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The physics of people's opinions

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ABSTRACT

This paper explores the abstraction of classical physics and applies several metrics that explore the evolution of social opinion. These metrics include an abstraction of Newtonian kinematics: mass, position, speed, acceleration, and Newtonian dynamics, an abstraction of force. Poll data is fit to a 2nd-order polynomial and a logistic function. These fits are used to understand the acceleration of opinion shift, and we explore recent social, cultural, and environmental trends, such as views on global climate change. We compare our results with the evolution of communication technologies and time spent on devices over the past 120 years. We show that the model connects the evolution in opinion with an abstraction of a Galilean concept: acceleration is independent of mass. Finally, we discuss the model of social polarization and the non-linear effect of media such as echo chambers.

Introduction

Poll taking is a well-established research tool to assess public opinion from a particular sample, for example, recited in this complete compilation of polls taken by Gallup through 2005¹. Polls reveal social and cultural change and, by their very nature, are averaging data using binary-type questions (e.g., Do you support or don't support a particular issue?). Details of the make-up of options, the strengths of opinion, the polarity of views are hidden within this averaging. Several papers have explored social change, particularly the shifting of persons within various social roles and social conditions classifications. One such paper used Markov chains to examine temporal changes in frequency distributions within categories defined by social roles and other social conditions². In this approach, the author, Kenneth Land, explores two populations and their social statistics from the earlier work of Sheldon and Moore (1968),³ where time-series data on changes in the American society (and other societies) have been systematically collected in ever-increasing numbers since the 1950s. In this approach, Land points out the usefulness of the mathematical approach. However, he pointed out that among various shortcomings of the model, perhaps the most looming problem resulted in reducing a complicated system of "estimated structural equations to a few meaningful concepts."² A complementary method includes modeling social interaction using Cellular Automata (e.g., Nowak and Lewenstein (1996)⁴), where they studied intrinsic dynamics and emergent properties in populations. Other authors explore social systems, such as multi-agent systems, to better understand social structure and norms^{5,6} or the impact of social change and various initiatives⁷. Still, other approaches include studies of social interaction via different media intervention and collective action in role modeling (e.g., Bilali *et al.*, 2017⁸).

The challenge of simulation in modeling a complex system such as human decision, opinion, and behavior is multi-fold⁹. Early on, Abbott points out that significant historical transformations are not amenable to representation through existing simulation models¹⁰. The number of degrees of freedom in social phenomena is extensive and constantly changing, making even uniform changes (e.g., large-scale changes in segregation) hard to identify the underlying causes and drivers¹¹. For example, the role of emotions in decision processes is one of many such complex phenomena that even if a simulation can attribute a good result, the underlying features are difficult to identify¹².

The above approach falls into a class of micro-level models that address social behavior at the individual level via agent and simulation. An alternative approach is to study social behavior and hence opinion change in a global view using macro-level models. These models provide a view of the collection of underlying mechanisms that drive change. This paper takes this approach and addresses social change regarding the ensemble of human decisions in a large population (millions) over an extended period (at least ten years). In this vein, the modeling of many interactions resembles physical systems where myriad small interactions produce a net effect.

Therefore, this paper poses a new approach to understanding social change using an abstraction of Newtonian laws. Though perhaps unorthodox approach, we show that abstraction of physical laws and principles produces dynamics and can explain long-term trends in culture change and opinion. We parallel classical kinematics and dynamics, though we do not focus on individual dynamics, only the ensemble effects. Though quantum mechanics can treat the micro view of physical reality, this tool is generally inappropriate to explore phenomena at larger scales where classical mechanics is appropriate. We use this framework to explore both long-term trends in culture and opinions on environmental goals, namely views towards climate

change.

One of the older polls in the USA includes the Gallup Polls, founded by George Gallup in 1935 and continues to provide numerous polls on various social opinions. This poll offers a long baseline of information for this study¹³.

We proceed by 1) formulating a generalization of Newton's Laws or an *abstraction of Newtonian kinematics* or the study of abstract motion. In Section 1, we describe the abstraction of classical physics and present poll data from the Gallup polls. Next, we present 2) a comparison of the model with information extracted from curves that fit the poll data (Section 2). Finally, in Section 3, we discuss the results in the context of social models and explore other areas where the abstraction of classical mechanics may help study non-linear social behavior.

1 Methods

1.1 Social Data and non-linear behavior

To test the *abstraction of Newtonian kinematics* (ANK), we use Gallup polls of long-term trends in social opinion for several significant concerns in the USA^{13,14}. Data is shown in Figure 1. We also include PEW Research data on recent polling on environmental and climate data¹⁵.

