

Counterfactual imaginative culture as evidence hallucination in support of anxiety reduction

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ARTICLE INFO

Keywords:

Symbolic culture
Anxiety reduction
Predictive modeling
Active inference
Entropy reduction
Thermodynamics

ABSTRACT

Why do human beings invest work in creating representations of objects and situations that do not exist, cannot be proven to exist, or exist by cultural convention? This study offers an explanation of this phenomenon by identifying counterfactual cultural production as a form of evidence hallucination, where anxiety-reducing cultural and cognitive models are made to be 'true' by flooding the perceptual environment with fabricated evidence of their truth. The theoretical framework builds on concepts from information theory, thermodynamics, and active-inference approaches to agent–environment interactions; it is tested against two cultural phenomena—religious evangelism as articulated in the four Gospels of the King James Version (KJV) Bible and symbols of collective identity in the form of national flags. The first study encodes English words into 64 categories using their sensorimotor associations, and predicts that the KJV should address existential anxiety by over-sampling positively valenced words with large semantic size from each sensory category—and in doing so, generate an implicit world-model that is lower in unpredictability than that of background English. The second study predicts that the visual entropy of national flags will positively scale with endogenous anxiety (collective worry about internal conflict) and that internal contrast will negatively scale with exogenous anxiety (collective worry about external threats)—with contrast anchoring entropy in the low contrast position. These studies are consistent with the view (but do not prove) that it is possible to predict detailed features of high-level cultural activity from affective dispositions using a straightforward formalism and without a 'thick' model of human cognition.

1. Introduction

Human beings are unique in their exposure to counterfactual realities. That is, to representations of objects and states of affairs that are acknowledged not to exist, which cannot be proven to exist, or which exist only by way of social convention (Searle, 1995; Van Hoek et al., 2015). These include religion, literature, art, popular culture, mythology, ideology, and other forms of symbolic or material fabrication that, to greater or lesser degrees, innovate on or compete with what is known to be the case. Moreover, this is not a minor phenomenon: One estimate suggests that the average Briton spends 6% of their waking life immersed in counterfactual realities (Nettle, 2005), and this figure is likely to generalize cross-culturally. The question that emerges is why this should be the case. Unlike practical culture, for which there is an obvious payoff (Henrich, 2016; Henrich & Henrich, 2007), counterfactual cultural elaborations are—at least on the surface—wasteful of cognitive resources like attention and memory, and are often complicit in reproducing illusory folk beliefs about the nature of reality and where humans feature in it (Bering, 2006; Pinker, 2007). How do we explain this puzzle?

This study accounts for the existence of counterfactual cultural elaboration as a form of evidence hallucination, where explanatory models of the world are made to be 'true' by flooding the perceptual environment with evidence that their predictions are correct. The core claim is that the incentive to do this comes from the desire to reduce anxiety. As a concomitant of chronic stress that is actuated by unpredictability in the environment (Dar et al., 2017; Grupe & Nitschke, 2013; Umberg & Pothos, 2011), anxiety is future pointing: not knowing what will happen next feels unpleasant. From this, it follows that anxiety avoidance will take the form of uncertainty reduction—typically, by constructing predictive models of the environment. Necessarily, if these models are to bring about anxiety reduction then their predictions must be accurate. In scientific modes of inquiry this is secured by hypothesis testing against independent data. But the human capacity for counterfactual thinking offers a more efficient shortcut: If I can saturate the environment with low-cost, perceptually salient *simulations* of evidence, then I gain the benefits of anxiety reduction without the extra work of hypothesis testing. Thus, counterfactual cultural

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<https://doi.org/10.1016/j.newideapsych.2025.101179>

Received 27 January 2025; Received in revised form 21 April 2025; Accepted 21 June 2025

Available online 5 July 2025

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elaboration can be explained as the attempt to reduce anxiety by performing ‘cheap’ work on the environment that makes it conform with model predictions. Given that hallucinated evidence is typically not veridical, the ultimate failure of most predictive models means there is a persistent stimulus to produce either new evidence or new cultural and cognitive models—and hence the generative nature of counterfactual fabulation.

This hypothesis draws on several lines of theoretical and empirical inquiry. Firstly, foundational work in thermodynamics and information theory demonstrates the convertibility between information and work (Bennett, 2003; Landauer, 1961), which gives an in-principle viability to the idea that there can be trade-offs between model construction and environmental manipulation. In particular, the Landauer limit gives the minimum possible amount of energy required to erase one bit of information, where E is the energy, k_B is the Boltzmann constant, and T is the temperature of the system in Kelvins [Eq. (1)].

$$E \geq k_B T \ln 2 \quad (1)$$

Because every model of the world is a representation that involves a deletion of some aspect of the world that is noisy with respect to the model, the principle here is that simplification requires work. Physical intuition for this idea is typically provided by thought experiments like Maxwell’s demon (Thomson, 1874). Specifically, the eponymous demon uses their omniscient knowledge of the velocities and positions of gas molecules in a box to open and close a partition between the two halves of the box. By selectively letting only high velocity particles into one partition, the demon creates an energy gradient and thereby converts information into work. But one can just as easily come from the other direction and see that work that compresses physical particles of any specific type into a smaller volume increases the predictability of a system, and thus work can also be converted into information. Whilst these abstract considerations may seem a far remove from cultural processes that operate at orders of magnitude above the Landauer limit, they have already been used speculatively to formulate potential solutions to the Fermi paradox by predicting the behavior of more technologically advanced civilizations (the ‘aestivation’ hypothesis (Sandberg et al., 2017)). From the more mundane perspective of the present study, their value lies in showing that cultural modeling and environmental manipulation are linked by deep thermodynamic principles that do not require an especially rich account of human cognition.

