Chapter 8
InCREDulity in Artificial Societies

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Abstract This paper describes an artificial society in which the simulated agents behave and interact based on a computational architecture informed by insights from one of the leading social psychological theories in the scientific study of secularization and religion: "credibility-enhancing displays" (or CREDs) theory. After introducing the key elements of the theory and outlining the computational architecture of our CRED model, we present some of our initial simulation results. These efforts are intended to advance the quest within social simulation for more authentic artificial societies and more plausible human-like agents with complex interactive and interpretative capacities.

Keywords Artificial societies · Agent-based model · CRED · Supernatural beliefs · Personality · Worldview · Religion

Introduction

The use of agent-based modeling to construct artificial societies in which social scientists and policy professionals can explore and test their hypotheses has been growing rapidly in recent years. These tools have proven themselves useful for demonstrating the emergence of macro-level social patterns from micro-level agent behaviors and

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interactions, even when the latter are relatively simple. The next step for computational modeling and simulation is to develop best practices for creating agent architectures and artificial societies that more adequately incorporate insights about human behavior from disciplines such as cognitive science, social psychology, sociology, and economics. To this end, the present paper presents an artificial society whose simulated agents have variables related to the sorts of emotional attitudes, norms, and identity markers that we believe will be required for adequate representations of "sociality" in multi-agent artificial intelligence models.

More specifically, the artificial society described below attempts to implement some of the empirically driven theoretical insights into human sociality derived from research on the role of "credibility-enhancing displays" (CREDs) on the growth or decline of religiosity in human cultures. CRED theory was first outlined in 2009 by Joseph Henrich [1], who argued that a primary predictor for the expansion of religiosity is the extent to which an individual's social environment is characterized by costly behavioral displays of belief, which signal that ostensibly incredible beliefs (e.g., the existence of hidden supernatural agents) are in fact truly believed. CREDS, in other words, provide social legitimacy to worldviews that contain elements that are not particularly self-evident or obvious. This hypothesis has received support from several empirical studies, including some on the factors that contribute to theism [2] and the spread of secularization [3]. Other studies have shown that CREDs seem to be an important factor in differentiating religious believers from non-believers [4] and in predicting the age at which individuals embrace atheism [5]. More recently, scholars have explored the role of credibility-*undermining* displays, CRUDs (behaviors inconsistent with one's belief) which seem to weaken the power of religion in human populations, as illustrated in research on the response to pedophilia scandals in the Roman Catholic Church in Ireland [6]. CRUDs, in other words, signal the illegitimacy, immorality, hypocrisy, or inefficacy of aspects of a worldview. It is important to emphasize that CREDs and CRUDs are intentionally or unintentionally transmitted, two sides of the same coin, and not necessarily religious. Other sorts of displays, such as the adoption of veganism (a CRED indicating the belief in animal welfare) or a widely publicized fraudulent charity (a CRUD undermining the belief in donations and/or humanitarian aid), can affect the diffusion of non-normative public goods [7]. This suggests the potential policy relevance of this research, and further motivates our interest in constructing an artificial society in which we experiment with the role of CREDs in shaping human behavior.

The aim of the CRED model is to explore the conditions under which—and the mechanisms by which—(non) religious beliefs and behaviors increase or decrease in an artificial society designed to represent a contemporary Western city.

Methods

The CRED Model

The CRED model described here is an extension of the Simulation of Extended Time Integration (SETI) model [8]. The Artificial Society Analytics Platform on which both of these models are based has been outlined in more detail elsewhere [9]. A complete ODD + D protocol for the CRED model can be found online at: https://github.com/ivanpugagonzalez/CRED_Model. Here we provide a brief description of the main features and procedures of the model affecting the worldview (WV) values and religious affiliation of agents.

Agents. The artificial society represented in the CRED model is inhabited by individual human agents who attend school, work (get hired and fired), marry, and reproduce. They are categorized as belonging to a majority or a minority group. They have variables related to demography (age, majority/minority group, education, employment, etc.); to personality (the HEXACO factors plus charisma, susceptibility, frustration, motivation to join a club (MTC) and club tolerance (CT)); to worldview (WV; from secular to religious on a continuum between [0,1]); and to religious affiliation. Religious clubs are membership organizations that exist to support agents with a religious WV; each club has a leader, defined as the agent with the highest charisma value. Agents affiliated to a religious club tend to have WV values in the religious spectrum (0.5, 1.0]; but agents with a secular WV may also affiliate with religious clubs. Agents have memories of interpersonal encounters and the cognitive capacity to evaluate the (in)consistency of CREDs displayed by others. Due to CRED interactions, agents may change their WV and (dis)affiliate with/from religious clubs.