The plot indicates the evolution of states on their opinion to either remove a ban or increase a prohibition. We divide the data into two sets of information: 1) data showing states that support (or prohibit) issues and 2) data of polling of popular topics. The former are indicated with thick lines in the figure, and circles at the end of these lines indicate a constitutional amendment or Supreme Court decision. The latter set of data include various trends: percentage of the population with no religious affiliation church membership, willingness to vote for a woman for president, desire to vote for a black president, ideal family size (Family Size), and woman's preference to work outside of the home (Family Life)^{16,17}.

Figure 1. The number of states that support various social issues (thick lines) and Gallup Polls on different trends (thin lines, dots, dashes, and symbols).

We show the non-linear behavior of each curve by comparing the R^2 for linear, 2nd-order polynomial, and logistic fits. A short description of the poll is given in Table 1. Two examples demonstrate the linear, polynomial, and logistic fits to the data, see Figures 2 and 3. A linear fit might initially describe rising (or descending) data from Gallup polls. Yet the trend is generally better fit by a 2nd-order polynomial or logistic curve as opinion starts to change at a faster rate. The logistic curve,

$$P(t) = \frac{a}{1 + e^{-k(t-t_0)}}, \quad (1)$$

describes an evolving phenomenon and a characterizes a leveling off of the data. Typically $a = 100$ for a plateau of 100% or $a = 50$ for the maximum number of states. The values k and t_0 are fit to the data.

		R^2
Name	Description	linear / 2nd-ord. poly / logist
<u>Tracking Change in States</u>		
Interracial Marriage	Number of states that support interracial marriage, up through the Loving vs. Virginia Supreme Court decision of 1967	0.878 / 0.902 / 0.896
Prohibition	The number of dry states prior to the 18th Amendment (Prohibition)	0.268 / 0.493 / 0.363
Woman’s Suffrage	Number of states that let women vote in presidential elections before the 19th Amendment took effect	0.683 / 0.892 / 0.899
Abortion	Number of states that allowed at least some abortions before the Supreme Court ruled in Roe vs. Wade Decision	0.798 / 0.829 / 0.703
Same-sex Marriage	Number of states that allowed same-sex marriage before the Supreme Court ruled in Obergefell vs. Hodges in 2015	0.711 / 0.920 / 0.928
Recreational Marijuana	Number of states where recreational marijuana is legal	0.725 / 0.813 / 0.823
<u>Polling of Popular Topics</u>		
Non-religious Affiliation	Percentage of Americans with no religious affiliation. (1948-2009)	0.893 / 0.899 / 0.890
Church Membership	Trends in American attendance in church/synagogue/mosque (1952-2019)	0.619 / 0.754 / -
Women for President	American’s willingness to vote for a woman for president (1937-2019)	0.935 / 0.955 / -
Black for President	American’s willingness to vote for a black president (1958-2019)	0.904 / 0.967 / -
Ideal Family Size	Americans’ views on ideal family size with no more than two children in a family (1936-2018)	0.520 / 0.568 / 0.466
Woman’s Work Preference	Woman’s preference in America to work outside of the home (1974-2016)	0.390 / 0.391 / 0.363
<u>Environmental and Climate Topics</u>		
Protecting the Environment	Percentage of Americans who support prioritizing policies to protect the environment (2009-2020)	0.802 / 0.819 / 0.802
Stricter Environmental Laws	Percentage of Americans who say stricter environmental laws are ‘worth the cost’ (1994-2019)	0.802 / 0.819 / 0.802
Climate Change Issues	Percentage of Americans who support prioritizing policies to mitigate against climate change (2009-2020)	0.803 / 0.939 / 0.836

Table 1. Gallup polls¹³ showing social positions, environmental and climate data¹⁵ along with R^2 fit values. The best fits are in bold.

1.2 Newton's Laws of Motion

We define the abstraction of "distance" or "position" of people's opinion from a specific position, $x \rightarrow \tilde{x}$, the abstraction of mass or the inertia to change of opinion from a norm $m \rightarrow \tilde{m}$, the abstraction of the rate of change opinion or speed, $v \rightarrow \tilde{v}$, and the abstraction of momentum, the product of the mass and speed, $p \rightarrow \tilde{p}$. A natural extension of the abstraction of Newtonian kinematics is Newtonian dynamics (study of force). The abstraction of force, the push, pull or influence "acting" on a population with an opinion, $F \rightarrow \tilde{F}$. The notion of time remains the same in the abstraction.

