Adaptive **Behavior**

Whispering Down the Lane: The Economics of Vicarious Information Transfer

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This article presents a model of the use of communication about personal experience or experiences of third parties (gossip) in the context of cooperation. To date, previous research on the effect of gossip on cooperation has focused primarily on the manipulation of reputations. We present a formal model of vicarious information transfer, as a social learning strategy, between (potential) cooperative and competitive group members. We build on theories that have shown how effective communication can solve the adaptive problem of the high costs of individual learning. By communicating about the strategies of others, individuals can vicariously learn at faster rates and lower cost. The costs and benefits of social versus individual learning have been modeled extensively. In this article, we focus on the unexplored and more basic question of when an individual should initiate the sharing of vicarious information that can potentially affect the fitness of a cooperative or competitive receiver.

Keywords gossip · social learning · communication · cooperation

1 Introduction

Communication enhances cooperation. Even brief conversations with other players can increase trust and cooperativeness in the context of popular social dilemmas, such as the prisoner's dilemma, and other public good games (e.g., Frank, 1988; Orbell & Dawes, 1993; Orbell, Dawes, & Van de Kragt, 1988). Not only communication between cooperators, but also communication about cooperators (e.g., gossip) can substantially increase the level of cooperation. Cox, Sluckin, and Steele (1999) have shown how cooperation in large social settings increases when communication about cooperators is allowed, and when players interact with sufficient frequency to have knowledge about others' strategic behavior. Communication by language is often viewed as a highly efficient means of conveying information and describing experiences. Verbal communication and the concomitant nexus of intense and productive interactions in the context of increasing social group size among ancestral humans have been interpreted as evidence in support of the development of our highly encephalized "social brain" (Byrne, 1995; Dunbar, 1998a, 1998b). One reason why language enables cooperation in larger social settings is because it helps construct and manipulate the reputations of individuals. Reputation management is an important avenue for the evolution and maintenance of stable cooperation in large groups because much behavior about individuals will not be observed directly (Panchanathan & Boyd,

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2003, 2004). Linguistic-based reports allow for tracking of image scores or "standing" (Milinski, Semmann, & Krambeck, 2002; Nowak & Sigmund, 1998).

To date, much of the research on the effect of linguistic information in the form of gossip on cooperation has focused primarily on the manipulation of others' reputations. This article focuses instead on the question of fitness-relevant information transfer via gossip to group members who may belong to some coalition, family, task group or other set of interacting members with inter-dependent utility functions, as well as to those with whom some form of conflict is present. Our framework allows conflict among kin or coalition members, and cooperation with non-kin. The information we refer to is *vicarious information*, whereby a sender has the potential to positively or negatively impact the fitness of a receiver based on the utility of the information conveyed. This information may be based on either first-hand or second-hand sources (see below).

A core idea of this article is that effective linguistic communication can solve the adaptive problem of the high costs of individual learning because social transmission of fitness-relevant information enables the accumulation of knowledge (Boyd & Richerson, 1985; Pinker, 1995; Rogers, 1988). Social learners will act upon, mimic, or adopt fitness-relevant information about successful or unsuccessful strategies from others if they receive and believe these ideas that are based on the trials of others.

A rich body of research and models has addressed the question of when information should be employed to shift or update behavioral strategies (e.g., diffusion of innovations, social transmission). According to these transmission models, information should spread when it is reliable, and when the effect from employing this new information is observable and of sufficient magnitude. The costs and benefits of social versus individual learning has previously been modeled extensively (Boyd & Richerson, 1985; Feldman & Laland, 1996; Henrich & Boyd, 1998; Rogers, 1988), and there has been a rich literature on the epidemiology of ideas and information (Atran et al., 2002; Krebs & Dawkins, 1984; Sperber, 1996). Not all information will be useful to an audience, and the audience directs its attention towards information that is most relevant to them (see Sperber & Wilson, 1986, for discussion of relevance theory).

Most depictions of information transfer have focused on the reliability and consequent *imitation* of information by receivers. In this article, we examine costs and benefits of information sharing that are either dependent on or independent of whether a receiver will act upon the received information. We specifically address the question of when an individual should *initiate* sharing of a piece of exclusive information that can potentially affect the fitness of a receiver.

In Section 2, we define vicarious information and its role in fostering cooperation in human groups. In Section 3, we outline a model for when such information should be shared with others. Finally, in Section 4, we discuss some preliminary tests of this model with existing empirical studies and explore predictions and implications for further research.

2 Vicarious Information and the Role of Communication, Cooperation, and Conflict

Learning occurs when behavior is modified by experience or knowledge. We learn from our own and from others' experiences. Our own experiences (direct, first-hand experienced) may be fairly limited and so we may attempt to seek out and incorporate the direct (first-hand observed) or indirect (second-hand heard) experiences of other individuals, and weight such experiences based on the reliability, contextual relevance and status of the sender or source of information (Atran et al., 2002; Henrich & Gil-White, 2001; Krebs & Dawkins, 1984; Sperber, 1996).

