Dynamic Value-based Cognitive Architecture Model

This document describes the Overview, Design concepts and Details (ODD) of the Dynamic Value-based Cognitive Architecture model (DVCA-model V.1.0). The model is formalised within Netlogo 6.1.1 software. To structure the description of this agent based model in a concise and neat manner, this document follows the ODD protocol of Grimm et al. (2010).

Purpose

The purpose of this model is to illustrate the design of heterogeneous populations within agent-based social simulations by equipping agents with Dynamic Value-based Cognitive Architectures (DVCA-model). The DVCA-model uses the psychological theories on values by Schwartz et al. (2012) and character traits by McCrae & Costa Jr (2008) to create an unique trait- and value prioritization system for each individual. Furthermore, the DVCA-model simulates the impact of both social persuasion and life-events (e.g. information, experience) on the value systems of individuals by introducing the innovative concept of perception thermometers. Perception thermometers, controlled by the character traits, operate as buffers between the internal value prioritizations of agents and their external interactions. By introducing the concept of perception thermometers, the DVCA-model allows to study the dynamics of individual value prioritizations under a variety of external perturbations over extensive time periods. Possible applications are the use of the DVCA-model within artificial sociality, opinion dynamics social learning modelling, behavior selection algorithms and social-economic modelling.

1 Entities, state variables and scales

The DVCA-model contains one single entity: 1000 persons within their adulthood. These people have three different attributes: values, character traits, and perception thermometers. One time step in the model was initially set to one week in reality and the duration was set to ten years (520 ticks). Depending on the specific application of the model, these settings can be altered. The model currently doesn't consists of a spatial scale.

1.1 State variable: Value prioritizations

Within this model, values are described as "trans-situational goals, varying in importance, that serve as the guiding principles in the life of a person or group" (Schwartz, 1994, p. 21). Values which are highly affiliated with their group (Table 1) have a higher prioritization score (towards 100), while values on the opposite of the circle have a lower prioritization score (towards 0). To generate unique value prioriziation systems, the personal values are determined using a normal random distribution in which the mean is high (**value-facet-mean**[1]) and low ($100 -$ **value-facet-mean**) for respectively affiliated and conflicting values. The standard deviation for the normal distribution can be adjusted with the **value-std-dev** parameter.

Afterwards, by using two conditions discussed in Heidari et al. (2020), the value prioritization systems are adjusted to make them consistent with the value theory of Schwartz.

$$\text{Condition 1} : \forall i, j \in 1..10 : 0 \leqslant \tau(V_i) - \tau(V_j) \leqslant |i' - j'| \cdot \theta \tag{1}$$

Where θ is **cd1-max-range-between-values**; $\tau(V_n)$ is prioritization of value n; and

$$i' = \begin{cases} i & \text{if } 1 \leq i \leq 5 \\ 10 - i & \text{if } i > 5 \end{cases} \qquad j' = \begin{cases} j & \text{if } 1 \leq j \leq 5 \\ 10 - j & \text{if } j > 5 \end{cases}$$

The first condition is that values that are close to one another within the Schwartz's Value circumplex (*neighbouring value pairs*) should hold a similar prioritizations (see Equation (1)). The maximum difference

[1] Within this chapter, descriptions in **'bold'** show the adjustable input parameters of the model

FIGURE 1: Overview of the ordering of the ten universal values within the Schwartz's Value Circumplex (Schwartz et al., 2012)

in prioritization between *neighbouring value pairs* are capped and can be adjusted by the **cd1-max-range-between-values** parameter. The second condition is that values on the opposite site of the circle (*antagonistic value pairs*) cannot BOTH have a high prioritization (see Equation (2)). Therefore the sum of the prioritization of each of the antagonistic value pairs is capped and can be adjusted by **cd2-max-sum-antagonistic-value-pairs** parameter.

$$\text{Condition 2}: \begin{cases} \text{if } \tau(V_j) = 0 & \tau(V_i) > 50 \\ \text{if } \tau(V_j) \neq 0 & 0 < \tau(V_j) + \tau(V_j) \leq \Lambda \end{cases} \tag{2}$$

Where Λ is **cd2-max-sum-antagonistic-value-pairs**; $\tau(V_n)$ is prioritization of value n; and $J = (5 + i)\%10$

Within Heidari et al. (2020) the setting for the **cd2-max-sum-antagonistic-value-pairs** parameter is capped at 100. Simulation of this model however shows that this would limits the possibility for values to increase in importance, resulting in the tendency that on the long run, the total prioritization of all values decreases. Because of this effect, the limitation of the maximum sum of antagonistic value pairs can be (dis)activated by using the **cd2-active-limitation-max-sum-antagonistic-value-pairs?** switch.

