

Documentation of an agent-based model to generate social practices

Georg Holtz

Institute of Environmental Systems Research, University of Osnabrück, Germany

gholtz@uos.de

Conceptual framework

The conceptual framework outlined in the following is based on resp. inspired by social practice theories. Specifically it includes the components proposed by Shove and colleagues (e.g. Shove and Pantzar 2005), individuals who integrate these components in the performance of practices, and processes linking the components. Social practices themselves are chosen not to be part of the conceptual model but are understood as emergent properties which should be generated by the (simulation) model. In the following the components are introduced. Then the concept of “coherence” is developed which will be referred to in several processes, and finally a set of processes which contribute to the emergence of coherent practices and their diffusion is proposed.

Components of practices and individuals

The components used are taken from Shove and Pantzar (2005) and Røpke (2009) and define three broad categories of elements of practices: *material*, *meaning* and *competence*. In empirical studies, these components encompass various more fine grained elements that are linked within but also across these components to form a ‘block’ of interconnected elements – the practice. For sake of simplicity and because no generalised systematic account of elements exists the model operates on the level of components and does not differentiate the involved underlying elements. The following describes the components and illustrates them with the example of “going to work”:

- *Material* covers all physical aspects of the performance of a practice, including the human body. It is a sequence of bodily activities involving the usage of material artefacts. For example, one may go to work by car individually, by car-pooling, by bike or by bus. Material then covers all kind of activities such as going to the bus stop, buying a ticket, taking a seat, signalling the bus driver to stop, etc.
- *Meaning* incorporates the issues which are considered to be relevant with respect to that material, i.e. the understandings, beliefs and emotions. Issues of relevance associated with the travel mode of going to work are for example: price, environmental effect, social status and flexibility. Someone going by bus regularly may associate it with being cheap, having time for reading, or enjoying the company of others.
- *Competence* incorporates skills and knowledge which are required to perform the practice. Examples are driving skills, cycling skills, and knowledge about public transport routes. For example, the bus user knows where the bus stop is, which ticket is cheapest, which bus number to take, and where to get off the bus.

The components are integrated by *individuals* who carry out a practice. The *individual* is considered to be an “empty” container in which meaning and competences are embedded and evolve, and which adopts a material, making the practice as composition of components complete.

Coherence

It is proposed that “coherence” of the components involved in a practice is required for a practice to be successful, i.e. to persist and to spread. The coherence of a practice is a central concept of the framework and has been elaborated in Holtz (2012a). It is rooted in the idea that practices are routine

behaviour and therefore, by definition, a successful practice must encompass elements whose specific constellation facilitates such routine behaviour. A “working” routine implies that the individual does not experience any (strong) inconvenience when performing the respective behaviour. Coherence is an umbrella for the respective required complementarities of the involved elements. It is argued that (at least) two conditions have to be met:

First, coherence relates to the phenomenon of cognitive consistency (Read & Simon 2012). A routinely performed social practice with neither change in behaviour nor reflection of behaviour implies that the individual does not experience (strong) cognitive dissonance (Cooper 2007; Festinger & Carlsmith 1959). Cognitive dissonance indicates that what you do is inconsistent with what you think (you should do) and is experienced as unpleasant psychological tension that provokes change in either behaviour or mind set. The hypothesis derived from these considerations then is that a set of complementary elements that forms a coherent and successful practice must not contain elements whose combination provokes cognitive dissonance. In terms of the components approach introduced this means that *material* and *meaning* must fit.

Second, routine behaviour implies that people do not act based on well-deliberated conscious decisions but based on habits, i.e. behaviour which is efficiently, effortlessly, and unconsciously repeated or transferred from similar situations to the current situation (Aarts, Verplanken, & Knippenberg 1998). Acting without major cognitive effort is only possible if the individual has acquired the appropriate skills and knowledge through experience (Anderson 1982). That means that *competence* and *material* must “fit”.

