Infostorms

Pelle G. Hansen
Dept. of Philosophy and Science Studies
Roskilde University
Denmark
pgh@ruc.dk

Vincent F. Hendricks
Dept. of Philosophy
University of Copenhagen
Denmark
vincent@hum.ku.dk

Rasmus K. Rendsvig
Dept. of Philosophy
University of Copenhagen
Denmark
rendsvig@gmail.com

Published in *Metaphilosophy* 44(3):301-326, 2013

Abstract: It has become a truism that we live in so-called information societies where new information technologies have made information abundant. At the same time information science has made us aware of many phenomena tied to the way we process information. This paper explores a series of socio-epistemic information phenomena that results from processes that tracks truth imperfectly: pluralistic ignorance, informational cascades, and belief polarization. It then couples these phenomena with the hypothesis that modern information technologies may lead to their amplification so as to give rise to what we call "info-storms". Ultimately this points to the need for studying further the exact relations between information technologies and such info-storms as well as the ways we may design technologies to avoid being misled from what we have good reasons to believe.

1. INTRODUCTION

1.1: Three examples

In 1995, a little noteworthy book – *The Discipline of Market Leaders: Choose Your Costumers, Narrow Your Focus, Dominate Your Market* written by two market gurus Michael Tracy and Fred Wiersema – suddenly came in as no. 8 on *The New York Time's* bestseller list where it sat for 15 weeks and as no. 1 on the *BusinessWeek* bestseller list. This was despite the fact that several reviews had rated it as mediocre or even straightforwardly bad.

In 2007, the long forgotten and also little noteworthy book titled *Love Letters of Great Men and Women: From The Eighteen Century To The Present Day* collected in the 1920's by C.H. Charles suddenly climbed Amazon.com's bestseller list, ultimately peaking its rise to the stars at No. 134. The book was bought by thousands of people and quickly sold out. The interesting thing about the book was not its content. Rather, the interesting thing about the book was that it was bought by accident by thousands of consumers looking for another book that didn't exist.

In April 2011, a postdoc student at UC Berkeley logged on to Amazon to buy his lab an extra copy of yet a third little noteworthy book, at least to anyone working outside of *Drosophila* developmental biology, *The Making of a Fly: The Genetics of Animal Design* (1992) by Peter A. Lawrence. Although a classic work in developmental biology and out of print, two retailers could offer a new copy, but at a prize that was surprisingly high: $1.730.045,91 and $2.198.177,95, respectively, (+$3.99 in shipping). Even more surprising was that the price's at which the book was offered increased even more for each day that passed. On April 18th, the price ultimately peaked when Bordeebook offered the book at a startling $23.698.655,93.

1.2: Social information processes

What connects these three events is not only that they all concern books. More importantly, they concern how *social information processes* may affect individual beliefs in large groups of agents in ways that track truth imperfectly, so that people end up believing false propositions and as a result possibly act contrary to their goals and interests when faced with uncertainty.

In the first case, agents on the book market came to believe that the book *The Discipline of Market Leaders* was worth reading because it featured on the otherwise highly credible bestseller lists of *New York Times* and *BusinessWeek*. What they did not know was that the two authors, Michael Tracy and Fred Wiersema, had actually bought 10.000 copies of their own book at the bookstores from the sales of which these bestseller lists were compiled – lists that are compiled in order to direct the buying behavior of agents on an inherently uncertain market by providing information about what other readers have bought. As a result, agents on the book market in search of a good and useful book on marketing came to believe that the book was worth reading and hence buying – an, according to most reviewers, false belief which was only corrected when this was too late and when their buying behavior had already fed into the bestseller system itself.

The 'bestseller list' is just one such technology or information system for handling a massive book market and short-cutting the tiresome process of reading book reviews. It simply samples bookstores' sales to determine which books are selling the best with the aim of advising people as to what is a good buy. However, to work as intended a system like the bestseller list depends crucially on its ability to reflect or lead us to the 'truth' (what books are worth buying) on the basis of its input (books sold). Thus, the system works like a social heuristic for individual decision-making by trying to answer a complex question with

a simpler one. The authors of *The Discipline of Market Leaders* knew how to short-cut this system to their own advantage and to the disadvantage of the users of the bestseller lists.

The second case of *Love Letters of Great Men and Women* resulted from the automatic pairing by computers of offers on Amazon triggered by a scene in the 2007 box office movie *Sex and the City* and based on search words by users. In the scene, the main character Carrie Bradshaw reads a book titled *Love Letters of Great Men* from which her husband to come "Mr. Big" later sends her quotes by e-mail. As a result, thousands of fans of the movie logged on to Amazon and searched for the book to get a piece of the big city romance. Unfortunately, no such book turned up in their search since the book did actually not exist. Instead the search engine on Amazon suggested the 1920s collection *Love Letters of Great Men and Women* as a possible match, leading multiple customers to click on this entry and ultimately some of them to buy the antiquated version. This in turn lead Amazon's computers to automatically pair the book in special offers with various merchandise related to the *Sex and the City* franchise, leading even more costumers to believe that this was actually the book they were in search of and hence to buying it. Soon the book rose to take a prominent place on Amazon's bestseller list as the no. 134 best-selling book.

1.3: Info-storms

The hypothesis is that modern information technologies have magnified and amplified phenomena for which social information processes threaten to distort truth, making us more vulnerable to err than ever and on a much larger scale. The abundance of information driven by technologies such as the fast printing press, radio, computers and in particular the World Wide Web has forced us to increasingly rely on information technologies that short-cuts traditional cumbersome search processes that cannot cope with the abundance of available information as well as offers tempting avenues for by-passing traditional slow gate-keepers of truth. Relying more and more on social information technologies or systems like these not only makes such side-tracking possible and more likely to occur; it also increases the numerical reach, if not the proportional, of the spreading of false beliefs and consequences thereof – intentional or non-intentional. When this happens we call the resulting phenomena *info-storms.*

The problem is that while the information phenomena magnified by such technologies have always existed, they now take on new proportions with possible severe consequences for the democratic institutions underpinning the information societies we live in. The more we uncritically rely on automatic information technologies, the more likely it is that the consequences go unnoticed, sometimes with absurd results.