On initialization, agents are assigned variables drawn from suitable distributions that vary according to the group they belong to (majority or minority). Agents attend school for at least 16 years (with a maximum determined by their total education variable) and then move to the work force. The likelihood of employment depends on agents' sex and group category; and on enforced antidiscrimination for agents from the minority (22–29 in Table 8.1). Agents die with a certain probability or if they reach their life span. Agents may get married after reaching an age threshold; to marry, agents must satisfy age, education, and worldview compatibility conditions. Once married, agents may have children; newly born agents inherit the HEXACO personality traits of their parents. Other personality traits such as worldview, charisma, susceptibility, frustration, etc., are derived from the inherited HEXACO personality values (Fig. 8.1).

CRED Interactions. On a weekly basis (52 times a year), agents encounter a CRED interaction with a randomly selected agent from each of its three different social networks: family (mother and father), worldview club (if affiliated), and neighborhood. Agents must be 12 years or older to interact. In club interactions, agents have a higher likelihood of interacting with the leader of the club than with any other club member. CRED displays have values ranging on a continuum between

Table 8.1 Parameter range values in the CRED model

Parameter	Range
CRED Importance related:	
(1) Importance of a CRED display by a leader of a given club	[0.05, 1]
(2) Importance of a CRED display by a leader of my club	[0.05, 1]
(3) Importance of a CRED display by a religious agent	[0.05, 1]
(4) Importance of a CRED display by a secular agent	[0.05, 1]
CRED Impact related:	
(5) Effect of being affiliated to a religious club on CRED impact	[0.05, 1]
CRED consistency related:	
(6) Effect of conscientiousness on CRED consistency	[0.5, 9]
(7) Effect of frustration on CRED consistency	[0.5, 9]
(8) Sigmoidal curve determining effect of club and world view conflict on consistency	[0.4, 0.6]
(9) Error of display consistency of credibility enhancing display (CRED)	[0.25, 0.75]
Other CRED related:	
(10) Probability of interpreting a CRED as a CRUD	[1, 40]
(11) Dampening effect of the leader of a club on the increase of an agent's frustration	[1, 10]
Affiliation related:	
(12) Probability of joining a religious club when holding a secular world view	[1, 60]
(13) Minimum hypocrisy threshold value	[0.5, 0.9]
(14) Minimum joining threshold value	[0.5, 0.9]
Society related:	
(15) Number of adults in initial population	[500–1000]
(16) Initial percentage of agents from the majority group in population	[0.6, 0.9]
(17) Number of religious clubs from majority	[5–15]
(18) Number of religious clubs from minority	[5–15]
(19) Initial percentage of population affiliated to a religious club	[0.1, 0.9]
(20) Human Development Index	[0.25, 1]
(21) Family Impact on Pluralism Index	[0.1, 1]
Employment related:	
(22) Number of Employers	[5, 15]
(23) Percentage of females from the majority employed	[0.75, 0.95]
(24) Percentage of females from the minority employed	[0.75, 0.95]
(25) Percentage of males from the majority employed	[0.75, 0.95]
(26) Percentage of males from the minority employed	[0.75, 0.95]
(27) Probability of losing employment majority	[0.05, 0.15]
(28) Employers' minority friendly (mode)	[0, 0.9]
(29) Enforced Antidiscrimination	[0, 0.9]