1.2 State variable: Character traits

Whereas values describe the long-term goals of individuals, character traits describe how people tend to act in different situations. Character traits are defined as "endogenous basic tendencies that influence patterns of thoughts, feelings, and actions and that can be altered by exogenous interventions, processes, or events that affect their biological bases" (McCrae & Costa Jr, 2008, p.168). According to McCrae & Costa Jr (2008) "the development of personality traits occurs through intrinsic maturation, mostly in the first third of life but continuing across the lifespan; and through other biological processes that alter the basis of traits" (McCrae & Costa Jr, 2008, p. 165). Within the model the character traits, in contrary to values, are assumed to be static as i) the people impersonate adults after the first third of their lives and ii) the external events and interactions that occur during the simulation do not affect the biological processes that alter the basis of traits.

Table 1: Value score for the different groups of value orientations (Schwartz et al., 2012)

	Growth	***Personal-Focus***	***Self-Protection***	***Social-Focus***
Self-Direction	High	High	Low	Low
Stimulation	High	High	Low	Low
Hedonism	High	High	Low	Low
Achievement	Low	High	High	Low
Power	Low	High	High	Low
Security	Low	Low	High	High
Tradition	Low	Low	High	High
Conformity	Low	Low	High	High
Benevolence	High	Low	Low	High
Universalism	High	Low	Low	High

Based on the OCEAN model of McCrae & Costa Jr (2008), people are equipped with 5 different character traits: *Openness*, *Conscientiousness*, *Extraversion*, *Agreeableness* and *Neuroticism*), which have a stable score between 0 (low affiliation) and 100 (high affiliation). According to the meta-analyses (Figure 2 of Parks-Leduc et al. (2015) the prioritization of values are correlated with 4 of the 5 OCEAN character traits (i.e. *Openness*, *Conscientiousness*, *Extraversion* and *Agreeableness*). The last character trait, *Neuroticism* does not show any correlation with the value prioritization of individuals. Based on this research, this model creates unique trait systems by using the value prioritization system of individuals. Based on the weighted mean from the **bold** correlations from the table below and the value prioritization scores, each individual computes its own mean for each of their traits. By using a normal random distribution with this computed mean and the **trait-std-dev** parameter an unique trait score is configured. For the *neuroticism* trait the mean for each agent can be set by the **neuroticism-trait-population**.

	Openness to Experience	Agreeableness	Extraversion	Conscientiousness	Emotional stability
Power	−.06	**−.42**	**.31**	.05	.03
Achievement	.11	−.24	**.31**	**.17**	−.01
Hedonism	.09	−.11	**.20**	−.19	.01
Stimulation	**.36**	−.05	**.36**	−.16	.02
Self-direction	**.52**	−.07	.17	.01	−.01
Universalism	**.33**	**.39**	−.05	−.02	−.03
Benevolence	.13	**.61**	−.05	.07	−.01
Conformity	**−.27**	**.26**	−.17	**.27**	−.05
Tradition	**−.31**	**.22**	−.25	.10	−.03
Security	**−.24**	.00	−.05	**.37**	−.03

Note. Generalizable results (in bold) refer to results for which the 80% credibility interval does not include 0.

Figure 2: Correlations between Schwartz's values and OCEAN traits (Parks-Leduc et al., 2015, Table 10)

By using the previous described methods of computing individual value-trait systems, each of the five population scenarios (growth, personal, self-protection, social and mixed) result in the following population distribution of value prioritizations and trait scores (see Figure 3.