2.1 Exploiting the Expertise of Others

Direct first-hand experience can be very costly in terms of time, energy, money, or risk. For example, behavior of mobile animals and associated predation risk are obvious contenders for second-hand information, or social learning (Scalise Sugiyama, 1996, 2001; Williams, 1966). Learning from others can entail first-hand observations and subsequent imitation of direct actions of others (Henrich & Gil-White, 2001; Tomasello, Kruger, & Ratner, 1993), or can be based on the communication of information through language (Pinker, 1995).

First-hand observation of others is the process of recording behavioral patterns of people without communicating with them (Bandura, 1969, 1977). Learning from others is not unique to humans and has been described among other animals (Gigerenzer & Todd,

1999; Heyes & Galef, 1996; Reader & Laland, 2002), most recently among sponge-using bottlenose dolphins (Krutzen et al., 2005) and gorillas (Breuer, Ndoundou-Hockemba, & Fishlock, 2005). The use of observational learning is very common among the great apes (van Schaik, Deaner, & Merrill, 1999; Whiten et al., 1999) but has also been seen among monkeys (Hauser, 1998). Tomasello, Kruger, and Ratner (1993) argue that human imitation differs significantly from other nonhuman primates' and other animals' imitation techniques in that humans do not merely copy, but pay careful attention to each detail and try to imitate a given behavior as much as possible. Human observational learning is often referred to as "cultural, social learning", or "true imitation" (Henrich & McElreath, 2003; Richerson & Boyd, 1992; Scalise Sugiyama, 1996, 2001; Williams, 1966). True imitation rests on the exploitation of the expertise of others (Russon, 1997), and can be regarded as a fast and frugal heuristic (Gigerenzer & Todd, 1999), because it enables individuals to make future decisions with reduced cost in time and energy. That is, true imitation enables the imitator to accumulate experiences quickly at a low cost.

Humans can also accumulate experiences at a fast rate by *talking* about the behavioral strategies of others (e.g., Henrich & McElreath, 2003; Scalise Sugiyama, 1996, 2001). This enables information transfer to individuals who did not observe the actions of the talked about subject. Many famous anecdotes show very clearly how the value of information gleaned by others can have immediate survival consequences in ancestral environments (Gaulin & McBurney, 2004): For example, plants to eat or avoid, processing techniques that can render toxic foods edible and nutritious, snakes or predators that may be dangerous, safe places to sleep without threat of raiding or predation. Information of less immediate value can nonetheless have important adaptive consequences on fitness via potential impacts on mating opportunities, child rearing, productive performance, shifting alliances, or any other aspect of life with potential costs and benefits on self, biological kin or allies. For example, in the context of foraging, Ache men will often converse about their daily encounters with game and give great detail about many aspects of animal behavior and their own actions, mistakes or successes during pursuit (Kaplan & Hill, 1992). Before hunter–gatherer boys ever start hunting themselves, they have already accumulated hundreds, if not thousands, of hours of others' hunting experiences. Presumably such experience can positively impact the rate of increase in hunting performance (Gurven et al., n.d.).

2.2 Vicarious Information

We refer to all stories, anecdotes, advice, testimonial, or other forms of verbal communication that can either directly or indirectly impact the fitness of a receiver as *vicarious information*. Vicarious information is not directly concerned with the reputation of a subject, but merely focuses on some salient experience of the subject that it may be fitness-relevant to others to mimic or avoid. The focus lies on strategies the subject has tested (see 2.2.2).

The function of vicarious information transfer is to spread fitness-relevant information about strategies that can improve the welfare (and ultimately fitness) of receiving members of a listening audience. Vicarious information is produced by a sender for impact on his or her audience. It concerns what Boyer (2001) terms "strategic information" that activates the social mind. Vicarious information is strategic in the sense that the sender has the intention of making the receiver engage in an action (mimicking or avoiding strategies). The outcome of sharing vicarious information relies on other people's actions.

2.2.1 The Content of Vicarious Information: Fitness-endangering and Fitness-promoting Calls We increase our vicarious experience with the successes and failures of others. Our attention will be driven to stories about both potentially damaging or threatening situations, and advantageous situations that provide opportunities for profit (Tooby & Cosmides, 2001). In both cases, individuals paying attention to "vicarious, orchestrated, imagined or fictional experience" p. 23) can benefit from quick learning at low costs, rather than real-time direct learning at high cost.

While both danger avoidance and welfare enhancement can lead to an increase in fitness, the two categories should be distinguished because they are likely to entail different benefits (if believed, followed or acted upon) and costs (if not). Two fictional examples illustrate our point:

> Once Stan won that NSF [National Science Foundation] Graduate Fellowship, his professors took him seriously and gave him major investment. No one paid attention to

> his interests before! He didn't realize that it was so well respected. Apparently funding agencies thought it was cool too, because he later had no problem getting additional funding. I asked him about this and he was convinced that he got that last grant only because of the graduate fellowship…

> Rosie got killed by one of those Highland Court Crew guys [gang in Little Rock, AR]! That was the group she was observing undercover… they say the guy became suspicious because Rosie didn't do her hair right, and had memorized the wrong version of their code… the guy suddenly freaked out one day and shot her in the head.