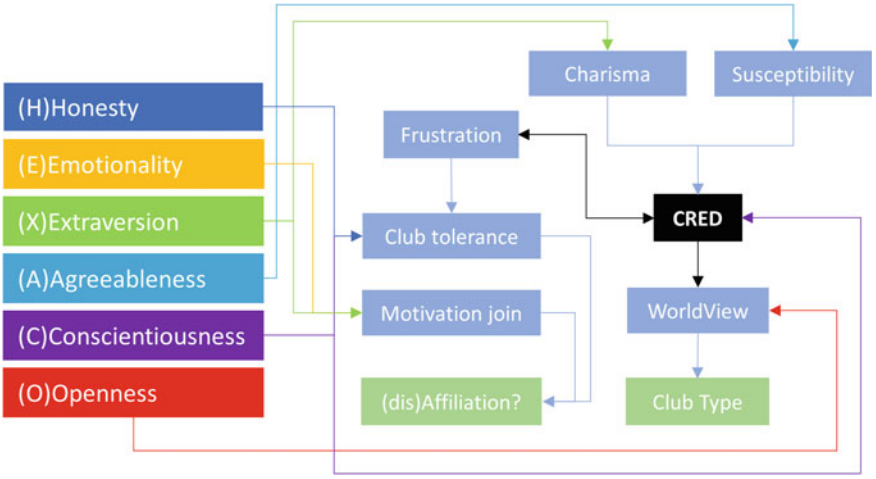

Fig. 8.1 Relation between HEXACO personality factors, CRED displays, WV values, and (dis)affiliation with/from religious clubs. Openness influences initial WV value of the agent; agreeableness influences susceptibility; extraversion influences charisma; honesty and conscientiousness influence club tolerance (CT); emotionality and extraversion influence motivation to join a club (MJC); and conscientiousness and frustration influence CRED consistency. Observing others display CREDs may change/reinforce agent's WV values and may increase /decrease their frustration. High frustration may lead to club disaffiliation and/or reaffiliation via CT and MJC

[−1,1]. Thus, CRED displays can be positive/credibility enhancing (CRED) or negative/credibility undermining (CRUD). The value of the display depends on an additive composite equation with three main factors: display importance, display impact, and display consistency. Display importance depends on whether the "exemplar" (agent displaying the CRED) is the leader of a club, and on the type of WV (religious or secular) of the exemplar. In the latter case, we distinguish between the importance of secular and religious WV. Leaders of a club enhance the importance of the display (1–4 in Table 8.1). Display impact depends on the exemplar's charisma, the observer's susceptibility (based on personality variables) and age, as well as the age difference between exemplar and observer. CRED/CRUD impact, then, reflects the tendency of charismatic agents to be more influential than others, the tendency of susceptible agents to be more easily impacted, and the role of age and age difference on the displayed CRED/CRUD (5 in Table 8.1). Display consistency depends on the exemplar's conscientiousness, frustration, worldview, and club affiliation. Exemplars who are not frustrated, highly conscientious, religious, and affiliated with a club will tend to display consistent CREDs. Exemplars who are very frustrated and low in conscientiousness, as well as agents with a secular WV affiliated with a religious club will tend to send inconsistent CREDs (i.e. CRUDs) (6–9 in Table 8.1). Additionally, secular agents (WV < 0.5) may interpret CREDs from religious agents (WV > 0.5) as CRUDs. The likelihood of this happening is determined by the degree of secularism of the agent and a parameter (10 in Table 8.1).

Modulators of CRED intensity After the exemplar has displayed a CRED or a CRUD to an observer, two other factors further modulate the intensity of the display: pluralism and existential security indexes. The pluralism index [0,1] represents the heterogeneity of WV values an agent experiences in its close (family) and broader (neighborhood) environment. The importance given to the family (Q) and neighborhood (1-Q) may vary (21 in Table 8.1). Indexes with values close to 0 represent homogenous WV values and will have no effect on the CRED display. Values close to 1 represent a heterogenous WV environment and will mute the intensity of the display by a maximum of 50%. The existential security index may not only mute but also amplify the intensity of a display. Importantly, this enhancement/dampening occurs only on displays from religious exemplars that are CREDs (not CRUDs). The existential security index is calculated from a composite equation involving two elements: the income class of the agent adjusted by the human development index (HDI) of the society (20 in Table 8.1), and the degree to which an agent perceives social threats (expressed by the agent's variables for shared norms (between minority and majority) and out-group suspicion). The HDI moderates the effect of income on an agent's existential security index: the existential security of low-income agents is higher in a society with high HDI (e.g. ~ 0.83 in Norway) compared to a society with a low HDI (~0.212 in the Central African Republic). The existential security index varies between [0.5,1.5], meaning that at its lowest value religious CREDs will be amplified by 50%, and at its highest value religious CREDs will be dampened by 50%.