This uncritical reliance is what produced the third case above when Peter Lawrence's *The Making of a Fly* reached the startling price of $23.698.655,93. Behind this absurd price setting was the use of automatic price setting algorithms by two retailers – *Bordeebook* and *Profnath* – who had set their prices on the book conditional upon each other by 0.9983 and 1.270589, respectively. This automatization of price adjustment led to the gradual increase in price that ultimately resulted in the absurd valuation.

While this example, like the two former, did not have severe consequences for our democratic institutions, it exemplifies what may happen to the reflection of truth – *in casu*, the true market value – when we solicit our decision making power to, and rely unconditionally on, information technologies and processes. In other cases the result of relying on such processes may amplify information phenomena that track truth imperfectly in ways that give us reasons to believe the truly unbelievable with severe consequences for society.

This paper explores three such information phenomena. It then couples these with the hypothesis that modern information technologies may give rise to their amplification so as to give rise to "info-storms". If this empirical hypothesis should turn out to be true, it follows that the social epistemological study of information phenomena and the way they interact with modern information technologies become some of the most important research areas of our time. Hence, analogously with the biases and heuristics program of behavioral economics, which has turned out to offer insights of individual decision making important on societal level, the info-storms program potentially offers insights on social decision making with relevancy on the same scale, but for areas where agents even act rationally. Ultimately this leads us conclude the urgent need for studying further the exact relations between information phenomena, information technologies and info-storms as well as the ways we may design these technologies to avoid being misleading. As is evident from the paper, we believe that formal epistemology has a central role to play in this effort.

2. INFORMATION PHENOMENA

2.1: Rational interaction and information phenomena

Rational action is determined by the knowledge agents have, their preferences, the arguments they can muster for their opinions, decisions and actions. However, societies – modern as well as traditional – are constituted by the fact that individual decision-making unavoidably takes place in social settings comprising the interactions among agents in various structures. Thus, communication and intelligent information processing are prerequisites for informed decision-making, carrying out important actions, and obtaining true beliefs – all of which are cornerstones in rational human interaction.

Yet, recent studies in social psychology, social science, economics, computer science and jurisprudence show that concepts central to rational collective behavior since the Enlightenment, like qualified decision, informed action, truthful justification, etc., are acutely sensitive to the way in which agents or members of a group *process* their information in order to rationally interact.

The notion of an 'information phenomenon' covers robust and reproducible phenomena of belief configurations and dynamics that results from the flow, exchange and interaction in social processes and systems of information, reasonable beliefs and their consequent actions. In particular, we will focus here on such phenomena when they track truth imperfectly by giving rational agents reason to believe false propositions and thus result in actions that miss their intended purpose.

Given this definition, information phenomena are conceived differently from cognitive biases, since they do not result from the biased individual processing of information or perception. Rather, they are consequences of the rational workings of what Kahneman has labeled as system 2 thinking in social settings (Kahneman 2011).

2.2: Derailing rational agents

The aforementioned empirical findings, especially those from social psychology and economics, demonstrate in various ways how the beliefs of agents may become derailed from the truth. Core notions that have been produced by these efforts are such as *pluralistic ignorance* [Krech & Crutchfield 48], [Halbesleben & Buckley 04]; *informational cascades* [Bikhchandani et al. 98], [Centola, et al. 05]; and *belief polarization* [Cooper et al 04], [Sunstein 06].

Following [Hansen & Hendricks 2011] we may classify these various phenomena up until recently primarily studied by social psychology *as components of information phenomena* according to how they are produced by information processes.

Information phenomena		***Information problem***		***by information process***
Informational Cascades	… generated by…	too much information	… coupled with…	social proof
Bystander effect	… generated by…	too little information	… coupled with …	social proof plus pluralistic ignorance
Belief polarization/extremism	… generated by…	information selection	… coupled with …	Echochamber

Such phenomena, and others like them, are potentially dangerous to collective deliberation, decision-making and action, since they may, with very unfortunate collective consequences, tap into the way in which "informed" agents make "rational" decisions, perform "rational" actions and hold "rational" beliefs. Further, if embedded in information technologies each one of these phenomena is likely to generate info-storms. Fortunately, it seems that these "rational" pitfalls may be resolved by dealing with them as information control problems. However, in order to control information in the right way, one has to properly identify and analyze the structure of information problems as well as the information processes involved. To this end, formal epistemology is beginning to make some significant contributions.

3. THE STRUCTURE OF INFORMATION PROBLEMS AND PROCESSES

Each one of these phenomena comes with a structure, some of which may be properly characterized by formal means.

3.1: Informational Cascades

The notion *informational cascade* can be interpreted to cover a wide range of different phenomena. Among these are the bestseller example mentioned in the introduction, jay-walking, changing your mind about eating at an empty restaurant, because the place across the street is close to filled (Banerjee, 1992), and in general using popularity as a measure of quality.

All these examples are empirical in nature. However, the original definition of an informational cascade was given in relation to a specific behavior of Bayesian-rational agents in a mathematically defined setup (Bikchandani et. al 1992), and by now, a variety of different models exist (see, e.g., Smith & Sørensen, 2011; Anderson and Holt, 1997; Banerjee, 1992; Easley & Kleinberg, 2010).

3.1.1: Structure

In general terms, the structure underlying informational cascades consists of

1. A set of rational agents that act sequentially,
2. A set of options between which the agents can choose, and
3. A preference order on the outcome of each choice.

Typically, agents are modeled as Bayesian maximizers of expected utility. The decision is made under uncertainty in the sense that no agent knows which action leads to the jointly preferred outcome. That there is a jointly preferred outcome is essential when it comes to the epistemic assumptions made. There is no strategic interaction in the decision problem, so no agent will have an incentive to mislead later agents by choosing in contrary to the best of their knowledge. This in turn means that subsequent agents may base their decision not only on their private information, but also on the action of those that act before them. Specifically, the following epistemic assumptions are in order:

1. The underlying structure is known to all agents; the sequence of agents is known to all,

2. Each agent makes a rational decision based on available information, which consists of

    a. A *private signal* about which action will lead to which outcome, which is known to be more often right than it is wrong.
    b. A *public signal* consisting of the string of actions performed by the previous agents,

3. Knowledge among the agents that their signals are equally likely to be correct, and

4. Knowledge of rationality as described in 2.

Notice that in b. it is only the *actions*, and not the *signals*, of previous agents that can be observed. Furthermore, one should notice that the sequence of agents is known to all is in conjunction with b. taken to imply that any agent knows what public signal any previous agent received.

