environmental behavior, measured intentions only partly correlate with actual behavior (Webb and Sheeran, 2006).

In his overview paper "Environmental Psychology Matters" Gifford (2014) therefore calls for a theoretical framework that is more parsimonious than macro approaches,

such as social practice theory, but more inclusive and predictive of environmental behavior than meso approaches, such as the RAA. This model should include more contextual factors and attend to the barriers between intention and behavior.

In conclusion, the RAA gives us insight in what factors influence intentions, but to correctly model the influence of contextual factors such as triggering habits or giving opportunities another model is needed.

Chapter 3

Model

In this chapter we further our first aim, theory constructing: to make a model that captures the influence of context using the concepts of agents and social practices. Note that whenever we state 'the influence of context' we limit ourselves to context giving opportunities or triggering habits.

We aim to make a model that (1) gives insight in our research question - how can we improve intervention given the influence of context - (2) is parsimonious, but (3) still adequate in view of intuition and literature - most importantly the limited success of interventions targeting intentions rather than context. The model is illustrated by focusing on the choice to eat vegetarian or meat. The more precise research question for this model is thus: how can we improve contextual interventions *to increase vegetarian dining*. In chapter 6 we discuss if we can extrapolate these results to the more general case of interventions targeting environmental behavior.

This chapter will continue by first describing the target scenario, high-level modeling choices, and the content of the model and agent. In section 3.4 we describe how an agent decides what to eat: meat or vegetarian meals. We will argue for requirements for the habitual, intentional and evaluative part of the deliberation and validate each module on these requirements. In section 3.5 we describe how an agent chooses his context. We finish this chapter by explaining how we use an agent's values to relate different parameters. Note that this chapter only highlights the core aspects of the model, the code-specific implementation in Repast Simphony can be found on GitHub.[1] The validity of the model as a whole will be covered in the next chapter.

[1] https://github.com/HydraNL/meatSimPro

3.1 Description of Target Scenario

We propose the following scenario to study how we can improve interventions to increase vegetarian dining. The scenario comprises a group of acquaintances that have to make decisions regarding dining. They will decide once per day:

- where they want to dine;
- with whom they want to dine;
- what they want to eat.

These decisions will be influenced by habits, intentions and their evaluation of past actions. Within this system we focus on the influence of context on the choice to eat vegetarian or meat.

3.2 Some High-level Modeling Choices

- One tick represents one day. Every tick the agents choose in random order a location and dining group, after they all made this decision they choose *one* dish each.
- There are only vegetarian or meat dishes, i.e. no fish, mixed or vegan dishes.
- There are only four types of locations: homes (12 for every 30 agents) and vegetarian (1 for every 30 agents), meat (1 for every 30 agents) and mixed venues (2 for every 30 agents).[2] Apart from interventions the environment stays stable
- The agents in this model form a social cluster completely separated from other agents.

3.3 Agents

An agent is defined by two kinds of objects: its social practices and values. Firstly, in line with Dignum et al. (see section 2.2) each agent has his own representation of a social practice: information to guide the deliberation about this practice. In this model the agent will only have a 'dining' social practice (see figure 3.1).

A social practice consist of the following elements:

[2] The amount of homes and venues are based on Statista (2015) and **?**.

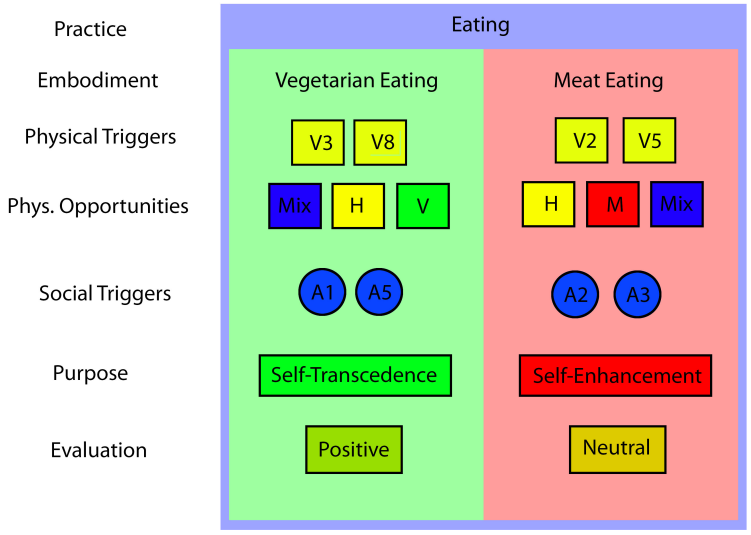


FIGURE 3.1: A possible instantiation of the social practice of eating. In this model only the embodiments and their purposes are fixed per agent, other variables can change over time and differ per agent.

Embodiments refers to the set of possible actions or plans that the agent will use to guide its behavior within this practice; [3]

Opportunities describe features of the context that enable an embodiment;

Physical e.g. a meat venue gives the opportunity to eat meat;

Triggers describe features of the context that habitually trigger an embodiment;

Physical e.g. venue two triggers choosing a meat dish;

Social e.g. agent five triggers choosing a vegetarian dish;

Purpose refers to the meaning of the practice, i.e. the values it furthers;

Evaluation captures agents own judgment about past enactments of practice

As described in section 2.2 some of the variables (e.g. opportunities, triggers, evaluation) of social practices are unique to an agent as they depend on its own history. Other variables are similar to all agents (e.g. purpose and embodiment) as they are part of a shared idea of the social practice. To what degree and which part of practices are similar depends on the practice, target scenario and can change over time. These variables all play a role in the deliberation of an agent as we will describe in the next sections.

Secondly, in line with Schwartz (see section 2.4) the agent has a set of values that constitute what the agent finds important. The agent has four values: self-enhancement,

[3] In this scenario 'embodiment' can be interpreted as 'action'.

self-transcendence, openness (to change) and conservation. Each agent attributes a different strength to each value. We modeled the distribution of value strengths with a normal distribution, i.e. $\mathcal{N}(1, 0.25)$. In line with Schwartz the normal distribution of self-enhancement and self-transcendence are negatively correlated with 0.8, just as openness and conservation. Values have two functions in this model. Firstly, the values of self-enhancement and self-transcendence play a central role in intentional behavior. This will be further explained in section 3.4.2. Secondly, they define the personality of an agent as, for example, having a strong disposition to go into habits. How values correlate with such tendencies is explained in section 3.6.

3.4 Deliberation of the Agent: What?

The deliberation of the agent consist of three parts. The agents will firstly choose where and with whom to eat (i.e. its context) and then what to eat. In this section, we will firstly treat the choice of what to eat as this will make it easier to motivate and explain how an agent chooses his context. We thus for now isolate the third stage of the deliberation and give an overview of how the agent chooses between the embodiment of eating vegetarian and eating meat (see figure 3.2).

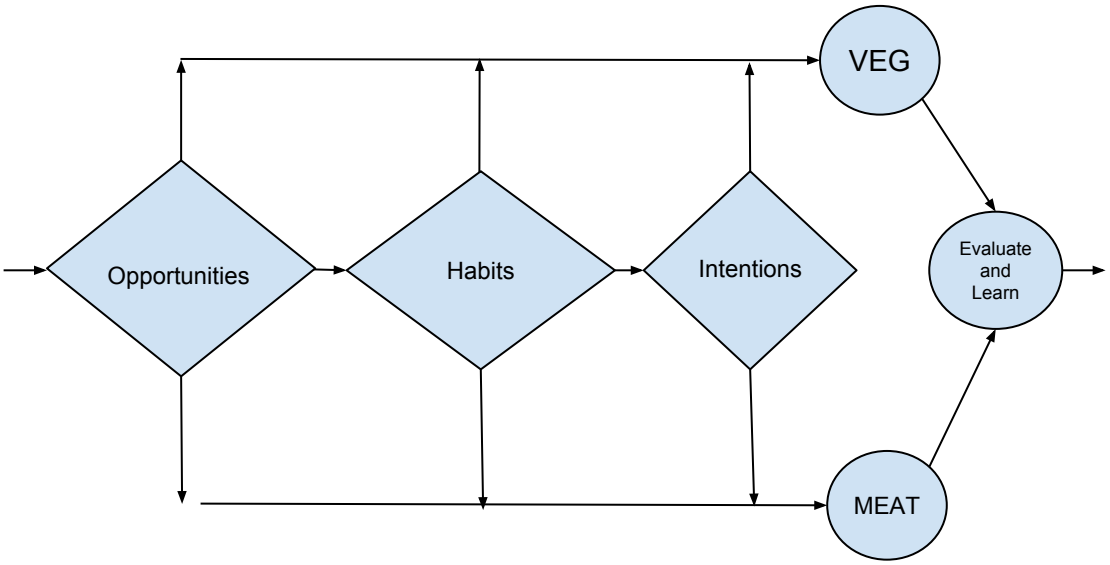


Figure 3.2: Schematic overview of the deliberation cycle of an agent.

The deliberation of an agent acts as a filter on the set of embodiments a social practice can result in. When there is only one embodiment left the agent will enact that without further deliberation, this can lead to fast (habitual) behavior. When there are multiple embodiments left the agent will continue deliberation until it reaches a conclusion on

one embodiment. The motivation to treat these modules as a sequence of filters comes from the limited success of interventions targeting intentions rather than context. As said in the introduction we study the possibility that this might be due to agents acting upon opportunities or habitual triggers without consulting their intentions. In chapter 4 we validate if this model can indeed reproduce the results of such interventions.

In the first stage of the deliberation an agent filters the impossible behavior out by comparing its current context with the social practice. In complex scenario's sensing the environment could compromise several stages where, guided by the social practice, the agent jumps between experiencing and past experience. In this scenario the agent simply senses the venue (i.e. physical context) to determine if it has the opportunity to eat meat, vegetarian or both.
In the second stage of the deliberation an agent filters its embodiment based on habitual triggers. The agent filters the least salient embodiment out by comparing its current context with the social practice. In this scenario other agents (i.e. social context) or the location (i.e. physical context) can trigger a habit to eat meat or vegetarian. This stage is further specified in section 3.4.1.
In the third stage of the deliberation an agent will use his values to make an intentional choice out of the remaining possible embodiments. This stage is described in section 3.4.2.
After the enactment an agent will learn. Firstly, by updating its history of enactment by keeping track of the past performance context in the trigger variable of the social practice (this is part of the habit section 3.4.1.. Secondly, it will evaluate if it wants to do the behavior again. This stage will be further specified in 3.4.3.

This thesis now continues by treating the different stages of the deliberation of an agent: habitual (sec. 3.4.1), intentional (sec. 3.4.2) and evaluation (sec. 3.4.3). For every module we first try to argue for the requirements for an adequate model given our object of study, intuition and the literature, secondly we describe choices that had to be made to come from these requirements to a precise well-defined model, we then describe the model and lastly we show that that given a certain parameter setting the requirements hold in the defined model.

Note that for ease of explanation and validation we will sometimes treat modules as if they were isolated from the others. In reality, these modules are intertwined and the separate results might have limited validity. We acknowledge that for further validation of the model the interaction as proposed in this section should be validated against micro empirical data. For example, do we really use intentions as a tiebreaker? For now, we have found no such empirical data. This is indeed an important limitation of the work as further discussed in chapter 4 and 6. However, we still feel supported in

our modeling choice as it resembles the filtering properties of habits and opportunities as disscussed in the literature (see chapter 2). Moreover, as we will see in chapter 4 this *combination* of these modules furthers our aim: it can explain the limited success of interventions that target intentions over context.

3.4.1 Habit Model

In this section we describe how habitual triggers come about and are used to filter on the most salient embodiments. We aim to study how contextual interventions might increase vegetarian dining, where interventions solely targeting intentions might not. For us habits are thus interesting as automatic responses that often prevent an agent to enact its intentions, but that under certain circumstances (e.g. contextual interventions) can be parried. For example, say that, for all his life, Bob intentionally shoves down burgers at his local bar. Bob now, upon entering the bar, automatically orders the burger, something an environmental awareness campaign targeting his intentions changes little about. Our central requirements are thus:

1. After repeated enactment often an agent will start acting out of habit.
2. Under certain circumstances people can act differently than their habit.

We think an agent might not enact his habit in two cases. The first case happens when an agent puts a lot of attention towards the action and uses a more deliberate mechanism to make his decision. We propose that this attention is influenced by the evaluation of past enactments. For example, when Bob's habit to order a hamburger consistently gets negative feedback (from himself or others) he might think harder about this decision the next time. The second case when an agent does not enact a habit is when he does not enter the habit triggering context. For example, Bob enters a luxurious venue with his wife instead of his local bar, the venue invokes no automatic action so he uses his intentions to make a decision. In line with Wood and Neal (2007) (see background chapter 2.3) we thus argue for the following requirements:

3. Habits (can be captured by action-'context cue' associations that) emerge when behavior co-varies with context;
4. Habit strength is the product of (1) past frequency and (2) context stability;
5. Once formed, perception of a context cue triggers the associated action only if the habit strength surpasses a certain threshold (independent of the agent's intention);

6. The height of this threshold differs per person and is influenced by the attention one attributes to the embodiment, which in turn is influenced by the evaluation of past enactments.

Most habits seem to stay with a person for a long time, but in a few cases they can be intentionally overwritten. For example, after a lot of bad feedback Bob consistently puts a lot of attention towards not habitually ordering the burger, but instead intentionally ordering the vegetarian lasagna. Eventually Bob will need to put less and less attention in this decision until he might even develop a habit to order the lasagna. Note that this resembles the cognitive plausible Hebbian learning mechanism: if the context representation fires together with(out) the action representation the habit increases (decreases).[4] Thus:

7. Habit strength decreases if one does another competing embodiment in the same context;

Although habits increase when past frequency increases the relation does not seem to be linear. For example, Bob's habit seems to increase more in the first year of consistent burger eating than in the 15th year. Furthermore, even life-long habits can in some cases be broken in a year. We think this is because at some point a habit does not become stronger anymore. In line with Lally et al. (2010) (see background section 2.3) we argue for the following requirements:

8. Habit strength increases on an asymptotic curve.
9. Habit strength has a (per agent different) maximum and minimum;

Furthermore in a fixed context with an intention to do one action, based on Lally et al. (2010), we argue for the following requirements:

10. Agents differ in the height of the maximum strength and how long they take to reach this maximum;
11. Habit strength reaches his maximum on average in 66 days with a standard deviation of 52.

[4] See (Klein et al., 2011) for more on a Hebbian learning habit model.

3.4.1.1 Some Modeling Choices

Habits might exist between any abstract level of a practice (e.g. eating, eating noodles with chopsticks) and any abstract level of context (e.g. the city, Japanese venues). Moreover, these different context-practice relations might influence each other. For example, eating noodles at your local Japanese venue could quite possibly increase your habit to eat noodles in any Asian venue, or even to generally dine out in this city. To our knowledge little is known about this complex hierarchy of context-practice relations, moreover in this thesis we aim to study contextual interventions more than the interconnectedness of habits.

We thus choose to simplify habits to the context-action relations central to our aim, those between agents, locations, vegetarian eating and meat eating. We simplify the interaction of habits by giving habitual information from outside the current performance context a weighted (ω) influence on the habit strength. For example, eating meat alone in venue one will to some small extend (i.e. ω) increase a habit to eat meat with friends in venue three.

Note that our model thus is limited in capturing the nuances of habit relations. For example, a habit in a mixed venue might have a larger effect in other mixed venues than in meat venues, as these venues are in some extend similar. This turns out to be an important limitation as we will further discuss in chapter 6.

3.4.1.2 Formal Model

Every embodiment of a practice is (possibly) associated with each possible context cue. A context cue can be an agent or a location. An an association can be strong (max. 1) or weak (min. 0). The habitual information an agent has can thus be represented by a matrix like this:

	Action1	Action2
A1	0.6	0.3
A2	0.8	0.1
....		
V1	0.7	0.1
V2	0.3	0.6
....		

TABLE 3.1: Matrix representation of habitual information. A1 represents an agent and V1 represents a venue.

A field in this matrix can be referred to $H(e,cc)$ and represents the strength of the habitual association between embodiment e and context cue cc. Each field is initiated with 0.5 as to start the simulation in the middle of habit acquisition.

We can distinguish between storing habitual information and retrieving the information. After an action we postulate the following formula for storing the new habit strength for each context cue *cc in the performance context of the agent*:

$$H(e,cc)_{new} = \begin{cases} (1-\alpha)\cdot H(e,cc) + \alpha * 1 & \text{if } e \text{ is enacted} \\ (1-\alpha)\cdot H(e,cc) + \alpha * 0 & \text{if } e \text{ is not enacted} \end{cases} \tag{3.1}$$

where α is the habit learn rate of the agent. Much like Hebbian learning the habit strenght increases when both the embodiment and context-cue 'fire' and decreases when only the context cue does.

We postulate that an agent retrieves the (total) habit strength $H(a,c)$ of an action a within context c as:

$$H(e,c) = A(e,c) + \omega \cdot B(e,c) \tag{3.2}$$

The retrieval formula has two parts. Firstly, we calculate $A(e,c)$ the habit strength *in context*. Secondly, as said in 3.4.1.1, $B(e,c)$, i.e. the habit strength outside of the current performance context, also have a weighted influence. ω thus represents how context specific the agent deliberates. Both $A(e,c)$ and $B(e,c)$ are calculated by averaging over the context-cues, where both the location as the average of all the agents take equal part.