Effect of CREDs/CRUDs on agents' WV and frustration. After the exemplar makes a display to the observer, the observer's WV and frustration are updated according to the paths followed in two decision trees, one for religious agents and another for secular agents (Fig. 8 in ODD + D protocol). Both decision trees consider whether the observer and exemplar are affiliated with a club and the WV value of the exemplar. In addition, when the observer is religious, the decision tree considers whether the openness personality trait of the observer is high or low, and the type of religious club (majority or minority) with which the exemplar is affiliated. The leaves of each tree illustrate the effect that a CRED or a CRUD has on the WV and frustration variables of the observer. Updates may increase, decrease or leave equal the WV and frustration values of the observer. Further, when the observer's frustration increases, the increment in frustration is smaller when the observer is affiliated with a club. This dampening effect is proportional to the leader's degree of charisma (11 in Table 8.1) such that the more charismatic the religious club leader, the lower the increase in frustration of the observer.

(Dis)Affiliation with/from religious clubs. Religious clubs are the only type of club included in the model. When the increase in frustration is so high that it surpasses the agent's hypocrisy threshold (Fig. 8.1; 13 in Table 8.1), the agent disaffiliates from its current religious club. Further, if the agent's frustration is higher than the agent's specific motivation to join a club (Fig. 8.1; 14 in Table 8.1), the agent joins a new religious club. The club that the agent joins is the one from which it remembers the most intense CRED display. When the agent is secular, there is still a probability

for the agent to join a religious club. This probability is inversely proportional to the agent's degree of secularism. In other words, the closer the agent's WV value to the religious spectrum (~0.5), the higher its likelihood of joining a religious club. Again, the club that the agent joins is the one from which it remembers the most intense CRED display.

Simulations, Parameter Variation and Data Collection

Social processes related to education, income, and marriage were parameterized according to demographic data from the city of London and are not explored in the present study. The ranges of values for variables related to CRED display and effects (Table 8.1) were proposed by our subject matter experts. We sampled the parameter space (Table 8.1) using Latin hypercube sampling [10] with the 'lhs' r library [11]. We simulated each parameter combination once but swept the parameter space in some detail (1,500 combinations). Each simulation lasted 30 simulation years and every year consisted of 52 weeks. In every simulation year, we recorded the average *WV* values of (a) the whole population, (b) the majority group, and (c) the minority group. In addition, we recorded the average percentage of agents affiliated with a religious club at (a) the population level, among the (b) majority and (c) minority groups, and among agents holding a (d) secular or (e) religious worldview.

Statistical Analysis

Before analyzing the data, we visually inspected each of the response variables (average WV and percentage of affiliated agents) to corroborate that the input parameters indeed produced appropriate variation in the response. Then, to analyze the data we used R statistical software version 3.5.1 [12], proceeding as follows. We first built a correlation matrix between each response variable (average *WV* values: (a) population, (b) majority, (c) minority; percentage of affiliation: (a) population, (b) majority, (c) minority, (d) secular (e) religious) and all input parameters (Table 8.1) plus simulation year. From these correlation matrices we identified 1) whether input parameters were strongly correlated with each other and 2) whether the input parameters were significantly correlated with the response variable. Then we ran GLM models for each response variable. The input parameters included as predictors in each of the GLM (Generalized Linear Model) models were selected according to the following criteria. First, if inputs were highly correlated among each other ($r > 0.5$), then the input with the highest correlation with the response variable was kept and all others were excluded since keeping them may produce collinearity problems. Second, when the correlation coefficient between two input parameters was higher than the correlation coefficients between these inputs and the response variable, the input with the highest correlation with the response was kept and the other

was excluded since keeping both may also produce collinearity problems. Third, if the correlation coefficient between the input and the response variable was below 0.05, then the input was excluded. A correlation coefficient of 0.05 means that the input explains only 0.25% of the variance. Thus, our threshold was liberal, since we included inputs with a potentially low explanatory value. With the selected inputs we ran seven GLM models (one per response variable).