It is assumed that the “fit” of component constellations and the entailed effects on routine behaviour are rooted in fundamental traits of the human body or in deeply ingrained aspects of the respective culture. I.e. it is assumed that it is similar for all individuals in the analysed system whether certain constellations of components induce cognitive dissonance and whether skills and knowledge are appropriate for the respective behaviour. The coherence of a practice then measures the level to which its three components fit and therefore indicates how smooth the respective routine behaviour goes. If a practice has a high coherence the individual does not experience urge to change anything, likely acts habitually¹, and reproduces the practice over time.

Processes

SPT do not provide a systematic account of processes involved in the emergence and diffusion of social practices. Therefore, the processes which are proposed in this section are deduced from two basic characteristics of social practices: they are routine behaviour and they are socially shared. Furthermore, it is considered that the processes should capture how coherent bundles of components arise and constitute practices, and that they should account for the recruitment of an individual to a practice as well as path-dependency of individuals’ involvement in practices. Assuming that an individual chooses among a set of practices according to some sort of criteria would re-introduce an individualistic account which is add odds with a (strict) interpretation of SPT (Røpke 2009). More in line with SPT are approaches which highlight that an individual’s experience with and involvement in practices influences strongly whether the individual is open for being recruited to a specific practice. The individual’s involvement in some practice for a certain amount of time leaves traces in the individual, such as acquired knowledge and skills and the accumulation of material artefacts. These “sediments” make it easier and more likely to become involved in some practices but not in others.

In total, five abstract processes are proposed that link components of practices in and across individuals. Similar to the components, the proposed processes identify broad areas of interest which

¹ See below for the connection between coherence and habitual behavior.

need to be considered to understand social practices. The empirical counterparts to these abstract processes may vary between empirical cases and one abstract process may incorporate several distinct empirical processes which have similar effects.

Three processes are derived from social practices being routine behaviour:

- *Adapt meaning to material*: for developing routine behaviour in the first place some process needs to be active that enhances cognitive consistency. The framework developed here therefore considers processes which adapt *material* and *meaning* and may work in both directions: *material* is adapted to *meaning*, or *meaning* is adapted to *material*. Empirically, both can be observed (Steg & Tertoolen 1999). For example, an individual who learns about the environmental effects of car use may choose to go by bike in the future (see *adapt material* below). But it has also been shown that environmental awareness decreased among car users after receiving information about the negative environmental effects of car use (Tertoolen, Van Kreveld, & Verstraten 1998), i.e. *meaning* is adapted to *material*.
- *Adapt competence to material*: in order to be able to develop a new routine after some change in *material* an adaptation of *competences* to *material* is required, i.e. some kind of learning in a broad sense has to take place. For example the introduction of a congestion charging scheme in London in 2003 and the parallel programme of investment in public transport changed the routine mobility behaviour of people living in the area of London (Shove & Walker 2010). After introduction of these policies a great amount of people shifted to a different travelling mode. Car usage declined considerably and the usage of bicycles increased strongly in the respective area. This involves the acquisition or improvement of respective cycling skills, identification of proper routes, and potentially improvement of physical fitness.
- *Habituation*: When behaviour is performed repeatedly it becomes habitual and is guided by automated cognitive processes (Aarts et al. 1998; Jager 2003). The situation in which the individual finds itself and its goals function as a stimulus which directly trigger a specific behavioural response, without reflection of alternative possible behaviours and respective evaluation and choice of the best behaviour (Aarts et al. 1998). Considering this, two different modes of behaviour are included: deliberate choice (of a material component) and habitual behaviour (keep currently used material component). The situation-goal-response connection is reinforced if the outcome of the habitual behaviour is satisfactory for the individual. The framework hence includes for each individual a “level of habituation” which increases through an individual’s repeated usage of the same material. The higher the level of habituation the lower the chance that the individual critically evaluates and potentially changes her behaviour. With regard to this “choice” between habitual behaviour and deliberate choice (and the respective invocation of *adapt material* described below) the level of habituation interacts with the coherence of the current practice. A high coherence reduces the chance for deliberate choice because it implies that the practice works and the individual does not feel the urge to change anything, i.e. is less inclined to rethink her previous choices. A high level of habituation also reduces the chance for deliberate choice because it implies that information that might indicate incoherence of the current practice is not perceived or processed by the individual (Aarts et al. 1998; Jager 2003). The interaction between coherence and level of habituation is hypothesised to be that the stronger the habit, the stronger a mismatch between components (low coherence) must be to break the habit, i.e. to invoke deliberate choice.