After retrieving the habitual information an agent filters the possible embodiments of a social practice on habitual triggers by the following algorithm:

An embodiment passes as a habit when the embodiment has been enacted so often that it passes the habit threshold times the attention. The habit threshold differs per agent by an individual habit threshold weight.The attention variable represents the amount of cognitive resources spent to determine if an action is a habit: when an agent pays little attention he has a higher chance to go into a habit. We postulate that the attention the agent pays is negatively correlated ($\rho = -0.5$) with evaluation (see section 3.4.3) and thus partly depends on the evaluation of the embodiment and partly on a random number r.

Algorithm 1 The algorithm to determine if an embodiment is a habit

Require: candidate embodiments that past previous filters CE, performance context c, random number r is drawn from $\mathcal{N}(1, 0.5)$, postulated negative correlation between evaluation and attention $\rho = 0.5$, the avarage habit threshold τ, the individual habit threshold weight hw

```
for all embodiments e in CE do
    HabitStrength = calculateHabitStrength(e, c)
    HabitThreshold = τ * hw
    Evaluation = calculateEvaluation(e, c)
    Attention = 2 − (ρ ∗ Evaluation + √(1 − ρ²) ∗ r)
    if HabitStrength > HabitThreshold * Attention then
        newCandidates.add(e)
    end if
end for
    return newCandidates
```

3.4.1.3 Parameter Settings, Validation and Verification

The requirements as stated in section 3.4.1 (with exception of 1,2 and 11) are mainly induced by the chosen model and not the exact parameter settings. This becomes clear when we compare the current model to an older version. In the old model an agent had no learning function but simply counts one frequency points per action-context cue pair for every enactment. In this model an action is a habit if it has accumulated (a lot) more frequency points than another action. The current model differs in that (1) the time of enactment matters, i.e. there is a higher gain in habit strength if the habit strength was low than if it was already high (req. 8). Secondly, the learning function induces a habit strength maximum (req. 9). In the old model the absence of a maximum led to the unintuitive result that life-long habits were inescapable due to their extreme habit strength. In the current model the habit strength follows an asymptotic curve in line with results found by Lally et al. (2010) which leads to a model where an agent can escape and overwrite habits.

After verifying that the propositions hold we try to assign parameter settings such that requirements 1,2 and 11 hold . An overview of the parameter space for the habit module is depicted in table 3.2.

There are two tasks here. Firstly, in conditions similar to the experiment in Lally et al. (2010) we should determine the parameter such that it takes appropriate time for an agent to reach his maximum habit strength (req.11) . We will call this timing the plateau time (in reality an asymptote has no maximum, but it does plateau at a certain point). Secondly, in general an agent should go into a habit, but his habit strength should be low enough so that under certain conditions he can still do something else

TABLE 3.2: Relevant parameters to fit the habit model to requirement 1,2 and 11, their description, test ranges and final value. The final value is decided by EXP3, for which the range in turn is decided by the exploratory EXP1 and EXP2.

Parameter	Description	range: EXP1 and EXP2	range: EXP3	Value
τ_μ (HTR)	Habit Threshold: Avarage	0.5 - 0.9	0.5-0.75	0.6
τ_σ (HSD)	Habit Threshold: Standard Deviation	0.1 - 0.5	0.1 - 0.35	0.25
α_μ (LR)	Learn Rate: Avarage	0.02 - 0.1	0.025 - 0.035	0.3
α_σ (LRSD)	Learn Rate Weight: Standard Deviation	0.1 - 0.8	0.4 - 0.6	0.5
ω	Outside Context Weight	0.25	0.25	0.25

(req. 1 and 2). We will thus measure the amount of agents going into a habit (habit ratio) and their maximum habit strength (plateau-value).

Lally et al. (2010) asked participants to carry out the same action every day in the same context and report on their habit strength. Likewise, in our first experiment (EXP1) we assign the agents a stable context and a disposition towards eating meat. We explore the parameter space (see table 3.2) with a recursive partitioning data mining technique called regression tree mining. We run 50 simulation runs per parameter setting and measure the mean and variance (over agents) of the plateau-time. One of the resulting decision tree depicting the standard deviation is depicted in figure 3.4.

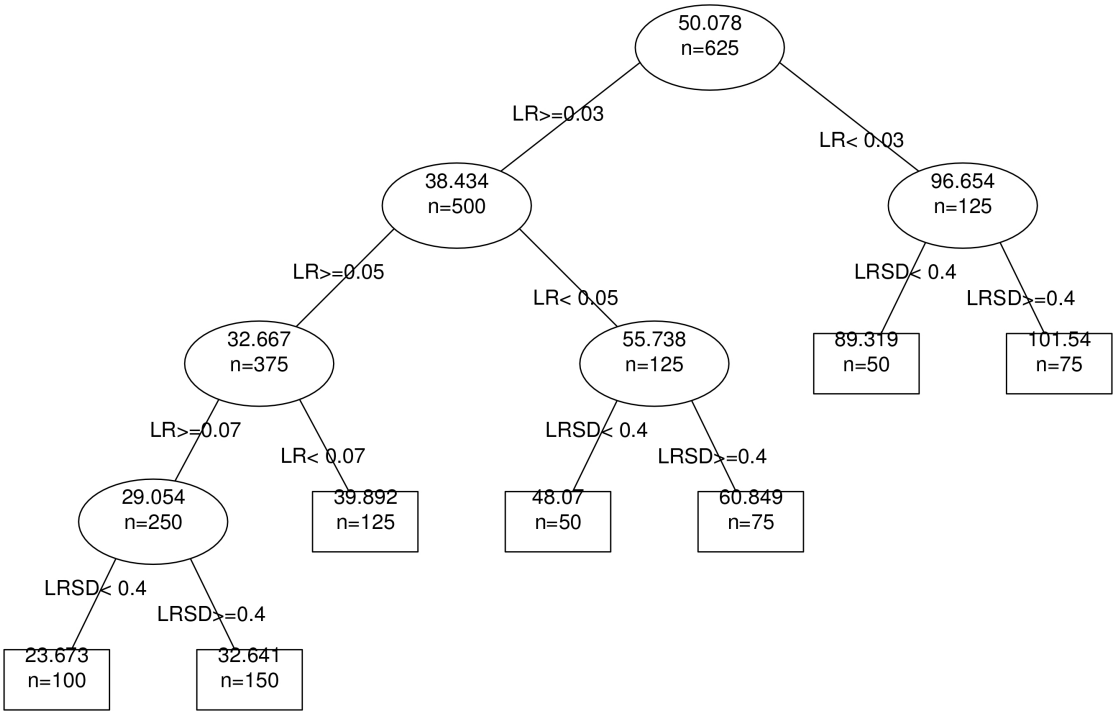


FIGURE 3.3: A decision tree showing partitions of the parameter space based on the standard deviation of plateau-time, i.e. how much agents differ in their time to reach their maximum habit strength. LR depicts the avarge Learn Rate (α_μ) of an agent, LRSD the Learn Rate Weight: Standard Deviation (α_σ). The fact that τ_μ and τ_σ do not show here means that they are not a big influence on the plateau-time.

We conclude that the timing of agents to reach their plateau is largely independent of τ_μ and τ_σ, but mainly depends on the α_μ and α_σ. In a sense we thus verify that the learn rate is the main influence on the speed of the habit acquirement. We can furthermore conclude (from other decision tree's) that after the agent reach their plateau the amount of agents acting out of habit stabilizes. Most importantly, this exploratory experiment allows us to narrow down the possible parameter settings.

In our second experiment (EXP2) we measure if the habit-ratio and plateau-value take an appropriate value. We postulate that in normal conditions (i.e. society has a slight disposition towards eating meat) about 80% of actions is done out of habit. This is based on intuition and some similar claims in Wood and Neal (2007) and Lally et al. (2010), but should be validated on more empirical research in further work. We again explore the parameter space (see table 3.2) with regression tree mining. The following decision tree depicts the habit ratio of agents at $t = 200$, i.e. where it is stabilized:

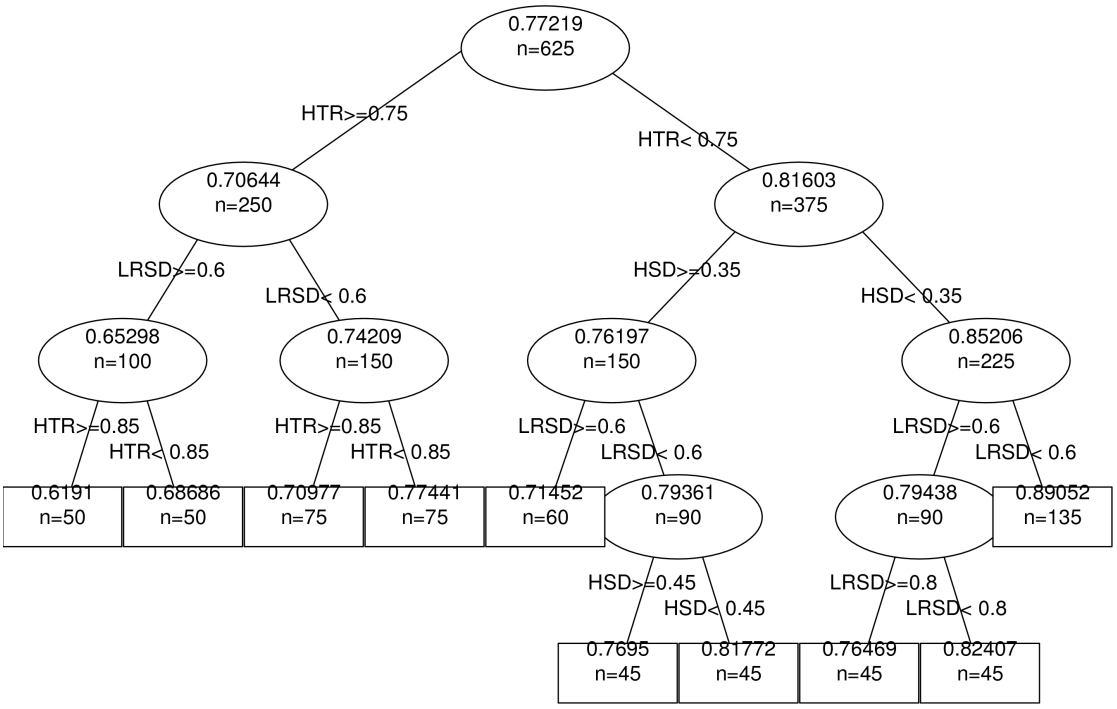


FIGURE 3.4: A decision tree showing partitions of the parameter space based on the habit ratio, i.e. the ratio of agents acting out of habit at $t = 200$. HTR depicts the average habit threshold (τ_μ) of an agent, HSD the standard deviation in the threshold weight (τ_σ).

We conclude from this and other decision tree's that the habit-ratio and plateau-value are mostly dependent on τ_μ and τ_σ, although still correlated with the plateau-time (req. 11). We further deduce that the habit-ratio in normal-conditions stabilizes after a warm-up period until $t = 100$. Most importantly, this exploratory experiment allows us to narrow down the possible parameter settings.

In the last experiment we thus search in an appropriate range of α_μ and α_σ as induced by EXP1 and in appropriate range ofτ_μ and τ_σ as induced by EXP2 (see EXP3 range column in table 3.2) to find parameters settings such that (1a) about 80% of agents acts out of habit, (1b) but agents can still move out of habits and (2a) in the described experimental settings it takes on average 66 days for an agent to reach his maximum habit strength (2b) with a standard deviation of 52. The parameter setting that minimizes the error on these four criteria is found in the 'Value' column in table 3.2. These settings indeed induce a graph that conforms to the results found by Lally et al. (2010) (see figure for their results) as depicted in figure 3.5.

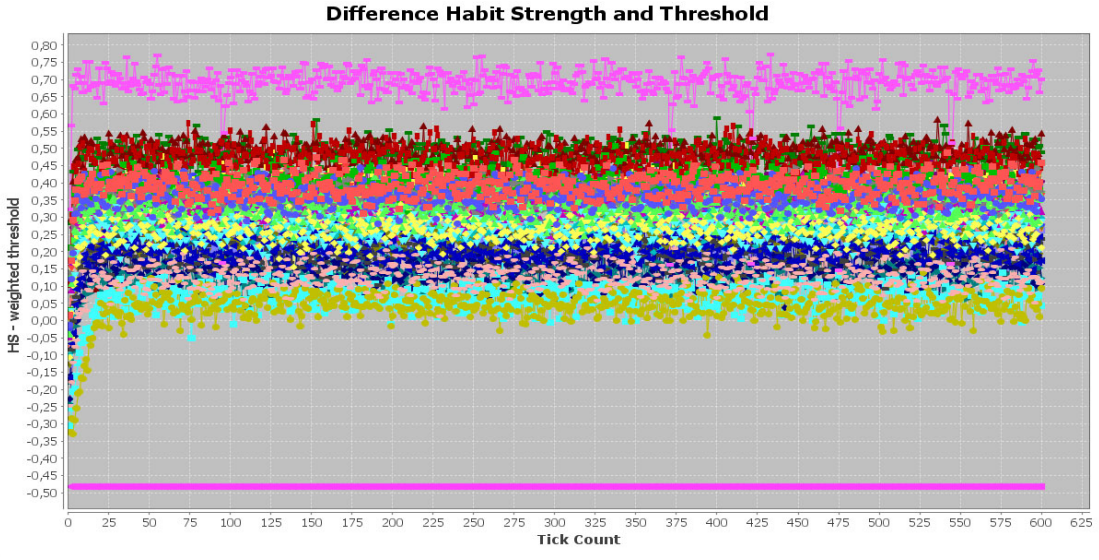


FIGURE 3.5: The difference between the habit strength and the (for every agent slightly different) threshold (y-axis) over time (x-axis), given the final parameter setting (see table 3.2). We can see that req. 8,9 and 11 hold, i.e. the habit strength curve follows a similar asymptote as found by Lally et al. (2010).

3.4.2 Intentional Behavior Model

In this section we describe how the agent uses his intentions to determine which of the remaining embodiments he chooses. Our research question focuses at the influence of context on decision making. For us intentions are thus interesting in providing the background on which opportunities and habits might take their effects, more than how they come about or how we choose between them. Foremost agents should be able to differ in their intention to eat meat or eat vegetarian. We argue that in the scenario of meat-eating, values can be used to explain the core of these personal differences in intentions. As said in section 2.4 reasons to eat meat (e.g. it tastes nice) can often be traced back to self-enhancement values and reasons to eat vegetarian (e.g. it is ethical) can often be traced back to self-transcendence values. Note that particularly in an ethical scenario like the choice to eat meat values might be a big influence; in such a

scenario they seem not only to influence the personal evaluation but also someone's disposition towards the social norm. Thus in line with the literature we argue for the following requirement:

1. Values are a primary determiner of intentions (especially in (partly) ethical choices as eating meat).
2. The higher one values self-enhancement, the higher the chance to eat meat.
3. The higher one values self-transcendence values, the higher the chance to eat vegetarian.

In reality intentional choices are not always consistent, that is, the fact that one values self-enhancement higher does not mean the agent *always* chooses to eat meat. Humans seem to keep a 'balance sheet' in moral and calculation-based action as an intentional meat choice (Truelove et al., 2014). For example, an agent might argue that it has done his fair share of pro-environmental behavior and now is justified in eating some meat. We thus argue for the following requirement:

4. Humans seem to keep a balance sheet on to what extend they have satisfied values.

Note that this does not mean that humans are either self-enhancement or self-transcendence persons. It is important to keep these as separated (but often negatively correlated) values. For example, people with plenty of resources (e.g. Bill Gates) might be able to satisfy both their self-enhancement and self-transcendence values. Other people might not be interested in satisfying either of the values (see e.g. (Braithwaite, 1994)). We thus argue for the following requirement:

5. Although in general humans are able to balance their actions in accordance with their values; there are also interesting cases where humans value (and satisfy) both values or neither.

Lastly, as we study interventions to induce behavior change it is important that intentions can change. We think intentions firstly change as a result of requirement 4, i.e. although values stay stable people keep a balance sheet and consequently switch up their intentions. More importantly, in line with the Reasoned Action Approach we argue that an important reason for humans to change their intentions is a change in personal or social evaluation of the action. For example, an agent decides to eat vegetarian because all his friends do (social evaluation) or he finds it more and more important to

help the environment (personal evaluation). We will talk more about how we model social and personal evaluation in section 3.4.3, but for now it is important to recognize that these influences can change intentions over time.

6. A human can change his intention over time due to the influence of (a change in) personal or social evaluation of the action.

Note that there is one more important influence on intentions according to the Reasoned Action Approach that we do not discuss in this section: perceived and actual control. For example, an agent might not eat vegetarian, because he does not have the appropriate control due to unavailability of a vegetarian dish or a habit to eat meat. As this influence of context is the focus of this thesis we integrate this influence with several parts of the model (e.g. section 3.4 and 3.4.1) instead of trying to capture it in one or multiple variable(s).