A *run* of such a model may be conceived as a line of agents, each waiting to make a decision between a (finite) set of choices. In runs where later agents choose to ignore their private information and act on the information conveyed by previous agents' actions, an *informational cascade* is said to be in effect.

3.1.2: Illustration: Initiating a Cascade

To illustrate, consider a situation where the agents have to make a binary choice between turning left or turning right at a junction in a maze – or just de-boarding a plane. Before receiving their private signal of *left* or *right*, each agent will be indifferent between the two options. When the first agent receives her private signal, say *left*, she will take this to indicate the correct path out of the maze. Given that she has no further information available, she will follow her private signal, thereby conveying a *left* action to all subsequent agents.

When the second agent must choose, the public signal of an executed *left* action in conjunction with knowledge of rationality may be used to deduce that the first agent's signal was *left*. Two situations may now have occurred: one in which the second agent received the private signal *left*, in which case she should choose to go left, or one where she received private signal *right*, in which case her available information – a *left* signal from agent 1 and a *right* signal from herself – will suggest opposite responses. Since both signals are known by 2 to be equally likely to be correct, rationality specifies no concrete plan of action. Hence the agent must choose based on some *tie-breaking rule*, e.g., by randomizing, choosing to follow her private signal, etc. The epistemic assumptions regarding tie-breaking rules are discussed below. For now, assume that the second agent received a *left* signal, and therefore chooses to go left.

The actions of agents 1 and 2 send a public (*left*, *left*) signal to agent 3. As agent 2, 3 can deduce the private signal of agent 1. Additionally, given suitable assumptions regarding the tie-breaking rule, 3 may also deduce that agent 2 received a *left* signal. As it is known that every private signal is equally likely to be correct, *it now does not matter for her action what signal agent 3 received.* If 3 received a *left* signal, she, too, should choose to go left. If she received a *right* signal, the information extrapolated from the public (*left*, *left*) signal results in left still being more probable than right. She will therefore choose to ignore her private information and act in accordance with the group behavior. Thereby agent 3 will be the first agent in an informational cascade.

Upon receiving the (*left*, *left*, *left*) action string, agent 4 will also choose to ignore her private signal in case this is *right*, and choose to go left. This action will be chosen on the same basis as 3 made her choice, namely the deduction of the private signals of agents 1 and 2. The fourth agent will, however, not have a stronger reason to go left than agent 3

had, since the choice made by agent 3 is *uninformative* to all subsequent agents. This is a corollary of agent 3 being in cascade: since 4 knows that 3 is rational and received the public signal (*left*, *left*), 4 can deduce that 3 would have chosen to go left *no matter what private signal she received*. Hence, agent 4 will base her decision only on the choices of the two first agents, and will also be in cascade. Similar considerations apply to all subsequent agents: they will all be in the cascade, ignoring both their private information, as well as the choices made by previous agents in the cascade.

3.1.3: Theme: Fragility

Given the example run above, it may be seen that *an informational cascade may have a very weak basis*, consisting of only the first two actions in the sequence.[1] This is the reason why cascades are often considered *fragile*: the balance in even a long-running cascade may be upset if actions contrary to the herd behavior are observed. If one allows for agents perfectly informed by their private signals in the model described, it will take *only one agent* to break the cascade.

To see this, assume that the fifth agent in the described left cascade *knows* that she should go right instead of following the herd. She would not ignore her own knowledge, but rather the public signals send by previous agents, and therefore choose to go right. Any subsequent agent may now take 5's action to indicate that 5 had hard information and then simply choose to follow her instead of the cascade. However, even if 5's action is only interpreted as 5 having received a private signal equal in likely correctness to all other agents' private signals, the action is still be enough to break the cascade. For now agent 6 will know that, agents 1 and 2 received *left* private signals, that the agents 3 and 4 were in a cascade, and that agent 5 received a *right* private signal. Hence, 6 will no longer ignore her private signal. In case this is *left*, she will go left, but if it is *right*, she will choose to act in accordance with the tie-breaking rule. Thereby, agent 6 is no longer in the cascade.

3.1.4: Theme: Epistemic Assumptions regarding the Tie-Breaking Rule

In the example above it was mentioned that the second agent could deduce the *left* signal of agent 1 and, given that 2 received a *right* signal, she should invoke a tie-breaking rule in order to decide what choice to make. Examples of such tie-breaking rules may be to randomize over the available option (Bicchieri & Fukui 1999; Bikchandani et al. 1992), choose an externally given option (Banerjee 1992; Bikchandani et al. 1992), act in accordance with private signal/preference (Anderson & Holt 1997; Banerjee 1992; Bicchieri & Fukui 1999) or something else.

The epistemic assumptions regarding the applied tie-breaking rule are seldom made clear. A note-worthy example is the use made by Bikchandani and colleagues when discussing their binary model (in structure identical to the above) and a tie-breaking rule, which

1 In case no cascade arises in the beginning of the sequence, one will occur in case there are *two more* agents that choose one action than there are choosing the other. Given that agents assume others signal to be as likely to be correct as they own, any cascade will commence on an equally weak basis.

requires randomization when indifferent. In the case where the third agent receives the equivalent of a public (*left*, *left*) signal and a *right* private signal, it is noted (as above) that the third agent will be compelled to ignore her private information and go left.

However, if it is generally known that all agents randomize to break ties, then the action signal string (*left, left*) will *not* inform agent 3 of the private signal of agent 2. This follows as 2's *left* action might be the outcome of the tie-breaking rule applied to 2's private *right* signal and her deduction of 1's private *left* signal. Hence, agent 3's private signal will determine her action, and she will therefore not be in a cascade. Given a *left* signal, she will go left, and given a *right* signal, she will again randomize. This randomization may again result in her going left, putting the fourth agent in her own shoes: though having received a pure string of public *left* signals, agent 4 cannot extrapolate any information other than the signal of the first agent, and will therefore not be in a cascade.