Two more processes that link practices of different individuals can be derived from the observation that practices are socially shared:

- *Adapt material*: individuals may observe the activities and material artefacts used by others and adapt their own *material* accordingly. It is proposed that individuals tend to not engage in a deliberate choice process but simply keep the current *material* component if their current practice is coherent and/or if they have developed a strong habit (see *habituation*). Change of behaviour is considered once a deliberate choice is invoked for one reason or the other. It is suggested that the individual then chooses the *material* component which is the most coherent with her own current *meaning* and *competence*. That is: reflexive individuals observe the activities of and material artefacts used by others and make sense of it in their own terms. This conceptualisation surely brings in some flavour of an individual-centric approach, but avoids a simple utilitarian perspective since *meaning* and *competence* which are drawn upon to select the *material* component are malleable and path-dependent, as outlined above in *adapt meaning to material* and *adapt competence to material*. This accounts for the history with practices which leaves “sediments” in the practitioner and influences the practitioner’s future adoption of practices.
- *Exchange meaning*: individuals communicate and exchange about values and beliefs. It is proposed that individuals tend to communicate more often and more intensively the more similar they are (McPherson, Smith-lovin, & Cook 2001). In terms of the components similarity of individuals and the implied probability of communication and persuasion can be understood as similarity of *meaning*. Communication may lead to a mutual alignment of the *meaning* of different individuals.

Implementation

General setting and components

The model is implemented in Repast Symphony 2.0. The basic structure is a grid with Moore neighbourhood, with each grid cell holding an *individual* which includes *meaning* and *competence*, and a *material* adopted by this *individual*. The components of a practice (*meaning*, *material*, *competence*) are represented as bitstrings of length N with each locus $\in \{0,1\}$. The representation as bitstrings does not imply an obvious interpretation of what actually a specific bit being either 0 or 1 would mean in empirical terms. But it allows expressing similarity between components as well as processes of mutual adaptation and is hence suitable as an abstract representation.

Coherence

The coherence of a practice is calculated as follows:

$$coherence = 1 - \max(|meaning-material|, |material-competences|)$$

with $|x-y|$ being the Hamming distance of the respective component bitstrings divided by the total length of the bitstrings. I.e. coherence $\in [0,1]$ and coherence =0 if either meaning or competences is completely opposed to material, and coherence =1 if both meaning and competences are identical to material.

Processes

In each time step individuals are updated using random asynchronic update. Five processes working on the components and individuals are executed in each step for each individual. Table 1 presents an overview and indicates the sequence of the processes invoked in each individual. The processes are in turn discussed below.

Table 1: Implementation of processes

Sequence	Process	Implementation
1	<i>Adapt meaning to material</i>	In each step select one random bit of <i>meaning</i> and (if different) change it to resemble the respective bit of the <i>material</i> adopted by this <i>individual</i> .
2	<i>Adapt competence to material</i>	In each step select one random bit of <i>competence</i> and (if different) change it to resemble the respective bit of the <i>material</i> adopted by this <i>individual</i> .
3	<i>Exchange meaning</i>	In each step select one random neighbour. Exchange of meaning between the individual and this neighbour happens with a probability that increases linearly in $[0,1]$ with the similarity of the <i>meaning</i> bitstrings of the two <i>individuals</i> . If exchange of meaning happens, then adjust s times a random bit of this <i>individual's meaning</i> to the respective bit of the neighbour's <i>meaning</i> (s is a parameter that can be set to an integer in $[0,10]$).
4	<i>Adapt material</i>	In each step a variable <i>deliberate choice</i> is set <i>true</i> if $r > 0.5h$, with h being the current level of habituation (see below) and r being a random number drawn from $]\min(0.5, 1-\text{coherence}), 0.501[$. If <i>deliberate choice</i> is <i>true</i> the <i>individual</i> inspects all <i>material</i> used by individuals in its neighbourhood (including itself) and then chooses the <i>material</i> that yields the highest coherence with its own current <i>meaning</i> and <i>competence</i> .
5	<i>Habituation</i>	In each step the current level of habituation $h(t) \in [0,1]$ is set to 0 if the material has changed in this step, and otherwise the level of habituation is increased: $h(t+1) = h(t) + (1-h(t)) * ha$ with ha being a constant in $[0,1[$ that regulates the speed of habit acquisition.

