A theoretical treatment of memetic traits using gene-meme, meme-meme and population equilibrium

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Abstract. Background: The term meme includes vertical trait transmission and laterally transmitted ideas that can be lasting or transient. Memes may sometimes follow the logic of population genetics, e.g. learned birdsong, but not when laterally transmitted. Much current work focuses on selection of memes rather than hosts. This paper investigates mathematically the interaction of behaviorally transmitted traits with host selection fitness. **Methods:** We analyze equilibrium between gene-meme and meme-meme competing propagators and consider whether a meme is linked to reproduction (e.g. vertical culture transmission), or not. We employ a genetic component and combined meme-induced fitness components for hosts, while memes have replication factors to distinguish from what's good for the host (fitness). We use a Monte Carlo simulation roughly calibrated to the Industrial Revolution to study meme effects on population stability. **Results:** A basic effective calculus of memetic trait competition and interaction with genes is derived and analyzed. The transient nature of many lateral memes may be a defense against accumulation of deleterious memes. Laterally transmitted (panmictic) memes with high spreading rate will often not equalize with a genetic trait, spreading outside of natural selection of the hosts, presenting a cumulative existential threat. Vertical transmission reduces replication rate and allows group selection against deleterious memes. Competing mutually exclusive memes contribute to inequality and altruism, but compete through adverse fitness since exclusivity assumes low conversion. **Conclusions:** The advantage of a portfolio of groups or species may not accrue to a single group. This understanding elevates meme-risk to the level of a candidate solution to the so-called Fermi Paradox.

Keywords

Meme, memetic, culture, altruism, evolution, Fermi Paradox

1. Introduction

The goal of this paper is to establish a theoretical calculus for the effect of behaviorally transmitted traits on human population fitness. As far as we know this theoretical basis has only been done for specialized topics. It was wished for and anticipated in Blackmore's *The Meme Machine*, [1] which suggests selection pressure favored those that made good choices regarding who or what to imitate, and imitated intelligently. This claim we intend to investigate mathematically. The following literature discussion will be taken as empirical findings to explain if possible, along with criteria as to when population genetics is applicable or what other calculus should be used.

A characteristic of memes we will address is that they may be associated with reproduction of physical meme carriers (hosts) through vertical cultural transmission, or their replication may be entirely separate from the reproduction of the carriers (laterally spreading). This separation of meme spreading from the reproduction of hosts causes unexpected results. We will show meme fitness as its own replicator is rather weakly linked to the fitness of the host as regards host

replication – unless groups remain small and meme (culture) transmission is largely vertical, to offspring in the group.

Memes are not the first evolutionary instance of lateral trait transmission. Bacteria are able to hand off genetic material independent of the reproductive process. Evolution largely suppressed this kind of lateral transmission between co-equal complex beings. It remains as viral pathogens and in rare cases an evolutionary step, such as the inclusion of mitochondria into eukaryotic cells, or the use of the Arc protein in mammalian memory which may be a repurposed retrovirus. [2] There is also similarity to microbiomes, though they are not usually considered a trait.

The word “meme” to mean roughly “behaviorally transmitted trait” originates from Dawkins’ *The Selfish Gene* appearing in 1976 [3], one year after Wilson’s *Sociobiology: The New Synthesis* [4]. The idea of socially transmitted behavior as culture, learning, fad or habit is thousands of years older, but the mid-1970s were a time of new understanding that a variety of behaviors were influenced by natural selection, and the basic idea seems to have been to consider non-genetic traits as entities undergoing propagation and natural selection. This paper is more concerned with how such dynamics affect host populations.

Originally meme was intended to be the smallest recognizable unit of cultural information and an independent replicator subject to mutation and natural selection. [5] In the Internet age “meme” came to be associated with a variety of transient phenomena that might last only days. These have been studied empirically with a view to eventually coming upon an analytical understanding through that route. Log normal distribution has been found for fast-spreading memes, [6] implying likelihood they spread by a stochastic growth process.

Models of fast-spreading/dying memes often need to be complex and typically there is an explosive rise to some limit of popularity and then a slower but still rapid decay. [7] The characteristics of spread and decay, occasional repetition of prior memes, perception of harm from many memes, and instinctive use of words like viral and contagion by the public have led to serious use of epidemiological models to describe meme propagation. [8]

Sterelny emphasizes lasting cultural aspects and distinguishes three mechanisms: (a) niche construction leading to group selection, (b) vertical flow of information from parents to children, (c) replication and spread of memes. [9] He argues the first two are definitely important in establishing lasting change, but spread of memes only *might become* important.

The last must be considered against the similarity of spread to that of a pathogen, which implies some kind of harm that is expunged by an immune-like reaction. And it can be considered against studies that find social media and attendant meme propagation to increase sub-group formation, isolation and polarization, such as their use in the delegitimization of 2016 US presidential candidates. [10] Fast-spreading ideas if given weight can cause revolutions and formerly were associated with words such as propaganda and ideology. *Making propaganda* we consider a meme. *Propaganda itself* the BBC termed “viral misinformation” and noted 20% comes from celebrities but accounts for 69% of engagement. [11]

Studying memes in connection with culture creation, Atran concludes that “unlike in genetic replication, high-fidelity transmission of cultural information is the exception, not the rule.” [12] A study comparing informational (truth, moral lesson) vs. emotional (disgust) factors in meme propagation found that greater disgust (ingestion of a contaminated substance) resulted in greater propagation. [13] Non-local media generally and Internet memes particularly may be thought of as lateral (or horizontal) as opposed to vertical cultural transmission, exposing people to ideas outside their local society that they would have rarely encountered centuries or millennia ago. But, as

recently as 2019 it was found that geography is still important in transmission of Internet memes. [14]

Lynch and Baker concluded from an analysis of birdsong memes that increased variability in memetic transmission support “high levels of among-population differentiation . . . in spite of high levels of migration . . . [allowing] accumulation of new mutants in different populations before migration can disperse them.” [15] One supposes increased migration along with faster meme-driven group formation will affect human populations, part of which Ross and Rivers already found. [10]

At least one mathematical model of memetics was proposed by Kendal and Laland in a short 2000 paper in the *Journal of Memetics*, now defunct, but the paper is available on the authors’ website. [16] It uses concepts of dominance, susceptibility to invasion, and population frequency algebra. The authors say, “We reject the argument that meaningful differences exist between memetics and the population genetics methods.” The actual formulation appears to contain many considerations similar to, perhaps influenced by, the field of social learning.