It may be discussed whether rational agents should assume of other rational agents that they should act in the same manner when indifferent as they themselves would, however if this is assumed to be the default behavior, then cascades involving a randomizing tie-breaking rule will not require as weak a basis as the above section lead to believe.

Adopting the assumption that ties are broken by acting in accordance with ones private signal changes this situation. If all agents know that this is the tie-breaking rule used, then this will facilitate later agents' ability to deduce the correct signal of indifferent agents. One reason for adopting this tie-breaking rule in cascade models is that it fits laboratory evidence far better than the randomization (Anderson & Holt 1997; 2008). As the authors note, this assumption is also reasonable in a case where there is a chance that previous subjects have made mistakes in their decisions.

3.1.5: Theme: Positive and Negative Cascades, and info-storms

Informational cascades are neither good nor bad in themselves – they are merely there. A cascade is the result of rational agents basing their decisions on information extrapolated from the actions of those choosing before them to a degree where this supplies a stronger reason to act than their private information does. Given the assumption that correct private signals are more prevalent than incorrect ones, cascades will in the theoretical framework more often than not herd agents towards the correct choice. In the terminology of Sunstein (1999), such cascades are *positive*.

Still, given that there is a risk of the private signal being wrong, there will be a non-zero probability that a *negative* cascade will occur. That is, given that the agents' private signals do not *perfectly* inform them, there is a risk that even rational agents will herd towards the sub-optimal choice.

In relation to social media, the weak required basis along with the possibility of negative cascades form a problem for, e.g., comment architecture of opinion blogs, product reviews, etc., as it may be highly valuable for interested parties to high-jack the initial segment of a

comment thread using sockpuppets[2] in order to form public opinion. Such a use clearly marks how manipulation with public opinion come into play by the introduction of excessive information. Where multiple sockpuppets are used to voice seemingly similar views, it can be feared that this can lead to uncontrolled opinion formations in favor of viewpoints not otherwise support by the online community. Where rational agents may have good reasons based on higher-order reasoning to the private signals received by others, the use of biased sockpuppets may form opinion based on nothing more than the preferences of one involved party.

The same may be said about the introduction of new products on markets (Easley & Kleinberg 2010: 505). Here, as exemplified by the bestseller list in the introduction, later customers observe the choices of previous costumers, but not necessarily their satisfaction with the product. The same goes for real-estate bubbles. Prizes rocket to the heavens because misleading information is spread about the ever-growing value of real estate from the constant bombardment from real-estate brokers, government officials, bankers and financial advisors. The information ends at Mr. and Mrs. Regular Real Estate Owner who, based on the received overwhelming amount of information, ends up buying their new house at an unrealististically inflated price. Shiller calls this *Boom thinking* (Shiller 2008). This is manipulation with agents by using providing them with too much misleading information.

Though cascades have been reproduced in laboratory settings (Anderson & Holt 1997), there is reason to doubt that these cascades occurred because the subjects applied Bayes' rule, cf. (Huck & Oechssler 2000). Most notably, Huck and Oeschssler point out that applying Bayes' rule is mentally requiring, most notably in cases where Bayesian updating suggests something different from the counting rule, which suggests simply going with the majority. It is further noted by Huck and Oeschssler that the decisions made by subjects in both their own as well as in the experiments of Anderson and Holt are more often in conformity with “follow your own signal” than it is with Bayesian updating. This can on the one hand be taken to be good news, since this will seem to suggest that negative cascades are less likely to form in the real world. It may however also be taken to suggest bad news: if not even Economy students in an exam situation is able to analyze the higher-order reasoning required in a cascade setting to a sufficient degree to not merely act on their own signal, the chances that the average Amazon customer will be so able is highly unlikely. If it is granted that book shoppers who orientate themselves towards bestseller lists have no or a very weakly believed private signal, it may be hypothesized that the opacity of the informational situation at hand will lead them to choose by a simple heuristic, namely by simply following the salient indicator that many others have previously bought a certain book.

3.2: ‘Bystander Effects’

2 Fake and misleading online identities used to support, defend or praise a certain party. The sockpuppet is puppeteered by the party in question, but is posed as unaffiliated.

The bystander effect is a notion from social psychology taken to cover the seemingly paradoxical inaction of witnesses to emergency situations when multiple witnesses are present. A paradigmatic example is the story of the murder of Kitty Genovese as referred by amongst others (Cialdini 1984) and (Bicchieri 2006). Bystander effects have frequently been reproduced in laboratory settings (see (Latané & Nida 1981) for a review), most notably by Darley and Latené (1968), and multiple explanations have been suggested. Among these are that bystanders believe that others are more qualified to aid than they themselves are, that bystanders have averse feelings towards acting alone in comparison to acting in accordance with a majority, and that bystanders are in a situation of *pluralistic ignorance* resulting in a wrong belief that no help is needed. A notable study utilizing the latter two is (Bicchieri & Fukui, 1992). Bicchieri and Fukui construct a model involving rational agents in a setting of pluralistic ignorance and (a non-sequential version of) informational cascades to explain the introduction of various unpopular norms, including the bystander effect, college binge drinking, and violent gang behavior.

With an outset in the bystander effect one may deal with the belief dynamics generating situations involving pluralistic ignorance. The initial focus is on the epistemic assumptions underlying the higher-order reasoning of the social comparison mechanism in play.

3.2.1: Structure

The structure generating this sort of bystander effect includes

1. A set of agents that act concurrently in a number of rounds,
2. Three possible actions in each round, and
3. A preference order on the outcome of choices.

Illustrating the setup with the bystander effect, there may be a set of witnesses to an emergency, who act simultaneously in a number of rounds. They can choose to help, not to help or to inquire or survey further to obtain more information. All agents prefer to help if help is required, but not help otherwise, i.e., their preference in choice depends on the true state of the world. If an agent chooses to help or not to help, the agent cannot choose in later rounds. It is however cost-free to “skip a round” by inquiring further or surveying the situation.