Energy can also be considered in the abstraction. Potential energy can invoke the change of opinions $\tilde{V}$ and kinetic energy $\tilde{T}$, the energy associated with the motion or change in opinion, towards or away from a norm. The lack of physical dimensions means that the abstraction is meaningful for speed but not a vector quantity such as velocity. The abstraction represents kinematics created from a constant force, not different than the equations of motion generated from the Lagrangian of an object in a (nearly constant) gravitational potential such as the one found near the Earth's surface. A sketch of the abstraction is given in Figure 4. For completeness, the abstraction of the three classical laws are shown in Table 2.

Figure 2. Example of data (non-religious affiliation) with a maximum value of 100%

Figure 3. Example of data (same-sex marriage) with a maximum value of 50 states

Figure 4. Abstraction of the acceleration and force with reflection to Galileo's experiment of 1591 ^{18,19}

The equations of motion for an object under constant force becomes,

$$x(t) = x_o + v_o t + at^2/2, \quad (2)$$

Law	Description	Equation	Abstraction
1st	Law of Inertia: An object at rest will stay at rest, and an object in motion will stay in motion unless acted on by a net external force.	$\sum \mathbf{F} = 0 \Leftrightarrow \frac{d\mathbf{v}}{dt} = 0$	The opinion of a population will remain as it is unless a net driving force (influence) acts upon it.
2nd	The rate of change of momentum of a body over time is directly proportional to the net driving force and moves in the same direction as the applied force.	$\mathbf{F} = \frac{d(m\mathbf{v})}{dt} = m \frac{d\mathbf{v}}{dt} = m\mathbf{a}$	The rate of change of the abstract momentum is directly proportional to the external influence (force) applied and occurs in the same direction as the force.
3rd	All forces between two objects exist in equal magnitude and opposite direction. If one object A exerts a force F_A on a second object B , then B exerts a force F_B on A , and the two forces are equal in magnitude and opposite in direction.	$F_A = -F_B$	All influences acting on a population exists in equal magnitude and opposite direction: if one object A exerts a force F_A on a second object B , then B exerts a force F_B on A , and the two forces are equal in magnitude and opposite in direction.

Table 2. Newton's Laws and an abstraction

with the natural abstraction,

$$\tilde{x}(t) = \tilde{x}_o + \tilde{v}_o t + \tilde{a} t^2 / 2, \quad (3)$$

and therefore the acceleration and force become,

$$\tilde{a} = \frac{2 \cdot (\tilde{x}(t) - \tilde{x}_o - \tilde{v}_o t)}{t^2} = \tilde{F} / m. \quad (4)$$

1.3 Extraction of data

The logistic function, $f(x) = a / (1 + e^{bx})$, or S-curve naturally describes the asymptotic population growth²⁰ with origins in ecology modeling²¹ that models exponential growth with a carrying capacity limitation. The model characterizes a process that grows slowly, accelerates in the growth, and then tapers off to an asymptotic level. In this work, the process (opinion poll data) grows theoretically from 0% in agreement or 0 states in agreement to 100% agreement ($a = 100$) or all $a = 50$ states in agreement. Assuming that the opinion polls complete their theoretical trend, the logistic behavior of the polls can be interrupted as grains of sand falling from a tipped bucket. At first, few grains fall (few people changing their opinion), then many (inflection point), then few as the bucket is emptied (saturation is reached as most have changed their opinion on a matter). Of course, poll data can plateau at a level less than the theoretical maximum, or reverse and descend in value, or even fluctuate. The later describes woman's preference to work outside of the home (see Figure 1). The logistic function converges to the exponential function for small x , of which the Taylor expansion is, $e^x = 1 + x/1! + x^2/2! + x^3/3! + \dots$ and is approximated by the 2nd-order polynomial (Eq. 4).

2 Results

The evolution of acceleration (circles) and force (squares) are plotted in Figure 5. The abstraction of mass population (Eq. 4) is normalized to the 1910 US population, $\tilde{m}_{1910} = 1$. The inflection point determines the year (data abscissa) shown in the examples of Figures 2 and 3. Statistics from the polls are used to determine the uncertainty for each data point. We do not include the uncertainty inherent to fitting the logistic function to the data; we assume that the theoretical maximum of the curve is 50 (for states data) or 100 for percentage data.

Within statistical error, the evolution of the acceleration for the three data sets (Table 1) is flat, 0.0002 ± 0.0003 percentage points per year. Three environmental polls (bottom set of data from Table 1) have been included in the analysis. However, the limited statistics "protecting the environment" and "climate change issues" were not included in the fit (blue line).