The account of cognition that is required is provided by active inference models that identify surprise minimization as the principle guiding the interactions of an agent with its environment—and in particular, those models based on the free energy principle (FEP) originated by Karl Friston and colleagues (Buckley et al., 2017; Clark, 2012, 2016; Friston, 2009; Palmer et al., 2015). Though these models do not often explicitly discuss the Landauer limit, they do allude to it (Friston, 2019; Friston et al., 2023), and the constraints it sets are implicit in how they describe agent–environment interactions. In this regard, agents are described as acting so as to not find themselves in sensory states that lie outside the expected values of the sensory states that evolution has encoded into their cognitive and somatic architectures. For instance, the fact that I have lungs rather than gills means that I will act so as to not to surprise my respiratory system by spending long periods of time underwater. In general, this is done by generating on-the-fly predictions about the sensory data I *should* be receiving and gauging these against the sensory data that I *am* receiving. Where these diverge, I act so as to decrease this divergence, which has an upper bound in the negative log probability of my sensory state. This approach is evolutionarily useful because it reduces the computationally intractable task of modeling the entire environment to the estimation of those environmental states that are relevant to the agent. Once again, the value of active inference approaches here lies in their cognitively ‘thin’ nature, which allows them to be applied to natural and cultural phenomena, ranging from collective behaviors in animals (Heins et al.,

2024) to narrative cognition in humans (Carney et al., 2019; Friston & Frith, 2015).

Anxiety enters the picture by way of ‘dark room’ objections to active inference models (Friston et al., 2012). Specifically, if the object is to act so as to minimize surprise, then the easiest solution is to seek out environments that are highly predictable (the dark room). As this does not capture the totality of any agent’s behavior, there is clearly a need for prediction to be guided by a flexible cognitive orientation that conditions predictions on what is known about specific environments and calibrates actions accordingly. The literature converges on anxiety—in both its clinical and non-clinical manifestations—as a negatively valenced aversive response to uncertainty in the environment in this way (Charpentier et al., 2017, 2022; Wilson et al., 2023). Usefully, this can be connected with the active inference and thermodynamic frameworks described above by way of Shannon entropy, H (hereafter, just entropy) (Kuzemsky, 2017; Shannon, 1948, 1951) [Eq. (2)]

$$H(X) = - \sum_{i=1}^n P(x_i) \log P(x_i) \quad (2)$$

To the extent that entropy represents the expected value of surprise across all the states x_i of a system, increases in anxiety should track increases in entropy. Equivalently, any predictive model will reduce anxiety by reducing surprise. Qualitative appreciations of cultural models have long recognized the link between certainty-offering rituals and aesthetic practices and anxiety reduction (Malinowski, 1954; Woringer, 1953); more recent work by the present author and others has explicitly formalized this in terms of cultural models as entropy reduction devices that serve to minimize anxiety (Carney, 2020; Carney & MacCarron, 2017; Carney et al., 2019; Hirsh et al., 2012).

Putting all of these considerations together, what emerges is an account of counterfactual cultural production that sees it as a form of low-cost work that reduces anxiety by flooding the environment with simulated evidence for a predictive cultural or cognitive model. However, before proceeding to the two studies that explore this claim, two high-level reflections are in order.

Firstly, there is the question of the similarities and differences between the evidence hallucination approach and the FEP active-inference models of cognition that have come into such prominent view in recent years. Clearly, there is a common ground between the two and it is certainly the case that the evidence hallucination approach is conceptually dependent on FEP models. However, there is also an important difference. The emphasis placed on anxiety in the evidence hallucination account is absent in FEP models, where surprise minimization is not attributed to any specific somatic or affective competence. While this is what grants these models their impressive generality as theories of agency, it is also why they are somewhat insensitive to the idiosyncrasy of human cultural fabulation. There is a very obvious sense in which human symbolic practices are qualitatively different from those of other species (Deacon, 1997), and the addition of anxiety to FEP-oriented active inference models explains this difference. Active inference models are, ultimately, adaptive: free-energy minimization allows resources that would otherwise be used in expensive cognitive modeling to be diverted to towards reproductive success—and this can only happen if surprise is minimized by predictive success. While anxiety obviously has an adaptive value too, anxiety minimization imposes a weaker threshold on prediction: all that matters is that predictions *appear* to be successful. For this reason, the evidence hallucination hypothesis is much more sensitive to the explosion in seemingly non-adaptive sign and symbol production that has attended human cognitive activity for at least 70k years.

The second reflection concerns the testability of the evidence hallucination hypothesis. While the two studies offered here are empirical in the sense that they volunteer hypotheses which are tested using the apparatus of inferential statistics, it is important to be clear from the outset that they are suggestive rather than conclusive. The role of hypothesis testing with respect to cultural materials is a fraught

one, and to reprise it here would be to rehearse the long history of how explanation has been theorized in the social and human sciences. It is better, perhaps, to be satisfied with the result that the evidence hallucination hypothesis is not obviously *disproven*. As Claude Lévi-Strauss long ago observed, “The human sciences never—or very seldom—explain completely, and they do not predict with complete certainty. But for all that they may be able to foresee in one out of two or four cases, they are yet able [...] to give to those who practise them something that comes between pure knowledge and practical efficiency—*discrimination*” (Lévi-Strauss, 1964, 539). The point here is that one should proceed with as much rigor as is available given the data, but without allowing the peremptory demand for an excess of rigor to paralyze the action of thought.