The decision is again to be performed under uncertainty: agents do not know whether the situation in fact calls for assistance. As with informational cascades, there is no strategic interaction in the decision problem, so no agent will have an incentive to mislead subsequent agents by choosing in contrast to the best of their knowledge. Therefore the choices of other agents can again be interpreted as conveying information regarding others' interpretation of the situation.

Given this, as was the case with informational cascades, agents may choose to base their action not only on their private information, but also on the information extracted from

their peers. The following epistemic assumptions are made pertaining to the information dynamical structure:

1. The underlying structure is known to all agents,

2. Each agent makes a rational decision in each round based on the available information, which consists in

    a. A *public signal* about the true state of the world,
    b. A *public signal* consisting of the actions *performed* by the previous agents,

3. A belief among the agents that others,

    c. given that they believe help is required, are more likely to help, than they are likely to either inquire or not help,
    d. given that they believe help is not required, are more likely to not help, than they are likely to either survey or help, and

4. Knowledge of rationality as described in 2.

Regarding 2., three things are to be noted. First, in a., agents are assumed to receive a *public* signal about the true state of affairs. This signal consists in the emergency event, e.g., a visual impression that an elderly lady falls. This signal is assumed to be *common knowledge*, as everybody can see that everybody else can see the event, etc. It is however not known to other agents how the individual agent *interprets* this signal. Second, agents are not assumed to be made aware by the end of a round whether their actions were in accordance with the true state. That is, no external source of information is available between rounds to inform agents in later rounds. Third, notice the emphasis in b.: in contrast to the informational cascade case, it is not only assumed that agents perceive the choice, and not the private signal, of other agents, but also that they only perceive the *performed output* of this choice. This is essential, as the choices to survey and to not help are *output equivalent*.

The assumption made in item 3. is that the group of agents already face *pluralistic ignorance* with regard to the decision rules used in the situation. This is a situation "where a majority of group members privately reject a norm, but assume (incorrectly) that most others accept it" (Centola et al. 2005: 1010), but where the norm in question is not a true social norm, but rather a decision rule. In conjunction with suitable assumptions regarding payoff and degrees of belief, *every agent will have a propensity to survey the situation instead of helping or not helping*. However, qua 3., all agents also believe that others reason by a *different* choice rule, namely that they would choose to help or not help under the same circumstances. To illustrate how this assumption affects agents' interpretation of the public signal, an example run is now considered.

3.2.2: Illustration: Not Initiating a Rescue

To illustrate the bystander effect using a simple setup, consider three agents witnessing an event where an elderly woman trips in the street. Assume that the agents have 2 rounds to decide whether or not to help. The fact of the matter is that the lady needs help. The public signal send by the event is, however, ambiguous: it may be interpreted as the lady tripping without being hurt or as the lady having badly twisting her ankle. Assume that all agents interpret the signal correctly, and therefore initially believe that the lady requires assistance.

Let us focus on a particular agent, *a*. Given that *a* believes that she is no better at interpreting the public signal than others are, it will be reasonable for her to survey. By surveying, *a* can observe the actions of others, and thereby gather information regarding their interpretation of the public signal. Under the assumption that others are at least as good as herself in estimating the true state from the public signal, this further information will lead to a stronger basis upon which she can later choose to either help or not help.

Notice how the reasoning for choosing to survey implicitly utilizes the assumption of pluralistic ignorance from 3. above. For *a* to be able to infer information from other agents' actions in the first round, it must be assumed that these actions reflect the agents' private beliefs, even though the action chosen by *a* does not reflect her own beliefs to others.

To see how *a*'s action misrepresents her beliefs to others, recall the assumption in 2b. above, stating that agents perceived the *performed output* of the choices of other agents. In the presented case, the choice to survey and the choice to not help are however *output equivalent*: other agents cannot distinguish these to choices from each other, as both outcomes consists in standing still and witnessing the situation at hand. Following the assumption of pluralistic ignorance, all other agents now believe that *a* has chosen *not to help*.

Given that all agents have acted as *a* did in the first round, what new information is *a* left with after she is done surveying the situation? She has seen two other witnesses not doing anything, and as she, due to pluralistic ignorance, believes that they follow a different choice rule than she, she will infer that they both interpreted the public signal to show that the true state is one in which no help is required. As this goes for all agents, a situation of *belief-oriented* pluralistic ignorance has occurred: a situation in which “no one believes, but everyone thinks that everyone [else] believes [that no help is required]” (Krech and Crutchfield 1948: 388-89).

As *a* takes the two other witnesses to be her epistemic peers, she will now have compelling reasons for revising her belief. Since the roles of all agents are symmetric, agent *a* is not a special case, though, and hence the second round will commence with all three agents believing that no help is required. As they can obtain nothing from surveying further (as this is the last round), the rational choice will be to *not help*.

In conclusion, a group of rational witnesses suffering under pluralistic ignorance regarding each others' decision rules may by social comparison cause a bystander effect.

3.2.3: Theme: Acting in Conformity

The outlined model for the bystander effect ignores the possibility of agents' having *interactive* preferences. If the structure outlined above is conjoined with a preference to act in conformity with a majority, a model for the emergence and persistence of unpopular norms may be constructed, cf. (Bicchieri and Fukui 1997). Though the bystander effect may occur on solely epistemic grounds, as illustrated above, conformity to group behavior plays an important role in situations with a similar structure, cf. (Miller and McFarland 1987).

A good example of how pluralistic ignorance incorporating a preference to conform in a bystander effect-like setting may have negative consequences is in board decisions regarding strategic choices of organizations (see (Halbesleben and Buckley 2004) for a short review of the historical developments of pluralistic ignorance in organizational settings). A round table discussion regarding a strategic choice may easily be seen to have a similar structure: a number of executives will all be witnessing poor firm performance, but will fear suggesting to remedy the situation due to adverse feelings about acting as a minority, due to a concern to maintain the respect of their fellow board members, against a majority who believe that poor performance is due to outside factors, and not a current poor strategic choice, cf. (Westphal and Bednar, 2005). Based on survey studies, Westphal and Bednar argue that when firm performance is relatively low, outside directors will have a tendency to underestimate the degree to which peer directors share their private concerns regarding the status quo strategy, and when less concern is expressed, the tendency towards underestimation increases. They further argue that personal friendship ties seem to diminish this underestimation.