Results

The combination of input parameters produced large variation in average WV value and percentage of agents affiliated with a club at year 30 (Fig. 8.2). Values ranged from [0.1–0.9] and from [0.03–0.94] at the society, majority, and minority group level for average WV and percentage of individuals affiliated, respectively (Fig. 8.2). The percentage of club affiliation among secular agents was low in most simulations and the reverse was true for agents with a religious WV (Fig. 8.2). Nevertheless, variation was still moderately high: [0–0.5] and [0.12–0.85] for secular and religious agents respectively (Fig. 8.2).

GLM Models Predicting Average WV Value

After exploring the data visually and selecting potential predictors, we used the *leaps* library and *regsubsets* function to perform multi-model inference. Based on the adjusted R^2 values, the best model at the society level is shown in Table 8.2. The model explained ~ 54% of the variance of the average WV values and included 9 predictors (results for the majority/minority groups are qualitatively similar, except that in the minority model simulation year was not significant). From the nine predictors included in the final model, only a few explained most of the variance (Table 8.3).

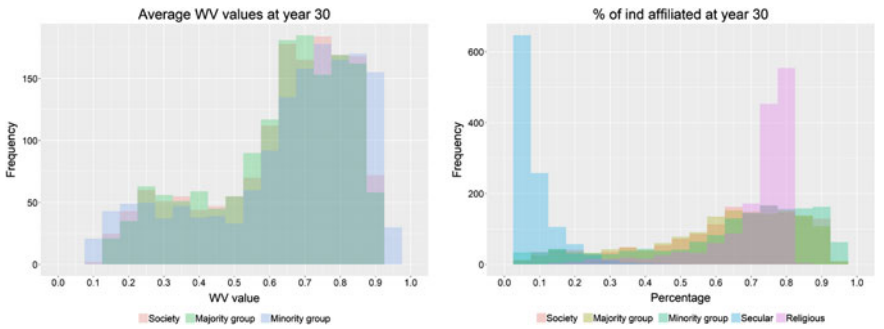

Fig. 8.2 Histograms of average WV and percentage of individuals affiliated with club at year 30

Table 8.2 Best GLM model predicting average WV values at the society level, and percentage of the total variance ($R^2 = 0.54$) explained by each predictor (var exp). In **bold** predictors explaining at least 1% of the total variance

	Est. (SE)	t-value	P-value	Var exp
(Intercept)	0.124 (0.01)	23.47	<0.001	–
Effect of conscientiousness on CRED consistency	0.034 (0.00)	166.03	<0.001	0.56
Effect of frustration on CRED consistency	0.020 (0.00)	98.63	<0.001	0.19
Initial % of Population Affiliated	0.228 (0.00)	104.75	<0.001	0.20
Simulation Year	0.002 (0.00)	28.92	<0.001	0.02
Probability of interpreting CRED as CRUD	0.001 (0.00)	27.22	<0.001	0.02
Effect of club and world view conflict on consistency	0.178 (0.01)	20.69	<0.001	<0.01
Minority friendly	−0.008 (0.00)	−4.14	<0.001	<0.01
Human development index	−0.024 (0.00)	−10.34	<0.001	<0.01
Family weight on Pluralism index	0.008 (0.00)	4.32	<0.001	<0.01
Adjusted R^2: 0.54. F-stat: 5772 on 9 and 44,988 DF. p-value: <0.001				

The effect of conscientiousness and frustration on CRED consistency explained ~ 56% and ~ 19% of the total variance, respectively (Table 8.2). These parameters determined CRED consistency: the higher their value, the more consistent the CRED (see Fig. 4 in ODD + D protocol) and the higher the increase in worldview religiosity. Further, the initial percentage of the population being affiliated explained ~ 20% of the total variance; the higher this percentage, the higher the increase in worldview religiosity. Finally, simulation year and the probability of interpreting a CRED as a CRUD explain ~ 2% of the variance each. All other predictors explain less than 1% of the variance.

GLM Models Predicting Percentage of Affiliation

Based on the adjusted R^2 values, the best models are shown in Tables 8.3–8.5. All models explained > = 73% of the variance. Final models included the same 12 predictors; however, the percentage of variance explained by each predictor varied substantially.