We reserve the word “fitness” to describe the ordinary reproductive success potential of a meme host. The spreading rate of the meme is called replication factor, and includes a statistical average of the sort of individual preferences social learners might express in their choices. A fast-spreading meme may reduce the fitness of its hosts, and this we explicitly model. Exactly how the meme is connected to ordinary reproductive fitness will determine the course of natural selection, not the replication ability of the meme alone. We find most prior treatments obscure the relation between genes and memes, and we wish to throw light on it, find results that are unobtainable with a population genetics approach, and characterize exactly when we might use population genetics with memes.

Meme competition has been studied empirically and through simulation. Nogueras and Cotta compared good and bad memes in networks and in panmictic spreading and concluded the “increased takeover time” associated with the non-panmictic topologies are “essential for improving the chances for good memes to express themselves in the population by improving their hosts,” and that performance enhancing memes are more successful in spatially structured spreading (c.f. geography finding above) than in the panmictic case. [17]

The propagation of two viral-like memes in a network is studied by Wei, using a susceptible-infected-susceptible (SIS) model extended to handle two infectious agents. [18] The contagion strength of each meme along with a probability per unit time of self-healing of an infected node are defined as basic propagation parameters. Propagation on two separate networks is compared with cross contamination. This might be relevant to vertical vs. lateral spreading. Wei, et. al. also apply their methods to study competition of true and false information rumors on two networks such as Facebook and Twitter, simulated by a composite network (much as their other study). [19] It is clearer in this study how the infection model studies of meme competition ultimately are decoupled from genes and the fitness of population members.

Weng et. al. used competition for limited individual and collective attention to find support for “heterogeneity in the popularity and persistence of memes . . . without the need to assume different intrinsic values among ideas.” [20] From limited user attention Gleeson et. al. derived heavy-tailed distributions of meme popularity. [21] More recently Spitzberg attempted a comprehensive model able to forecast numerous meme features based on competition “at multiple levels to occupy information niches.” [22] These types of models satisfy the urge to understand people’s use of the Internet. But few memes of the type studied by these models are semi-permanently established

with a lasting role in human culture. They are assumed to be transitory.

The agency aspect of social learning agrees with Atran's thesis that processing by a multimodular mind (one created by evolution) reduces the fidelity of transmission and creates constant, rapid mutation, especially when processed by children. [12] However, systematic study does support the idea that children irrationally mimic their parents' choices (for example in food). [23] In a social learning study, Wisdom, et. al. show that "participants combined multiple sources of information to guide learning, including payoffs of peers' solutions, popularity of solution elements among peers, similarity of peers' solutions to their own, and relative payoffs from individual exploration." [24] The study further finds that "when peers' solutions can be effectively compared, imitation . . . can also facilitate propagation of good solutions . . ."

Social learning can also be non-rational in a strict sense. A long standing puzzle is human behavior in an ultimatum game in which one person proposes how to divide a pool of money, and the other decides to accept, or reject in which case no one gets anything. Game theorists claim it is rational to accept very small portions, but actual human participants rarely settle for less than 40%, perceiving less is unfair. Boyu Zhang shows how social learning in an environment in which there are strategies and mutations contributes to this real world outcome. [25]

Social learning is often associated with the evolution of cooperation in games such as Prisoner's Dilemma and public goods. While it was initially assumed to be a primary enabler of the evolution of cooperation, Matthew Burton-Chellew and associates have been showing that as people learn about game theory they decrease their cooperation, and social learning has a specific role in this. [26-27] The author's own work demonstrates that this is not misguided, as excess cooperation by the poor with the wealthy leads to a worsening of their situation and an increase in wealth inequality. [28] Further, small changes in inequality in a couple of population deciles can empirically account for a national average motorway death rate difference of a factor of three. [29]

2. Approach

There is no concept of a "generation" with memes. They may reside statically in the environment, without destruction, when not actively influencing a host.

We define a **meme replication factor** R_M which is based on a **time period** T . Depending on the speed of a meme's propagation, the time period could be a month, a year, whatever is convenient. The replication factor is the number of new instantiations of the meme in a host created from each existing instantiation in a single period T . If propagation is allowed to run its full course, the period T can be variable, such as time until the next mutation. Usually in our case the host is a human, but it could be a computer, bird, anything over which a meme has influence. We assume there is some intrinsic replication rate based on the appeal and difficulty of transmission, which is represented via the replication factor.

The **population of hosts** is P , and the **instantiations of the meme in P** is P_M . Denoting the number of instantiations at the end of the period as P_M' and neglecting for the moment population change over the period we can write:

$$(1) \quad P_M \leq P$$

$$(2) \quad P_M' = \text{Min}\{P_M(1 + R_M), P\}$$

We will cease writing the "Minimum" constraint for brevity, though it is implicit. It is evident that the meme does not *directly* have the power to increase or decrease population P . It must act

through genetic traits to accomplish that.