3.2.4: Bystander Effects for Real (Estate)

From around 2003 up to and through the first half of 2007, prices on Danish corporate realty had been going through the roof; especially from 2005 the upward curve on corporate real estate had been extremely steep. General optimism in the market was high and among the three primary actors in the Danish mortgage deed market consisting of borrowers, investors (banks, credit institutions, private entrepreneurs) and mortgage merchants unrealistically so. On top of that, unfortunate carousels had begun to appear as a result of the easy access to money. Property sharks would take a mortgage deed to the bank to borrow money on it and often enough the investment would be geared such that the shark could walk away with a loan heavily exceeding the value of deed and property. The shark would then venture out to acquire new property, issue new mortgage deeds, take out a loan on those or sell them to other sharks which would then try their luck with investors for yet more capital to invest. And so it went on for some time while the prices on corporate realty in Denmark went berserk and nobody really checking whether there was value for money. Banks and credit institutions were so eager to issue loans that credit assessment became sloppy to non-existent. Right before the bubble burst property sharks were mostly trading among themselves at fictitious prices in a world of financial fiction creating a phenomenon later referred to as *mortgage deed merry-go-rounds*.

Until a Danish newspaper, *Jyllandsposten*, started publishing a series of papers on the mortgage-deed merry-go-rounds in late 2007, nobody interfered although there parties enough witnessing the unrealistic prices that much corporate realty went for and had vested interest. Between The Danish National Bank, The Ministry of Business and Growth, The Danish Financial Services Authority and miscellaneous banks and credit institutions it should have been clear that regulatory intervention would have been in order way before the bubble came to a burst. But it did not happen partially for socio-epistemic reasons. Unsure as to whether to do something or at least propose intervention in the carousels the different by-standing parties began observing each other either as to become wiser pertaining to a course of intervening action or because every party thought that the other parties would issue a suggestion as to what to do. Since every party observed every other party all at the same time, nobody did anything exactly because nobody did anything. The mechanics was a bystander-effect to the mortgage-deed merry-go-rounds. Even if one party thought, as a matter of fact, even if all witnesses to the incident thought, that intervention was in order, they could observe that all other parties doing nothing. Thus, The Danish National Bank, The Ministry of Business and Growth, The Danish Financial Services Authority and so forth started subscribing collectively to a norm of non-intervention which they may very well have privately rejected.[3] That amounts to a state of pluralistic ignorance (Hendricks & Rasmussen, 2012).

3.3 Group Polarization

3 There is indeed evidence to the effect that some players, including the director of The Danish National Bank on more than one occassion, before the bubble burts, warned against the overheated corporate realty market without doing anything about it.

The example involving C.H. Charles' 1920 *Love Letters of Great Men and Women* illustrates a common feat of modern web technologies, namely inherent *information selection processes*. On Amazon, shoppers are prompted to buy additionals based on what they are currently viewing; on facebook, the amount of interaction with friends determine their *edge rank* in relation to you, which in turn determine how frequent they appear in your news feed, and Google by default use your last 180 days' search history to provide Personalized Search for Everyone.[4]

A further common feat of modern web technologies is *social*. Most web-pages offer a built-in button to “like”, “share” or “comment” on the displayed item. This provides the opportunity to show interest in, or discuss, the content easily on social sites and in the associated comment thread. This allows friends of yours who share your attitude towards a given issue to like the news item, be notified of comments so to participate in the discussion and re-share it with their social network.

In relation to social discussion an interesting phenomenon is *group polarization*. Group polarization refers to a re-producible product of group deliberation where each of the group members following a discussion ends up holding a more extreme position regarding some viewpoint than they did prior to deliberation. The phenomenon can reliably be reproduced in lab settings (see (Myers and Lamm 1975, 1976; Myers 1982) for reviews of experimental literature), among others using a setup like the following.

Structure[5]

Group polarization can occur in situations in which there are

1. A set of agents,
2. An issue on which agents' degree of agreement can vary on a scale with neutral midpoint and two extreme poles,
3. A division of agents into sub-groups, which are homogeneous with respect to their degree of agreement relative to the midpoint,
4. A group deliberation process in which agents are free to discuss their opinions and arguments.

Given such a situation, a sub-group is said to *polarize* or *shift* in case the product of the group discussion has shifted further towards the pole initially favored. The shift is measured by comparing the average degree of individual pre-discussion expressions of agreement with a post-discussion expression. The latter may be given by either asking for post-discussion expressions from individual agents and finding the mean, by requesting the

4 Even when signed out, cf. http://googleblog.blogspot.dk/2009/12/personalized-search-for-everyone.html (retrieved 6 Jan. 2013).

5 The following structure is based on one of several experimental approaches described in (Myers 1982).

group to reach consensus or by requiring that the group determines this value by majority vote.

Based on homogeneous group experiments much akin to the above in setup, several studies have documented group polarization. In (Myers 1982) an overview of some of these studies is provided. Two examples include racial attitudes among high-school seniors and responses to fictive international military crises involving the USA among U.S. Army officers, ROTC[6] cadets and university students. In the former, students were divided into high-, medium and low-prejudice groups, and following discussion it was seen that the high and low groups had polarized. The high group had moved from ~1.7 to ~3 on a scale from -4 to 4, with zero being neutral, -4 being low prejudice and 4 being high prejudice. The low group moved from ~2.8 to ~3.5. In the latter study, groups consisting of respectively U.S. Army officers, ROTC cadets and university students were asked to choose between 10 responses ranging from bilateral negotiations to nuclear force. Here, students initially favored the softer responses, whereas officers recommended the more militant solutions. After discussion, these two groups polarized, whereas the ROTC cadets where more neutral in both pre- and post-discussion scores.