The normalized force increases by 0.001 ± 0.001 percentage points per year (blue, solid line). The increase is compared with the accumulated time spent on various technologies in the period 1900 to 2010. Technologies include (light green to dark blue or top to bottom in the figure) printed paper and postal mail, radio, landline telephone, emails, other internet messaging, mobile phones, instant messengers (including text messaging), and social networks. The force increases similarly to the time spent on using (or reading) printed paper, postal mail, landline telephones, mobile phones, and instant messengers.

In contrast, the time spent listening to the radio, interacting on social networks, and the accumulated time for all technologies, rises faster than the force. The slope of the accumulated time is 0.042 ± 0.011 percentage points per year (green, dash line). The yellow trapezoid in the figure shows the continuation of time on technology from 2010-2071.

Figure 5. Acceleration and force verse year. Details of the technologies and fits are given in the text.

3 Discussion

Our model, an abstraction of Newtonian mechanics was used to study the rate of opinion change of several social and environmental topics. The main finding in this research is that the rate of change of opinion has remained flat over the past 120 years. When the population is included, the new metric, an abstraction of force, does increase over this same period at a rate of 0.001 ± 0.001 percentage points per year. This increase is consistent with the USA's time spent on various technologies types (hours per day).

3.1 Connection to social models

The influence of mass media has dramatically increased, especially in recent years^{22,23}, begging the question, how much does it influence our opinions. What are the underlying forces that motivate opinion change? Are the drivers for opinion change individuals who decide on their own after learning about a topic, or is opinion change primarily media-driven and opinion shift occurs because most individuals are influenced by media personalities that convince the listener what they should believe? The answer is likely a combination of these two views. An extensive amount of research has been conducted on this topic,^{24,25,26} (We have seen earlier, social behavior has been explored in either micro- or macro-level theories.) The salient question remains: how much do others influence us? The acceleration of opinion change is flat; however, the rapid development of social media in the past 20 years may result in a measurable rise in the acceleration of opinion change in the next few years. The time spent on this new media format may provide users with a critical level of selective reinforcement, resulting in a non-linear change in the acceleration in Figure 5. Selective reinforcement has been studied in psychology²⁷ and has applications to politics²⁸ and therefore an interest for further study.

3.2 Areas to explore

The polarization of opinion can result from a number of drivers, including media storms²⁹, feedback loops (media affecting personalities and personalities affecting media attention), and information "echo chambers."^{30,31,32} Fits using a 2nd-order polynomial or the logistic function characterize the average acceleration of evolving opinion, but two polarized opinion subsets would remain hidden in our analysis. Understanding these non-linear effects is critical for better understanding the dynamics of polls and better discerning of the malicious spread of misinformation³⁰. Polarization might be studied in a similar vein as we approached this research using classical mechanics, but now using an approach for many-body interactions, the framework

of thermodynamics. This approach might help elucidate underlying mechanisms and complement recent social simulations exploring this issue³³.

4 Conclusions

We show that polls measuring the change in opinion have been characterized by an abstraction of acceleration, which is flat over 120 years. On the other hand, when the population is considered, the abstraction of force rises over time. This rise appears consistent with the increase of time on various technologies, not including social media. The next question to pursue might include how the polarization of opinions can be studied in the same context with a similar abstraction of classical physics.

Supplementary Material

This section includes the questions from the surveys used in Figure 1. The questions for the trends of popular topics include¹³:

1. None-religious Affiliation: How important would you say religion is in your own life - very important, fairly important, or not very important?
2. Church Membership: Do you happen to be a member of a church or synagogue?
3. Women for President: If your party nominated a generally well-qualified person for president who happened to be a woman, would you vote for that person?
4. Black for President: If your party nominated a generally well-qualified person for president who happened to be black, would you vote for that person?
5. Ideal Family Size: What do you think is the ideal number of children for a family to have? 0, 1, 2, ..., 6 or more, no opinion.
6. Woman's Work Preference: If you were free to do either, would you prefer to have a job outside the home, or would you prefer to stay at home and take care of the house and family?

Survey questions for environmental and climate topics include:

1. Protecting the Environments: Should protecting the environment be a top priority, important but lower priority, not too important, or should it not be done?³⁶
2. Stricter Environmental Laws: Which comes closer to your view — even if neither is exactly right. Stricter environmental laws and regulations cost too many jobs and hurt the economy or stricter environmental laws and regulations are worth the cost?³⁵
3. Climate Change Issues: Should dealing with global climate change be a top priority, important but lower priority, not too important, or should it not be done?³⁶

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Competing financial interests

The author (Daniel S. Zachary) declares no competing financial interests nor non-financial interests in relation to the work described. .

Data availability. All data used in this study are available from the corresponding author on request.

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