The present study trials this approach against two representative examples: a religious model of the world, as articulated in the Gospels of the King James Version Bible; and secular representations of collective identity in the form of national flags. As these test cases span linguistic and visual modes of representation, the cultural salience of the examples is complemented by a more robust test of the core claim.

Study 1: A linguistically articulated religious world model

While it is unlikely that religion can be collapsed into any single function (Atran, 2005), it is clear that *one* of its functions is to reduce existential uncertainty (Engstrom & Laurin, 2020; Hogg et al., 2010; Höllinger & Muckenhuber, 2019). One way religions can do this is by offering low entropy, positively valenced, and transcendently oriented predictions about situations of maximal uncertainty—with death, for obvious reasons, being chief amongst these. To make the predictions credible, the evidence hallucination hypothesis maintains that religious believers will populate the environment with perceptually impacting stimuli that reduce complexity and evince a positively coded postmortem reality. That this is so can be seen readily enough with ecclesiastical architecture, which simplifies the spatial environment by providing navigation points and, by way of perceptual salience, intrudes religious ideas on the attention. Here, the conversion of thermodynamic work into predictability comes via reshaping the landscape into a lower entropy state. But if it is cheaper to build a church than an afterlife, linguistic representations are cheaper still, so this tendency should be even more visible in religious language. This gives the following hypothesis:

- H_1 : Religious models should saturate the perceptual environment with low entropy linguistic constructions that, relative to the implicit model of background English, stimulate positively valenced, transcendently oriented sensory experiences.

That low entropy linguistic and discourse-level constructions (whether religious or not) can reduce anxiety is evidenced from research on creative bibliotherapy (Carney & Robertson, 2022), narrative social psychology (Carney et al., 2019), and narrative psychotherapy (Pennebaker & Seagal, 1999). These all converge on showing that predictable linguistic and discourse features alleviate anxiety by injecting real or hallucinated predictability into the environment. The idea here is that the low entropy language of the KJV allows for the creation of sentences and discourses that are themselves also low in entropy, and hence anxiety reducing.

1.1. Methods

Testing this hypothesis requires an encoding of language that allows for all of the relevant variables to be quantified. The Lancaster sensorimotor norms for English provide one efficient way to do this for sensory states (Lynott et al., 2020). By providing human-sourced scores for how strongly each of 39,707 lemmas is associated with 11 sensorimotor dimensions (the five senses plus interoception and the motor effectors

Table 1
Median split for three example words on six sensory modalities; 0 indicates a score below the 50th percentile for all words in that modality and 1 a score of greater than or equal to it. Words with the same binary vector are mapped into the same sensory category.

Modality	PIZZA	SPIRIT	ACHE
Auditory	0	1	0
Gustatory	1	0	0
Haptic	1	0	1
Interoceptive	0	1	1
Olfactory	1	0	0
Visual	1	0	0

of head, arm/hand, leg/foot, torso, and mouth/throat), the Lancaster norms capture the embodiment profile for most common English words. Significantly, the norms show that even abstract concepts have a stable sensorimotor profile across individuals [Fig. 1]. No less significantly, the norms allow for English to be partitioned into equivalence classes of words that have a similar sensorimotor profiles. This is important because it creates a probability distribution across the equivalence classes that allows entropy to be calculated. That is, if there are N equivalence classes and religious language uses words from each class with a different probability than English as a whole, it becomes possible to measure the entropy difference between religious language and background English with respect to their sensorimotor impact. In effect, this amounts to vocabulary reduction, where lemmas are mapped into a small number of superordinate ‘words’ that are defined by their somatic impact rather than their meaning, allowing that the two will be related. (Food related lemmas, for example, are likely to map into the same category.) On the one hand, this makes for a more succinct formal model; on the other, that fact that religious behavior is as much a matter of *corporeal* experience as cognitive suggests the procedure is especially appropriate to the phenomenon of interest (James, 1902; Tan, 2016; Cappellen, Cassidy, & Zhang, 2023; Winter & Granqvist, 2023). Here, the reduction was done by performing a median split on the score of all 39,707 lemmas on the six sensory modalities (the motor modalities being incidental to the hypothesis under test). This generates $2^6 = 64$ possible sensory states into which words can be mapped [Table 1]; an interactive plot showing a 3D projection of all 39,707 lemmas grouped by the 64 sensory states can be accessed [here](#).

The religious model chosen was that articulated in the four Gospels of the 1611 first edition of the King James Bible (KJV). Though any religious text should show the same result, the KJV was chosen for its significance as a book “designed to control the language of salvation and to occupy the linguistic high ground in such a way as to allow its rivals [...] less verbal space, less legitimacy, less power” (Carroll & Prickett, 2008, xxix)—in other words, for its representativeness as an evangelical document. The text was prepared by tokenizing, lemmatizing, and removing the stopwords from the four Gospels using a custom function built in the spaCy natural language processing library for python (Honnibal et al., 2020). This meant breaking the text into words, reducing morphological variation in words to a root form (‘ran’, ‘running’, ‘runs’ → ‘run’), and stripping out words with no semantic content like prepositions, conjunctions and articles. The result was a Bible vocabulary of 2,398 meaningful lemmas. Intersecting this with the sensorimotor lemmas gave 1,960 words for which data was available; all 64 sensory states were represented in these words. (It should be acknowledged that sensorimotor norms were scored by speakers of modern English, so their application to the KJV is necessarily anachronistic. Nevertheless, the semantic accessibility of the KJV to modern readers suggests that the anachrony is not large enough to disqualify the use of the sensorimotor norms.)