For the model predicting affiliation at the society level, four predictors explained 99% of the total variance (Table 8.3). Not surprisingly, the initial percentage of population being affiliated was the best predictor, followed by the effect of agents'

Table 8.3 Best GLM models predicting percentage of affiliation at the society level and percentage of the total variance ($R^2 = 0.73$) explained by each predictor (var exp). In **bold** predictors explaining at least 1% of the total variance

	Est. (SE)	t-value	P-value	Var exp
(Intercept)	0.074 (0.01)	10.19	<0.001	–
Initial Percentage of Population Affiliated	0.646 (0.00)	290.99	<0.001	0.68
Effect of conscientiousness on CRED consistency	0.031 (0.00)	149.86	<0.001	0.21
Effect of frustration on CRED consistency	0.019 (0.00)	90.68	<0.001	0.07
Simulation Year	0.003 (0.00)	56.47	<0.001	0.02
Minimum joining threshold value	−0.171 (0.00)	−38.74	<0.001	0.01
Human development index	0.018 (0.00)	−7.85	<0.001	<0.01
Minority friendly	−0.012 (0.00)	−5.96	<0.001	<0.01
Effect of being affiliated to a religious club on CRED impact	0.028 (0.00)	10.96	<0.001	<0.01
Importance of a CRED being display by a religious agent	0.022 (0.00)	8.73	<0.001	<0.01
Minimum hypocrisy threshold value	0.059 (0.00)	13.28	<0.001	<0.01
Dampening effect of leader on the increase of frustration	0.002 (0.00)	−9.87	<0.001	<0.01
Initial percentage of agents from the majority group	−0.049 (0.01)	−8.29	<0.001	<0.01
Adjusted R^2: 0.73. F-stat: 10,070 on 12 and 44,985 DF. p-value: <0.001				

conscientiousness and frustration on CRED consistency. All predictors had a positive effect on affiliation except minimum joining threshold. This is expected, since the higher the minimum joining threshold the more frustrated the agent must be before trying to join a club.

For the model predicting affiliation among religious agents, simulation year explained most of the total variance followed by the initial percentage of the population affiliated and the effect of conscientiousness and frustration on the consistency of the CRED. All these predictors had a positive effect on affiliation (Table 8.4).

Finally, for the model predicting affiliation among secular agents, simulation year explained 78% of the variance (Table 8.5). In this case, however, year had a negative effect, meaning that as time goes by the percentage of secular agents affiliated with a religious club decreases. Initial percentage of population being affiliated was the second-best predictor and four other predictors were the third-best (Table 8.5). Three of these predictors had a negative effect: minimum joining threshold, effect of religious club on CRED impact, and importance of the exemplar being religious. Minimum hypocrisy threshold had a positive effect.

Table 8.4 Best GLM models predicting percentage of affiliation among religious agents and percentage of the total variance ($R^2 = 0.74$) explained by each predictor (var exp). In **bold:** predictors explaining at least 1% of the total variance

	Est. (SE)	t value	P value	Var exp
(Intercept)	0.015 (0.01)	2.01	0.04	–
Simulation Year	0.019 (0.00)	301.72	<0.001	0.69
Initial Percentage of Population Affiliated	0.386 (0.00)	166.14	<0.001	0.22
Effect of conscientiousness and CRED consistency	0.019 (0.00)	85.82	<0.001	0.06
Effect of frustration and CRED consistency	0.012 (0.00)	53.80	<0.001	0.03
Human development index	−0.004 (0.00)	−1.51	0.13	<0.01
Minority friendly	−0.015 (0.00)	−7.18	<0.001	<0.01
Minimum joining threshold value	−0.104 (0.00)	−22.45	<0.001	<0.01
Effect of being affiliated to a religious club on CRED impact	0.063 (0.00)	23.54	<0.001	<0.01
Importance of a CRED being display by a religious agent	0.063 (0.00)	23.60	<0.001	<0.01
Minimum hypocrisy threshold value	0.010 (0.00)	2.12	0.03	<0.01
Dampening effect of leader on the increase of frustration	0.001 (0.00)	2.62	0.01	<0.01
Initial percentage of agents from the majority group	−0.054 (0.01)	−8.74	<0.001	<0.01
Adjusted R^2: 0.74, F-statistic: 10,900 on 12 and 44,985 DF, p-value: <0.001				

Discussion

The goal of this CRED model was to explore the conditions under which—and the mechanisms by which—religious beliefs and behaviors increase or decrease in an artificial society designed to represent a contemporary Western city. Two main insights stand out from our initial simulation experiments. First, the consistency of CREDs (shaped by conscientiousness and frustration) seems to drive both the increase in religiosity and the percentage of agents affiliated with a club at the population level. However, whereas consistency is the main driver of the increase in religiosity (Table 8.2), this is not the case for percentage of affiliation. The initial percentage of agents affiliated appears more important for the latter than CRED consistency (Table 8.3).