Our first step will therefore be to explore the relation between genes and memes. For genes we find it not necessary for the comparison to use the full capability of population genetics. We examine only one allele for a dominant trait and count **trait instantiations** P_G within hosts as the relevant factor of interest. Thus we have a constraint similar to (1) on P_G :

$$(3) \quad P_G \leq P$$

We assume an **average population growth rate of R_p** , prior to meme introduction and including mortality if needed, and to be defined over time interval T rather than generationally, thus we have:

$$(4) \quad P' = P(1 + R_p)$$

This brings us to the question of fitness. For our gene-meme comparison, we need to set up a competition. We thus assume the genetic trait of interest has a positive beneficial fitness. Here again we must adjust from a general time base, in which fitness is usually defined, to the period time base. Then we let **F_G be the excess instantiations of the genetic trait of interest**, over and above R_p , in one period.

For convenience we let average population growth be zero: $R_p=0$ so that **$1+F_G$ is the relative per period increase in the genetic trait**. What's important is not that the population is in equilibrium with its environment, but that we are only interested in the relative changes caused by the gene of interest, and the invading meme. The spread of the genetic trait in one period is then given by:

$$(5) \quad \begin{aligned} P'_G &= P_G(1 + F_G) \\ \Delta P_G &= P'_G - P_G = F_G P_G \end{aligned}$$

The **meme induced (or conferred) fitness (of the host, not of the meme) is assumed to be $-F_M$** , with the minus sign explicit to remind us of its deleterious nature. This sets up a competition. Otherwise it would be beneficial for both the genetic trait of interest and the meme to spread among the whole population. We can now write:

$$(6) \quad P'_M = P_M(1 - F_M)(1 + R_M) = P_M(1 - F_M + R_M - F_M R_M)$$

Removing the second order term and writing for the change in meme host population:

$$(7) \quad \Delta P_M \approx P_M(1 - F_M + R_M) - P_M = (-F_M + R_M)P_M$$

These are not all new individuals. The $R_M P_M$ components are conversions. The $-F_M P_M$ term is a presumed loss of individuals if the induced fitness from the meme is deleterious.

3. Development

3.1 Panmictic Meme-Gene Equilibrium

There are two conditions for full equilibrium. First is population equilibrium, in which the number of individuals does not change. Physical ΔP is set to zero and conversions are ignored:

$$(8) \quad F_G P_G = F_M P_M$$

The second equilibrium condition is cessation of spread of the meme, which is realized when the meme hosts die as fast as the meme infects (converts) new ones:

$$(9) \quad R_M P_M = F_M P_M$$

Population equilibrium (8) is achieved when the population growth from the new gene is offset by the population loss from the deleterious meme. If there are no factors that oppose the meme, its condition for spreading is $R_M > F_M$. If it spreads faster than it kills, it will reach 100% penetration. It is difficult to prevent the spread (i.e. awareness) of memes. Later we will consider meme defenses including dominance and exclusivity, but undefended memes spread as indicated.

If population equilibrium is obtained *before* the meme achieves 100% penetration, *and* panmictic meme transmission allows it to reach the entire host population, *and* the meme induced fitness for the host is deleterious in a population fitness sense, *and* if no other factors change the intrinsic population growth factors (recall we assumed it was initially in equilibrium), *then* the population theoretically declines until it is extinct. There is nothing selection alone can do to stop it. Evolution can stop it by introducing a new gene or meme with sufficiently positive fitness boost, but this does not eradicate the meme. It becomes memetic load, like genetic load.

We call this ***meme extinction risk***, the risk of extinction from deleterious memes whose propagation is not checked by natural selection, because they spread faster than their hosts die. Further it is cumulative. ***A negative balance in incoming meme induced fitness will eventually cause extinction.*** We will discuss counter strategies below.

Notice the presence of conditions which make problems hard to detect. It's hard to identify the source because correlations are displaced in time. Symptoms are relieved when the population is in equilibrium. But as the meme spreads equilibrium is again lost. There is a delay built into the system which confounds most kinds of control loops, natural or created by the species.

3.2 Vertical Transmission of Memes

Instead of panmictic transmission of the meme, we now assume vertical transmission along with reproduction, confined to a small cultural group. After N periods children mature and some number mate into out groups. They can carry the meme with them and infect new groups. Otherwise there is little contact between groups and no meme transmission.

This condition does not change panmictic mating for gene transmission. It reduces meme transmission approximately by some parameter of the order of N . We assume the meme replication rate is applicable only during one of N periods. Then we have new equilibrium conditions:

$$(10) \quad P_M R_M / N = F_M P_M$$

Aside from the immediate benefit of reducing the meme replication rate by an order of magnitude, group selection comes into play. A fast-spreading meme will easily establish itself in a small group, and if deleterious, the performance of that group will suffer. They may lose a battle, or be ostracized from mating, and the meme may not spread at all outside the group. These chance events are difficult to quantify and model, so we leave it at equation (10).

By allowing group selection to filter meme's, this delay in transmission produces the effect observed by Nogueras and Cotta that non-panmictic meme propagation allows time for "good memes" to distinguish themselves by improving their hosts. [17]

3.3 Defensive Conditions

Now we examine some defensive conditions. The use of vertical culture transmission we have already discussed. This is a meme itself. It is therefore dangerous itself. Modifications to it may well

be deleterious. A possible modification is to hold ideas from other cultures under suspicion until those cultures have exhibited superior fitness characteristics. This approach also inhibits the spread of useful ideas, and is discriminatory. Many people currently advocate abandoning suspicion of vertical culture.