1.2. Results

The first prediction of H_1 is that the entropy of religious language will be lower than English as whole, measured relative to the distribution of words across sensory states. That is, religious language,

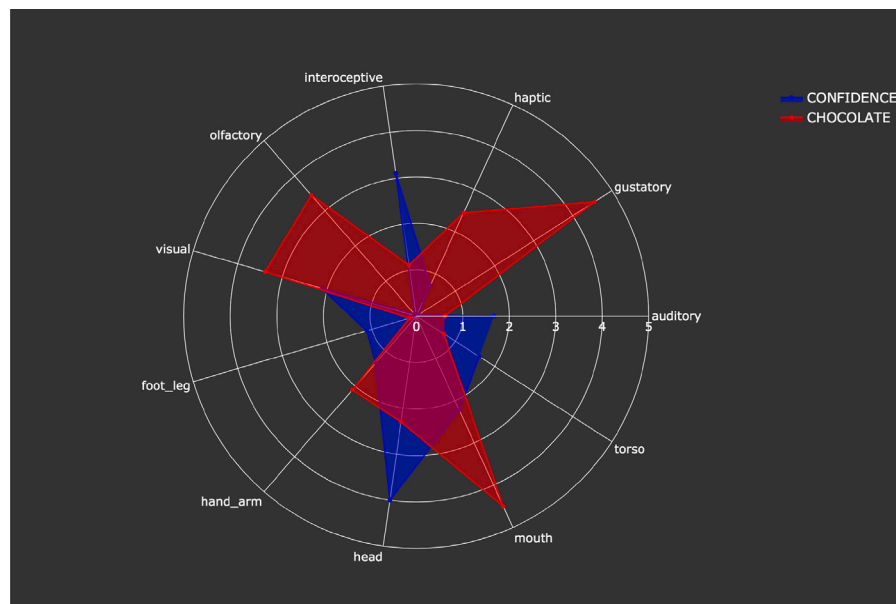


Fig. 1. Sensorimotor norm scores for CONFIDENCE and CHOCOLATE.

compared to English as a whole, will over-sample words from some sensory states and under-sample from others, thereby making the over-sampled states more perceptually salient. This was tested by creating two probability distributions defined by normalizing the number of words in each sensory state relative to the total vocabulary size for the KJV and English as a whole respectively. As predicted, the entropy of the KJV Gospels (5.274 bits) was lower than the entropy of English as a whole (5.415 bits)—a difference of -2.673% . (Entropy was calculated as per Eq. (2) using the SciPy python library (Virtanen et al., 2020).) This value is about what one would expect for a text that is designed to normatively regulate everyday life: too large a simplification invites falsification of hallucinated evidence by experience, and small entropy difference like 2.673% ensures that the KJV is complex enough to represent most human sensory states, but simple enough to make them more predictable. The wider implications of this difference for predicting the frequency of religious behaviors will be developed further in the discussion below.

The second and third predictions of H_1 relate to positively valenced and transcendentally oriented language. That is, the language of the KJV Gospels should, relative to background English, select words from the 64 sensory categories that engender pleasant sensory states (Cappellen, Zhang, & Fredrickson, 2023) and index values that point to a supra-mundane reality (James, 1902). Both variables can be calculated using the valence-arousal-dominance norms published in Warriner et al. (2013) and the semantic size norms in the Glasgow norms of Scott et al. (2019). Valence is a straightforward measure of positive sentiment; semantic size is slightly more complicated and concerns how 'large' a word is felt to be. For concrete words, this tracks physical size: CATHEDRAL has a larger semantic size than CHAPEL. In the case of abstract words, the tracking is guided by psychological or cultural salience: VOTE has a larger semantic size than CHOOSE. Given this, semantic size provides a useful proxy for the 'transcendental' freight of a word. As the two data sources use different scales for rating words, valence and semantic size variation were rescaled between 0 and 1.

Both predictions were evaluated by scoring lemmas from the KJV and background English for both valence and semantic size across each of the 64 sensory states [Fig. 2]. These scores provided DVs for separate two-way ANOVAs that took source (KJV Gospels vs background English) and sensory category as the IVs. Tests were conducted using the pingouin statistics library for python (Vallat, 2018). For valence,

there was a statistically significant difference in the predicted direction with respect to sensory state ($F(63, 30120) = 19.83, p < .001, \eta^2 = 0.039$), as there was also for source ($F(1, 30120) = 258.67, p < .001, \eta^2 = 0.009$). Similarly, differences for semantic size were in the predicted direction for sensory state ($F(63, 30120) = 99.72, p < .001, \eta^2 = 0.173$) and source ($F(1, 30120) = 139.123, p < .001, \eta^2 = 0.005$). As expected from the entropy results, there were no significant interaction effects for source and sensory state in either model: i.e. there was a substantial overlap across all sensory categories between the vocabulary of the Gospel writers/translators and background English. This is likely because a complete decoupling of the two vocabularies would make the KJV inapplicable to everyday life, and hence negatively impact on the 'plausibility' of the hallucinated evidence.

These results do not disqualify the claims of H_1 with respect to the likely cognitive and perceptual effects of hallucinated evidence generated by a textually articulated religious model. That is, that the KJV selectively over-samples words with a high transcendental freight and that are associated with positively valenced sensory states, and its vocabulary encodes a world model that is lower in entropy than that implicit in background English.