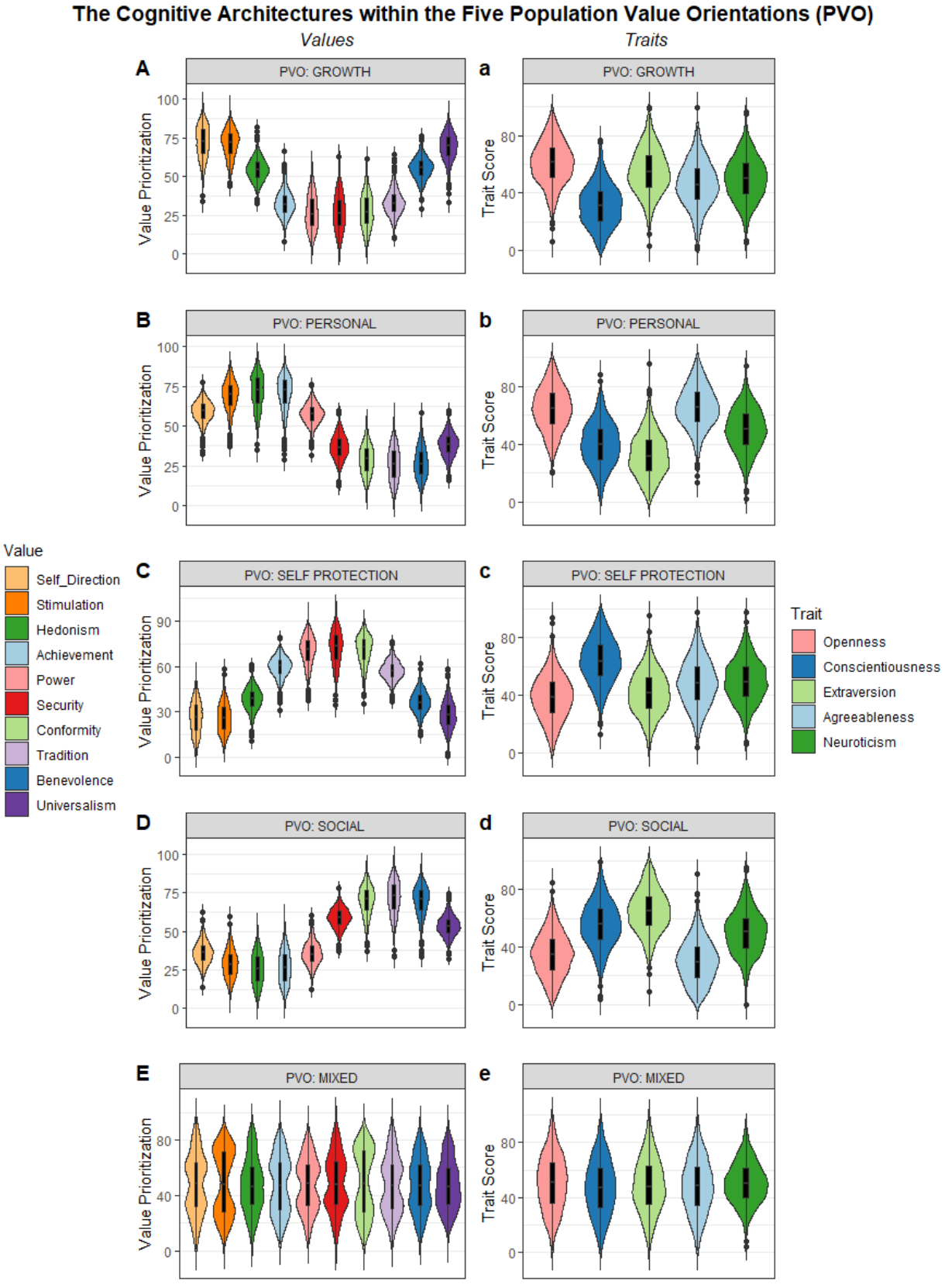

FIGURE 3: Overview of the population distributions of the value prioritizations and trait scores.