Both stories are potentially very informative, the first for an aspiring new graduate student and the second for an aspiring new police officer. If acted upon, the first describes a welfare- promoting opportunity (i.e., get an NSF grant if you want an easier time in graduate school), and the second describes danger-avoidance (i.e., make sure you do your homework if you're ever doing undercover work). The first example can be compared to a "food call" in animals, while the second example can be seen as an "alarm call." The increase in welfare gained by paying attention to welfare-promoting information (food call) is likely to be greater than that gained from danger-avoidance information. In the case above, paying attention to the second story only serves to maintain the status quo (being alive). Similarly, the costs incurred by ignoring fitness-endangering information (alarm call) are likely to be greater than those incurred for fitness-promoting information. Death or serious injury is a high cost to pay in the example above.

The point of this exercise is to suggest that even if net benefits from paying attention to welfare-promoting and danger-avoidance information were equivalent, the costs and benefits will differ in each context, especially when the information is not true. A wealth of studies have shown that costs and benefits are not weighed equally in many domains of decision-making (Kahneman & Tversky, 1979, 2000) and that danger-avoidance can decrease the subjective relevance of baseline probabilities ("truth" of risk). For example, there is evidence that a "negativity bias", whereby attention is captivated more by negative news and events (Rozin & Royzman, 2001; Taylor, 1991) helps to keep these events better retained in memory (e.g., Ito, Larsen, Smith, & Cacioppo, 1998).

We also make a distinction between true and false fitness-related calls. True messages contain vicarious information about fitness-promoting opportunities and fitness-endangering risks that are actually present. False messages contain vicarious information about fitness-promoting opportunities and fitness-endangering risks that do not exist. In their decision to act upon or ignore a piece of vicarious information received, receivers are always confronted with degrees of uncertainty. In line with signal detection theory (Green & Swets, 1966) acting upon true information and ignoring false information are beneficial "hits" and acting upon false information and ignoring true information are costly "misses."

When a piece of information is TRUE ($t = 1$), we define B as the benefit a recipient gains when she believes (hit) the information and C as the cost incurred when she does not believe (miss). When B outscores C, the vicarious information concerns clear fitness-promoting information (e.g., example 1 from above), when C outscores B, the vicarious learning information concerns fitness-endangering information (e.g., example 2 from above).

If the information is false, then belief and subsequent action can again have different impacts in terms of costs and benefits. The magnitudes of the effects will depend on the situation and the accuracy of the information. When the information is FALSE ($t = 0$), we define B' as the benefit gained when the information is correctly believed to be false (and therefore not acted upon; a hit), and C' as the cost incurred when it is incorrectly believed to be true (miss). Acting upon information that is false can be very costly in fitness-endangering situations, but may only involve a loss of time or energy in a fitness-promoting situation. Ignoring false information may be helpful in fitness-endangering situations (i.e., you know what not to do), but is less likely to have as significant an impact as true information (i.e., you know what to do) in those contexts. The cost of ignoring true information is similarly higher in fitness-endangering situations. This is summarized in Table 1 with a fictional example.

The category of vicarious information could be further sub-divided based on different referent selection pressures, such as "survival vicarious information", "mating vicarious information" and "social vicarious information" (see De Backer, 2005). These subcategories of information may map onto a kind of folk taxonomy of ideas about the world (see Atran, 1990). However, in this article we do not narrow down the

Table 1 Different cost and benefit values for welfare-promoting versus danger-avoidance vicarious information: An example

Type of vicarious information	Information is TRUE		Information is FALSE	
	Receiver acts upon (believes TRUE)	Receiver ignores (believes FALSE)	Receiver ignores (believes FALSE)	Receiver acts upon (believes TRUE)
Fitness promoting	$B = 1$	$C = 0$	$B' = 0$	$C' = 1$
Fitness endangering	$B = 0$	$C = 3$	$B' = 1$	$C' = 4$

term "vicarious learning" to different contents. Although several researchers (e.g., Sperber & Wilson, 1986) have argued that different transmission rules apply for different content categories, we instead follow the tradition of others, such as Boyd and Richerson (1985), who claim that general transmission models are applicable in many content domains.

2.2.2 The Subjects of Vicarious Information Subjects of vicarious information function merely as carriers of the message. Replacing a subject of vicarious information with another subject does not change the connotation of the message dramatically. For example "My aunt died from suffocation when the construction of her wallbed fell down on her in the middle of the night. She was only reported missing a few days later, and by the time they came into her apartment she had died." Replacing the subject "my aunt" with another subject, for example, "my boss" does not change the main connotation of this message, which is: wallbeds can be dangerous, especially for people living by themselves. In contrast, if you change the subject of a piece of reputation gossip, you get a different message. "My aunt is the prettiest woman I know" is not the same as "My boss is the prettiest woman I know." The value of vicarious information is independent of the exact identity of the subject (Baumeister, Zhang, & Vohs, 2004).