Study 2: A visually encoded model of national identity

The evidence hallucination hypothesis is *prima facie* true with respect to symbols of national identity. Few would question that politics flood the perceptual environment with thermodynamically 'cheap' evidence that they are permanent and pervasive in the form of flags, anthems, currency, crests, parades, and other identity-projecting symbolic devices. Given this, the question becomes whether increases in collective anxiety positively predict the extent to which this evidence hallucination occurs. This second study evaluates this question with respect to national flags, the most common symbol of collective identity.

The first question in this connection concerns whether low-entropy visual artefacts can, in fact, reduce anxiety. Whilst there are no studies that focus specifically on flags, there is evidence that both contemplating and producing low entropy images have anxiety-reducing effects. On the contemplation side, predictable images (like nature scenes) are established as having a calming effect on hospital patients (Lankston et al., 2010), while entropy-reducing features of images like symmetry are preferentially attended to and are associated with higher positive

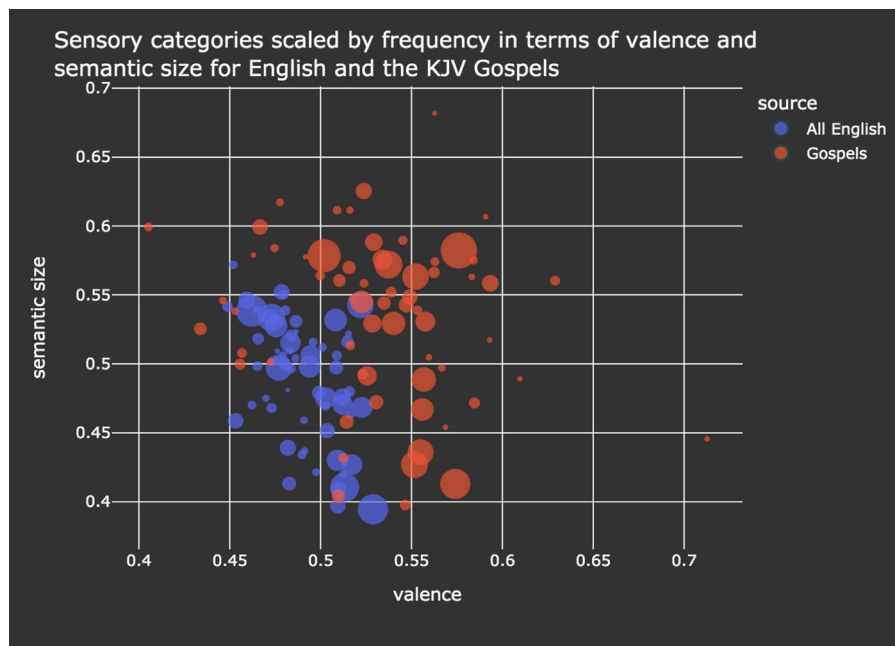


Fig. 2. Sensory categories scaled by frequency in terms of mean valence and semantic size by sensory category for English and the KJV Gospels. See [here](#) for an interactive version of this plot that allows categories to be compared across sources.

valence (Yi et al., 2018). On the production side, the literature on art therapy attests to the value of low entropy images like mandalas when it comes to reducing anxiety (Curry & Kasser, 2005). Though these lines of evidence do not directly show that national symbols like flags impact on the experience of anxiety, they do evince that visual artefacts and anxiety can be placed in relation to each other.

This leads to the second question, which asks, in the case that there is a potential relation between flags and anxiety, what *type* of anxiety does the evidence hallucination associated with symbols of national identity alleviate? For nation states, the principal anxiety must concern persistence over time. The historical record makes visible the fact that collective identity is not stable, and this, clearly, is a threat to any individual or group that is materially or politically invested in a given identity. This divides into two forms of collective anxiety: *exogenous* and *endogenous*.

- **Exogenous anxiety:** Conflict between societies is a historical staple. Indeed, war has been hypothesized as a key driver in human evolution (Duntley, 2015). As this poses an existential threat to the loser in the conflict, it is unsurprising that war and the fear of war is one of the most persistent causes of anxiety (Stearns, 2006). In this scenario, collective representations are valuable as focal points around which identities can coalesce in opposition to competing external identities.
- **Endogenous anxiety:** There are no human societies that do not contain internal divisions. The incest taboo alone means that every individual must, at the most basic level, observe the distinction between kin and non-kin (Lévi-Strauss, 1969). Where anxiety arises is in relation to the fact that divisions are often factional, and thus corrosive of solidarity and competitive with respect to their claim on collective identity symbols (Northern Ireland Human Rights Commission, 2013).

National flags act as an implicit cultural model that alleviates these anxieties. At the most trivial level, this is done by associating national identity with permanent features of the natural world, like stars (EU, USA, China, Australia), vegetable forms (Lebanon, Canada, Haiti, Fiji), and animals (Uganda, Wales, Mexico, Papua New Guinea). Clearly, the intention here is to provide reassurance that the historically contingent

fact of national identity is actually a *natural* state of affairs—and thus permanent. Equally, by mapping an intractably complex entity — a nation — into an iconic visual representation, flags reduce entropy and with it anxiety. Where this picture becomes more complicated is with respect to the two different forms of anxiety, principally because these exert competing pressures on the visual features of flags.