The Black Box of Group Discussion

The main task in explaining the general phenomenon of group polarization consists in unpacking the black box of group deliberation leading to an opinion shift cf. (Myers 1982; Isenberg 1986). One suggested explanation focus on *informational influence*. According to this theory, subjects in the deliberation processes receive and weigh information which affect their opinion towards the issue at hand. It is assumed that the initial lean in direction influence the amount of arguments pro and con the given direction in favor of the leaned to pole, and that more arguments in favor of the initial lean are therefore presented. Given that not all arguments have been considered by all agents, some agents will become more convinced of the leaned to direction, thereby shifting the mean opinion of the group towards the given pole.

Several studies indicate that there is a certain structure to the arguments that provide a shift in opinion. Myers and Bishop (1971), Bishop and Myers (1974) and Vinokur and Burnstein (1974) have suggested and supported that the group shift is based on a number of parameters, being the direction of argument (which pole it favors), the cogency or perceived validity of the argument, and it's novelty (the degree to which the argument was new to agents in the discussion).

To exemplify, assume a homogeneous group of three agents initially agreeing on some stance to degree 2 on a scale from -4 to 4 because they each recall two arguments in favor of the positive direction. During discussion, they all advance their arguments, each hearing one novel argument from either of the other agents, one of which they find convincing. Assuming that each argument affects their degree of agreement by one, each agent will after the discussion have changed their degree of agreement to 3, thereby producing a group attitude shift of 1.

6 U.S. Reserve Officers' Training Corps – a college-based training program.

The informational influence approach explains why already quite polarized groups show less polarization than initially less polarized groups – the individuals in the former are in the initial state closer to the distributed ”knowledge” fix-point.

It is argued (Myers, 1982), that an additional element of *argument rehearsal* in group discussions amplify the belief formation in groups, thereby creating a stronger polarization effect. This is supported by findings to the effect that being passively presented with arguments in favor of a direction does not produce as large a shift as active discussion does. Instead, arguments need to be rehearsed and internalized in order for an attitude change to have proper effect. Myers (1982) further proposes that discussion prompts agents to take a more one-sided line of argument, whereas solemn contemplation elicit a more diverse approach.

Social Comparison

In addition to the information influence theory, it has also been suggested that group polarization occur as a product of *interpersonal comparison*. The main idea behind this approach is that people in groups seek to represent themselves in a favorable light. In order to obtain this goal, subjects must obtain a notion of what qualities are desired in the present group, and following act in accordance with these qualities. If subjects further have a wish to present themselves not just in a favorable light, but in more favorable light than others in the very same group, and all act according to this maxim, the group will elicit a shift in action towards what is viewed the more favorable light (Myers and Lamm, 1975, 1976; Myers, 1982, Isenberg, 1982).

There are at least two variants of social comparison theory (Isenberg, 1982), one favoring the dissolution of pluralistic ignorance through group discussion, and one favoring band-wagoning effects.

The pluralistic ignorance explanation suggests that the viewpoints presented by agents strike a compromise between the agents’ personal ideals and the perceived norm of the group. Given that all agents have initially underrated the degree of agreement with the given direction, group discussion may gradually dissolve this pluralistic ignorance and a general opinion shift can be observed. This viewpoint is referred to as ”release theory” in (Myers, 1982), as the discussion ”releases” agents from the hold of pluralistic ignorance.

The driving force in band-wagoning explanations is that agents wish to “one-up” others. Given that one pole is thought to be the favored viewpoint of the group, an agent may claim to hold a position slightly more extreme than the perceived mean. Through discussion, agents' perception of others’ position move in the favored direction, which in turn means that the individual will adopt a slightly more extreme position in the final evaluation.

In a meta-analysis of collected data, Isenberg (1986) concludes that the information influence and social comparison approaches describe conceptually independent processes, which in most cases co-occur. The processes have however been shown to exist in isolation. Experiments in which social comparison cannot be used since agents were unaware of either each others’ initial choices or were not informed of the eventual scale on which the

group decision were to be assessed still demonstrate polarization effects, which lend credit to the information influence explanation. However, situations in which only the attitudes of others are made available, but discussion eliminated, also show group shift, lending credit to the social comparison theory, cf. (Myers 1982).

Online Information Selection and Homophily

We are daily surrounded by information selection processes which provide us with information akin to what we have previously searched for or liked. In relation to group polarization and information influence, we fear that living in such *filter bubbles* (Pariser, 2011) provide logs to fuel the fire of group polarization, since such information selection processes provide us primarily with arguments in favor of our initial views. Pairing this up with the further information selection processes of both natural and artificially enforced homophily, produced by mechanisms such as edge ranking on social network sites, may further produce stronger tendencies to share, like and discuss events with like-minded, allowing both informational influence and social comparison dynamics to run out of control.

4. INFO-STORMS

The previous section described three different types of social information phenomena: informational cascades, 'bystander effects' and group polarization. These may affect individual beliefs and actions in large groups of agents in ways that track truth imperfectly, so that people end up believing false propositions and as a result possibly act contrary to their goals and interests when faced with uncertainty. While these phenomena have been studied empirically for years in social psychology, formal approaches such as logic, game theory, decision theory as well as the general analytical approaches well known to philosophers offer rigid frameworks for analyzing the exact components involved in derailing otherwise rational agents from the truth. From this perspective, social information phenomena become just as interesting from a philosophical point of view as more classic areas of epistemology that focus on how individual agents may obtain justified true beliefs in non-social settings.

Rigid philosophical approaches to social information phenomena may turn out to be particularly fruitful to society if applied to the many information technologies and systems devised to deal with information overload in 'the age of abundant information'. Not only because it seems clear that these technologies and systems play a crucial role in boosting problematic social information phenomena so that they may be characterized as info-storms; but also because it seems that if these technologies and systems could be designed according to insights obtained from rigid epistemological approaches to social information phenomena with their emphasis on truth tracking and truth preservation, this could be of great benefit to democratic society at large.