3.4.2.1 Some Modeling Choices

In the previous subsection we argued that given our research question there are two central concepts that influence intentions: values and evaluation. To simulate behavior change we thus separate the two notions: values as the stable component, evaluation is the dynamically changing one. Often this is the reality, but in some cases values might change and evaluation might stay stable. Moreover, the notion of evaluation in the literature often encapsulates the notion of values. In this model we choose to separate the notions as to get more insight in the interaction of a stable component and a dynamically changing component.

Furthermore we make two modeling choices concerning values. Firstly, we postulate a one-on-one relation between values and embodiments. In reality we can satisfy values by multiple embodiments and some embodiments satisfy multiple values. Moreover, in this model all agents homogeneously attribute the same purpose (with the same weight) to the same embodiment. As our research question is about how context interferes with intentions, more than how intentions compete we choose to simplify this to a one-on-one relation. Secondly we choose to model the 'balance sheet' humans seem to use when intentionally acting upon values by a model of drives. In line with Tosto and Dignum (2013) we transpose the biological terms of needs and satisfaction to the domain of values. We do not argue that drives are values (e.g. one does not biologically'need' to eat vegetarian), but just that this is a intuitive model that satisfies the 'balance sheet requirement.

3.4.2.2 Formal Model

The agent attributes a *threshold* and a *satisfaction level* to a value. The threshold represents how important the agent it finds to further the value. This threshold differs per agent and per value as it is based on the normally distributed value strength of each agent. The satisfaction level slowly decreases over time, but an action can increase the satisfaction level. Formally, the satisfaction of value v after enacting embodiment e is updated with the following formula:

$$Sat(v)_{new} = \begin{cases} Sat(v)_{old} + \beta * tanh(1-k) & \text{if } v \text{ is the purpose of } e \\ Sat(v)_{old} + \beta * tanh(0-k) & \text{if } v \text{ is not the purpose of } e \end{cases} \tag{3.3}$$

where β is a weight that scales the satisfaction gains and losses to the threshold and k is the loss of satisfaction per tick. The *need* to further a value is calculated by comparing the threshold to the satisfaction level. For example, in figure 3.6 the agent's need is highest to further its self-enhancement value. The agent will thus choose to eat meat and increase his self-enhancement value satisfaction. To decide on an embodiment the agent does not only look at the need of the related values, but also to the evaluation of past enactment of the embodiment.

In sum, the agent uses algorithm 2 to determine which embodiment to enact:.

Algorithm 2 The algorithm to determine an intentional embodiment.

```
Require: candidate embodiments that past previous filters CE
  for all embodiments e in CE do
      Threshold = e.purpose.Strength
      Satisfaction = e.purpose.Satisfaction
      e.Need = e.Threshold/e.Satisfaction
      e.IntentionStrength = e.Need * e.Evaluation
      totalIntentionStrength += e.IntentionStrength
  end for
                              ▷ Picks Random Embodiment in Ratio of IntentionStrength
  r = random ∈ [0, totalIntentionStrength]
  for all embodiments e in CE do
      if r < e.IntentionStrength then return e
      else
          r - e.IntentionStrength
      end if
  end for
```

The need of an agent is thus determined by dividing the threshold by the satisfaction. After that the evaluation of past enactment is used as a weight: the better the evaluation the larger the intention (see section 3.4.3). Lastly, an embodiment is chosen in ratio

to their intention strength. Note that the satisfaction in the model is bounded by a minimum (m) and a maximum ($m + r$). The threshold is scaled to be on average in the middle of these two boundaries (i.e. value strength + $r/2$).

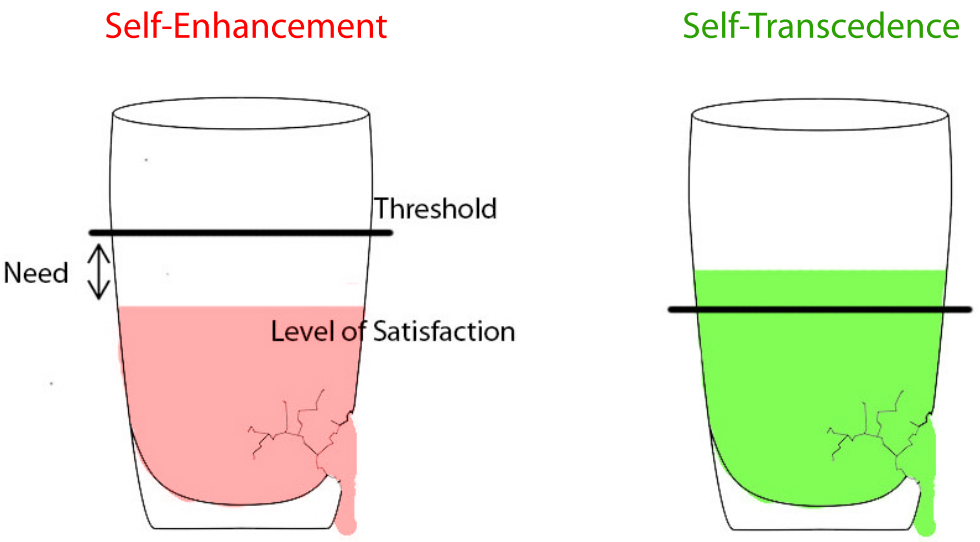


FIGURE 3.6: The agent's, need, satisfaction and threshold depicted as a water tank. The water tank slowly leaks 'satisfaction', but satisfaction can be added by doing the right action.

3.4.2.3 Parameters, Validation and Verification

We found the following parameter setting such that the propositions as stated in section 3.4.2 hold:

TABLE 3.3: The parameters of the intention module and their set value.

Parameter	Description	Value
k	Loss of satisfaction per tick.	0.5*value strength of purpose
β	Scales satisfaction gain or loss.	0.1
m	The minimum satisfaction.	1
r	The range of satisfaction.	1.7

Firstly, k is set so that on average it takes one action to compensate the satisfaction loss of doing the opposite action (req. 4). The satisfaction loss is weighted by the value strength, such that stronger values need to be acted upon more often (req. 2 and 3).

Secondly, the range of β is tuned by choosing an intuitive ratio of a satisfaction gain of one action, e.g. intuitively each action should not double the need. We postulate $\beta = 0.1$ as giving intuitive fluctuations in need.

Thirdly, we postulate m on 1 and test r for different values between 1 and 12 as to find a value such that (1) after a habitual period one wants to compensate 'unintentional' behavior (req. 4), but this compensation does not take forever and (2) in non-habitual circumstances the enforced satisfaction maximum and minimum does not interfere with the desired action ratio as induced by the value ratio (req. 1,2,3) (see appendix figure A.1 to see the results for different ranges).

Lastly, because we use two dimensions (i.e. two values instead of one) to represent one's disposition towards meat-eating we obtain four different types of agents (req. 5). As shown in figure 3.7 there are agents who are able to balance their needs: agent 3 with a disposition towards self-transcendence and agent 4 with a disposition towards self-enhancement. But there are also agents like agent 1 who do not strongly value self-enhancement nor self-transcendence, their needs lower over time and they become (slightly) indifferent. And there agents like agent 2 who value both self-enhancement and self-transcendence highly and as such have high but highly fluctuating needs.

3.4.3 Evaluation Model

In the previous two subsections we have seen how an agent uses his evaluation in his deliberation. To summarize, the higher the evaluation of an action the more likely the agent is (1) in not paying attention (i.e. not using cognitive resources) towards a decision and going into a habit and (2) intentionally doing the action again. In this section we describe how an agent evaluates its behavior. As the aim of this thesis is to study behavior change, it is important that evaluation can change over time. We argue that in this scenario there are two influences that might change an evaluation. Firstly, there is a personal component, i.e. do I like the action? For example, do I really like meat? Secondly there is social component, i.e. do others like the action? For example, do my friends eat vegetarian dishes? According to the literature (e.g. the Reasoned Action Approach (see section 2.4)) agents differ in what weight they attribute to either component, but in general both are important. For example, an agent might eat meat, because everyone does it, although it itself does not like meat that much. Another agent might eat vegetarian although everyone else eats meat, because it does not care what others do. In general though humans seem to care about both aspects. We thus argue for the following requirement:

1. An agent evaluates an embodiment based on two weighted components:
   (a) Personal evaluation, i.e. do I like the embodiment?
   (b) Social evaluation, i.e. do others like the embodiment?

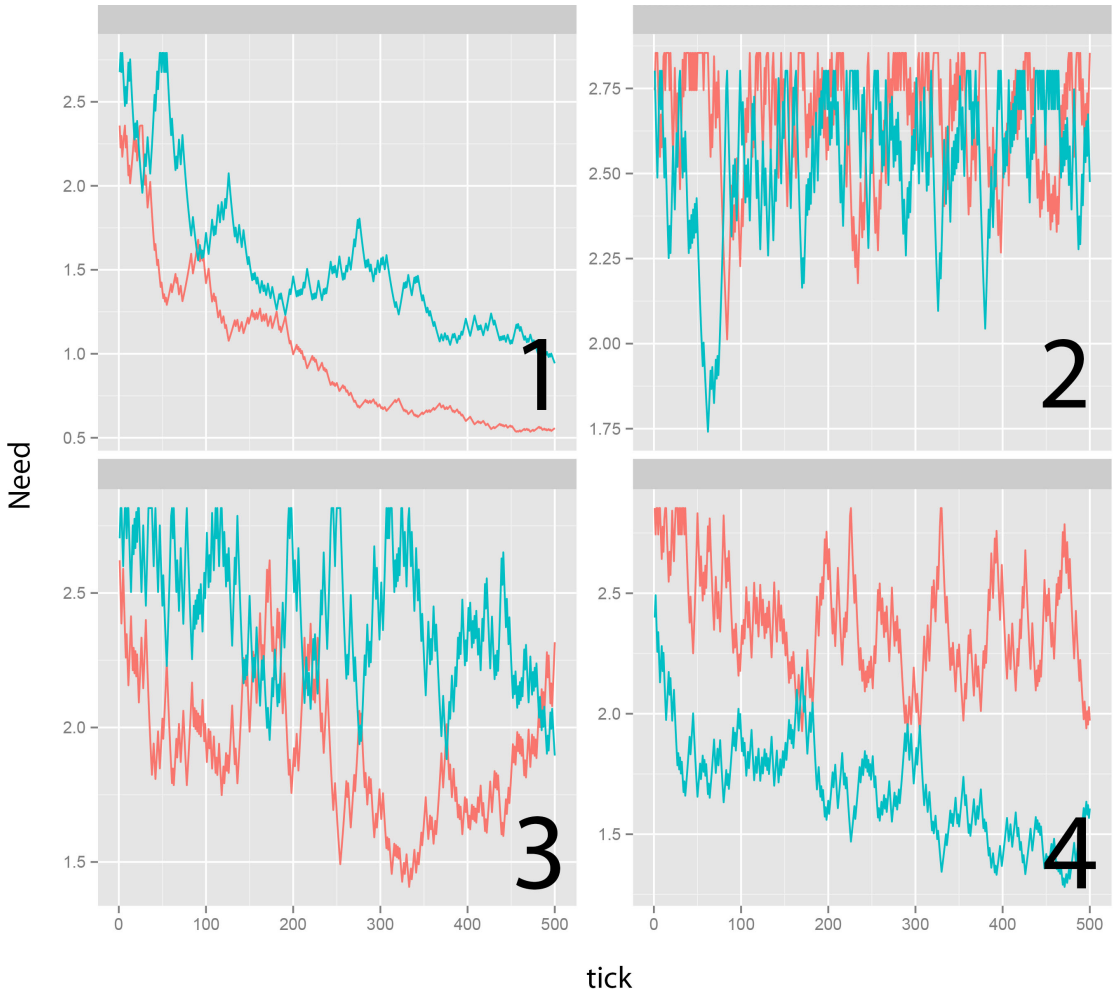


FIGURE 3.7: Need to further a value (green = ' self-transcendence', red= 'self-enhancement') of four different agents over time. The need goes down when one embodies a value, but goes up when one does the opposite.

As we study the influence of context it is important to ask if the evaluation of an action is context-dependent. For example, do we evaluate meat-eating differently around our male friends than when alone? To our knowledge there is little known about the context dependence of evaluation, but as we want to study the influence of context it is interesting to model the influence of context on evaluation as well. That evaluation is dependent on context is an important assumption for which we discuss the relevance in chapter 6.

2. Evaluation is context-dependent.

Lastly, there is some literature on the consequences of social evaluation on the macrolevel. In Salganik et al. (2006) introducing a mechanism that allowed for social evaluation polarized the results. In other words, when people are allowed to see what others prefer

they adapt and converge as a group to certain choices. For example, certain groups largely become vegetarian or a society largely eats meat. We thus argue that:

3. Allowing a group of agents to socially evaluate their behavior polarizes their behavior.

3.4.3.1 Some Modeling Choices

To keep the model parsimonious we model evaluation in terms of concepts we already defined. Firstly, the personal evaluation is based on an agent's values. Note that an agent's values do not always overlap with his action, e.g. an agent might have chosen an action out of habit. The personal evaluation of an agent thus becomes a mechanism that inhibits habits that do not represent one's values. An alternative choice could have been to evaluate if an action is in accordance with an agent's intention (instead of its more elementary value strength). Intention though, as described in section 3.4.2 is influenced by evaluation itself. As a result of this loop the agent's intention strength of any action would be either zero or limitless (which we find unintuitive.).

Secondly, the social evaluation is based on how many other agents *in this performance context* enacted the same embodiment. This is sometimes referred to as the 'descriptive norm', i.e. 'that what is', which differs from the 'injunctive norm', i.e. 'that what ought to be' (Cialdini et al., 1990). In this scenario it is not entirely clear how an agent might deduce what ought to be, but it's very clear what is. Due to time constraints we leave the more complex injunctive norm for further work and simplify the social evaluation to the descriptive norm.

Lastly, we choose to change the evaluation once per deliberation-cycle after the enactment of an embodiment. Although in reality many events can change the evaluation of the agent, in this scenario not much else happens after an agent makes a decision.

3.4.3.2 Formal Model

Similar to the habit module information about the evaluation is stored in a matrix (like table 3.2) where each field is a pair of context cue cc and embodiment e. After embodiment e in context c the embodiment is evaluated with the following formula:

$$E(e, cc) = \frac{E_p * w_p + E_s * w_s}{2} \tag{3.4}$$

where:

E_p : personal evaluation determined by by the value strength of the agent that matches the purpose of embodiment e;

w_p : an individual weight attributed to the personal evaluation;

E_s : the social evaluation determined by the difference between the amount of agents in the performance context enacting the same embodiment and the agent enacting a different embodiment ;

w_s : an individual weight attributed to the social evaluation of an agent.

The information is stored in the matrix with following learning formula (like habit formula 3.1):

$$E(e,cc)_{new} = (1-\eta)\cdot E(e,cc)_{old} + \eta * E(e,cc) \tag{3.5}$$

where η is the evaluation learn rate of the agent. And the information is retrieved with:

$$E(e,c) = A(e,c) + \omega \cdot B(e,c) \tag{3.6}$$

where analogue to habit retrieval formula (3.2) A(e,c) is the evaluation in context, B(e,c) the evaluation outside context and ω is the same weight representing how context specific the agent deliberates.

3.4.3.3 Parameters, Validation and Verification

We obtained results in accordance with the propositions by normalizing the arguments of the evaluation-function 3.5 to $\mathcal{N}(1, 0.25)$ and normalizing the result by a Sigmund function to the range of [0,2]. As stated earlier in the habit section the outside-context weight is set to 0.25. We postulate the average evaluation learn-rate as 0.25 and agents differ in their learn-rate by an individual (learn-rate) weight. Figure 3.8 depicts an experiment that shows one of the effects of the evaluation module. We executed 300 simulation runs, half of the runs we used the evaluation module (green) and in half of the runs evaluation was always a stable 1.0 (red). At the end of each run (t=500) we calculated the fraction of agents eating meat. Introducing evaluation polarizes the model, the population has more chance to evolve in a complete meat-eating or complete vegetarian-eating society; related to this agents also have more chance to completely act habitual. This aligns the model with the third requirement, i.e. to match the polarizing effects of evaluation as found by Salganik et al. (2006).

