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Error correction mechanisms in social networks can reduce accuracy and encourage innovation

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ABSTRACT

Humans make mistakes but diffusion through social networks is typically modeled as though they do not. We find in an experiment that high entropy message formats (text messaging pidgin) are more prone to error than lower entropy formats (standard English). We also find that efforts to correct mistakes are effective, but generate more mutant forms of the contagion than would result from a lack of correction. This indicates that the ability of messages to cross "small-world" human social networks may be overestimated and that failed error corrections create new versions of a contagion that diffuse in competition with the original.

1. Introduction

How do errors in a social contagion, and attempts to correct them, impact diffusion over social networks? A substantial body of research examines diffusion, or the tendency for ideas, beliefs, and behaviors to spread through human social networks (e.g., Centola, 2010, 2011; Coleman et al., 1966; Montanari and Saberi, 2010; Rogers, 2003; Wang and Soule, 2012). What is common to all of these contagions is the transfer of information between individuals; in order for someone to adopt a new behavior they must learn that it exists, what it is, and how to perform it.[1] But while humans make mistakes and often misunderstand each other, existing research treats the "nodes" in social networks as perfect relays rather than fallible individuals, leaving many key questions unanswered. How rapidly do errors accumulate in human networks? Are particular message formats, or ways of transmitting the information, more prone to error than others? And do human efforts to correct errors improve or harm message fidelity?

We address these questions with a unique laboratory experiment using human subjects exchanging textual messages as a model for information diffusion. We find that semantic errors (i.e., mistakes that compromise meaning) can accumulate rapidly as messages pass through a network. When taken as a model of error in information spread more generally, our results suggest that the effective reachability in small-world and scale-free social networks (Watts and Strogatz, 1998; Watts et al., 2002) may be lower than previously thought and that social contagions may have difficulty saturating a large network, even when given ample time. We also find that the error rate is influenced by message format; longer (i.e., lower entropy) messages (e.g., standard English) are able to preserve meaning more effectively than shorter (i.e., higher entropy) messages (e.g., text messaging pidgin) even though they include more characters, and therefore more opportunities for errors to occur upon retransmission. This suggests that increasing usage of communications technologies that encourage the use of shorter messages (e.g., text messaging) may impede the diffusion of social contagions. Finally, while individual efforts to correct error generally improve accuracy, over the course of diffusion they also result in diversification (i.e., accumulation of grammatically valid but semantically distinct versions) of the diffusing message. In contrast, transmission without error correction results in corruption (i.e., accumulation of grammatically invalid but semantically similar versions). This suggests a new mechanism through which cultural diversity can be maintained: efforts to imitate others lead to unintended innovation, generating distinction as a direct result of efforts to conform. Paradoxically, innovation may often be the result of imitation.

2. Background

2.1. Diffusion and social contagion

Beliefs or behaviors that spread from person to person, intentionally or unintentionally, are known as "social contagions," and

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[1] Some studies of diffusion focus on how attitudes toward an innovation diffuse, but these fundamentally rely on the movement of information (i.e., how others feel about something) and thus are consistent with our perspective.

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their spread is often referred to as "diffusion."[2] While many entities can spread via social networks, relatively few are regarded as "social contagions". Schaefer (2007) argues that entities passing through social networks can be distinguished based on their transferability, and their duplicability. An entity that is transferable can be received from one person, and passed on to a different individual; a person can receive a book from one associate, and pass it on to a second associate. In contrast, an entity that is non-transferable can be received from one person but not transferred to a second; a person can receive an affectionate touch from a spouse, but cannot pass that same touch on to another individual. An entity that is duplicable can be copied, with the giver retaining the entity even as it is given to another; if I share a rumor with an associate, I do not as a consequence forget the rumor myself. An entity that is non-duplicable is given up in the process of transferring it to another; if I give an associate five dollars, I cannot have that same five dollars myself. In general, research on diffusion and social contagion concerns itself with entities that are transferable and duplicable. If they are not transferable then diffusion, as usually conceived, is impossible, and if they are not duplicable then there can be no sustained diffusion process. However, it should be kept in mind that transferability and duplicability overlap in complex ways. For example, a book in common usage is a transferable, non-duplicable artifact, and thus not a social contagion, while the information contained in the book is both transferable and duplicable, and therefore is a social contagion.