1.3 State variable: Perception thermometers

Within this model the change in value prioritizations are induced by value-weighted perturbations which can have be interactions with technology (Section 2.1) and social developments (Section 2.2) (van de Poel, 2018). According to Schwartz's Value Theory however, the change in prioritization is only limited and only occurs when experiencing life changing events (Sagiv et al., 2017)). So to simulate impact of value-weighted perturbations on changes in value prioritization and to prevent eruptive and invalidated behaviour, it is necessary to create this buffer between the environment and value prioritization systems. Perception thermometers function as these buffers as they absorb the impact of value-weighted perturbations by increasing or decreasing its temperature. Once the temperature of a value-related perception thermometer reaches 0 or 100 degrees Celsius, the connected value will respectively decrease or increase with the pre-set **value-change-para** parameter. The moment the prioritization of a value changes, the complete value system will be aligned according to condition one and two, respectively 'neighbouring value pairs' and 'antagonistic value pairs' (see Section 2.3). After the value is changed, the temperature of the related perception thermometer will reset to the level of status quo; 50 degrees Celsius (see Figure 4) .

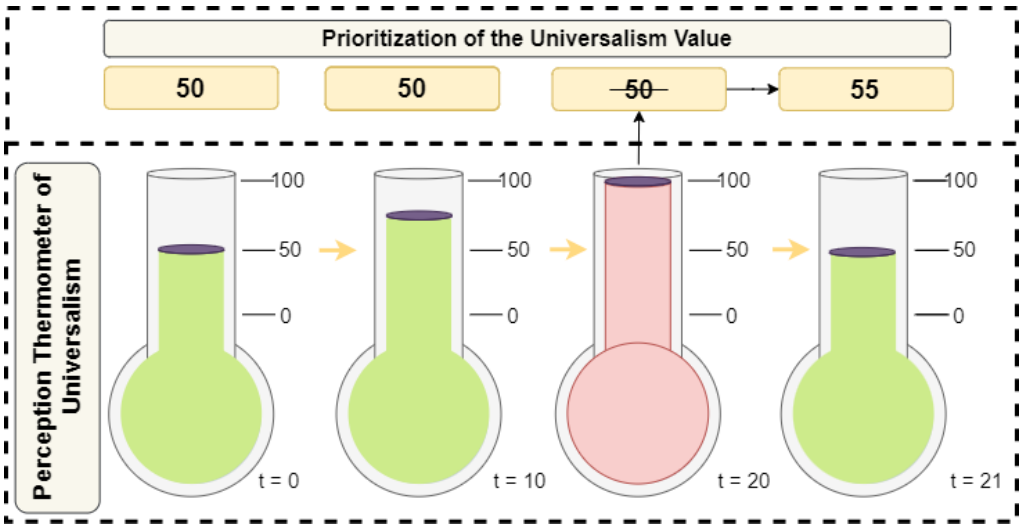

FIGURE 4: Visualisation of the change in perception thermometers during a tick.

Combining this mechanism with the assumption that the impact of value-weighted perturbations diminishes over time, the temperature of the perception thermometers always tend to return to the level of status quo (50 degrees Celsius). This diminishing effect is dependent on the score for the *openness* trait of individuals (see Figure 5). The more open an individual tends to be, to more receptive it will be to new ideas/influences. So the tendency to return to the status quo of an individual is the product of the negative openness of an individual times the **ptc-rsq-modifier** parameter.

All in All, only after continuous and one-sided impacts of value-weighted perturbations, change in value prioritizations will occur for more information on the functioning of perception thermometers within this research.

2 Process overview and Scheduling

The processes within the model are mainly divided in to three parts in the following order: i) the interaction with technology, ii) social interaction, iii) update value prioritizations based on perception thermometers. The execution order of the process in which people are involved are done in a random order and all state values except the value prioritizations[2] calculated by a process are updated immediately (asynchronous updating).