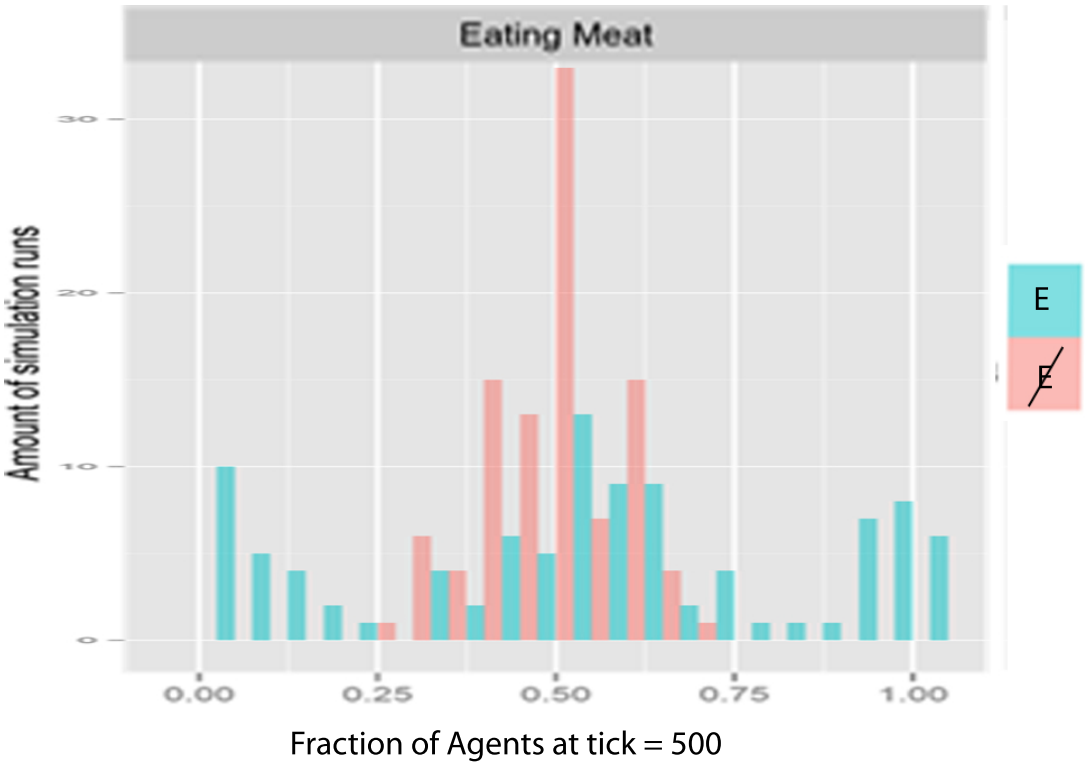


FIGURE 3.8: The graph shows the amount of simulation runs ending with a specific fraction of agents eating meat. The green bars show the results when the evaluated module is 'on' and the red bars where evaluation on a stable 1.0.

3.5 Deliberation of the Agent: Where and with Whom?

In this section we will describe the first two stages of the choice an agent makes: where he will eat (physical context) and with whom he will eat (social context).

The motivation to add this module is that with our object of study, the relation of an agent and its context, the control over that context seems central. Early simulations where an agent is placed in a fixed context show static uninteresting results: the agents behavior is often a direct and stable consequence of either the venue or value strength we assign to the agent. In reality, the agent gains a preference for a physical and social context and these preferences dynamically interact; with each other and with the choice of what they eat. For example, a meat-eating agent and their friends obtain the same preference for a meat venue. When this venue closes the agent follows his more open-minded friends to a vegetarian place, where under social pressure he changes his behavior.

Such dynamics might be best modeled by social practices. The choice of context can be seen as a social practice *an sich* with its own opportunities and habitual and intentional behavior. In this thesis the object of study is not the connection of social practices, as

such we try to simplify this complex topic. We simplify by seeing the choice of where and with whom to eat as a means to what to eat. Thus in this model, agents do not intentionally choose a fancy new venues or that interesting woman from work, but intentionally choose a location because it allows or helps them to eat meat or vegetarian.[5] In terms of social practices, the choice of context has no purpose of its own.

This simplification still allows the preference for agents and locations to dynamically interact, namely via habitual (and not intentional) preferences. The agent develops habits for certain venues and people. This habit information is maintained and in an analogue way to the earlier described habit model (section 3.4.1). This allows the central and interesting dynamic that an agent chooses a location or dining group (and consequently a dish) for other reasons than its originally assigned value.

3.5.1 Formal Model

First off, an agent is designated to a random home where, most of the time, he eats with the other agents that are part of the household. As a modeling choice agents do not coordinate if they will eat at home or not, but this is determined with a chance based on StatisticBrain (2015).

The agent then chooses his physical and social context. The order in which the agent does this is determined by a 'chooseOnPhysicalRate'-variable set. The size of the dining group is determined by a Poisson distribution based on average sizes of public groups as researched in Coleman and James (1961). Algorithm 3 depicts how an agent chooses his context.

The main difference between choosing firstly on the physical or firstly on the social context is in what we filter. An agent can choose the venue first and filter the dining group by which agents accept an invitation to that venue. The agent always accept an invitation if it serves their needs and sometimes (see section 3.6) if it does not. An agent can also first choose the dining group and then filter out the venues that not everybody accepts.

When picking a venue, or buddy to eat with, an agent considers its opportunities, which venue is open, who is available, its habits, with whom and where have I eaten

[5] Note that an agent can, in theory, intentionally choose a venue that gives it the opportunity, habit or intention to eat what it intentionally wants to eat. Wood and Neal (2007) speak of intentionally putting oneself in a context where one will act out of habit. In this thesis we limit ourselves by only looking at choosing a venue because it gives the opportunity to act upon ones intentions.

Algorithm 3 The algorithm to determine the dining location and group of an agent.

```
Require: a list of available agents to dine with CV, a list of venues to dine at CV
  chosenVenue = null
  diningGroup = {me}                                  ▷ choose physical context first
  if r > choosenOnPhysicalRate then
      chosenvenue = pickVenue(CV)
      while diningGroup.size() < groupSizeDistribution() do
          b = pickCandidateEatBuddy(CA)
          if b.acceptInvitation(chosenvenue) then
              diningGroup.add(b)
          end if
      end while
  else                                                ▷ choose social context first
      while diningGroup.size < groupSizeDistribution() do
          b = pickCandidateEatBuddy(CA)
          diningGroup.add(b)
      end while
      candidateVenues =
        filterOnGroupPreference(diningGroup, CV)
      chosenvenue = pickVenue(candidateVenues)
  end if
       return chosenVenue, diningGroup
```

before and its intentions, what venue or agent serves my dining needs, to make a decision. In the end the agent thus has a habitual and intentional preference for venues and agents that dynamically interact with their dining choice.

3.6 Values and their Correlation with Parameters

In this section we describe the relation between some parameters used in the model and the values of the agent. There are a number of processes in the deliberation where different agents might take a different approach. For example, some agents might have a stronger tendency to go into a habit, accept invitations faster or find it more important with whom they eat than where. As a modeling choice we normally distribute ($\mathcal{N}(1, 0.25)$) such tendencies over the agents. As mentioned in the background chapter (section 2.4) values cannot only be seen as triggers for actions, but also as criteria to guide the deliberation of an agent. In this model we thus have the opportunity to correlate these tendencies in a realistic way using values. The following table shows the correlation between values and parameters as postulated in this model; these correlations should be validated by empirical research in further work.

	habit threshold	individual evaluation	social evaluation	refuse invitation	priortize social context	learning speed	meat-eating	vegetarian eating
self-enhancement		+		+	-		+	
self-transendence			+	-	+			-
openness	-			-		+		
conservation	+		+	+		-		

TABLE 3.4: This table shows the correlation of the four values an agent has with certain parameters in the model. Note that the correlation with meat-eating and vegetarian eating is complex, as described in section 3.4.2.

Chapter 4

Validity of the Model

In this chapter we discuss the validity of the model. We define validity as that the model holds up to the requirements we set. These requirements should be set as to serve the research question. The first sub research question of this thesis is: can we explain the limited success of interventions that target intentions rather than context, with a model that uses the concepts of agents and social practices? The main requirement is thus that the model can explain the limited success of interventions that target intentions rather than context. When we say 'explain' we mean that the model should not only be able to reproduce the (macro) data, but also do this with (micro) concepts and mechanisms that hold up to literature and intuition. This is sometimes called aiming for structural validity instead of replicative validity (Troitzsch, 2004). [1] In this chapter we will explain how we have validated the micro concepts and mechanisms and after that we will show that our model matches the main macro requirement.

Let us first shortly discuss the difference between validation on quantitative or qualitative requirements. When validating on qualitative requirements one expects the model to reproduce the exact data from empirical experiments. When validating on quantitative requirements one expects that the model can reproduce ordinal or categorical relations between variables. For example, the requirement 'the higher one values self-enhancement, the higher the chance to eat meat' is qualitative, but the requirement that 'an agent reaches his maximum habit strength in 66 days' is quantitative. In this study we mostly validate on qualitative requirements. The reason for this is twofold. Firstly, precise data on contextualized decision making is often simply not available. For example, to our knowledge there is no longitudinal study on how many meat-eaters can be convinced to choose vegetarian dishes as a product of their context. Let alone that

[1] Note that complete 'structural validity' is not wished for. One does not want to copy the complete mechanism with which a system produces a result, but to simplify the system to its crucial aspects as to gain more insight.

such studies report on exact data on the context, habit strength and intention strength. Secondly, our aim is not to exactly match data on contextualized decision making, but to use rather high-level concepts to gain more insight in how in several scenarios humans might act in context. In principle it would be better to have exact data, but one can often question if this data is not a product of variables that are not interesting in this modeling exercise. It is important to recognize that we validate our model on qualitative requirements as this means that the relevance of our results can be at most qualitative as well and not quantitative.

Let us continue on the subject of validation of the micro-concepts and mechanism in light of literature and intuition, i.e. the structural validity of the model. In chapter 3 we have set out such requirements in light of the literature in chapter 2. In section 3.4.1.3, 3.4.2.3 and 3.4.3.3 we have shown that the separate modules hold up to these requirements and thus are valid. We acknowledge again that validity in these terms is limited. Foremost because we do not set out requirements on the *interaction* of these modules. We have set no such requirements because little is still known about how habits, intention and evaluation relate to each other and context. A formal model can help though in highlighting where gaps of knowledge exist (which will be further discussed in chapter 6). Moreover, simulations with this model highlight which modeling choices produce crucially different results and can thus give analytical evidence as to which choices to make when one wants to study certain macro-phenomena. In this case the macro-phenomena we want to study is the limited success of interventions that target intentions rather than context.

We will now thus describe a simulation experiment that confirms that our model can reproduce the limited success of interventions that target intentions rather than context, i.e. the replicative validity of the model. In table 4.1 one can see the parameters that are used in the experiment. The amount of agents, time of the simulation and end of the simulation are chosen as a result of exploratory experiments that show that these variables produce a balance between computational time, allowing the model to warm-up and stable results. We introduce a new variable, namely an 'Intention Modifier'. This variable acts as a weight to either the intention to choose a meat or vegetarian dish. Firstly, we induce a meat-eating orientated society by modifying the intention to eat meat.[2] Interestingly, as can be seen in figure 4.1 only a small intentional disposition towards meat-eating (10%) leads to a predominantly meat-eating society. This is due to the polarizing effects of habits and evaluation (as described in 3.4.3.3). Secondly, the

[2]The reason that we target the intention and not for instance the value is that we think this disposition can not be captured in just *one* of the variables that influence intention, but should be captured in an unknown, per scenario different, *distribution* over the variables that influence intention.

Table 4.1: Parameter settings used in the experiments described in this chapter.

Parameter	Value
Agents	30
End of Simulation (in ticks)	500
Time of Intervention	250
Intention Meat Modifier	1.2
Intention Vegetarian Modifier	1.0
Post-Intervention Meat Modifier	1.0
Post-Intervention Veg Modifier	1.2

intention modifier is used to simulate an intervention at tick 250. We model the intervention as to increase the intention to eat vegetarian and decrease the intention to eat meat. The result is shown in figure 4.1. The graphs shows that our model reproduces the limited effect of an intervention targeting intentions.

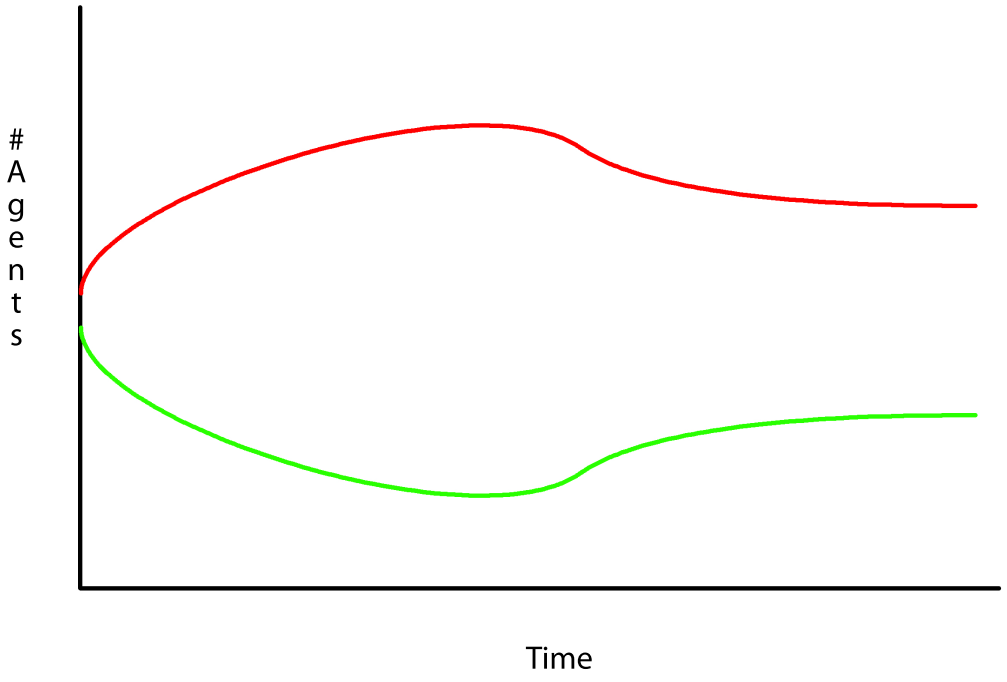


Figure 4.1: Simplified depiction of the amount of agents (y-axis) that eats meat (red) or vegetarian (green) dishes over time (x-axis). The agents are subject to habits, intentions and evaluation.

Given that we have a formal implementation we can now try to explain what happens. Firstly, when the model is edited as to simulate no gains in habit strength or change in evaluation an intervention on intentions would have the desired effect (see figure 4.2). This shows that in the model the inertia is an effect of the contextual decision making in the habit and evaluation module instead of an effect of the intention module. In particular, it shows that it is mainly the habits and context-dependent evaluation that

have an effect more than the opportunities in this scenario. This makes sense as the agents can always choose to go to a context where it has the opportunity to eat meat.

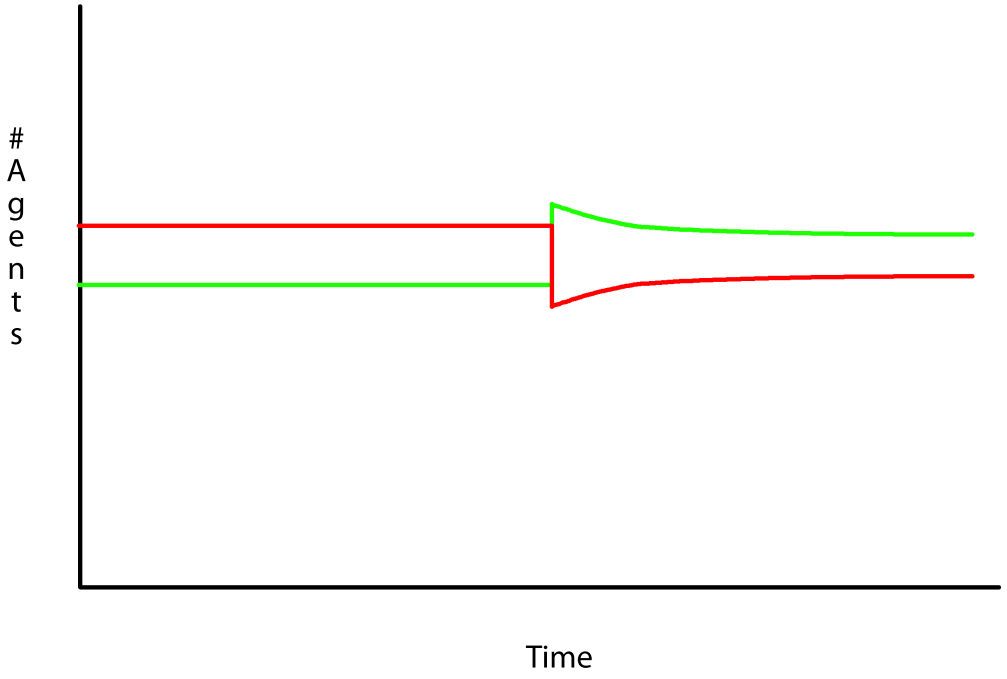


FIGURE 4.2: Simplified depiction of the amount of agents (y-axis) that eats meat (red) or vegetarian (green) dishes over time (x-axis). The agents are only subject to intentions and not habits or evaluation.

In figure 4.3 we show several graphs that can provide insight in why the intervention has a limited effect. In the top-left corner we see that the need to intentionally eat meat decreases and the need to intentionally eat vegetarian increases. Then why does the agent not change its behavior? In the top-right corner we see that the meat eating habit strength for most agents keep stable: the initial meat-eating habit does not change when the agent's intention does. The habit in fact only induces more automatic actions in line with the habit and thus strengthens itself. In this model an agent can only escape his habit for two reasons. Firstly, they could change their context, but by now the agent has a habit in its choice of context. For example, an agent might have settled by now on his favorite mixed venue where upon entering he automatically chooses a meat dish. As long as we do not intervene in the context this does not change. Secondly, the agent's evaluation of meat eating could decrease and as such they would pay more attention towards the action. When an agents puts more attention towards his action he has a chance of enacting his vegetarian intention instead of his meat-eating habit. As we can see in the graph in the bottom-left corner the agent's evaluation of meat-eating decreases a little, but apparently not enough. In the bottom-right corner we see why: although the individual evaluation (yellow) decreases the social evaluation (purple)

keeps rather stable. The agent thus thinks less of the eating meat when he compares it with its own intentions, but think its still 'okay' to eat meat because everyone else does it.