The identity of the subject may add to the reliability of the information or provide additional useful context, and thereby affect receivers' willingness to copy, incorporate, or use the information (Henrich & Gil-White, 2001). Indeed, there is good evidence that people are selective in their copying behavior. Some of this may pertain to context: for example, older women may prefer information where subjects are older women rather than young men, due to compatibilities of age and sex (Henrich & Gil-White, 2001). Cues of high status are especially important for copy bias (Bandura, 1969, 1977). Well-respected or publicized role models, healthy or attractive individuals, wise elders—each of these may be likely candidates for imitation or copying (Henrich & Gil-White, 2001). Nonetheless, receivers should be interested in the transmitted fitness-relevant information if they can learn from it, even if they do not know the subject.

Furthermore, subjects of vicarious information vary from being the sender himself to being known or unknown third parties, depending on who shares the information.

2.2.3 Senders of Vicarious Information Individuals may communicate information based on direct experience, or based on the experience of others. We distinguish three types of vicarious information that can be used to acquire experience at a fast rate with low costs. Second-hand verbal transmission of experience can be (1) transmitted by the person who experienced the information himself or herself to someone who did not observe his or her actions, (2) by others who have directly observed the situation to others who did not observe the situation, or (3) by others who have heard about the experience from others. We assume decreasing information reliability going from the first to the third form of information transition. The most reliable situation, when the sender experienced the situation themselves, we call *vicarious self-disclosure*. Self-disclosure is obviously impossible with respect to pertinent information about life-or-death situations when the direct experience resulted in death. When the sender of the vicarious information has not experienced the situation directly, the vicarious information involves talk about third parties, which can be considered a form of gossip (e.g., Arno, 1980; Ayim, 1994; Bergmann, 1993; Eder & Enke, 1991; Foster, 2004;

Table 2 Different types of vicarious information

Type of information transfer	Subject	Reliability to sender	Reliability to receiver
Vicarious self-disclosure	Same as sender	High	Low
Vicarious gossip	Third party	High	Low
Vicarious rumor	Third party	Low	Low

Merry, 1984; Morreall, 1994; Nevo & Nevo, 1993; Spacks, 1982, 1985; Wert & Salovey, 2004). We will also use the distinction raised by others where gossip is spread among individuals who know and trust each other, and rumors are spread freely among interested parties who lack these trust relationships (Bergmann, 1993; Foster, 2004; Orr, 1999; Smith, Lukas, & Latkin, 1999). A sender of *vicarious gossip* either believes that the piece of information is true (e.g., because the sender witnessed the situation), or intentionally spreads a lie. The reliability of rumors, but not gossip, is uncertain from the perspective of the sender. When the sender of vicarious information has no clue whether the content is true or not, we term the information *vicarious rumors*. An overview of the different types of vicarious information is given in Table 2.

2.3 Vicarious Information, Cooperation and Conflict

Group living, cooperation and conflict among humans are keystones of the human adaptive niche. The reliance on difficult-to-acquire, nutrient-dense wild foods requires juveniles to be dependent consumers for up to twenty years (Kaplan, Hill, Lancaster, & Hurtado, 2000). Cooperation in food production and distribution is crucial for ensuring adequate nutrition on a daily basis, and especially during periods of low production due to juvenility, old age, injury, illness, pregnancy or high dependency. A division of labor by age, sex and ability is observed in all hunter–gatherer groups. Among the small-scale subsistence-oriented groups most resembling our human ancestors, the extended household is a basic unit of production and distribution, its interests intersecting with those of other households via kinship, friendship, exchange or trade networks, or social visitation. Any given set of group members will therefore have interests which are either tightly coincident, partially overlapping, non-overlapping or conflicting with those of every other set of other group members. We will term those members with joint interests one's *cooperative inner circle*. Improving the welfare or education of group members within one's inner circle is likely to have positive externalities that will impact one's own welfare.

Because of the pervasive potential of defection in social groups and the often disjoint interests even among cooperating group members (Embler, 1978; Krebs & Denton, 1997; Lewin, 1993; Tooby & DeVore, 1987), conflict is always part of the selective backdrop in social interactions, even among kin (Trivers, 1974). Trivers (1974) defined conflict as any interaction where natural selection would favor different outcomes for different participants. Inequalities, conflicting interests, and struggles for status are among the many causes of conflicts (Cashdan, 1980).

Communication where conflicts of interest are present for manipulative senders and skeptical receivers is purported to evolve in an evolutionary arms race, resulting in costly signals such as rituals (Krebs & Dawkins, 1984). On the other hand, communication where common interests between sender and receiver was guaranteed did not evolve in such an arms race, and resulted in cheap signals or "conspiratorial whispers."