There is selective pressure in the vertical culture system to increase mating time, at least with respect to modulating meme transmission. In the U.S. average age of marriage has increased from 20 to 27 years since 1950. [30] While we do not posit there has been time for this to evolve from the selective pressure we postulate, it might confer an advantage in the an age of information and Internet meme spread. Marriage age has other constraining factors. In 1985 marriages beyond the late 20s were less stable due to inadequate role performance. [31] The Institute for Family Studies reports stability now increases into the 30s. [32]

Increased generation time can be used to impart more complex cultural memes which might possibly have less deleterious or even positive fitness. Parental investment by hypothesis benefits fitness of offspring. Studies of parental investment are often oriented toward explaining mating patterns and sexual behavior and which parent provides the care rather than focusing on offspring success [33-35] including modern game theory approaches which predict lower likelihood for mutually cooperative relationships based on unequal cost factors, although they do address reproductive fitness. [36]

The above are passive defenses not specifically attacking memes. It should be possible to increase efficiency by a specific defense. If the defense is generally against all memes, it amounts to a retreat from being a meme-capable species. More likely it would be selective. We posit several types.

Resistance against marrying into groups with *different and unproven* culture, an in-group vs. out-group defense, might increase the time N required to export the meme, or reduce the export rate. For example, after an out-group has stood for some time and its fitness observed to be equal or greater than the general population, then marriage into the group or accepting mates from it might be held in higher desirability. Even without vertical confinement “test of time” fitness evaluation might be a useful screen against fast-spreading memes, reducing their spreading rate until the fitness is evaluated. This might remove the most dangerous memes. But memes with delayed effects would still be spread. The spread of negative emotional content memes [13] might be as cautionary tales.

Another selective criterion might be to *limit the lifetime of laterally spread memes*. This amounts to positing directly the transient behavior of Internet memes. Limited lifetime memes will overlap less and have lower cumulative effect. Perhaps faster spreading memes would have the shortest lives. Perhaps boredom is an instinct developed in part as meme defense.

An interesting possibility is *occasional adaptive resets*. Selection is on length of accumulation and modification. Long term memes are assumed to be more useful than short-term memes, but still after a long time negative modifications may pose a risk. Religions change every few thousand years. Civilization, itself a complex of memes, rarely has lasted longer than a thousand years.

3.5 Meme Equilibrium

Equilibrium for short-term memes would have to do with channel saturation and has been investigated adequately in the literature we cited. We first consider long term non-interacting memes. One does not forbid or encourage the other, etc., and they may both exist in a population as long as they or their combination do not cause extinction, and both will approach 100% saturation if

not opposed by a meme defense. The only case not already considered is when both memes are expressed in the same individual. How do their properties combine? Under the assumption of no direct interaction, for small replication and fitness values, a linear approximation to their combination should suffice. Anything else constitutes interaction.

We will attempt to find the equilibrium conditions under which meme-driven growth equalizes with population growth. To this end we use the concepts from analysis of market volatility and individual equity vs. market returns: [37, chapters 1 and 3]

- a) In a geometric progression (e.g. population growth), geometric positive increments must be greater than negative increments to achieve net zero return (e.g. 10% down is balanced by 11.1% up, and as the deviation increases the required difference in up/down increases).
- b) In a portfolio of investments (or of species) components of which yield geometric returns (as above), the average value can be obtained. But if randomly selecting just one element (one species), the median value is the expected return. Often with geometric progression the median is less than the average, more so with high volatility.

Memes potentially increase volatility. We might in the future switch from carbon to silicon based life (aka artificial intelligence) after 10,000 years of strongly meme-based civilization, whereas the switch from prokaryotic to eukaryotic cell structure took 1 to 1.5 billion years. [38]

We use a spreadsheet model to perform a Monte Carlo simulation of various meme profiles, varying in their volatility (magnitude of induced fitness deviations, which we call dispersion) and central bias (average of the deviations, which we call bias). Fifty populations are simulated as they absorb 1000 memes randomly generated by selection of one of two values of a binomial with the desired dispersion and bias. The fitness values are not for a specific time period, but the cumulative population change attributable to each meme. We model the Industrial Revolution as a multi-meme event, and see if any fit and how they vary. The results are shown in Table 1.

Table 1. Various fits of Monte Carlo simulation to 800% world population increase since start of Industrial Revolution

F _M up	F _M down	Bias	Dispersion	Max	Min	StdDev	Median	Average
5.37%	-4.63%	0.37%	5.00%	23096%	64%	4018%	864%	2265%
3.26%	-2.74%	0.26%	3.00%	6563%	151%	1262%	859%	1295%
2.23%	-1.77%	0.23%	2.00%	2809%	256%	448%	783%	856%
1.72%	-1.28%	0.22%	1.50%	2036%	236%	390%	770%	837%
1.22%	-0.78%	0.22%	1.00%	1383%	386%	248%	807%	853%
0.71%	-0.29%	0.21%	0.50%	1075%	551%	117%	805%	789%
0.46%	-0.04%	0.21%	0.25%	1022%	686%	70%	806%	821%
0.33%	0.08%	0.21%	0.13%	847%	694%	29%	780%	782%
0.26%	0.16%	0.21%	0.05%	845%	784%	13%	814%	814%
0.22%	0.20%	0.21%	0.01%	820%	810%	2%	815%	815%

The number of long term memes since the start of the Industrial Revolution depends on how one categorizes and counts them, which we address below. The shaded green area in Table 1 contains the cases the author thinks more likely. For dispersions below 1%, median and average values converge and standard deviation drops. Low dispersion cases presumably would correspond to biological evolution if it is characterized by small changes. There is no real reason to believe meme fitness changes are small. However, the standard deviations for dispersions of 2% and higher are quite large. Do we really believe there is a good chance the world population might in 2020 be 1.6 billion (barely more than before the industrial revolution) or 33 billion (likely not sustainable with present technology)? Thus the choice of the green shaded area was made largely on the basis of reasonable standard deviation. This suggests the upward bias of meme evolution in humans in the

last 250 years is around 0.2% fitness improvement per meme if it is rather arbitrarily divided into about 1000 memes. If one believes there were more memes, the value of each is proportionally lower. The function is nearly linear for these small change rates. The binomial dispersion, that is, the variance from meme to meme on average, is almost certainly less than 1.5% and more than 0.1%. Values below 0.5% are relatively safe, i.e. reasonable standard deviations.