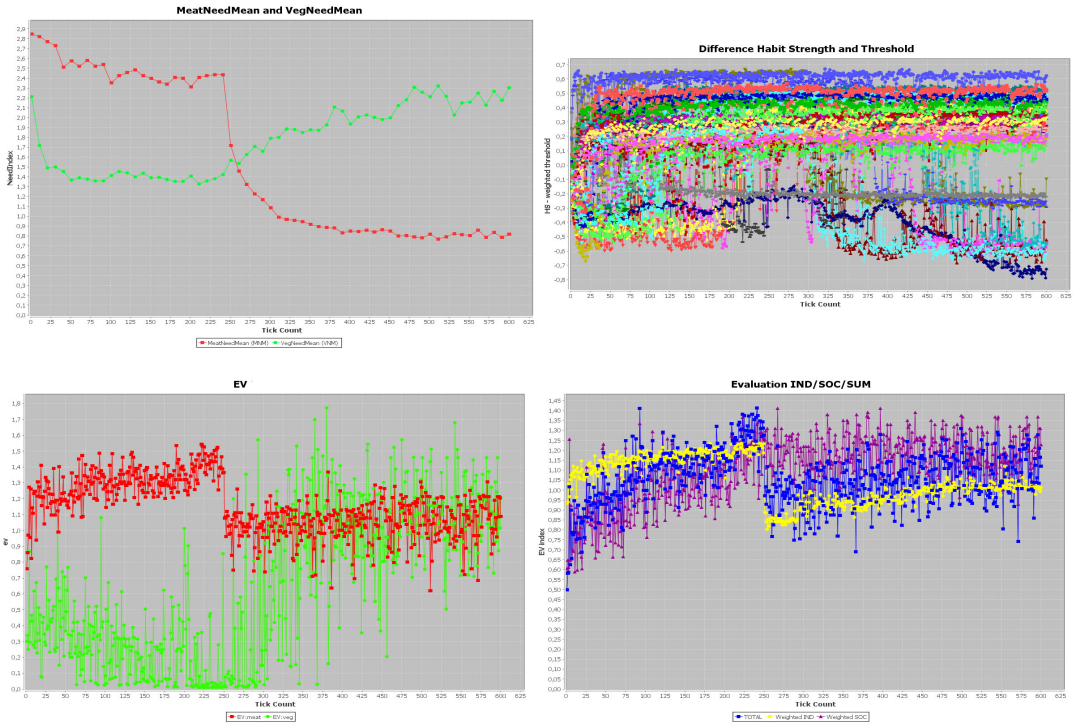


FIGURE 4.3: Four graphs that provide insight in the society inertia to keep eating meat after running an intervention that focuses intention. Topleft shows the avarage intentional need to eat meat (red) or eat vegetarian (green). Topright shows the difference between the agents meat habit strength and threshold over time. Bottomleft shows the agents avarage evaluation eating meat (red) or eating vegetarian (green). Bottomright shows the agents avarage evaluation of thier last action (blue) decomposed in a social component (purple) and an individual component (yellow).

We completed our first aim: to make a model that (1) explains the limited success of interventions focusing on intentions instead of context (2) represents contextualized decision making, (3) uses agents and social practices as a parsimonious framework and (4) is grounded in intuition and literature. We made this model to gain more insight in our main research question: how to improve interventions given the influence of context on decision making? We can already conclude two interesting aspects. Firstly, in this scenario context predominantly plays a role by triggering a stable meat-eating habit and a positive meat-eating evaluation and not so much in providing no opportunities to eat vegetarian. Secondly, although agents do evaluate meat-eating lower because it is not in line with their intentions, they do not escape their habits because they see that other agents keep doing the same behavior.

We take these two insights to our next sub research question: what happens if we aim our interventions on context? We will discuss the relevance and the generalization (outside the domain of meat-eating) of these insights and make suggestions for further work in chapter 6.

Chapter 5

Experiments and Results

In this chapter we will describe experiments revolving around the second sub research question: what happens if we aim interventions at the context? Our first aim is to show that our model is not only helpful in explaining why interventions on intentions *might not* work, but also in which context interventions *might* work. In the next section we firstly analyze our model and explain why simulating the model could help to gain insight in contextual interventions. In section 5.2 we describe the experimental set-up, i.e. with which parameters do we simulate in the hope of getting interesting results. In section 5.3 we describe the experiments we simulate. We show that in these simulations some contextual interventions (intuitively) work and others (surprisingly) do not, moreover we can explain with our model why some work and others do not. Our second aim is to use these results to gain more insight in how we can improve interventions given the influence of context. Note that to transpose the results from the experimental setting to the real world is often the most difficult step. We will contribute to our second aim by discussing the relevance of our results in the next chapter.

5.1 Model Pre-Analysis

In this section we would like to firstly analyze our model to gain insight in the interesting dynamics it encapsulates and secondly show that computer simulations could help to better understand the model.

In our model the agents' behavior is interconnected. That is, the behavior of one agent depends on the behavior of other agents. Firstly, because the social context of an agent can activate a habit. For example, eating with your friends automatically triggers ordering a hamburger. Secondly, because the social context of an agent can influence

an agent to evaluate its behavior as being better. For example, everyone around me eats meat so I do not question my own meat consumption. This means that if one agent changes its behavior this could influence another agent in changing his behavior eventually leading to a domino effect of change. Moreover, it is intuitively not easy to predict if an individual agent will change its behavior when we intervene in its context. For example, if an agent changes his location this might lead to new opportunities and the enactment of new intentions. However, the new location might also have the the same social context, the same evaluation or the same habits and eventually lead to the same behavior. In sum, it is difficult to analytically predict the behavior of agents due to their interconnectedness and the influence of multiple variables. Simulations could help to gain more insight into the model by capturing when and how a society globally changes his behavior.

Before we head into our experiments we want to explain it is almost impossible to make effective contextual interventions in a pre-dominantly meat-eating society if there is no intention to eat vegetarian. In other words, although empirical data shows (and our model explains) why interventions on intentions *alone* do not work, interventions on the context *alone* will probably not work either. There are several empirical studies that show that it is the combination of multiple interventions that brings significant results (Abrahamse et al., 2005). In the next few experiments we will thus study what (combination of) contextual interventions might have an effect given that (possibly due to other interventions) we already changed the intentions of the agents. This is a quite simplistic approach and we acknowledge that the complex interaction of intentional and contextual interventions could be interesting. For example, the timing of the two types of interventions might be relevant. We have done some exploratory experiments and the effects of the timing of such interventions had no significant effect in our model, but this is important to keep in mind for further work.

5.2 Experimental Set-Up

- Simulation with large groups of agents (e.g. 200) led to a seemingly random choice of venue and dining group, due to, among others, a lack of a complex social network. In our experiments we chose a group of 30 agents; which is big enough to show variation between agents and small enough to represent a group of people that know each other.
- Based on the modeling choices described in section 3.2 this results in 12 homes, 2 venues that serve a mixed menu (mixed venues), 1 venue that only serves meat

dishes (meat venues) and 1 venue that only serves vegetarian dishes (vegetarian venues).

- Based on exploratory experiments the simulation needs about 200 ticks to warm-up, we intervene at time-step 250 and end the simulation at time-step 800. In all the simulations it takes a while for interventions to have an effect, but in general the effects seem to plateau around 800 ticks. An intervention might even have an effect two years after it started, but within this study we are more interested in the immediate effects.
- Every intervention is modeled mainly as a change in intentions. Pre-intervention we modify the meat eating intention by multiplying it with 1.2, post-intervention we modify the vegetarian eating intention by multiplying it with 1.2 (and reducing the meat-eating modifier to 1.0).
- When comparing two experimental set-ups we run a simulation 100 times for each set-up and average over the different independent runs.

5.3 Experiments

We present three experiments that simulate possible interventions that target the context and might help facilitate interventions that target intentions. There are many interventions one can try and that might be interesting. We chose to present these three as they (1) show that simulations can produce results that are difficult to predict, but can be explained by the model and (2) bring interesting insights in how to improve interventions.

Our first two experiments comprise of two interventions that are easy to facilitate and intuitively expect to help the vegetarian cause. First we simulate what happens if we add extra vegetarian venues. For example, the government subsidizes new venues if they provide a vegetarian only menu. Second, we simulate what happens if we expand the menu of the meat venue to include vegetarian dishes. For example, the government subsidizes Kentucky Friend Chicken if it starts offering palatable vegetarian dishes.

We take several insights from these simulations and try to apply them to a short successful intervention. In this intervention the agents are invited to a vegetarian week challenge where, if they accept, they will eat vegetarian for one week. One advantage of such a simulation is that it is could be repeated a few times and easily combined with other longitudinal interventions.

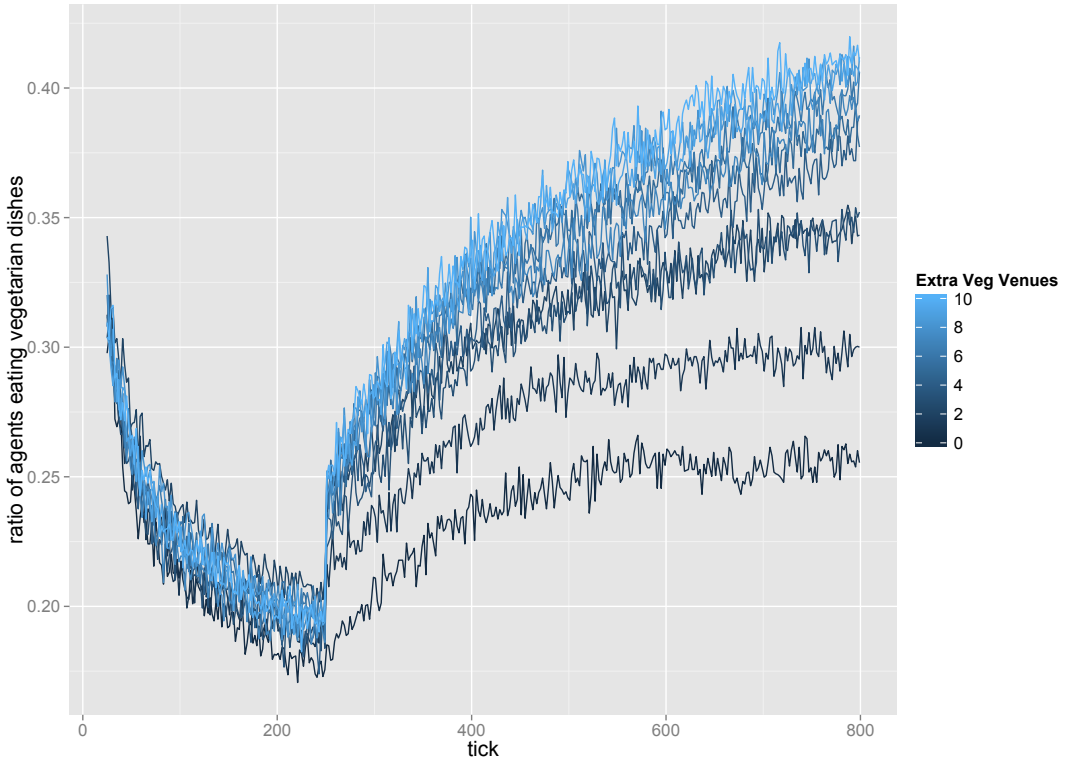


FIGURE 5.1: The ratio of agents eating vegetarian dishes (y-axis) over time (x-axis). We depict the results for interventions where a open 0 (control group) to 10 new vegetarian venues. The difference between opening 8 or 10 vegetarian venues results in no significant difference in vegetarian dining at timestep 800.

5.3.1 Increase the Amount of Vegetarian Venues

In figure 5.1 we depict how the ratio of agents eating vegetarian dishes increases as a result of the intervention. Before tick 250 the conditions for all the runs are the same; the difference that can be see in the graph up till tick 250 is thus purely a result of randomness. After tick 250 the bottom-line shows the only slight increase that happens when we only intervene on intentions (as described in chapter 4). The remainder of the results show that in general there is a positive correlation between an increase in vegetarian dining and the amount of vegetarian venues that are opened. The effect of opening extra vegetarian venues is only significant up to a certain amount. Furthermore, although there is a stronger intention to eat vegetarian than eat meat and we are opening extra venues at most our society plateaus at a 45% of vegetarian dining.

Given that we have our formal implementation we can try to trace why the agents in the model eat more vegetarian dishes, but not so much as their intention dictates. In the remainder of this subsection we take the intervention of adding 5 extra vegetarian venues as an example.

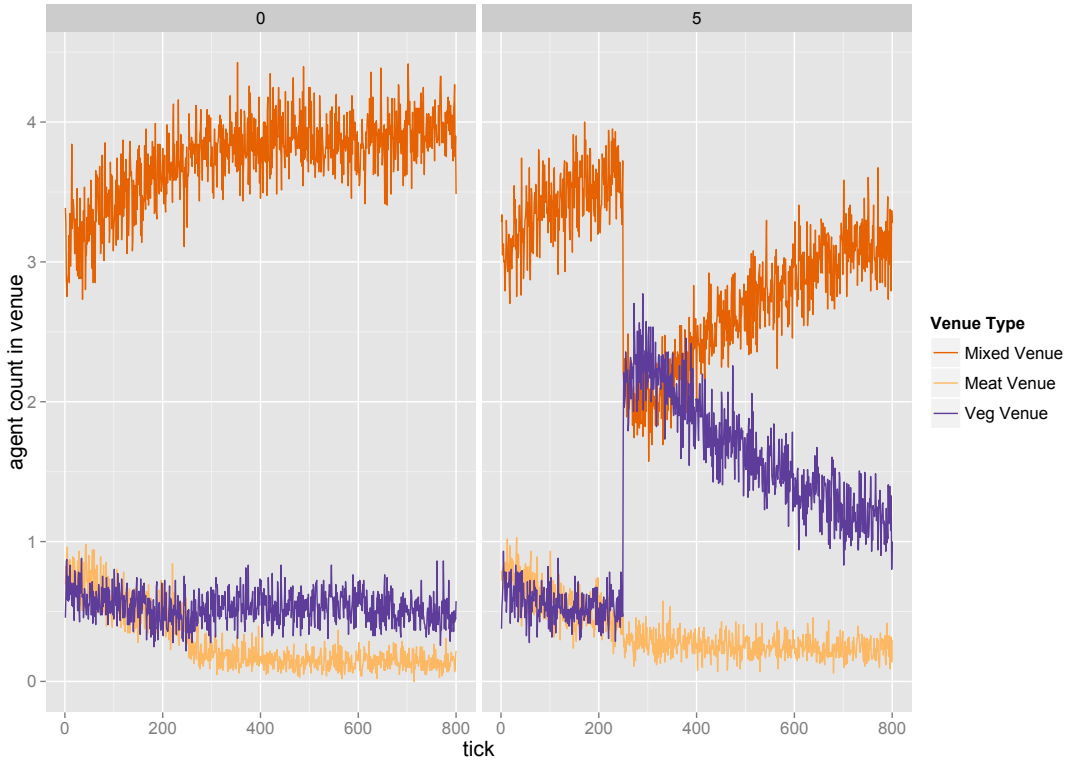


FIGURE 5.2: The ratio of agents per type of venue (y-axis) over time (x-axis). We depict the results for adding 0 (left) or 5 (right) vegetarian venues. Adding the venues causes agents to switch from mixed venues to vegetarian venues.

Let us first ask, do agents go to the new venues? In figure 5.2 we see that the amount of agents going to vegetarian venues increases. These agents seem to switch from the mixed venue to the vegetarian venue. This can be explained by the fact that when a group of agents intend to eat vegetarian they do not distinguish between a mixed venue or a vegetarian venue *by intention*. Thus given that there are now more vegetarian venues than mixed venues the agent has a high chance of going to a vegetarian venue. While the agent might have a habit to eat meat in the mixed venue, he does not have such a habit in the new venue and he intentionally chooses a vegetarian dish.