One the one hand, endogenous anxiety demands that flags project the different internal divisions of a nation into their material form. For example, the green, white, and orange of the Irish tricolor map Catholicism (green) and Protestantism (orange) into a space of mutual amity (white), just as the 50 stars of the USA flag represent the 50 federated states of the union. In practice, this implies a positive correlation between internal divisions and visual entropy. Visual entropy measures how predictable one patch of an image is from another — low entropy images are highly self-similar — and is calculated using Eq. (3) following the protocol described in Haralick et al. (1973), where i and j are pixel pairs. (That is, entropy is calculated relative to the unpredictability of the distribution of differences in pixel intensities.) It therefore follows that flags which need to represent large numbers of internal divisions will have higher entropy in virtue of needing to do more visual ‘work’ in mapping these divisions.

$$\text{Entropy} = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} P(i, j) \log P(i, j) \quad (3)$$

On the other hand, exogenous anxiety will aim for flags that are maximally perceptually salient relative to other flags. If a flag is to adequately capture the difference between a nation and its competitors, this flag should be immediately and unreflectively identifiable. This implies that the flag should have low internal contrast, where contrast in an image of N pixels is calculated by Eq. (4) as the expected value across $N - 1$ pixels of the squared difference in hue intensity between all possible pairs of pixels (i, j) in the image (Haralick et al., 1973) :

$$\text{Contrast} = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} (i - j)^2 \cdot P(i, j) \quad (4)$$

The logic here is that images with high internal contrast act as camouflage—think how zebra or tiger stripes serve to blend their bearer into the background environment (Desimone & Duncan, 1995; Eckstein

et al., 1997; Troscianko et al., 2009). On this view, a flag should maximize perceptual salience by keeping internal contrast low.

The complication here should be evident. Because visual entropy and contrast are partially positively correlated (Haralick et al., 1973), endogenous and exogenous anxiety are to some degree in competition with each other with respect to the visual features of national flags (i.e. raising entropy will usually also raise internal contrast). This means that the optimal flag for reducing overall anxiety is one that maximizes entropy while minimizing corresponding gains in contrast. However, given that the ultimate purpose of a flag is to signal a coherent collective identity, the demands of exogenous anxiety *should* anchor variations of entropy in the low contrast position. This generates the following hypothesis:

- H_2 : Higher levels of exogenous anxiety will produce flags with low visual contrast, while higher levels of endogenous anxiety will produce flags with high visual entropy—with low contrast trumping high entropy as the optimized variable.

1.3. Methods

Flag data were acquired by downloading a comprehensive dataset of 254 national flag bitmaps from the [Flags of the World](#) website. As these are normalized for size and resolution, they ensured that all image metrics would be standardized. Entropy and contrast scores were extracted for all flags using the *mahotas* image processing library for python (Coelho, 2013). This provided the two dependent variables.

As exogenous and endogenous anxiety cannot be measured directly, proxies were used for both. In the case of exogenous anxiety, the proxy used was the number of land borders a country has. It is an established result that the frequency of conflict scales with the number of borders a country shares, so from this it is reasonable to infer that exogenous anxiety will be more pronounced in countries with more borders (Richardson, 1960; Starr, 2006; Wesley, 1962). (It is certainly the case, for example, that proximity to porous and contested borders in general engenders higher levels of anxiety (Almond, 2016; Simmons & Shaffer, 2023).) Border counts were obtained using the *pycountry* library for python by counting the number of neighbors each country had (Ehmann, 2022). A proxy for endogenous anxiety was obtained by using the internal fractionalization data published in Alesina et al. (Alesina et al., 2003), which provides indexes of ethnic, religious, and linguistic division for 185 countries. Each index is calculated by estimating the probability that two randomly selected individuals will belong to a different ethnic, religious, or linguistic group. Here, a mean was taken across all three indexes to capture the aggregate level of internal division for each country. (This, in addition to missing border data for some countries, reduced the number of usable flags to 181.)

1.4. Results

Two linear regressions were performed with contrast and entropy as DVs and mean internal social division and number of borders as IVs. As expected, number of borders predicted a decrease in the contrast of flags ($DF = 180$, $\beta = -4.524$, $t = -2.067$, $p = .04$, $R^2 = 0.023$). Also as expected, mean internal division positively predicted the entropy of flags ($DF = 180$, $\beta = 0.435$, $t = 2.402$, $p = .017$, $R^2 = 0.031$) [Fig. 3]. There was no statistically significant effect of number of borders on entropy, or of mean internal division on contrast. These results were consistent with the claim that flags can be thought of hallucinated evidence that serves to reduce collective anxiety, and that increases in exogenous and endogenous anxiety have predictable effects on the visual features of flags.

The prediction that contrast would anchor entropy variation in the low contrast position was tested by zero-centering the entropy and contrast scores relative to the midpoint of each range and performing a χ^2

test of goodness of fit on observations by quadrant. The results showed there to be a statistically significant effect of quadrant on frequency of flags ($DF = (3, 253)$, $\chi^2 = 216.866$, $p < .001$, Cramer's $V = 0.533$). 96% of observations were below the midpoint for contrast, confirming the prediction that contrast would anchor entropy variation in the low contrast position, with there being no observations at all in the least optimal high-contrast, low-entropy quadrant [Fig. 4]. Assuming that the optimal flag is the flag that offers highest entropy for lowest contrast and the least optimal is the flag offering lowest entropy and highest contrast, taking the absolute value of the product of entropy and contrast for each flag in the relevant quadrants allowed these to be identified. On this assumption, the flags of Benin and Saint Pierre and Miquelon respectively emerged as the most and least optimal for purposes of anxiety reduction [Fig. 5].

Discussion

Cultural models do not define a homogeneous population, so the two tests of the evidence hallucination hypothesis presented here cannot be more than illustrative. As already indicated, this is the nature of cultural data and should not need to be apologized for. However, it does mean that testing the hypothesis further will require patient, interdisciplinary work that treats each cultural model on its own terms with the methods appropriate to its nature.