3 Modeling Initiation of Vicarious Information

We present a simple model that outlines the costs and benefits of sharing self-disclosed, gossiped or rumored vicarious information with others; within the model, we will refer to an act of information sharing as cooperation, and an act of information hoarding as defection. A sender's decision to share information will take account of the benefits for the sender, the potential benefits to the receivers, the relationship between the sender and receivers, and any potential costs to the sender. We describe each of these and convert them into a single mathematical framework.

3.1 Benefits of Initiating the Sharing of Vicarious Information

There are two types of benefit that can be gained by senders of vicarious information. The first involves the impact that information can have when believed and acted upon by receivers. This may be thought of as the likelihood of internalization such that when presented with the appropriate context, a recipient will act upon that information believing it to be true. It is beneficial for a sender to improve his welfare by positively updating the experience knowledge of members with whom levels of cooperation are present and to maintain or negatively impact the welfare of people with whom a certain degree of conflict is present. Any particular person within or outside the inner circle may have a variable likelihood of coincident interest, joint production, coalitionary status or overall cooperativeness with a sender. We define c as the probability that a potential receiver has joint interests with a sender to the extent that an increase in the recipient's welfare is associated with an increase in the sender's welfare. The probability that any boost in that potential receiver's welfare will be associated with a (relative) net decrease in the sender's welfare is therefore $1 - c$. Although the truthfulness of any gossip is known by the sender, the potential for information to bear an impact on a recipient's welfare requires belief by the recipient that the information conveyed is true, and consequent imitation or non-imitation of the transferred vicarious information. We define b as the probability that a recipient believes that the information conveyed by the sender is true.

Second, the initiator of strategy learning gossip can gain merit from his or her audience by being a source of valuable information. Such status will be attributed to the sender under three conditions: (1) the receiver must believe the sender, (2) the information should be novel or contain a novel component from a receiver's perspective, and (3) the information is to some degree limited or rare. Reliable, exclusive, and novel knowledge can be an indicator of high social status and/or intelligence (Miller, 2000; Rosnow & Fine, 1976). As in costly signaling arguments, benefits can accrue to people who reveal honest evidence of high phenotypic quality because others will want to preferentially interact or confer benefits on valuable, high quality individuals (Zahavi & Zahavi, 1997). Alternatively, senders may directly trade information for other useful information, resources, services or other commodities. Senders of reliable, exclusive and novel knowledge may have extra leverage in social interactions and receive social attention. Exclusivity requires that no one else in a given social network has similar information. We define the probability that a piece of vicarious information is exclusively held by the sender as E. The potential gain in social status from displaying exclusive knowledge also depends on the degree of belief by the receiver. A receiver will only attribute status towards a believable source of exclusive knowledge. It may not be necessary, however, for receivers to act upon the received information in order for senders to receive prestige.

3.2 Costs of Initiating the Sharing of Vicarious Information

Sharing knowledge does not involve a complete loss of what is shared by the sender. Even though the sender gives away her knowledge, this does not imply that she loses access to that knowledge. The cost involved in the sharing of knowledge is that a sender loses *exclusive* access to the information. But this cost will be, on average, lower than in the case where a sender shares a material good and loses all access to the material good. The costs of sharing non-rival goods such as information have therefore been described as relatively low (Romer, 1994). Information exchange is thereby seen as a cheaper enterprise than material resource exchange.

However, information sharing can involve other costs. First, information that benefits competitors, or that negatively impacts cooperators (such as close kin or other members inside one's cooperative inner circle) will exact a cost on the sender—either through reduced efficiency of cooperation or reduced inclusive fitness in the case of kinship. Thus, it may be costly for a sender to deceptively manipulate the experience record of those with whom their welfare is positively correlated (cooperators), or to improve the experience record of those with whom the sender is in conflict (competitors). Second, it is likely that prestige bestowal will be lacking when receivers believe that a sender's information is not credible. Telling lies (or being accused of telling lies) can lead to numerous repercussions, threaten one's credibility and potentially damage one's reputation. Third, if information is rewarded in proportion to its exclusivity, then there is a danger that others can spread the sender's information and "steal credit." Other people can thereby potentially gain esteem at the expense of the original sender when this sender is not given credit

in the re-telling. A fourth possibility is that the quality of information can degrade over repeated tellings and interpretations. These latter two costs are not incorporated into our model.

3.3 When to Initiate Transfer of Vicarious Information?

In this section, we convert the benefits and costs described above into a mathematical framework and derive the conditions favoring the transmission of vicarious information by a sender to another individual. There are five components to both total benefits and total costs. These and variable definitions are summarized in Table 3.