This raises three questions. Firstly, do the agents not differentiate between these venues by habit? In other words, one could expect that an agent has a habit for his old (mixed) venue and does not change his location to a new vegetarian venue as soon as it opens up. However, in this simulation habits for a location are not that common, moreover, they break easily (see figure 5.3). The fact that these habits break easily seems to be correlated to two insights. Firstly, agents are often invited to venues they would not go to out of habit. Secondly, they often accept such invitations although they would not go there out of habit. We leave further discussion of this point for the next chapter.
The second question arises from the fact that although there is a significant rise in the amount of agents going to vegetarian venues, it is too small (about 1 agent per day) to

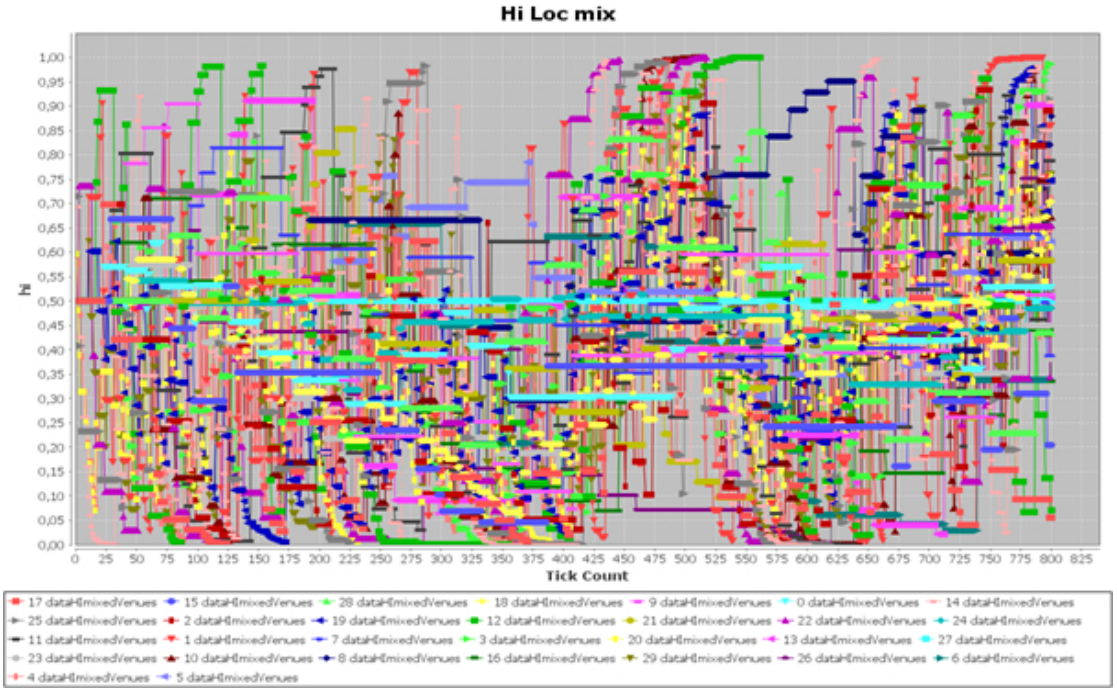


FIGURE 5.3: The habit strength (y-axis) over time (x-axis) in a mixed venue for each individual agent (colours). We can see that here and there agents do go into habits, i.e.. their habit strength is above the threshold (which is on avarage 0.62), but these habits are easily broken. Note that the horizontal bars are not stable habits, but an artifact caused when the habit strength is not updated for a while.

explain a 10% raise in vegetarian dining. Further exploration learns that this increase can be explained by the fact that the vegetarian dining in vegetarian venues transcends context. In other words, the agents who start eating vegetarian in vegetarian venues take this behavior back to mixed venues and more importantly, home (see figure 5.4). It is important to realize that although on average only 1 extra agent goes to a vegetarian venue, this could be a different agent each round. Every of these agents could take their new evaluation and new habits to their old context which might tip the scales in favor of vegetarian eating for other agents.

The third question that arises is: why is there a limit to the increase in vegetarian eating one can bring with vegetarian venues? To explain this it is important to realize that most agents still eat at home and at their old dining place, where they have meat-eating habits. Although some agents change their behavior and take that behavior to their old context, not enough agents switch their behavior to evaluate vegetarian eating as something entirely positive.

In sum, within our simulation opening up vegetarian venues slightly increases vegetarian dining as (1) more agents go to vegetarian venues and (2) some agents take the new vegetarian behavior to new context, but it increases only slightly as (3) agents mostly still eat at home or other venues where they have a meat eating habit.

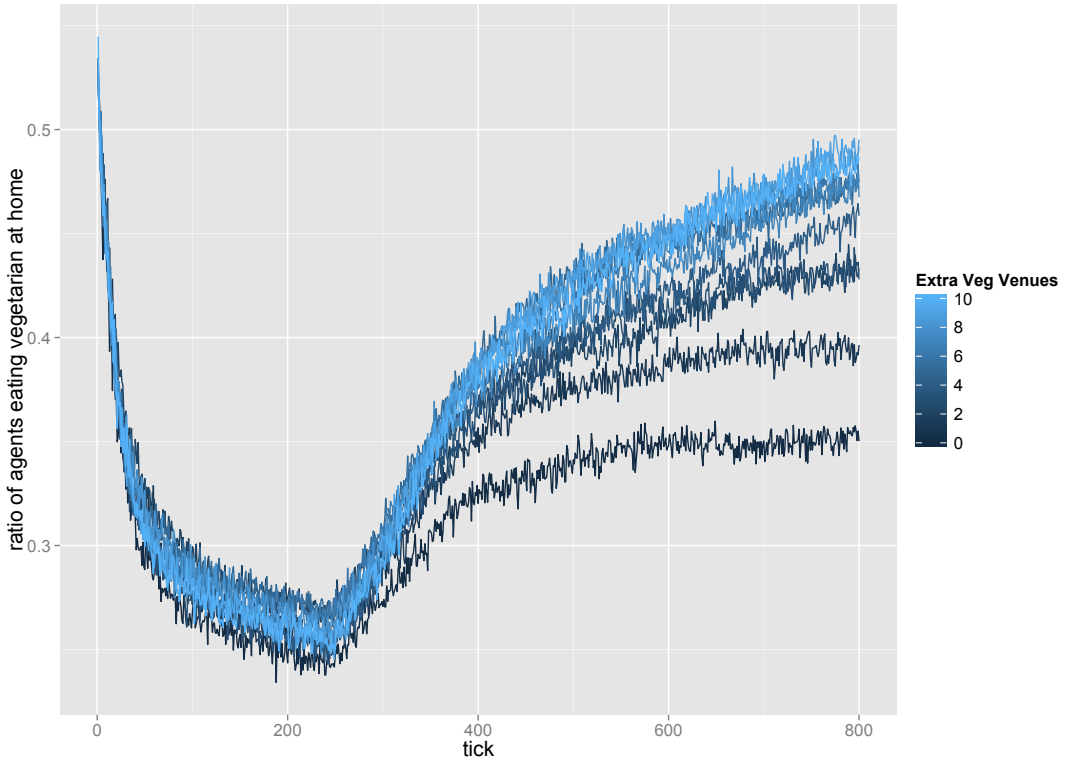


FIGURE 5.4: The ratio of agents that eat vegetarian *at their home* over time (x-axis). We depict the results for interventions where a open 0 (control group) to 10 new vegetarian venues. Adding venues does not only cause agents to go to vegetarian venues, but also influences how often they eat vegetarian at home.

5.3.2 Expand the Menu of the Meat Venue

In this section we describe the results of expanding the menu of the meat venue to incorporate vegetarian dishes. When we compare the experimental set-up to the control experiment of doing no contextual intervention we actually see a slight decrease, this is not significant though (p-value = 0.9196, see figure A.2). The first insight to explain that the effect is insignificant is that only few people go to the meat venue (see figure 5.5) pre-intervention. Thus even if those people change their behavior the effect is minor.

What we do see is that post-intervention slightly more people switch their preference from a mixed or vegetarian venue to a meat venue. Again, this can be explained because the choice is now, given their intentions, equal for them: the venues serve the same dishes. These agents do eat vegetarian at the venue, but at the same rate as they did before (see figure 5.6). As their is no new eating behavior the change does not effect their behavior at home either.

It is interesting that in the previous intervention the new context of the agent made them enact their new intention, i.e. eat vegetarian. While in this case the agent changes

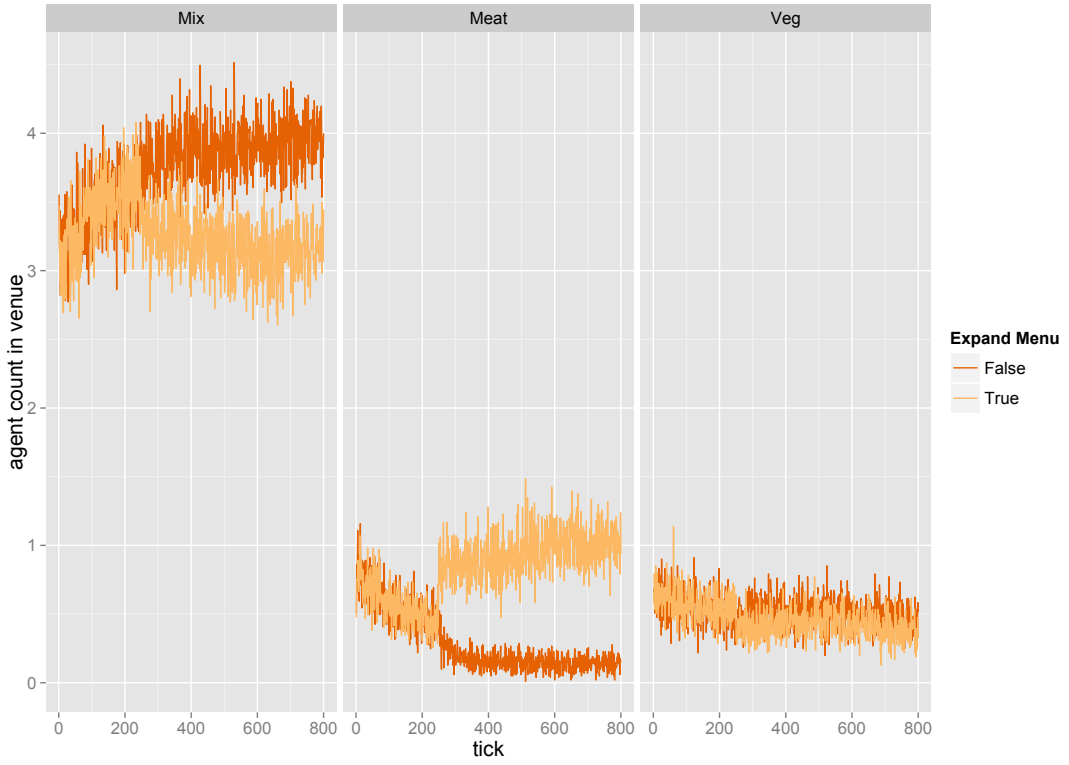


FIGURE 5.5: The amount of agents visiting a certain type of venue (y-axis) over time (x-axis). We depict the results for mixed, meat and vegetarian venues. We show the difference for no contextual intervention (dark-orange) and intervening by expending the menus of meat venues such that they also serves vegetarian dishes (light-orange).

its context, but as there is no restriction on its behavior, upon entering the context falls back in his old habit. In other words, when we present new possible locations to the agent where it can enact its intentions it seems to be important that upon entering we restrict the possibilities such that the agent cannot fall back in his old habits; because this can happen even if it deliberately chose this context to enact its new intention.

5.3.3 Organize an 'Eat Vegetarian' Week at a New Location

We can learn a few things from the previous interventions. First, agents might choose vegetarian locations out of intentions, while still having a meat eating habit. Their new vegetarian behavior might then transcend to other contexts. Second, when agents enter the new vegetarian location they should only be allowed to eat vegetarian, else their old meat-eating habit might transcend. Third, if we want to disrupt the habits of a larger part of society we need to make sure we affect the larger part of an agents routine, i.e. their home eating habits.

FIGURE 5.6: The ratio of agents eating vegetarian dishes for a certain type of venue (y-axis) over time (x-axis). We depict the results for mixed, meat and vegetarian venue's. We show the difference for no contextual intervention (dark-orange) and intervening by expending the menu's of meat venues such that it also serves vegetarian dishes (light-purple).

In this experiment an agent gets invited to a vegetarian week at a new location. It is promoted as a challenge, when it accepts the invitation he will commit to eat vegetarian for a week at the new location together with the other agents that accept the invitation. The agent accepts the invitation if he (1) intends to eat vegetarian *and* (2) a random number between 0 and 2 falls within his *AcceptRatio*. This *AcceptRatio* is normally distributed and correlated to his values as described in section 3.6. Every agent is initially invited once, but when an agent accepts the invitation he invites the other agents he often eats together with. As an example one can imagine the university offering such a vegetarian week: everyone who registers beforehand gets one week of free vegetarian meals in the university canteen. It is presented as a challenge, e.g. the meals are only free if one completes the whole week. If people accept the challenge they share this message on Facebook possibly leading to more participants.

We simulate for different means of the *AcceptRatio* and depict the results in figure 5.7. As the results show a vegetarian week can bring a significant raise in vegetarian dining. Surprisingly, an intervention of a week can have an effect up to two years after. The

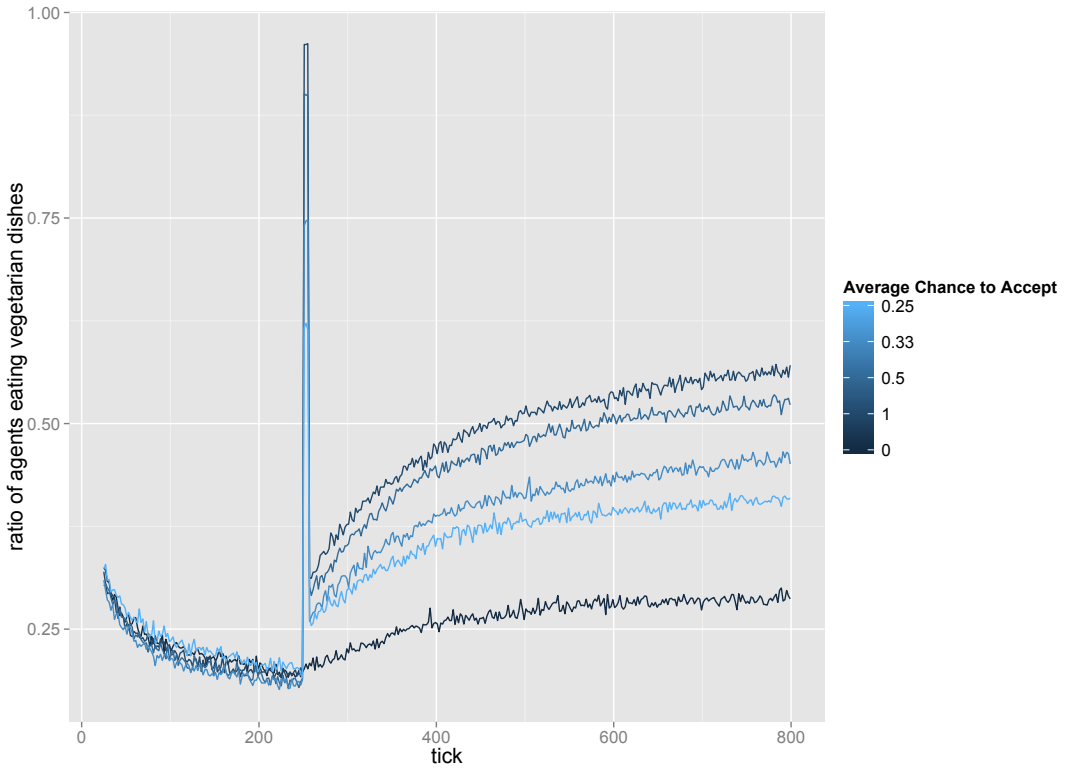


FIGURE 5.7: The ratio of agents eating vegetarian dishes (y-axis) over time (x-axis). At time step 250 we intervene by introducing a 'vegetarian week' that agents can accept or deny. We depict the results for different average chances of acceptance, where an average change of 0 means that there is no contextual intervention.

short burst in evaluation and disruption in habit invokes a chain reaction that consequently agents keep changing their behavior (although the chain reaction eventually wears off). We already discussed most of the insights that make this intervention to such a success. To summarize, the intervention works well because agents do intend to eat vegetarian and this interventions (1) calls upon this intention to lead them to a new location (2) where they cannot enact their old habit and (3) raises their vegetarian habit and evaluation for one week possibly pushing them away from old routines which effects later behavior.

One big advantage of this intervention compared to the previous two is that the intervention is short and we can thus repeat it or combine it with others to produce interesting effects. For example, in figure 5.8 we depict the results of doing the intervention again next year and in figure 5.9 of combining the intervention with opening vegetarian venues.