In biology one expects a *negative* bias in mutations. How then does life survive? From a few big positive mutations? Probably not. Life is divided into organisms (collections of cells) and species (collections of inter-mating individuals) in a sort of portfolio approach. Individuals die and species are expected to fail eventually, removing the worst mutations, but the portfolio keeps growing. Evidence either from the portfolio (all life) or a still-existing species will always show a positive median mutation benefit, which constitutes survivor bias.

Humanity has plans and desires to increase the upward bias. Our risk-based derivation actually can be inferred in both directions. If the upward bias is increased, that means bigger chances are taken. There are likely big successes and big failures. If, for example, the upward bias is doubled to over 0.4%, the dispersion will likely be above 5% and the standard deviation will mean that most of our future probabilities will contain relatively more dystopian scenarios.

3.6 Special Cases of Non-Linear Meme Interaction Can Emulate Genetics

A simple case of meme-meme interaction is suppression of one of the memes. Morality and compassion memes demand suppression of selfish impulses. Fairness memes demand we treat others as we would like to be treated, and we have seen that such a fairness meme apparently overrides rational application of game theory in the ultimatum game.

A second, perhaps less likely but not completely discountable reason for suppression, may be the source of a meme. It may come from a culture that is under domination. It may come from a parent or other caregiver who is not the favorite of the child, and be contaminated by rebellion.

In the vertical transmission of memes, a child receives cultural memes primarily from two parents, and secondarily from other members of the vertical culture group. Much of the time those other members will be associated with one parent or the other, for example family members or business and trade associates. So if memes are not expressed evenly in the society, that is if all persons do not express all the same memes all the time, then the child gets two sets of memes, a mother set and father set. Many memes are mutually exclusive to some degree because of time and energy costs. For example, a hunter may not also be a caregiver, at least not primarily. A farmer may not also be a doctor or lawyer because he or she is often unavailable, out working in a remote field.

It is possible then to have a situation of dominant and recessive memes, either in the manner of Mendelian genetics where the dominance and recessive qualities come from within the memes naturally, or because they are imposed by external circumstance and influence. Observable traits can also be influenced by many memes. For example honesty may be influenced by ethical, religious, rational and cooperation memes. This sounds like a continuous trait. So it might actually be appropriate to use some of the techniques of conventional population genetics. Possibly similar considerations influenced Kendal and Laland. [16]

3.7 Meme Competition Analyses

We now consider memes that are hostile to each other, and express this by actively reducing the fitness of the hosts of enemy memes and/or their meme's replication factor. This reduction comes at a cost to the meme hosts enforcing it, in a manner similar to punishment costs in

cooperation and the theory of evolutionary games. The reason in that case is to punish non-cooperative defectors. The punishment cost is offset by greater game rewards due to cooperation in games such as Prisoner's Dilemma and public goods games.

In our case we presume similar action arises to defend against the negative potential of invading memes. However, though that is an existential threat, it provides no automatic reservoir of increased payoff with which to fund the enforcement action. That could lead to domination and exploitation strategies being substituted for extermination and re-education. In our analysis we will only consider the relative survival of the competing memes and their hosts.

We assume the competing memes, $M1$ and $M2$, cannot be expressed in the same host. The hosts will choose sides for this type of combative meme.

Let K_1 be a reduction in fitness imposed on $M1$ by $M2$, C_2 be the fitness costs incurred by $M2$ in doing so, and vice versa for K_2 and C_1 . Further, let the actual fitness reduction/cost be proportional to the ratio of host populations, and let the reductions apply equally to replication factors and induced fitness. The modification factors are then $K_1 C_1 P_{M1} / P$ and $K_2 C_2 P_{M2} / P$. Note that the total population is the *relevant* population. Perhaps it is only local population for a tribal dispute. Only in world campaigns is it the world population.

Now we rewrite the gene-meme equilibrium conditions (8) and (9) for **two memes** by substituting $F_{M1} P_{M1}$ for the genetic term $F_G P_G$:

$$(11) \quad F_{M1} P_{M1} = F_{M2} P_{M2}$$

$$(12) \quad R_{M1} P_{M1} = F_{M1} P_{M1}$$

And add the fitness reductions/costs:

$$(13) \quad F_{M1} P_{M1}^2 K_1 C_1 / P = F_{M2} P_{M2}^2 K_2 C_2 / P \\ \Rightarrow F_{M1} P_{M1} = F_{M2} P_{M2} (P_{M2} / P_{M1}) (K_2 C_2 / K_1 C_1)$$

$$(14) \quad R_{M1} P_{M1}^2 K_1 C_1 / P = F_{M1} P_{M1}^2 K_1 C_1 / P \Rightarrow R_{M1} P_{M1} = F_{M1} P_{M1}$$

There is a third equation for spreading equilibrium of $M2$ not shown. The spreading condition does not appear to be changed since we elected to apply the same reduction factor to replication and induced fitness. If one wishes to change this assumption, then equation (14) will change.