Adapt meaning to material and *adapt competence to material* are processes which are assumed to work continuously as *individuals* perform their everyday practices – the longer something is done the more it becomes ingrained in the individual (and the higher the coherence of the practice becomes). Hence, these processes are executed in each simulation step. The random selection of specific bits to be potentially adapted to the material implies a declining chance for actually switching a bit the more similar the two respective components already are, as randomly picking a bit on which they differ becomes less probable. The resulting probability for changing a bit resembles an exponential function. This is in accordance with findings from the literature on improvement of skills: “Improvement is rapid at first but decreases as the practitioner becomes more skilled.” (Heathcote et al. 2000, p.185). Newell & Rosenbloom (1980) presented a wide range of evidence for this proposition, from diverse areas such as motor-perceptual coordination, perceptual tasks such as reading inverted texts, motor behavior and memory, and also to a more complex task (a solitaire game). They found that a power law describes best this observation and have called it the “power law of practice”. But this was challenged later on by Heathcote et al. (2000) who argued that the best fit of a power law was due to the usage of averaged data and that exponential curves fit better if non-averaged data is used.

Exchange meaning is a process of discussion with (like-minded) others about the issue. It is assumed that individuals communicate more often (about the respective issue) the higher the similarity of their meaning. The implementation resembles some features of Axelrod's famous model on the dissemination of culture (Axelrod, 1997). The parameter s can be used to vary the strength of this process compared to *adapt meaning to material* and *adapt competence to material*.

Adapt material only is executed if the individual makes a deliberate choice. As discussed in the conceptual framework, a strong habit and a high coherence reduce the chance for a deliberate choice. The implementation given in table 1 captures the following requirements:

- the stronger the habit, the higher the probability for acting habitually because information that might indicate incoherence of the current practice is not processed
- the higher coherence, the higher the probability for acting habitually because the lower the probability for an event that disturbs the habit and invokes deliberation
- if the coherence of the practice is very low² then the individual acts deliberately even if the habit is strong because the practice doesn't go smooth and either cognitive dissonance is strong or competences are missing
- if habit strength is low the individual chooses deliberately independent of the level of coherence because the possibility for acting habitually has not yet been developed

In case the individual deliberates on changing its material, the selection of the material follows a bounded rational approach, especially having limited information: only those materials used by some neighbour are observable and can potentially be adopted. The choice of the best material based on the achievable level of coherence resembles the idea of path-dependency of individuals' involvement in practices as discussed above.

Habituation follows a simple asymptotic process that converges towards $h(t)=1$ if a behaviour is repeated over and over. $h(t)$ increases fast for low levels of habituation and becomes slower the more the process converges while never reaching $h(t)=1$. A change in the material component implies that the recent habit is disturbed and a new habit must be developed ($h(t)$ is set to 0).

Visualization

Each grid cell represents the material component adopted by the individual on that cell as a coloured circle and the coherence of the individual's practice with a grey background (black: coherence=0, white: coherence=1).

There are several charts available:

- Clustering: the clustering coefficient in each time step measured as the average of identical bits between each individual's material and his/her neighbours' materials, corrected by the expectation of random matches, and normalised to [-1,1]
- Moran's I: Moran's I for each material component as another measure for the clustering of materials
- Coherence: the min, max and average coherence
- Average habit strength: the average strength of the habit developed through habituation
- Deliberate choices: the amount of individuals that make a deliberate choice
- Routine: the share of individuals who act habitually

² Coherence is "very low" is operationalized as (coherence \in [0, 0.5]) because the coherence of three random bitstrings is somewhat lower than 0.5

- ShareChangeMaterial: the number of individuals who decide to adopt a different material component
- Spread: the spread (market share) of the various material components
- Change material total: the total number of changes of material components aggregated over time

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