In terms of the results that are presented, the entropy differences between the KJV Gospels and background English provide an independent corroboration of the modes theory of religiosity, where religious practices are classed as either doctrinal or imagistic (Atkinson & Whitehouse, 2011; Pyysiäinen, 2004; Whitehouse, 2004). The doctrinal mode involves frequent, low arousal rituals (daily prayers, regular group worship), while the imagistic mode entails infrequent, high arousal rituals (rites of passage, ascetic practices). The small entropy difference between the KJV Gospels and background English means that the world-model encoded in the KJV would require evangelically oriented repetition and re-emphasis for it to perform work in reducing anxiety—and thus it naturally reproduces the dynamics of the doctrinal mode. That this was so is very much visible in the historical character of the Protestant Reformation, which, amongst other innovations, immersed worshippers in the Bible text, and explicitly encouraged the memorization and daily application of Biblical passages (Cameron, 2012). However, one can also see how the imagistic mode emerges from the evidence hallucination hypothesis. Much larger entropy differences can be obtained by using a simpler model of sensory states (for example by using fewer sensory modalities); this results in a compression and intensification of sensory experience, but at the cost of evidence plausibility—the language and material actions associated with such states are not compatible with day-to-day life. Thus, these larger reductions in entropy are likely to be highly ritualized and occur with far less frequency than the smaller entropy reductions identified in the KJV Gospels. What all of this shows is that the evidence hallucination hypothesis predicts the frequency of two features of religious behavior — day-to-day evangelism and infrequent sensory intensification or compression — in a way that consistent with existing anthropological models and data. Further testing would involve more granular analysis of variations in entropy within specific books of KJV, as well as extension of the model to religious texts outside the Anglophone Christian tradition.

The results on national flags offer fewer points of integration with existing scholarship—largely because (to the author's knowledge) no such scholarship exists. While there are many qualitative studies of flags and national symbols (Cerulo, 1993; Medway et al., 2019; Reichl, 2004), these are interpretatively oriented and do not make testable predictions with respect to the visual characteristics of flags and wider features of social life. Such contributions are important: the small effect sizes of the statistical models presented here show that there are many other factors at work in flag design than those analyzed. Nevertheless,

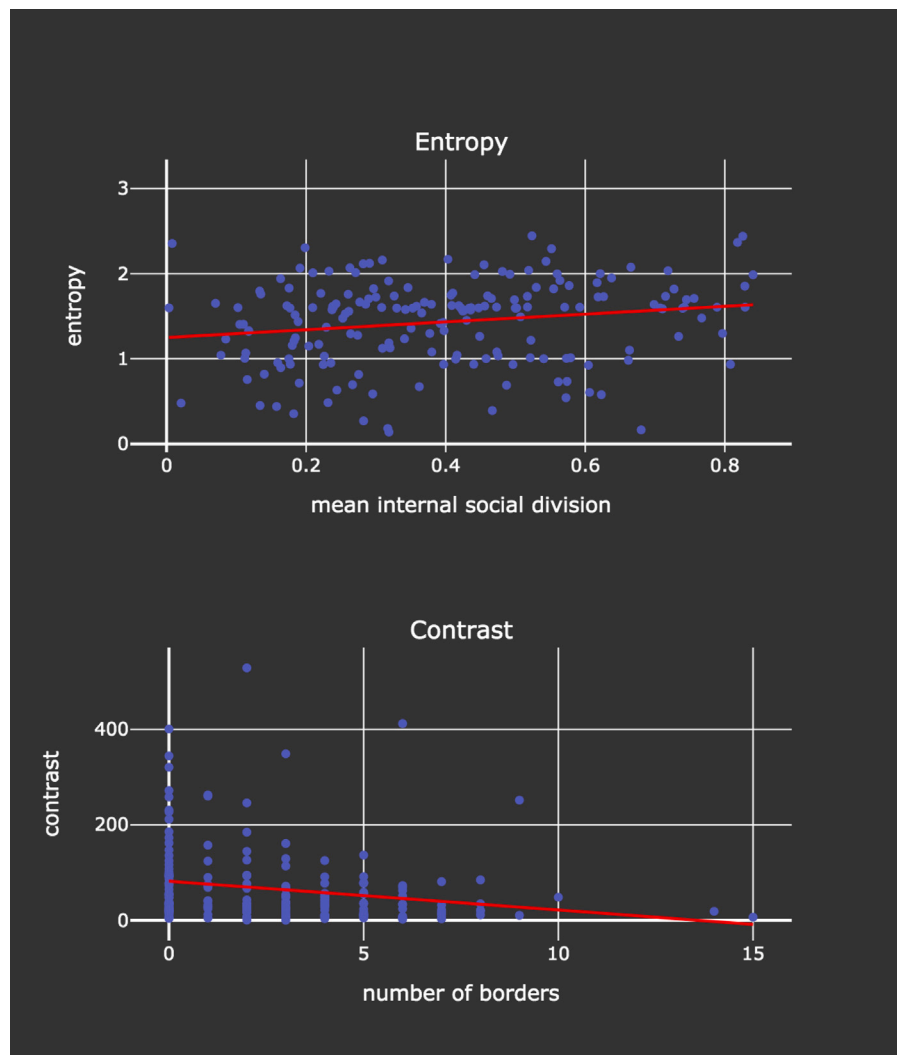


Fig. 3. Contrast and entropy over number of borders and mean internal social division for $n = 185$ flags.

the simple fact that high-level cultural tendencies *can* be predicted from low-level proxies for anxiety is an important in-principle advance for the quantitative analysis of counterfactual culture in its own right. Next steps would come with a more extensive analysis of symbols of national identity that includes as covariates their semantic content and historical context.