Equation (13) has been rearranged to look like (11) with all the modifications on one side. Total population P divides out entirely (though not necessarily if the parties face asymmetric external relevant populations). The meme host population ratio reflects an advantage to the larger meme host population. The ratio of fitness reductions to costs reflects tactical, strategic and raw physical or technical ability advantages.

If the sides are nearly balanced, the war is a dead cost with no benefit.

If significantly unbalanced and large fitness reductions can be inflicted to make a short war, then game theory logic dictates the side with advantage compares the induced fitness reduction from allowing invasion of the other meme, to its costs in conducting the war. For example, P_{M2} would incur fitness reduction F_{M1} if they allow $M1$ to invade. They would incur this indefinitely. If they wage war they incur $(P_{M2}/P_{M1}) (K_2 C_2 / K_1 C_1)$ for a limited time. Let's consider two cases:

- a) If $M2$'s advantage is primarily population, they are already ahead and it may not take long to reduce the remaining P_{M1} to surrender (perhaps they will give up their meme or at least agree not to evangelize it). This is the case of conventional war by a major power.

- b) If M_2 's advantage is primarily ability to impose greater costs than they receive, the war will take a long time and they will not be able to control its termination date. This is a situation of asymmetric war against a more numerous power. The objective is to be so annoying the more numerous power agrees to back off and not export its meme.

In both cases we consider that the result may stop short of extinction if agreements about meme spreading can be reached. This is theoretical. The author makes no claim that such agreements are achievable or enforceable. In the Cold War both sides aggressively exported their memes. When it ended, Russia did not cease as a major power, give up state control of major corporations, and in the long run did not cease expanding its hegemony. It quit selling communism.

Returning to the balanced situation, note that one can hide behind iron or bamboo or capitalist tariff/security curtains, but memes will eventually propagate anyway. If one side obtains a slight advantage, a credible threat of some version of war may persuade the other either to adopt the competing meme, if they can be persuaded it is not so deleterious, or mutual agreement may be reached for neither side to export their memes to the other side, along with agreements to manage population growth and resource consumption to avoid future conflict. This becomes a cooperation game, and there will be many "rounds" with cheating, punishment, and so forth. It is difficult to enforce such an idea in a free society where individuals and corporations may persist in exporting their memes.

While much of this may strike the reader as not new, it maps what is already well known into our model of memetic traits and their spread and interaction with population genetics. We have claimed almost every non-genetic aspect of society other than resource holdings is some kind of meme. If a theory of memetics had not been able to reproduce these commonly understood generalities, it would be in trouble.

3.8 Special Cases – Inequality, Power, Truth, Acceleration and Altruism

In competing exclusive meme equilibrium, if we assume that most new converts will occur vertically among the newborn (not always true) then we can examine several interesting cases by looking at the population fitness factors. Rewriting (13) for their ratio:

$$(15) \quad F_{M_1} / F_{M_2} = (P_{M_2}^2 / P_{M_1}^2) (K_2 C_2 / K_1 C_1)$$

If equation (15) is nearly balanced then changes in imposed and incurred costs will govern. Non-exclusive memes are easily invaded by exclusive memes because they offer no resistance. Eventually random mutations will produce a competing exclusive meme. Losing memes would either vanish before effective memes that exclude them, or the stimulus to exclusion might "kick in" when some threshold of threat was met, either a sign of extreme exclusivity in the lesser populated meme, or threatening spreading rate. We might expect to find one of the following cases for a pair of competing memes if at least one of them is exclusive of the other:

- a) One meme dominates and the other either vanishes or exists below the threat threshold.
- b) The memes exist in a near balance so that (15) is approximately satisfied.

The following discussion is limited to case (b), near balance, and observes the condition for changing the balance. The result of the change in fitness factors will be a change in meme host population, tipping the balance one way or the other.

WEALTH INEQUALITY: Consider a mutation M_1' of M_1 which changes either incurred or imposed costs, but not necessarily both. We assume the variant, at least initially, is accepted as non-exclusive

within $M1$. It will freely propagate in the $M1$ host population but not in $M2$. We might create a wealth accumulation meme within the general capitalism meme by using the idea of reducing the number of children in order to make each more wealthy. Then the wealthy version $M1'$ incurs a higher fitness cost C_1' . If $M1'$ spreads widely in the population of $M1$ -type hosts then $M1$ population declines relative to $M2$ by the factor C_1'/C_1 from direct cause, and then declines further as described below. We wouldn't expect this population fitness effect to completely explain inequality (e.g. see [36]). It is just one of several contributors.

POWER: In the above case as P_{M1} decreases, the ratio P_{M2}^2/P_{M1}^2 rises while F_{M1}/F_{M2} has fallen. With this positive feedback P_{M2} will continue to rise and P_{M1} will decline to a very small fraction of the population. This may halt when P_{M1} realizes the existential threat and/or sufficient wealth allows P_{M1} to again increase its reproduction rate. If P_{M1} becomes extremely small then it continues to exist only at the pleasure of P_{M2} unless it also accumulates power of some kind. Thus wealth accumulation memes are likely to include beliefs or techniques about power.

TRUTH: Wealth up to now is an extraneous factor in our model, acting only through costs of acquiring it. The same is true of "truth." Suppose consuming a certain substance (e.g. alcohol) increases reproduction rate, but causes wealth to decline (accidents, poor health or judgment). A meme which exposed this relationship (a truth meme) would remove the reproductive advantage if adopted. So the truth meme would incur a cost and decline just as did our wealth meme.