[2]For the updating of value prioritizations see Section 2.3

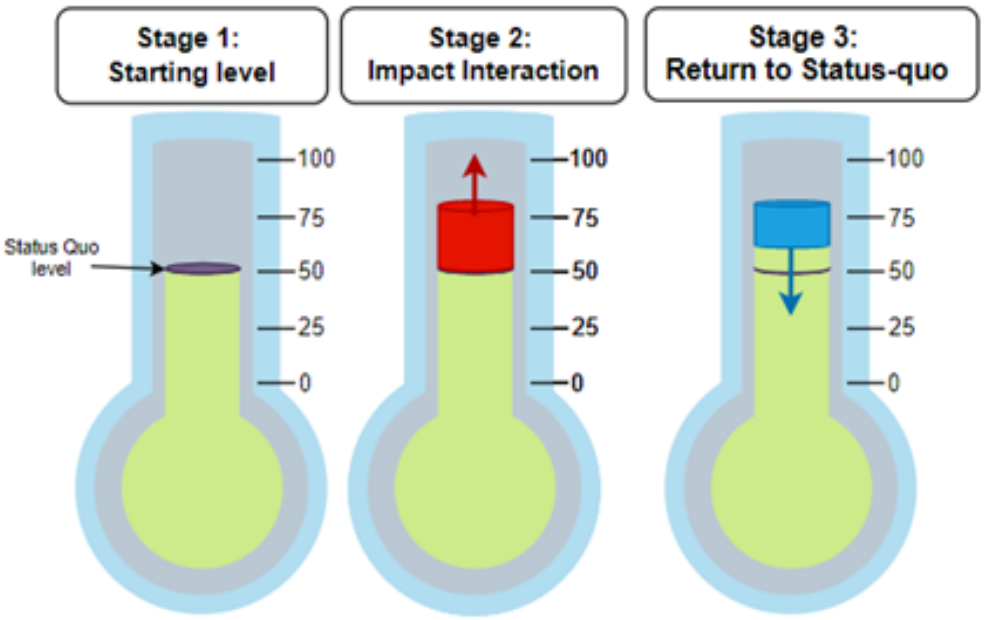

FIGURE 5: Visualisation of the change in perception thermometers during a tick.

Last, time moves forward in discrete steps in which each ticks resembles 1 week in reality.

2.1 The interaction with technology

The interaction with technology is understood as an event during which the acquisition of information and/or perturbations due to the use technologies[3] lead to the change in perceptions of individuals. During each tick only one events occurs that varies in three different dimensions: i) the values that are triggered by the event (i.e. event-orientation), ii) the impact of the event (event-impact), and iii) the magnitude of the event (i.e. event-magnitude).

2.1.1 Event Orientation

An event can occur in four different event orientations. Each of these events stimulates (+) the perception thermometers of the values that are in one of the Schwartz's Value Circumplex quarter, while suppressing (-) the perception thermometers of the values at the opposite quarter (Sagiv et al., 2017). Figure 6 shows for each of these event-orientations which perception thermometers are stimulated (+) and which are suppressed. The occurrence of the event-orientation is based on the probability settings of the following parameters: **%-conservation-event**, **%-self-transcendence-event**, **%-openness-to-change-event**, **%-self-enhancement-event**. Note that the sum of these probabilities should always equal 100, to let the model run correctly.

2.1.2 Event Impact

Although it is assumed that every individual experiences events, not every individual will adapts its perception thermometer. Only whenever the impact of the event exceeds the awareness-threshold of the individual, the

[3](e.g. due to the combination of technologies that can detect new knowledge about climate change and the social media technologies that can spread these new information among society, the people could give more priority to environmental well-being value)

Value / Event-type	Self-Direction	Stimulation	Hedonism	Power	Achievement	Security	Conformity	Tradition	Benevolence	Universalism
Self-Transcendence				-	-				+	+
Conservation	-	-	-			+	+	+		
Self-Enhancement				+	+				-	-
Openness	+	+	+			-	-	-		

FIGURE 6: Overview of which event types stimulates (+) or stagnates (-) which perception thermometers.

perception thermometers will change increase/decrease with the impact of the event. The awareness-threshold of individuals is an linear scaled attributed that holds a value between the **Min-awareness-threshold** and the **Max-awareness-threshold** parameters. It is assumed that the higher the individual score for the *openness* and *conscientiousness* trait the lower the individual awareness-threshold. The impact of the event is equal for each individual and is calibrated each tick using a exponential distributed random number of which the mean can be altered by using the **Event-mean-exponential-distribution** parameter.