Allowing that both the studies presented here can be extended, the question emerges as to how the evidence hallucination hypothesis can be tested in *other* domains—and ideally, with more rigor. In practice, this would mean finding a more direct way to manipulate two variables: threat relevance and unpredictability (with ‘threat relevance’ being understood to indicate how existentially relevant an anxiety-inducing stimulus is). Being able to manipulate these would yield the following four testable scenarios:

- high relevance + unpredictable = high rates of evidence hallucination
- low relevance + unpredictable = low rates of evidence hallucination
- high relevance+predictable = low rates of evidence hallucination
- low relevance+predictable = low rates of evidence hallucination

If ‘relevance’ here is construed as pertaining to basic bodily needs like gestation, reproduction, and homeostasis, then it is possible to see what more rigorous testing might look like. Historical variation in

food resources, for instance, provides natural experiments that predict a greater incidence of gustatory language and images in the cultural record associated with periods of food uncertainty. By the same token, it should be possible to test if experimentally manipulated hunger produces fewer food ‘hallucinations’ in language and thought when food intake (however restricted) occurs on a predictable schedule relative to an unpredictable one. The practical and ethical difficulties of implementing such experiments with human subjects would obviously be challenging, so if they are offered here, it is primarily to show how the evidence hallucination could in principle be falsified. But it is worth noting that, where they already exist, historical studies of food-related cultural elaboration (Strickler, 2005) and experimental interventions on the experience of hunger (Keys et al., 1950) are consistent with the evidence hallucination hypothesis.

It is worth closing with a general observation on where the evidence hallucination hypothesis sits in relation to other models of counterfactual cultural fabulation. As a rule, these models have oscillated between deterministic biosocial models that are naturalistically grounded or interpretive models that explain cultural processes by way of contingent historical factors. Models of the first type offer consilience with scientific knowledge but are often insensitive to the autonomy of cultural production; models of the second type respect the freedom and generativity of culture, but are hostile to the idea that culture is shaped by non-historical cognitive constraints. The bad-tempered dialogue between these traditions of cultural analysis suggests that they likely

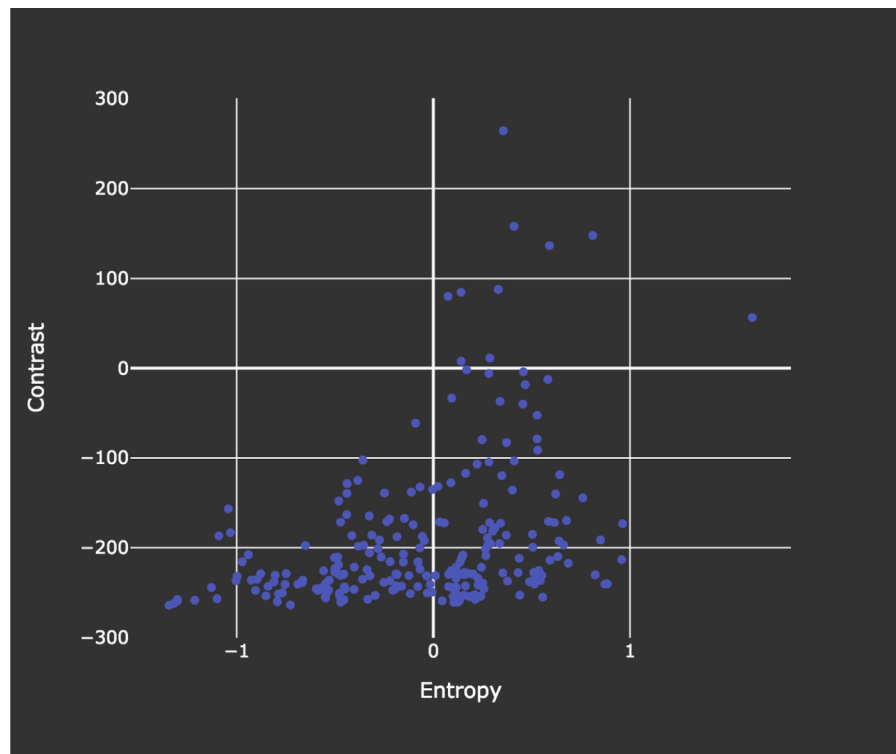


Fig. 4. The distribution of flags relative to the midpoints of the ranges of entropy and contrast, where data are scaled so 0 represents the midpoint.



Fig. 5. The flag of Benin (left) offers the optimal trade-off of entropy against contrast; the flag of Saint Pierre and Miquelon offers the worst. It is notable that the three-color model visible in the Benin flag is one of the most common flag designs.

track a fundamental interpersonal differences in how their protagonists approach the world. The evidence hallucination hypothesis offers a way out of this impasse. Its grounding in thermodynamic, active-inference, and information-theoretic concepts means that has a strong naturalistic orientation than can be readily reconciled with empirically and theoretically plausible accounts of the relation between work, cognition, and information. But at the same time, the evidence hallucination hypothesis is receptive to (and predictive of) the infinite creativity of counterfactual culture, and its application requires sensitivity to the historical factors that cause cultural and cognitive models to come into existence in the first place. In this sense, it is inherently needful of insights from across the spectrum of qualitative and quantitative disciplines. Whether it survives further testing is, as always, the key question, but the results presented here should illustrate its value as one possible solution to the puzzle of counterfactual cultural fabulation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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