ACCELERATION: A meme might encourage accumulating resources which can be used to accelerate the natural replication rate. For example, the wealthy or famous attract a disproportionate share of social media engagement with their ideas [21], wealth can be used to buy space in media channels which enhances transmissibility [22], fame (e.g. from acting or sports) can translate into the ability to get votes, wealth can allow time to devote to politics. There likely are thresholds of effectiveness involved, but taking a simple linear approach we define an acceleration factor $A1$ associated with $M1$ which accumulates separately over time at rate R_{A1} . Let $A1=1$ at period zero. When $M1$ initially appears its propagation is given by (7) but after N periods becomes

$$(16) \quad \Delta P_M(N) \approx (-F_M + R_M(1 + R_{A1})^N) P_M$$

Conversely a meme which promotes loss of a useful resource incurs a decrease in spreading effectiveness. This is the supposed dilemma of socialism in competition with capitalist societies, and a possible driver of long alternating cycles in society.

COMPETITIVE ALTRUISM: Now we introduce a variant of $M1$ called $M1'$ which has an incurred cost increase in C_1 as did the wealth meme, but also increases the imposed costs K_2 on the $M2$ population. If the following condition is met, other things unchanged, this variant increases P_{M1}/P_{M2} :

$$(17) \quad K_2' / C_1' > K_2 / C_1$$

Notice that the incurred fitness costs may mean that certain members of the $M1$ population will die before reaching their reproductive potential. The $M1'$ variant can spread laterally within $M1$ and does not require any children to do so. We've already established that a non-exclusive meme can spread and become permanently lodged in a population even if it is deleterious.

However, if (17) is met the population of $M1$ hosts increases. This may even aid lateral spread of $M1'$. Altruism can exist for this case without kin or group selection, though there must be a competing meme for it to have a material advantage. This is subject to the mutual exclusivity assumption, which confines memes to mostly vertical propagation. Thus, it is not useful as a conversion defense, only in exclusive meme defense. Other altruistic cases will emerge below.

3.9 Evolution of Exclusivity

We can use the technique of the previous section to analyze the evolution of memes with exclusivity. Since evolution usually occurs on a near-continuum of small changes, this brings up the degree of meme properties, which might be either the degree the meme advocates or the degree the meme host chooses to attach to it. For example, how much cost should be inflicted on an enemy meme, at what expense to oneself? Which of several enemy memes, arrayed on a spectrum of friend-foe, should be targeted by exclusivity actions?

To use our existing discrete analysis we assume there are discrete mini-meme variants of a general meme idea, representing *either* actual variation in the memes or in host implementations of them. They are non-exclusive of other meme variants within the same general meme idea until some threshold of distinction is reached, which does not concern us at the moment.

These will spread within the host population which doesn't exclude them, but since they express degrees of action they cannot all be dominant primary memes. We make a significant assumption in the interest of analysis, that *the most evolutionary advantageous meme (conferring the greatest host fitness) is the most frequently expressed form*. This can be argued from a social learning point of view, that people will likely copy the most successful memes. And it can be argued from a strict evolutionary point of view, that if holders of a certain meme have more children over generations they will come to dominate.

Neither is entirely true. If large families in financial hardship are the most reproductively fit, still not everyone may copy that meme. Since within a non-exclusive group of mini-memes we cannot guarantee vertical transmission, children may not express the same meme variant as parents. So this second assumption may produce results which are somewhat but not entirely true when compared with empirical data. Its use does not affect whether larger meme increments are supportable once established, only the analysis of their evolution in small increments.

Assume that most memes are deleterious. While we gave a simulation study that showed positive medians, that was after all meme defenses had been applied and frankly over a remarkable period in history. Even the fact that humans are not yet extinct means there is survivor bias.

Consider a meme $M1$ established in a population of hosts and an invading meme $M2$, bringing with it a fitness burden F_{M2} . By chance or other means there appears a variant $M1'$ opposed (or more opposed) to $M2$ so that $K_2' > K_2$. It brings to bear imposed fitness K_2' against $M2$, and incurs cost C_1' from doing so. The already established $M1$ primary variant already imposes and incurs costs K_2 and C_1 .

The fitness difference between $M1$ and $M1'$ is given by the difference between K_1C_1 and $K_1'C_1'$. We take all differences between $M1$ and $M1'$ to be expressed by the imposed and incurred costs and $F_{M1}=F_{M1}'$. If the difference between $M1$ and $M1'$ is small enough $M2$ does not take notice, then imposed fitness $K_1=K_1'$. We now have three cases:

- a) If $C_1' < C_1$ then $M1'$ is unconditionally more fit, and is efficiently exclusive.
- b) If the conditions of (17) are met then $M1'$ is relatively fit while in competition with $M2$, but might decay out of the population if the competition ends.
- c) If the conditions of (17) are *not* met, then $M1'$ might still prevail if the $M1$ -type host population is partitioned and subject to group or kin selection, otherwise decaying.

Again much seems familiar from the approaches to genetic evolution of altruism and selfishness. Points of view in the literature are summarized in a commentary by Sober and Wilson. [39] The author speculates that multiple well-conceived approaches might lead to the right

quantitative answer if meticulously developed, something Sober and Wilson do not dispute. It happens that the above approach relies on individual selection loaded with factors which derive from the actions of groups, at least groups of meme hosts. The importance here is not group or individual selection, nor is it meme selection exactly. It is a combination of meme propagation and selection as it interacts with individual and group selection. Certainly there may be different altruistic genetic tendencies in the hosts. In this section we weren't even concerned with altruism. It emerged when analyzing the evolution of exclusive memes, a consequence of the individual fitness burden of imposing exclusivity. The above populations all also might well have identical genetics and the analysis is unchanged.

It seems that all factions of human society currently dream of a cost-free formula for imposing their point of view (each side generally believing their point of view is right or at least justified). Perhaps the Internet has encouraged this idea, which itself might well be a meme. Our analysis simply suggests "cost-free" is not attainable, a kind of "Second Law of Memetics," and warring factions of altruists are a likely outcome.