It is interesting to compare vegetarian weeks to a recent intervention proposed by some institutions called Meat Free Mondays.[1] The idea is that on Monday mixed venues do

[1] http://www.meatfreemondays.com/

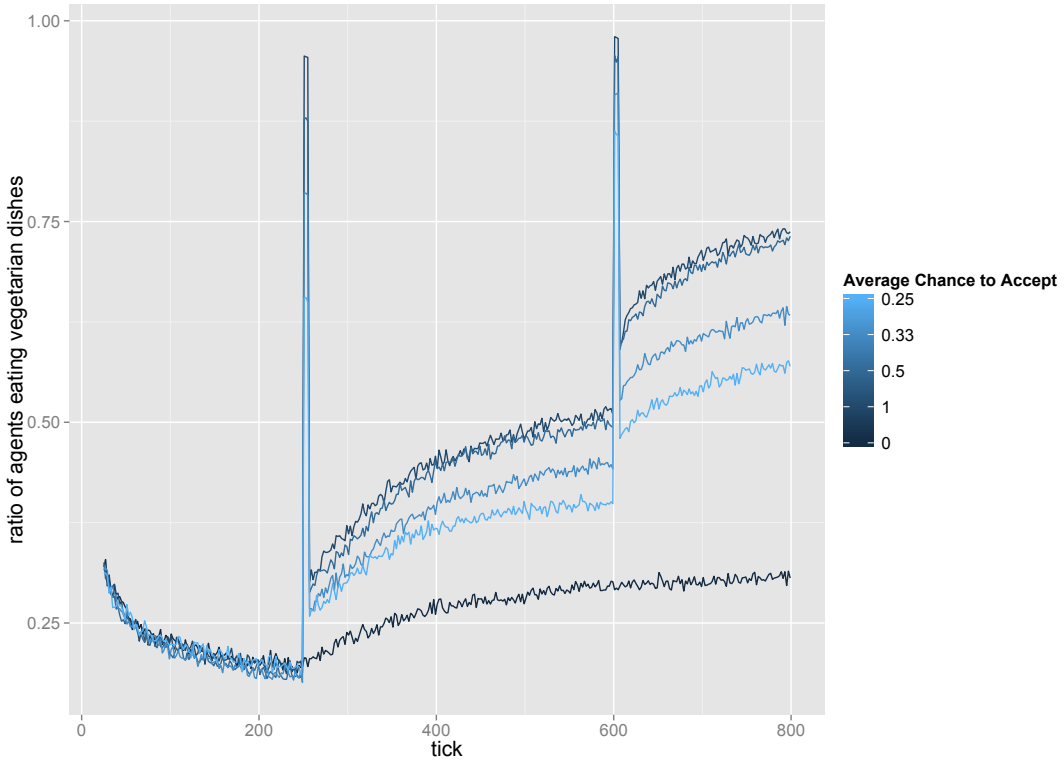


FIGURE 5.8: The ratio of agents eating vegetarian dishes (y-axis) over time (x-axis). At time step 250 *and* time step 600 we intervene by introducing a 'vegetarian week' that agents can accept or deny. We depict the results for different average chances of acceptance, where an average change of 0 means that there is no contextual intervention.

not offer meat dishes and that people are motivated to eat vegetarian at home. We simulate this intervention and depict the results in figure 5.10. Meat Free Mondays are quite effective as people keep going to mixed venue's by habit or (their primarily vegetarian) intention, but the mixed venue cannot trigger the meat eating habit anymore (similar to the insight obtained from the first two experiments). Within the range of the two years simulated they are less effective than a successful vegetarian week because this intervention does not disrupt the main part of the routine of the agent, i.e. eating meat at home.

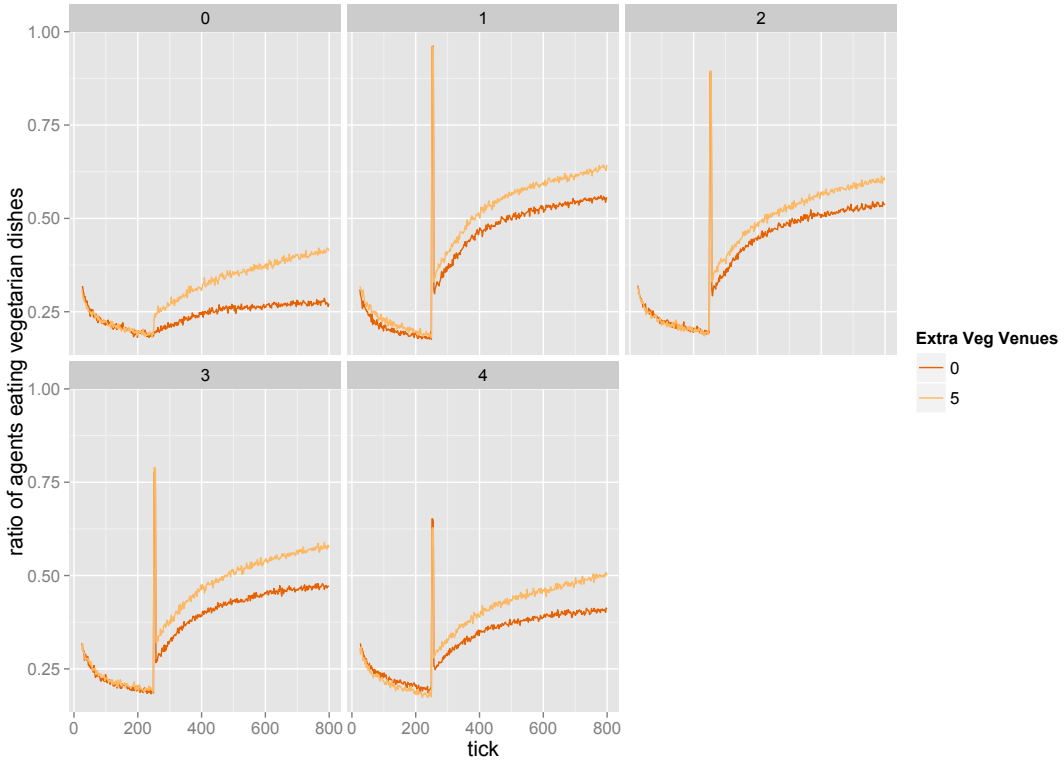


FIGURE 5.9: The ratio of agents eating vegetarian dishes (y-axis) over time (x-axis). At time step 250 *and* time step we intervene by introducing a 'vegetarian week' that agents can accept or deny. We depict the results for different average chances of acceptance, where an average change of 0 means that there is no contextual intervention. Per accept ratio we depict the difference between introducing no extra vegetarian venues (dark-orange) and 5 extra vegetarian venues (light-orange).

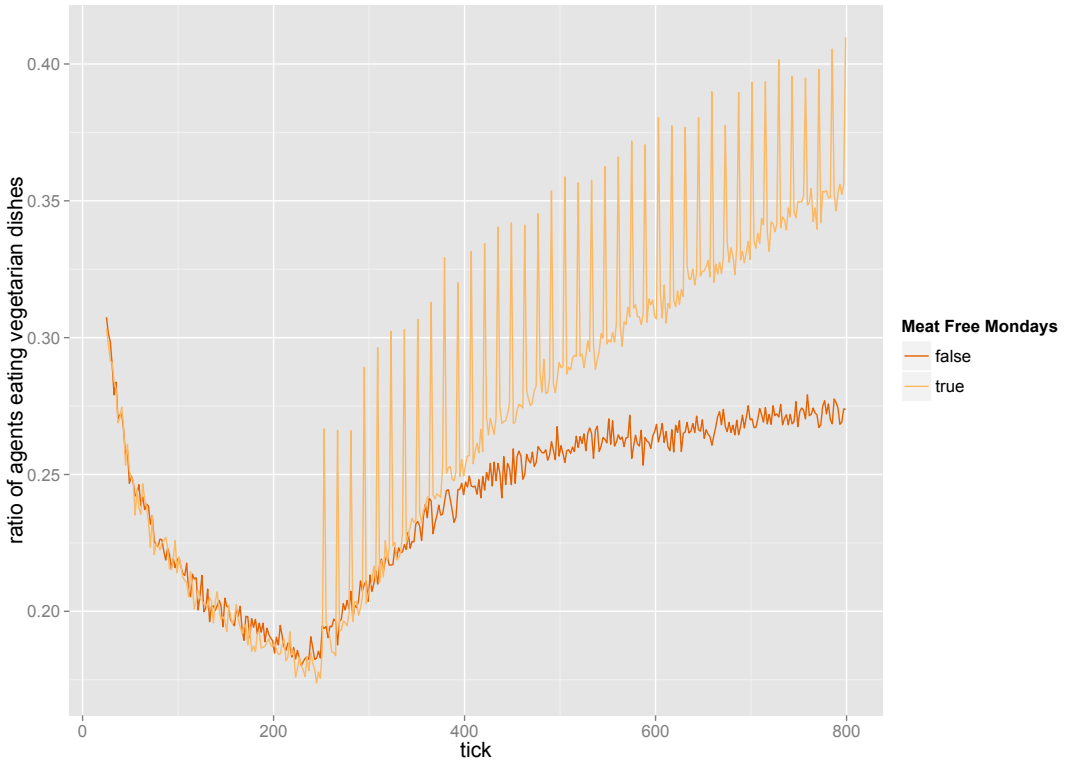


FIGURE 5.10: The ratio of agents eating vegetarian dishes (y-axis) over time (x-axis). At time step 250 we intervene on the context by introducing Meat Free Mondays.

Chapter 6

Discussion and Further Work

In the previous chapters we have shown a model for contextualized decision making and its use in explaining why some interventions might work where others do not. In this chapter we further our last aim: to discuss the relevance, limitation and generalization of the insights obtained in these chapters for our main research question: how can we improve interventions given the influence of context on decision making?

We would first like to make a note of carefulness. Results from agent-based simulations can rarely be translated one-to-one to the real world. We already discussed that our model uses qualitative facts and the insights obtained from it can thus be at most qualitative. We would like to add that the purpose of this study is not to exactly predict, but to provide more insight in the relation of variables and consequently give better direction to further work and policy. In the end it is extensive repeated empirical facts that can show if interventions worked (and even then often only in hindsight).

We indeed believe that this model has given us some interesting insights (and has shown that it can be the basis for more simulation experiments revolving around the influence of context). Firstly, we can conclude that although one might expect that increasing someone's opportunities is always helpful it can lead to very different results. In chapter 4 we concluded that in our model the limited success of interventions targeting intentions is a result of meat-eating habits and not so much a lack of opportunities to eat vegetarian. We can learn from this that although society has the opportunity to do the desired action, that does not mean it cannot grow a habit to do the opposite. This might seem obvious, but governmental contextual interventions often try to increase opportunities instead of breaking habits. For example, providing bike lanes, recycle bins, vegetarian food or green energy. Given the routines and habits of people such interventions are not enough. Moreover, as we have shown in chapter 5 increasing the opportunity can have very different effects. Changing the menu of meat venues to

incorporate vegetarian dishes had an insignificant effect, where increasing the amount of vegetarian venues had a significant positive effect. We can learn from this that even when an agent intentionally chooses a new context, if we do not restrict the possibilities the agent might fall back in his old habit. For example, one might move house partly because of the good available public transport, but without further motivation or restriction falls back in his old car use.

Secondly, temporarily disrupting the larger part of the routine and evaluation of behavior can lead to significant effects far after the intervention. As we have seen in chapter 4 one reason that the agent did not change his behavior is the self-reinforcing effects of habits and evaluation. In particular, we have seen that as the social context predominantly keeps consisting out of meat-eating agents, the agent does not even think about possibly changing their own habits to align with their new intentions. This point came back as one of the main possible defects of the first two experiments: the intervention does not break with the main routine of agents, i.e. to eat meat at home with their dominant peer group. In the last experiment we were able to temporarily break the main meat-eating habit and raise the (social) evaluation of vegetarian eating by placing agents in a new context with like-minded agents. Interestingly due to the interconnectedness of agents (and the nature of habit learning) such a small intervention can have effects far after it happened. Furthermore, it can be easily repeated without the effect falling off.

At this moment it is important to address an important limitation of this work. The previous insights depend on how habits and evaluation transcend context. Firstly, as agents might take their old (bad) habits and evaluation to new context. Secondly, as agents might take their new (good) habits and evaluation back to their old context. The transition of habits thus provides an opportunity to change behavior as well as a risk to keep doing the same behavior. As we described in section 3.4.1.1 and 3.4.3 little is known about how different context-actions and context-evaluations association are connected. In this model we simplified the influence of actions outside the current context by averaging over them and giving them a weighted influence. In further work it seems an important task for psychology to study how exactly habits transcends. For example, by what primary components do we dissect context and determine its similarity? This is an important question to determine the success of contextual intervention and in particular to determine if interventions in the public sphere might have an effect in the private sphere.

Thirdly, a crucial opportunity to break habits are moments where people can use their intentions to change their context. In our first experiment we have seen that agents go to the new vegetarian venues although it is not their habit to eat vegetarian. This is

because - in spite of meat eating habits - they are able to use their vegetarian intentions to choose their venue or accept an invitation. We already see this on small scale when people make plans to avoid context where they will do bad habits, e.g. the bar when one wants to study. Further work in psychology should study if indeed there are certain mechanisms, such as when invited, where one uses their intention and not their habits to make a decision. Note that their might be situations where one does not get invited to a new context, e.g. when there is such social cohesion that friends only present you with similar opportunities. In this model we did not use the concept of identity which seems to be a central mechanism needed to explain such social cohesion. However there might be more mechanisms than inviting that appeal to one's intentions to change their context. In further work a model which uses the concept of identity could be used to explore if such options still arise when there is strong social cohesion. Policy makers could use such mechanisms to motivate people to change their context and consequently their behavior.

In sum: providing new opportunities does not always have a positive effect, especially if it allows people to fall back in their old habits. Temporarily breaking someone's main routine and evaluation can have a long lasting effect. And lastly, a crucial opportunity to break habits is to appeal to people's intentions to change their context. In our last experiment (section 5.3.3) we have combined these elements in an intervention - the vegetarian week challenge - that promises great effects.

We would like to discuss a few more directions for further work. Firstly, as addressed in section 2.2 the interconnectedness of practices deserves more attention. In further work it is interesting to see how we can use a formal concept of social practices to model how choices in dining for example influence choices in shopping. As discussed in section 3.5 this could also help in modeling the relation between the practice of choosing context and the practices that are done within this context. Secondly, as addressed in section 2.2 the concept of social practices could be used to share information between agents. For example, agents might link self-enhancement more and more to meat-eating as they see that other people do so. Thirdly, we used the concept of values to postulate relations between certain variables as described in section 3.6. Further work could verify these relations with empirical results and further study the several function that values seem to have. These are not only important points to gain more insight in interventions, but in general to make a better model of social context-aware agents.

Lastly, we have used the example of meat-eating to illustrate our model. Some modeling choices have been made that apply to the specific scenario of meat-eating, e.g. data on how many times people act in the public sphere. We believe that the relations we

describe are about variables that are central to almost every scenario - location, people, intentions, habits - and can thus form the basis of every model. Having said this, note that to correctly extrapolate results careful case to case study is needed. For example, when one wishes to study the choice between using a car or bicycle it becomes more important what the relative location of people is and the mode should be adapted accordingly. Although this model might not be perfect in those situations one can always ask: what is your model?

Chapter 7

Conclusion

In this study we asked the question: how can we improve interventions given the influence of context on decision making? We focused on the influence of opportunities in giving opportunities and triggering habits.

To study this question we firstly asked ourselves: can we explain the limited success of interventions that target intentions rather than context, with a model that uses the concepts of agents and social practices?

In chapter 3 we presented such an an agent-based model that uses social practices on the micro level to give a parsimonious representation of contextualized decision making. We made sure that the model related to intuition and the literature discussed in chapter 2. In particular we studied two modes that play an important role in contextualized decision making: habits and intentions. We defined requirements for the model according to the studied literature and discussed where we had to make modeling choices. In particular we discussed that there is much unknown about the interconnectedness of context-action relations, which later showed to be a crucial ingredient in explaining the results. In chapter 4 we showed that the model indeed holds up to its main requirement - it can simulate the limited success of interventions that target intentions rather than context.

This model is firstly relevant because it helps in gaining insight in our main research question. For example, it showed us that in our scenario the limited success of interventions targeting intentions is a result of meat-eating habits and not so much a lack of opportunities to eat vegetarian. Furthermore, it showed us that although agents do evaluate meat-eating lower because it is not in line with their intentions, they do not escape their habits because they see that other agents keep doing the same behavior. This model is not only relevant because it helped us gain such insights, but also because

it answer the calls in several fields for an adequate model of contextualized decision making. For instance, it furthers the cause of Dignum and Dignum (2015) to make social agents that mimic the humans social nature and can efficiently plan in dynamic social context. Although as we discussed in section 2.2 and chapter 6 there is more work to be done on the topic of learning and the interconnectedness of social practices.

In chapter 5 we used to model to gain more insight in the question: what happens if we aim interventions at the context? We simulated opening extra vegetarian venues, changing the menu of the meat venue, and organizing a 'vegetarian week' at a new location. We showed that this model has great potential in explaining why some interventions on context might work where others do not. As we discussed in chapter 6 we already gained a few insights from these experiments. Firstly, providing new opportunities does not always have a positive effect, especially if it allows people to fall back in their old habits. Temporarily breaking someone's main routine and evaluation can have a long lasting effect. And lastly, a crucial opportunity to break habits is to appeal to people's intentions to change their context. We combined these insights in a 'vegetarian week' intervention that promises great effects (up till years after the intervention indeed.) We ended our discussion by explaining that such results largely depends on how habit transcends context and directed further work towards this crucial topic.

We conclude this study by stating that we hope this model will form the basis for many context-aware social agent models and that the resulting insights and the insights shared in this study will help policy makers to help prevent one of the most important problems humanity faces today: global warming.