Change in sender status is captured as the difference between components (1) and (6), or $E(2b - 1)$. This will be positive whenever the information is more likely to be believed than not, or $b > 0.5$. A sender will gain when a cooperator believes (2) or a competitor disbelieves (3) true information, but will suffer when a competitor believes (7) or a cooperator disbelieves (8) true information. The net benefit when a receiver believes true information is $B(2c - 1)$, which will be positive when the recipient is more likely to be a cooperator than a competitor ($c > 0.5$). Similarly, the net benefit when information is not believed but is nonetheless true is $C(1 - 2c)$.

If information is false but told to a recipient, again it can be either believed or disbelieved. A sender will gain when cooperators disbelieve (i.e., do not act upon) (5) and competitors believe (i.e., act upon as if it were true) (4) false information. Cooperator belief (9) and competitor disbelief (10) will result in costs from the sender's perspective because outcomes will be indirectly harmful to the receiver in the inner circle, and

Table 3 Components of costs and benefits to sender of vicarious information

BENEFITS TO SENDER				
(1)	(2)	(3)	(4)	(5)
Payoffs to exclusive knowledge	Cooperator believes true gossip and receives B	Competitor does not believe true gossip and pays cost C	Competitor believes untrue gossip and pays C'	Cooperator disbelieves untrue gossip and receives B'
Eb	$tbcB$	$t(1 - b)(1 - c)C$	$(1 - t)b(1 - c)C'$	$(1 - t)(1 - b)cB'$
COSTS TO SENDER				
(6)	(7)	(8)	(9)	(10)
Costs of others' disbelief	Competitor believes true gossip and receives B	Cooperator disbelieves true gossip and pays C	Cooperator believes untrue gossip and pays C'	Competitor disbelieves untrue gossip and receives B'
$E(1 - b)$	$tb(1 - c)B$	$t(1 - b)cC$	$(1 - t)bcC'$	$(1 - t)(1 - b)(1 - c)B'$

List of variables used in the model:
E = probability that knowledge is held exclusively by sender
b = probability that information is believed and will be internalized by receiver
t = probability that information is true
c = probability that receiver is cooperator with jointly associated welfare
B = benefit receiver gains if receiver believes true information
B' = benefit receiver gains if receiver disbelieves false information
C = cost incurred if receiver disbelieves true information
C' = cost incurred if receiver believes false information

beneficial to the competitor, respectively. As described above for the disbelief of true information, the belief of false information will benefit a sender when the receiver is unlikely to be a cooperator ($c < 0.5$). Analogous to the belief of true information, the disbelief of false information will benefit a sender when the receiver is likely to be a cooperator ($c > 0.5$).

Summing all benefits and all costs, we derive the inequality condition on exclusivity, E, favoring information transfer:

$$E > \frac{2c-1}{2b-1}[(1-t)(bC' - (1-b)B') - t(bB - (1-b)C)] \text{ for } ½ < b < 1 \quad (11)$$

$$E < \frac{2c-1}{2b-1}[(1-t)(bC' - (1-b)B') - t(bB - (1-b)C)] \text{ for } 0 < b < ½. \quad (12)$$

The condition on exclusivity changes around the point $b = 0.5$ because exclusivity will be damaging to a sender's reputation when belief is unlikely ($b < 0.5$) and rewarding only when information is believable ($b > 0.5$). Exclusivity is desirable only when others are likely to believe the information.

3.3.1 True Information ($t = 1$) When information is true ($t = 1$), the derivative of (11) with respect to c will be negative over a wide range of belief, b. A negative slope suggests that with increasing cooperativeness of the receiver, less personal prestige or exclusivity is necessary to make telling worthwhile when $b > 0.5$ and more prestige is necessary when $b < 0.5$. A positive slope will occur over intermediate values of b: ($C/(B + C) < b < 0.5$ when $B > C$; $½ < b < C/(B + C)$ when $B < C$). A positive slope means that with increasing receiver cooperativeness *more* exclusivity-based prestige is necessary to make telling worthwhile when $b > 0.5$, and vice versa when $b < 0.5$. The range of b values where the slope is positive increases with greater discrepancy between B and C.

When $B > C$ it will always pay a sender to tell information to a likely cooperator ($c > ½$) as long as the slope is negative. When the slope is positive under the intermediate range of b given above, it will still pay to tell information to a likely cooperator but only when exclusivity is below a critical amount given by (12), because exclusivity is harmful when $b < 0.5$. In this range of low credibility, it will never pay a sender to reveal information. When believability is very low ($< C/(B + C)$), a receiver who is unlikely to be a cooperator will suffer the costs of ignoring true information, and so exclusivity will only reduce the sender's payoffs. Thus, in this case, it's best to reveal the information but only when exclusivity obeys (12).