In summary, there is selection pressure, at least at the individual level (we have not analyzed groups per se) to evolve exclusive memes, upon which the preceding analysis of competing memes depends. Whether they will evolve is conditional with at least three main cases. Two of the cases are linked to some degree of altruism. It is a little surprising that this is exhibited within the *M1* population in case (b) without group selection. Dependence on conflict to maintain the trait in two cases merits investigation.

4. Discussion

4.1 Relation to Risk Compensation

Risk compensation posits that risky behavior has value. When behavior is made safer, people take greater risk, motivated by the value of the risky behavior. A related theory, risk homeostasis, posits that the behavior change is only due to a sort of risk thermostat, not necessarily some value in the risky behavior. Each explains some things well. Neither is satisfactorily quantitative. The author has developed a quantitative version of risk compensation from evolutionary principles (loosely called crash rate theory) while working for NASA. Its use was mentioned earlier in connection with quantifying an effect of wealth inequality. [29] Corporations or people who choose a near optimal risk vs. payoff position may not do so because of rational planning, but because the ones that happen to choose the better positions survive better, personally or financially.

We do not need a sentient entity to ascribe the use of this kind of strategy. It could well be in use by nature by evolutionary selection. Memes are very high risk and very high value. Nature appears to have managed the risk with heuristics like short-term memes and using a portfolio approach.

However, if humans greatly increase the induced fitness volatility through their own meme-leveraged technology and research, then likely they will suffer the crash events that act in a feedback loop to establish the optimal position. Memetics and crash rate are entirely different theories working in different ways (mostly, they share a common evolutionary basis). The volatility comes from the speed and power of memes in memetics. It comes from greed and over confidence in crash rate theory. The similarities of the forecasts make a case that each offers a degree of confirmation of the other.

4.2 Relation to the Fermi Paradox

In 1975 Michael Hart attempted to explain the absence of extraterrestrials on Earth. [40] The Drake Equation suggested there could be an astronomical number of planets suitable for life, and there should be a large number of civilizations. If they followed the progression that humans *seemed* to be following at the time, a few of them should have had the disposition and desire to colonize the galaxy. Even with modest 7% light speed travel, and time to terraform planets and make them into self sufficient entities along the way, an outbound civilization would colonize the Milky Way in approximately one million years. Hart coined the term Fermi Paradox for this apparent contradiction, based on a casual conversational remark years earlier by Fermi. It was a genius meme design, as the topic has become extremely popular.

Several books and many papers have been written on the subject. Webb's book details 75 proposed solutions. [41] The paradox only yields to solutions which *must* apply to *all species*, with no exceptions. Humans might decide not to colonize the galaxy. But if there are thousands of civilizations, those who study the problem deem it unlikely *all* would follow the same decision.

Hart discounts social explanations, saying social theories are not well developed. Since his paper, theories of sociobiology, evolutionary cooperation and game theory have developed to an extensive degree. The author has developed a socioeconomic theory of crash rate and provided quasi-empirical support for Burton-Chellaw's warning that cooperation declines under intelligence and social learning. [26-28] Herein we take some steps toward a general theory of memes, long and short-term. It may be time to give social causes a second look.

There is nothing particularly unique about humans in our meme theory. We specifically allowed it to apply to other kinds of beings. Resources to surmount interstellar distances *may* possibly require planet wide consolidation and cooperation, and aggressive sharing of ideas and methods. These are the conditions for which we found memes most dangerous. If the united group has sufficiently consolidated all other groups, fails severely (or undergoes an adaptive reset, rejecting established memes), and has used up critical starter resources, evolution on that planet is unable to follow this path again with variations.

5. Conclusion

We have introduced a calculus for meme-gene equilibrium which considers not only meme propagation but effects on host fitness and changes in host populations. It shows that memes, if not restricted to propagate along with reproduction (vertically, in small cultural groups), are easily lodged permanently in a host species, infecting eventually all its members. These memes then are not removed by natural selection, because of the spread independent of reproduction. The accumulation of them poses a meme extinction risk. Meme transmission is somewhat analogous to DNA sharing by bacteria, which is not done by more complex organisms.

We have seen how meme defenses are necessary. Memes could forbid or antagonize other memes, and a great deal of social conflict might be traced to meme defense if this point of view were taken in its analysis. If memes are used to defend against memes, the defensive memes may also pose extinction risk. Mutually exclusive memes are effective defenses, but only by affecting fitness. They also offer insight into mechanisms of inequality and altruism.

Dominant and recessive memes are likely and would follow something similar to Mendelian genetics, while traits with multiple contributing memes can be similar to continuous traits. Linear low-interaction memes behave like a dominant gene, except that they are not linked to host

reproduction and the independent spreading rate must be accounted to gauge their strength in selection, making them hard to deselect just because they are deleterious to the host.

Altruism emerges in the evolution of exclusive memes. In limited cases exclusivity can emerge on its own, but usually it is costly and requires altruism. In that case, it can emerge either as expected due to group selection or in one peculiar case if there is only meme competition.

The propagation of memes independent of their hosts already complicates feedback control of social phenomena. The accumulation of acceleration factors over decades or centuries may be connected to stuck states or long term cyclicity in society and its problems.

Finally, given the extinction risk uncovered and the likely necessity of planetary consolidation to support interstellar travel, we propose meme risk as a possible solution to the Fermi Paradox.

We have not analyzed group formation in this paper (recall birdsong and the postulated effect of memetic variation on group formation in Lynch and Baker [15]). It is a logical candidate for further investigation. Simulations and empirical investigation are also needed.

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