Appendix A

Figures

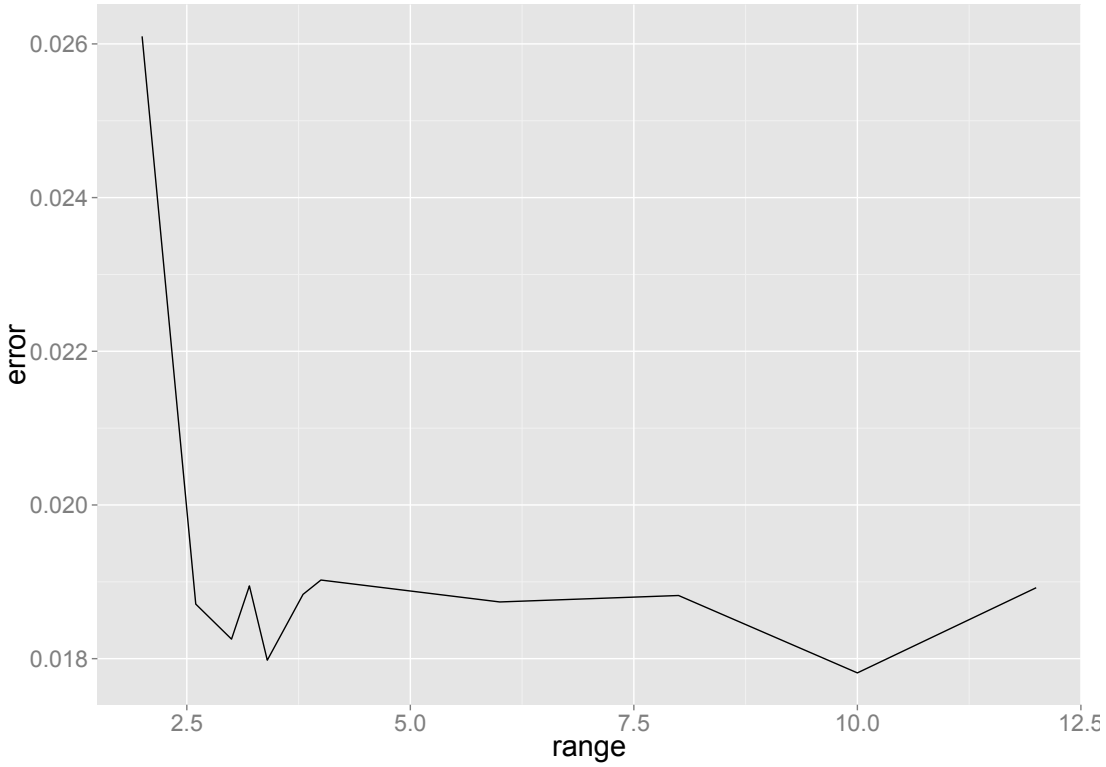


Figure A.1: Error as distance between desired action ratio and obtained action ratio expressed for different range (r) settings for satisfaction. The error is averaged over 500 simulation runs.

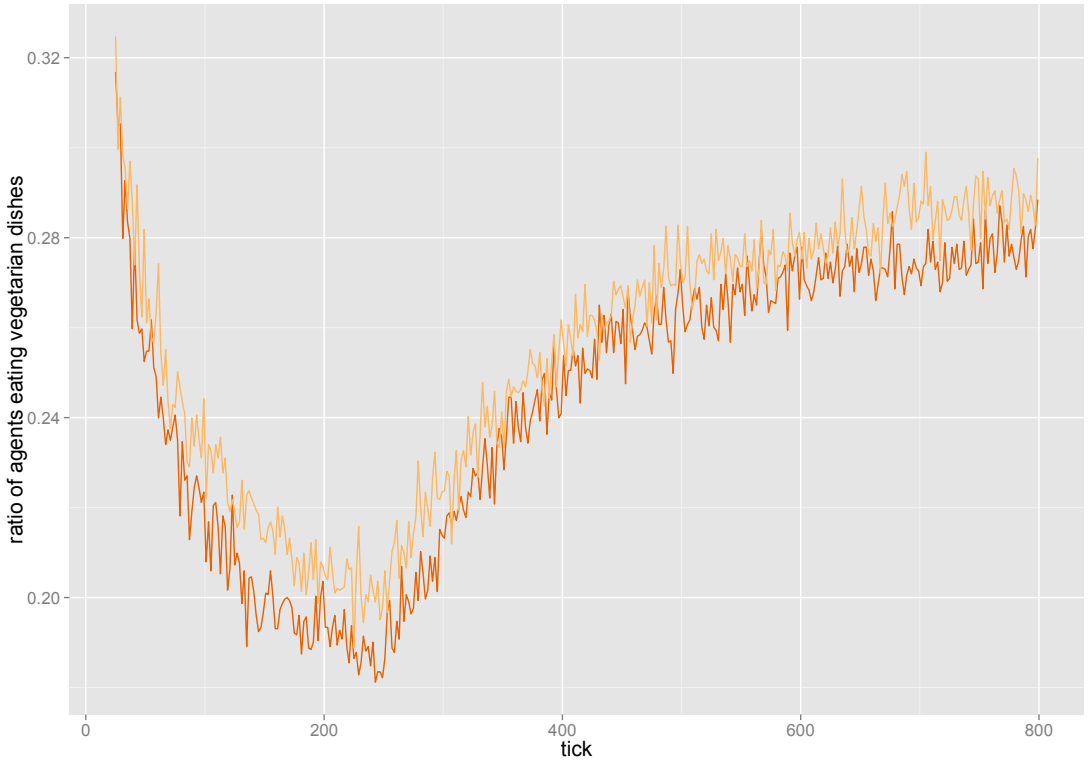


FIGURE A.2: The ratio of agents eating meat (y-axis) average over 100 runs over time (x-axis). We depict the difference when only intervenes by changing the agent's intention towards vegetarian eating (red) or when one also intervenes by changing the menu of meat venues to incorporate vegetarian dishes (green). The difference at time-step 800 is not significant (p-value =0.9196).

Bibliography

Robert Gifford. Environmental psychology matters. *Annu. Rev. Psychol.*, 65:541–79, 2014. ISSN 1545-2085. doi: 10.1146/annurev-psych-010213-115048. URL http://www.ncbi.nlm.nih.gov/pubmed/24050189.

Elke Stehfest, Lex Bouwman, Detlef P. Van Vuuren, Michel G J Den Elzen, Bas Eickhout, and Pavel Kabat. Climate benefits of changing diet. *Clim. Change*, 95(1-2):83–102, 2009. ISSN 01650009. doi: 10.1007/s10584-008-9534-6.

Christopher M Jones and Daniel M Kammen. Quantifying carbon footprint reduction opportunities for U.S. households and communities. *Environ. Sci. Technol.*, 45(9): 4088–95, may 2011. ISSN 1520-5851. doi: 10.1021/es102221h. URL http://www.ncbi.nlm.nih.gov/pubmed/21449584.

Intergov. Panel Climate Change. Climate Change 2014 Synthesis Report Summary Chapter for Policymakers, 2014. URL http://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5{_}SYR{_}FINAL{_}SPM.pdf.

Wokje Abrahamse, Linda Steg, Charles Vlek, and Talib Rothengatter. A review of intervention studies aimed at household energy conservation. *J. Environ. Psychol.*, 25: 273–291, 2005. ISSN 02724944. doi: 10.1016/j.jenvp.2005.08.002.

Mirra Seigerman. Manipulating Meat-Eating Justifications: A Novel Approach to Influencing Meat Consumption, 2014.

Linda Steg and Charles Vlek. Encouraging pro-environmental behaviour: An integrative review and research agenda. *J. Environ. Psychol.*, 29(3):309–317, 2009. ISSN 02724944. doi: 10.1016/j.jenvp.2008.10.004. URL http://dx.doi.org/10.1016/j.jenvp.2008.10.004.

Wendy Wood and David T Neal. A new look at habits and the habit-goal interface. *Psychol. Rev.*, 114(4):843–863, 2007. ISSN 0033-295X. doi: 10.1037/0033-295X.114.4.843.

Frank Dignum, R Prada, and GJ Hofstede. From autistic to social agents. *Auton. Agent. Multi. Agent. Syst.*, (Aamas):1161–1164, 2014a. URL http://dl.acm.org/citation.cfm?id=2617431.

G. Nigel Gilbert. *Agent-Based Models*. SAGE Publications, no. 153 edition, 2008. ISBN 1412949645. URL https://books.google.com/books?hl=nl{&}lr={&}id=Z3cp0ZBK9UsC{&}pgis=1.

Ana Luiza B Smolka. Social Practice and Social Change : Activity Theory In Perspective. *Hum. Dev.*, 44(6):362–367, 2001.

Virginia Dignum and Frank Dignum. Contextualized Planning Using Social Practices. *Unpubl. Artic.*, 2015.

Theodore R. Schatzki. *Social Practices. A Wittgensteinian approach to human activity and the social*. Cambridge: Cambridge University Press, 1996.

Elizabeth Shove, Mike Pantzar, and Matt Watson. *The Dynamics of Social Practice: Everyday Life and How it Changes*. SAGE Publications, London, 2012. ISBN 9780857020437. doi: 10.4135/9781446250655.n1.

Bente Halkier. A practice theoretical perspective on everyday dealings with environmental challenges of food consumption. *Anthropol. food*, (S5), 2009. ISSN 1609-9168.

Nigel Gilbert and Tina Balke. How Do Agents Make Decisions ? A Survey Introduction : Purpose & Goals Dimensions of Comparison. *JASS*, 17, 2014.

Virginia Dignum, Catholijn Jonker, Rui Prada, and Frank Dignum. Situational Deliberation Getting to Social Intelligence. In *Work. Soc. Sci. Soc. Comput. Sci. Two Sides Same Coin, Guildford, England, 23-24 June 2014*, 2014b.

Andreas Zimmermann, Andreas Lorenz, Reinhard Oppermann, and Sankt Augustin. An Operational Definition of Context. In *Context. Proc. 6th Int. Interdiscip. Conf. Model. using Context*, pages 558–571, 2007. ISBN 978-3-540-74254-8. doi: 10.1007/978-3-540-74255-5{_}42.

J Stanley Black, Paul C Stern, and Julie T Elworth. Personal and Contextual Influences on Household Energy Adaptations, 1985. ISSN 0021-9010.

Unna N Danner, Henk Aarts, and Nanne K de Vries. Habit vs. intention in the prediction of future behaviour: the role of frequency, context stability and mental accessibility of past behaviour. *Br. J. Soc. Psychol.*, 47(Pt 2):245–265, 2008. ISSN 0144-6665. doi: 10.1348/014466607X230876.

Lean O'Brien and Yoshi Kashima. Transformation to low carbon living. *Unpubl. Lit. Rev.*, 2015.

Sebastian Bamberg and Peter Schmidt. Regulating Transport : Behavioural Changes in the Field. *J. Consum. Policy*, 22:479–509, 1999.

Satoshi Fujii and Ryuichi Kitamura. What does a one-month free bus ticket do to habitual drivers? An experimental analysis of habit and attitude change. *Transportation (Amst).*, 30(1):81–95, 2003. ISSN 1572-9435. doi: 10.1023/A:1021234607980. URL http://link.springer.com/article/10.1023/A{%}3A1021234607980.

Phillippa Lally, Cornelia H M Van Jaarsveld, Henry W W Potts, and Jane Wardle. How are habits formed: Modelling habit formation in the real world. *Eur. J. Soc. Psychol.*, 40(6):998–1009, 2010. ISSN 00462772. doi: 10.1002/ejsp.674.

H C Triandis. Values, attitudes, and interpersonal behavior. *Nebr. Symp. Motiv.*, 27: 195–259, jan 1980. ISSN 0146-7875. URL http://www.ncbi.nlm.nih.gov/pubmed/7242748.

Martin Fishbein and Icek Azjen. *Predicting and Changing Behavior: The Reasoned Action Approach*. Taylor & Francis, 2011. ISBN 9781136874734.

Shalom H Schwartz. An Overview of the Schwartz Theory of Basic Values An Overview of the Schwartz Theory of Basic Values. *Online Readings Psychol. Cult.*, 2:1–20, 2012. ISSN 2307-0919. doi: http://dx.doi.org/http://dx.doi.org/10.9707/2307-0919.1116.

TL van der Weide. Arguing to motivate decisions. *SIKS Diss. Ser.*, 2011. URL http://www.narcis.nl/publication/Language/EN/id/170/RecordID/oai:dspace.library.uu.nl:1874/210788.

Francien Dechesne, Gennaro Di Tosto, Virginia Dignum, and Frank Dignum. No smoking here: values, norms and culture in multi-agent systems. *Artif. Intell. Law*, 21 (1):79–107, aug 2012. ISSN 0924-8463. doi: 10.1007/s10506-012-9128-5. URL http://link.springer.com/10.1007/s10506-012-9128-5.

Gennaro Di Tosto and Frank Dignum. Simulating social behaviour implementing agents endowed with values and drives. In *Multi-Agent-Based Simul. XIII*, pages 1–12. Springer Berlin Heidelberg, 2013.

J. I M De Groot and Linda Steg. Relationships between value orientations, self-determined motivational types and pro-environmental behavioural intentions. *J. Environ. Psychol.*, 30(4):368–378, 2010. ISSN 02724944. doi: 10.1016/j.jenvp.2010.04.002. URL http://dx.doi.org/10.1016/j.jenvp.2010.04.002.

Florian G. Kaiser and Katarzyna Byrka. Environmentalism as a trait: Gauging people's prosocial personality in terms of environmental engagement. *Int. J. Psychol.*, 46(1): 71–79, 2011. ISSN 0020-7594. doi: 10.1080/00207594.2010.516830.

Taciano L. Milfont and Valdiney V. Gouveia. Time perspective and values: An exploratory study of their relations to environmental attitudes. *J. Environ. Psychol.*, 26 (1):72–82, 2006. ISSN 02724944. doi: 10.1016/j.jenvp.2006.03.001.

Andreas Nilsson, Chris von Borgstede, and Anders Biel. Willingness to accept climate change strategies: The effect of values and norms. *J. Environ. Psychol.*, 24(3):267–277, 2004. ISSN 02724944. doi: 10.1016/j.jenvp.2004.06.002.

A. M. Nordlund and J. Garvill. Value Structures behind Proenvironmental Behavior. *Environ. Behav.*, 34(6):740–756, 2002. ISSN 0013-9165. doi: 10.1177/001391602237244.

P. W. Schultz. Values and their Relationship to Environmental Concern and Conservation Behavior. *J. Cross. Cult. Psychol.*, 36(4):457–475, 2005. ISSN 0022-0221. doi: 10.1177/0022022105275962.

Annika M. Nordlund and Jörgen Garvill. Effects of values, problem awareness, and personal norm on willingness to reduce personal car use. *J. Environ. Psychol.*, 23(4): 339–347, 2003. ISSN 02724944. doi: 10.1016/S0272-4944(03)00037-9.

Thomas L. Webb and Paschal Sheeran. Does changing behavioral intentions engender behavior change? A meta-analysis of the experimental evidence. *Psychol. Bull.*, Vol 132(2):249–268, 2006. doi: http://dx.doi.org/10.1037/0033-2909.132.2.249.

Statista. Average size of households in the U.S. 1960-2014, 2015. URL http://www.statista.com/statistics/183648/average-size-of-households-in-the-us/.

Michel C A Klein, Nataliya Mogles, Jan Treur, and Arlette Van Wissen. A computational model of habit learning to enable ambient support for lifestyle change. *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, 6704 LNAI(PART 2):130–142, 2011. ISSN 03029743. doi: 10.1007/978-3-642-21827-914.

Heather Barnes Truelove, Amanda R. Carrico, Elke U. Weber, Kaitlin Toner Raimi, and Michael P. Vandenbergh. Positive and negative spillover of pro-environmental behavior: An integrative review and theoretical framework. *Glob. Environ. Chang.*, 29:127–138, 2014. ISSN 09593780. doi: 10.1016/j.gloenvcha.2014.09.004. URL http://linkinghub.elsevier.com/retrieve/pii/S0959378014001599.

Valerie Braithwaite. Beyond Rokeach's Equality-Freedom Model: Two-Dimensional Values in a One-Dimensional World. *J. Soc. Issues*, 50(4):67–94, jan 1994. ISSN

00224537. doi: 10.1111/j.1540-4560.1994.tb01198.x. URL http://doi.wiley.com/10.1111/j.1540-4560.1994.tb01198.x.

Matthew J Salganik, Peter Sheridan Dodds, and Duncan J Watts. Experimental study of inequality and unpredictability in an artificial cultural market. *Science*, 311(5762): 854–856, 2006. ISSN 0036-8075. doi: 10.1126/science.1121066.

Robert B. Cialdini, Raymond R. Reno, and Carl A. Kallgren. A focus theory of normative conduct: Recycling the concept of norms to reduce littering in public places. *J. Pers. Soc. Psychol.*, 58(6):1015–1026, 1990.

StatisticBrain. Dining Out Statistics — Statistic Brain, 2015. URL http://www.statisticbrain.com/dining-out-statistics/.

James S Coleman and John James. The Equilibrium Size Distribution of Groups. *Sociometry*, 24(1):36–45, 1961.

Klaus G. Troitzsch. Validating Simulation Models. In *Proc. 18th Eur. Simul. Multiconference Networked Simul. Simul. Networks, SCS Publ. House*, pages 265—-270, 2004. URL http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.143.6554.