The study of diffusion as a larger phenomenon originates with both Gabriel Tarde's (1903[1969]) "The Laws of Imitation" and Georg Simmel's (1908[1964], 1922[1964]) essays on the stranger and connections between groups. However, truly systematic study of diffusion did not commence until the middle of the20th century, with Ryan and Gross' (1943) study of the diffusion of hybrid seed corn and Coleman et al.'s (1957, 1959, 1966) investigation of the adoption of a new antibiotic. These studies indicated that decisions to adopt a new technology were often influenced more by peers than by formal assessment of the behavior (See also Burt, 1980; Van den Bulte and Lilien, 2001). Diffusion influences recruitment into activism (McAdam, 1986) as well as voting decisions (Bond et al., 2012). The formation of norms and attitudes appears to be heavily influenced by contagion (Friedkin, 2001; Friedkin and Johnsen, 1997, 2011), and many health-related behaviors respond to diffusion, including fitness activities (Centola, 2010, 2011), cigarette, alcohol, and tobacco use (Kirke, 2004; Mercken et al., 2010), obesity (Christakis and Fowler, 2007; but see also Cohen-Cole and Fletcher, 2008a), and happiness (Fowler and Christakis, 2008; but see also Cohen-Cole and Fletcher, 2008b). A substantial literature has developed on the spread of innovations through social networks (Montanari and Saberi, 2010; Rogers, 2003), explaining how a novel invention can become ubiquitous throughout a community. The spread of information was pivotal for women attempting to obtain illegal abortions (Lee, 1969), allowing them to identify covert practitioners. Even organizations have been shown to adopt the strategies of similar others (Conell and Cohn, 1995; Davis, 1991; Holden, 1986; Soule, 1997, 1999; Strang and Soule, 1998; Wang and Soule, 2012), leading ultimately to organizational isomorphism (DiMaggio and Powell, 1983). In short, a huge variety of beliefs and behaviors exhibited by both individuals and groups appear to spread through social networks.

Scholars have attempted to determine the effectiveness of naturally occurring networks for promoting diffusion (Dodds et al., 2003; Lundberg, 1975; Pickard et al., 2011; Travers and Milgram, 1969; Watts et al., 2002), often finding that contagions can cross even large networks relatively quickly. However, while contagions may cross networks quickly, the diameter of real world networks can be large (Albert et al., 1999), and even when the network structure provides shortcuts, contagions often do not take the shortest path (Golub and Jackson, 2010; Liben-Nowell and Kleinberg, 2008). As a result, traveling from one side of a network to the other often requires many hops. Significant effort has also been devoted to exploring how different types of network ties, and structures, can accelerate or retard the diffusion process. One stream of research has shown how weak (Granovetter, 1973, 1995), bridging (Burt, 1992), and high bandwidth (Aral and Van Alstyne, 2011) ties can accelerate the diffusion of social contagions. Other research (Centola and Macy, 2007) has complicated this picture by suggesting that the "complexity" of the contagion can impact diffusion, at least initially (Barash et al., 2012), and favor strong ties over weak ties. Research has also striven to identify the individuals in networks who are most susceptible to contagions (Aral and Walker, 2012), as well as to distinguish tendencies to adopt the behaviors of our associates from tendencies to associate with those to whom we are similar (Aral et al., 2009; Lewis et al., 2012).

The existing research on diffusion and networks is rich, but has often artificially precluded the possibility of errors. First, research on the small world phenomenon (e.g., Lundberg, 1975; Travers and Milgram, 1969; Watts et al., 2002) has frequently relied on an experimental design in which subjects pass fixed packets of information (e.g., a physical letter) from person to person. This is convenient for the researcher, but many of the social contagions most interesting to social scientists probably do not traverse a social network in such a stable format (i.e., transferable/non-duplicable). Certainly researchers in this area have noted the frequency with which the packets failed to reach their targets, and this could be viewed as an extreme form of error, but the outcomes have remained binary. In other words, either a message reaches the target intact, or fails to reach the target, but never arrives with modification. Second, diffusion studies (e.g., Christakis and Fowler, 2007) have often examined an outcome, such as obesity, without measuring the behaviors that lead to this outcome. Because many behaviors can lead to the same end result (e.g., obesity can result from overeating, from insufficient exercise, etc.), changes in the contagion are undetectable so long as they lead to the same consequence. Third, a growing body of research examines contagion using social media, such as Facebook (e.g., Lewis et al., 2008, 2012), but in these studies behaviors and preferences are determined by simple on/off choices made by users (e.g., "liking" rock music). As a result, the underlying variation in actions and understandings (e.g., how music is understood or consumed) is undetectable. Finally, theoretical work on contagions (e.g., Barash et al., 2012; Centola and Macy, 2007; Rodriguez et al., 2014) has often employed simulation models that implicitly (or explicitly; see Carley, 1991, p. 334) assume that information is passed from node to node without error. The impact of errors is thus excluded a priori and with minimal, if any, theoretical justification. Error is therefore a relatively neglected issue in the study of diffusion.

2.2. Errors and diffusion

In his 1977 presidential address to the American Statistical Association Kish remarked, "...to err is human, to forgive divine but to include errors in your design is statistical." In other words, humans make mistakes because they are human, and effective research must take account of them in order to achieve valid results. However, errors do not just occur during the research process (e.g., errors in data collection), but in the social processes under examination (e.g., intermittent failure to follow formal organizational procedures), and therefore represent an important part of those

[2] The term "contagion" can refer either to a thing that spreads between individuals, or to the process of spread itself. For clarity, we use "contagion" to refer to the thing that spreads, and "diffusion" to refer to the process as a whole.