If $B < C$ then the costs of ignoring true information will loom large. When b is sufficiently high ($> C/(B + C)$), it will always be beneficial for a sender to reveal information to a likely cooperator ($c > 0.5$), and will be worthwhile to send it to unlikely cooperators if prestige due to exclusivity is high enough. When $b < 0.5$, one should never reveal any information to a likely cooperator because the receiver will suffer too much from ignoring true information. Once the likelihood that a receiver's probability of being a cooperative member with joint utility falls below $½ + (2b - 1)/2(C - b(B + C))$, it will always pay to reveal the unbelievable information because it is a competitor who will more likely suffer from ignoring true information. When $½ < b < C/(B + C)$, the slope of (11) becomes positive. Competitors should always be told information and thus no prestige is necessary, but prestige becomes necessary when $c > 0.5$. It is possible at sufficiently high c ($> ½ + (2b - 1)/2(C - b(B + C))$) that no level of prestige will ever make it worthwhile to reveal the information. The high cost that a cooperator pays for not believing true information when $B < C$ outweighs the benefit they receive from believing the true information, and thereby makes telling unprofitable.

Figures 1 and 2 graphically illustrate the conditions on E under several parameterizations of B/C and b. Table 4 summarizes the results of the model.

3.3.2 False Information ($t = 0$) When information is known to be false ($t = 0$), belief and action will now penalize the receiver while disbelief or inaction may be minimally rewarding. As done above for true information, we analyze the conditions that favor or disfavor the telling of false information (Table 4). The critical value for receiver belief that impacts whether a sender should tell false information is now $B'/(B' + C')$. Above this level, a sender should always tell competitors, whereas exclusionary prestige benefits are necessary to make the telling of cooperators worthwhile. When the receiver's likelihood of belief that the false information is true is less than this critical value, a sender will never tell a competitor and will only tell a cooper-

Table 4 When to share information with a receiver, as a function of whether the information is true (t), receiver cooperativeness (c), ratio of benefits to costs (B/C) and chance of the receiver believing that the information is true (b). Slope refers to the slope of the expression in Equations 11 and 12 (see text for details, examples given in Figures 1 and 2). b* and c* (= ½ + (2b − 1)/2(C − b(B + C))), are critical values of receiver belief and expected receiver cooperativeness, respectively (see text)

$t = 1$		$b^* =$		When to tell as function of c			
b	B/C	$C/(B + C)$	Slope	0 to c^*	c^* to 0.5	0.5 to c^*	c^* to 1
0.1	3	0.25	–	limit excl	limit excl	never tell	never tell
0.3	3	0.25	+	never tell	never tell	limit excl	limit excl
0.6	3	0.25	–	never tell	need excl	always tell	always tell
0.8	3	0.25	–	never tell	need excl	always tell	always tell
0.1	0.33	0.75	–	always tell	limit excl	never tell	never tell
0.3	0.33	0.75	–	always tell	limit excl	never tell	never tell
0.6	0.33	0.75	+	always tell	always tell	need excl	never tell
0.8	0.33	0.75	–	need excl	need excl	always tell	always tell
0.1	1	0.5	–	always tell	limit excl	never tell	never tell
0.3	1	0.5	–	always tell	limit excl	never tell	never tell
0.6	1	0.5	–	never tell	need excl	always tell	always tell
0.8	1	0.5	–	never tell	need excl	always tell	always tell
$t = 0$		$b^* =$					
b	B'/C'	$B'/(B' + C')$	Slope	0 to c^*	c^* to 0.5	0.5 to c^*	c^* to 1
0.1	3	0.75	+	never tell	never tell	limit excl	always tell
0.3	3	0.75	+	never tell	never tell	limit excl	always tell
0.6	3	0.75	–	never tell	need excl	always tell	always tell
0.8	3	0.75	+	always tell	always tell	need excl	need excl
0.1	0.33	0.25	+	never tell	never tell	limit excl	limit excl
0.3	0.33	0.25	–	limit excl	limit excl	never tell	never tell
0.6	0.33	0.25	+	always tell	always tell	need excl	never tell
0.8	0.33	0.25	+	always tell	always tell	need excl	never tell
0.1	1	0.5	+	never tell	never tell	limit excl	always tell
0.3	1	0.5	+	never tell	never tell	limit excl	always tell
0.6	1	0.5	+	always tell	always tell	need excl	never tell
0.8	1	0.5	+	always tell	always tell	need excl	never tell

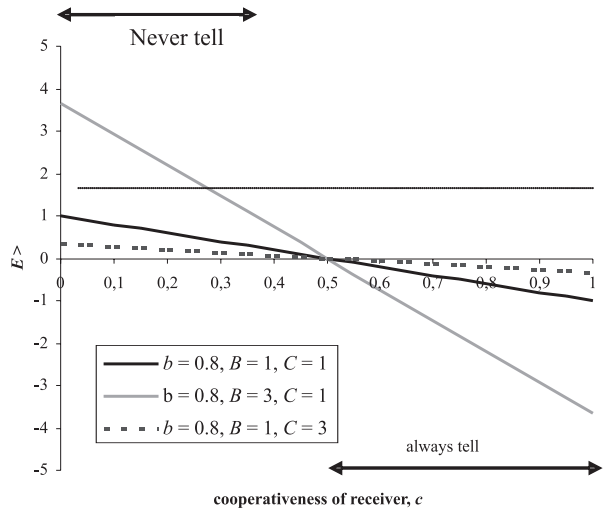

Figure 1 Condition on exclusivity, *E*, when information is true ($t = 1$). High credibility information ($b = 0.8$).