2.1.3 Event Magnitude

The magnitude of the event can differ between individual-level and global-level. During an event with an magnitude on the *global-level* every person experiences the same event (i.e. equal impact and equal orientation). On the contrary, for an event on the *individual-level*, every person generates its own event-impact and event-orientation. Whether the event-magnitude is on a individual-level or the global-level is determined by the probability **%global-event** parameter (A high setting will result on more global-events, while a lower setting will result in more individual events). This variation allows the adjust the globalisation and connectivity of the population (the more globalized and connected the population, the more often a global-event will occur).

2.2 Social development through social interaction

Social development is conceptualized as an emergent effect of multiple social interactions between peoples. Within this model, these social interactions actions is understood as a process of social learning in which two individuals who have an intimate relationship (friendship) persuade each other to adopt their own particular vision on life (i.e. value prioritizations). During this process of social learning both individuals ones play the role of persuader and ones the role of recipient. Whenever the persuader is able to convince to recipient (*Extraversion-trait of persuader* > (100 - *Agreeableness trait of recipient*)), each of the perception thermometers of the recipient will change. The direction of change for each perception thermometer is dependent on the positive/negative difference in prioritization between the persuader and recipient (e.g. if the prioritization of Self-Direction of the persuader > prioritization of Self-Direction of the recipient, the Self-Direction Perception Thermometer will increase). Whenever both individuals are not able to persuade each other, the possibility occurs of a moment of perception divergence (the probability of such an event can be set by the **perception-divergence-no-consensus?** parameter. During a moment of perception divergence the perception thermometers of both individuals will move away from each other. The increase/decrease of the perception thermometers due to social interaction can be adjusted by the **ptc-neighbour-consensus** parameter. Once every tick, each of the agents has an social interaction with one of their friends. It is assumed that agents have random friends, independently from their value system, which do not change over the course of the simulation. The number friends each agents has can be adjusted with the #**neighbour-friends** parameter.

2.3 Update value prioritizations based on perception thermometers

After the completion of the social interaction and the interaction with events processes, the value prioritization system will be updated based on the related perception thermometer have reached a critical level (below 0 or above 100 degrees Celsius). Also the return to the status quo mechanism of the perception thermometers is applied during this last process.

3 Design Concepts

To avoid repetition only the emergence, output parameters and initialization of the DVCA-model will be discussed.

3.1 Emergence

The emergent output of the DVCA-model is the change of value prioritization on a population level. The dynamics between the initial value prioritization of the population, the social network, the interaction within that social network and the impact and type of events causes emergent behavior of the value prioritization on the population level. Important to note, that tendencies on how the value prioritizations on a population level change, are highly dependent on the modelling assumptions (people with a high score on *extraversion* traits are more persuasive). Therefore, when drawing conclusions from change in value prioritization based on this model, it is recommend to keep this notion in mind.

3.2 Output parameters

The model output generated the following key performance indicators:

1. Global Event type
2. Global Event impact
3. Average change in value prioritization for each value for the entire simulated population,

Each of the indicators are collected every tick to see how the different indicators differ under different circumstances over the course of the simulation

3.3 Initialization

In Table 2 for every topic the input-parameters are listed with the default setting. The model does not use external input data to represent time-varying processes."

Table 2: Overview default settings input-parameters

Topic	**Input-Parameter**	**Default setting(s)**
General	Static-Seed?	False
	Allow-events-to-effect-value-prioritization?	True
Values	Population-scenario	*Mixed*, *Growth*, *Personal-Focus*, *Self-Protection*, *Social-Focus*
	Value-facets-mean	75
	Value-std-dev	15
	Cd1-max-range-between-values	25
	Value-change-para	5
	Cd2-active-limitation-max-sum-antagonistic-value-pairs?	True
	Cd2-max-sum-antagonistic-value-pairs	120

Traits	Trait-std-dev	15
	Neuroticism-trait-population	50
Interaction with Technology	Event-mean-exponential-distribution	5
	%-conservation-event	25
	%-self-transcendence-event	25
	%-openness-to-change-event	25
	%-self-enhancement-event	25
	Min-awareness-threshold	5
	Max-awareness-threshold	25
	Global-event-vs-individual-event	50
Social Interaction	# Neighbour-friends	7
	Ptc-neighbour-meeting	7
	Perception-divergence-no-consensus?	15
Perception Thermometers	Pt-rsq-modifier	0.1

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