As an example of a simple and well known information system, think of the ever-expanding market of books (partially caused by the decreased cost and complexity of producing this good), where bestseller lists have seized the role as a central 'information technology' for

guiding individual decision-making under uncertainty analogous in function to the heuristics often used in individual decision-making. Used by the consumer, bestseller lists exhibit several of the information phenomena discussed above. For one, it is used as a device to solve a general decision-problem generated by a situation where agents have too little information and thus look to other evidence to inform their impeding decision. However, the nature of the bestseller list is to compile overall sales in sampled bookstores from which a list is created showing the bestselling books in order. As such a bestseller list embodies a social information process, where consumers faced with the uncertain decision as to which books are worth reading, turn to this list for information, but usually forget that sales figures reflect aggregate buying behavior, rather than anything about the quality of the book bought.

Viewing online book shopping as a decision problem with *n* actions (books) that the buyer may choose from and assuming the book market as driven by a series of buyers who each take turn in buying a book, it is revealed that bestseller lists are likely to produce informational cascades. Each agent in the series of buyers chooses to buy a book, where the sale is used as input for the bestseller list facing the next buyer. Hence, if initial movers in this series all buy a particular book, then others are likely to follow thereby producing a cascade as known from Section 3. In fact, it was informal knowledge about the structure and dynamics of informational cascades that allowed the two authors of *The Discipline of Market Leaders* to manipulate their way to a high ranking on The New York Time's bestseller list and a good fortune.

However, it is also interesting to notice that besides exhibiting an informational cascade, a bestseller list exhibits pluralistic ignorance as well, since each buyer looks to social evidence in a situation of uncertainty, failing to see that the evidence he is witnessing might very well be the outcome of a search process identical to his, rather than an expression of qualitative evidence. Thus, bestseller list exhibit the interesting phenomenon of reproduction of pluralistic ignorance by an informational cascade as well as exemplifies the wider point that the information phenomena discussed in this paper often interacts.

While the bestseller list is not a paradigm example of an info-storm in itself, it is obvious that when systems similar to the bestseller list are implemented for directing choice of large masses of agents on the Internet, the number of people affected becomes ever larger and the consequences ever more severe. *Love Letters of Great Men* serves as one example of this, but to the extent that SEO ranking is determined by the number of clicks a site gets, the resulting info-storm is identical in informational structure to that of the bestseller list. People will click on sites when they feature high in the SEO ranking, because they believe that this indicates that these sites are valuable, albeit it only indicates that other people have clicked on these pages as well. Furthermore, this pluralistic ignorance may be reproduced on a higher-level as the belief that other people actually find interesting what is found on these pages and hence that there is something interesting on these.

Ultimately, this phenomenon may be seen as a crucial characteristic of the holy grail of modern on-line marketing: "Virality". If you can get enough people to click on a particular YouTube video or link, the video or link will be spread through huge numbers of agents –

it's gone "viral". While the fact that these links are usually consulted and the videos are watched before they are spread further adds a bit of complexity, it doesn't detract from the fact that the phenomenon just described. That people believe that other people actually find what is found on these pages interesting may ultimately override the private signal that the link or video is actually dull or stupefying, and lead the agent to share this link or video anyway in the hope of spreading an interesting link or video to his social network.

However, in the age of information overload the clicking on links may even engage with well-intended algorithms that end up inadvertently producing info-storms in the attempt to handle this overload by filtering out irrelevant information. Thus, for instance facebook's Edge-rank algorithm introduced in 2009 and Google's individualized search as well as programs such as Zite, may easily create so-called "filter bubbles" without users ever even noticing it (Pariser 2011). Basically, these filter bubbles have close shaves with group polarization – where the group in fact consists of a single real agent – by being constructed by algorithms that are trying to serve only what is relevant to you, but which ultimately amount to serving what fits your world view as revealed by you self through your clicking behavior. While your clicks will show a confirmation bias towards your leanings, the online world will come to reflect this bias. In turn, this phenomenon of belief polarization or singleton-group polarization may also hook up with pluralistic ignorance. You will be looking to Facebook, Google or Zite as honest conversation partners providing you with information about the world, while these algorithms are actually trying to select and feed you with information that you like.

5. INFORMATION CONTROL PROBLEMS

How to deal with infostorms is an open problem, nothing have so far been said about how rigid analysis may help to undermine their negative effects. Yet, information driven social epistemic-phenomena may be viewed like control problems in engineering. Initially the structure of the problem should be revealed and understood. In fact, even the informal structural characterization of informational cascades, pluralistic ignorance and 'bystander effects' above may be adapted to a formal logical setting exactly put in play to account for the informational processes and epistemic dynamics between interacting agents. Private and public signals, preferences, actions, events, scales, and weights are all crucial components isolated so far to account for the structure and the epistemic mechanics of the information phenomena in question.

By way of example, in (Rendsvig and Hendricks, 2013) investment behavior is scrutinized in light of the Skip, Gamble, Quit-game given the following narrative: Any investor, especially in wake of the current situation on the financial market, is faced with a difficult investment problem: Should I skip, gamble or quit? Uncertain as to whether skip, gamble or quit, in order to become wiser the investor starts looking around to other investors to see what they do. Other investors may be looking back because they are also unsure as what to do as they are likewise short of decisive information. Investors may start looking for *social proof* to facilitate a qualified decision. Given social proof, skipping, gambling or quitting for the individual investor all of sudden become contingent upon information about what the investor expects about the market crash, what other investors are expected to do based on

their expectations pertaining to the market crash, whether the other investors are (believed to be) aggressive or conservative with respect to their financial behavior. It also means that the collective behavior of investors become susceptible to the workings of socio-epistemic phenomena like informational cascades, pluralistic ignorance, bystander effects.

This makes investment behavior essentially an informational control problem of social proof including

- entities like agents, actions, expectations, modes of behavior,
- modeling tools like epistemic logic, game theory and judgement aggregation, and
- parameters like uncertainty, available information, decision rules as to what to do personally, interpretation rules of other agents' behavior and social network structure.

Control problems in engineering and technology are often *modular* in the sense that twitching or shifting entities, tools or parameters changes one control problem into another control challenges. The same is the case here. It turns out that one may go from the study of informational cascades to the study of bystander-effects by changing some modules while retaining others, plug the modules and press play (Hendricks & Rendsvig 2013). And so forth for other socio-epistemic phenomena like bandwagon effects, boom thinking, conformity, compliance, gullibility, opinion bubbles … We have only just begun to play.

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