Second, the percentage of affiliation among agents holding either a secular or religious worldview is mainly driven by time (simulation year). Time has a positive effect among religious agents but a negative one among secular agents (Tables 8.4 and 8.5). This result, however, may be an artifact of the way the model is initialized. At initialization, HEXACO personality values are drawn from a normal distribution ($\mu = 0.5$, $sd = 0.25$). Because openness influences the agents' worldview, at initialization populations will have an average of 50–50% of agents with a religious and secular

Table 8.5 Best GLM models predicting percentage of affiliation among secular agents and percentage of the total variance ($R^2 = 0.76$) explained by each predictor (var exp). In **bold:** predictors explaining at least 1% of the total variance

	Est. (SE)	t value	P value	Var exp
(Intercept)	0.069 (0.00)	19.55	<0.001	–
Simulation Year	−0.004 (0.00)	−144.50	<0.001	0.78
Initial Percentage of Population Affiliated	0.356 (0.00)	331.74	<0.001	0.14
Minimum joining threshold value	−0.100 (0.00)	−47.67	<0.001	0.02
Minimum hypocrisy threshold value	0.103 (0.00)	47.94	<0.001	0.02
Effect of being affiliated to a religious club on CRED impact	−0.047 (0.00)	−38.18	<0.001	0.01
Importance of a CRED being display by a religious agent	−0.045 (0.00)	−36.52	<0.001	0.01
Effect of conscientiousness and CRED consistency	−0.003 (0.00)	−29.68	<0.001	<0.01
Effect of frustration and CRED consistency	−0.002 (0.00)	−17.35	<0.001	<0.01
Human development index	0.003 (0.00)	2.22	0.03	<0.01
Minority friendly	0.003 (0.00)	3.62	<0.001	<0.01
Dampening effect of leader on the increase of frustration	−0.003 (0.00)	−31.06	<0.001	<0.01
Initial percentage of agents from the majority group	0.080 (0.00)	28.06	<0.001	<0.01
Adjusted R^2: 0.76, F-statistic: 11,770 on 12 and 44,985 DF, p-value: <0.001				

worldview. Thus, when the initial percentage of agents affiliated is above 50%, some of those who are affiliated will have a secular WV and therefore will tend to disaffiliate with time. And vice versa, in populations initialized with a low percentage of agents affiliated, agents with religious WV will tend to affiliate with time. This would then explain the positive/negative effect of time on the percentage of affiliation among religious/secular agents respectively. Hence, in future work, we will explore the dynamics that emerge when we fix the initial percentage of affiliated agents and the percentage of agents with a religious worldview at high or low values at the initialization of simulation runs.

Conclusion

Overall, the model highlights the role of initial affiliation and consistency of CREDs on religiosity. These results are also consistent with the theory and other empirical findings. In contexts where there is a large initial percentage of religiously affiliated individuals in a population, it takes time for secularization to occur, and this is slowed down by a high number of consistent religious CREDs. When consistency is low, on

the other hand, religiosity may decline more rapidly, as shown in a study investigating the effect of pedophilia scandals on people's religiosity [6].

The CRED model was intended to elucidate a social-psychological theory of religiosity, and in doing so it advanced the quest within social simulation for more authentic artificial societies and more plausible human-like agents with complex interactive and interpretative capacities. The model successfully simulates the processes of religious affiliation and disaffiliation observed within most western cities and does so through complex agent signaling and interpretation dynamics that conform closely to the theoretical and experimental literature on costly signaling. Hence, the model captures and reproduces the theory. Although in the present study no new insights were generated, in the future we plan to run optimization experiments to produce new insights, for instance, into the factors necessary for secularization to occur in the face of consistent CREDs.

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