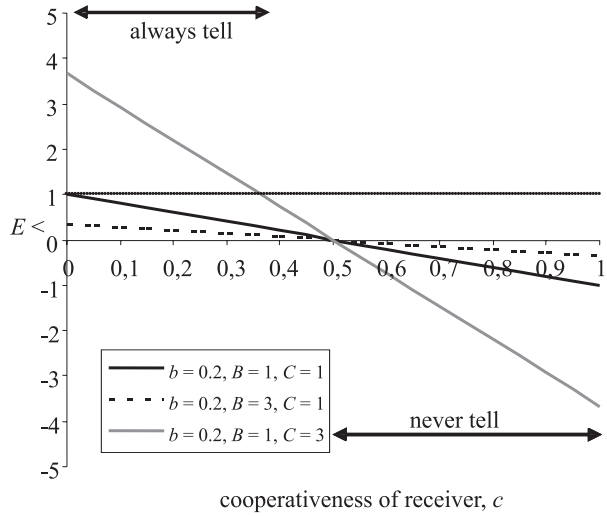

Figure 2 Condition on exclusivity, *E*, when information is true ($t = 1$). Low credibility information ($b = 0.2$).

ator if the exclusionary prestige is minimal or nothing. Prestige must be limited as argued in the case of true information, because majority disbelief by receivers only hurts a sender's reputation.

3.4 Implications of the Model

As implied by other researchers (e.g., Krebs & Dawkins, 1984) we show that useful, true vicarious information will be shared with cooperators and not shared with competitors. Harmful information, if believable, is better transmitted to competitors rather than cooperative receivers. However, our model predicts that vicarious information transfer may occur in other contexts, depending on the expectations of cooperativeness, reliability and exclusiveness. For example, exclusively held information, even if true and potentially useful, should not always be shared with cooperators if it is unlikely to be believed (low b). Alternatively, useful information may be shared with competitors when exclusivity-based reputational benefits are sufficiently high. False information that is unlikely to be believed by others, but can be traced back to the sender (high exclusivity) should not be told to anyone.

The formalization of costs and benefits in our model is an important exercise that helps illustrate the effects of both the reliability, exclusivity and utility of the vicarious information, and the extent of common interests between a sender and receiver, on the likelihood of information transfer. As Table 4 demonstrates, any particular decision to tell or not to tell critically depends on the estimated values of each of the model components. Our model predicts that true fitness-endangering alarm calls and fitness-promoting vicarious information (cooperative communication) will be shared with competitors if sufficient benefits can be gained by the sender from displaying reliable, exclusive knowledge. In a similar vein, such vicarious information will not be shared with cooperators under certain conditions of low exclusivity and reliability.

For intermediate ranges of receiver cooperativeness ($0 < c < 1$), different predictions are made by our model for fitness-enhancing and fitness-endangering vicarious information. Fitness enhancing ($B > C$) vicarious information will be shared (1) when common interests are high and believability is high, (2) when common interests are high, believability is intermediate to low and exclusivity is limited (e.g., uncommon cures for common ailments), (3) when common interests are low and exclusivity of the information is limited. Fitness-endangering ($C > B$) vicarious information will be shared in this intermediate range of receiver cooperativeness when (1) common interests and believability are high or (2) common interests are low and exclusivity is present (more costly).

3.5 Limitations of Model

There are several limitations to the model as presented. First, we did not incorporate the status of the subject

of second-hand vicarious information. The status of a subject could alter the likelihood that a receiver believes the information to be credible or worthwhile. Second, we let cooperativeness and state of belief be independent factors affecting the telling of information, but it is likely that individuals are more likely to believe what someone in their inner circle tells them (precisely because their interests are joint). Third, we focused our attention on whether information should be told to a single individual, rather than specify how many people of varying types should be told. An equivalent analysis can be done for the population by reinterpreting the probabilities we used as "proportions of the population." However, this kind of analysis assumes random interactions with people of varying degrees of cooperativeness or belief states. A population-level model could consider groups of varying social structure and embeddedness, and whose actors have varying centrality and connectedness (Wasserman & Faust, 1994). Finally, we did not differentiate content categories of vicarious information, some of which could show different transmission rates and believability (see De Backer, 2005).

4 Discussion and Conclusion

Information transfer allows receivers to benefit by gaining valuable experience at a fast rate and at low cost. We modeled the decision to initiate the sharing of vicarious information in the context of social groupings defined by cooperation and competition. We incorporated (1) the truth value of information, (2) its credibility and the expected impact on a receiver's likelihood of imitation, (3) the exclusiveness of the information, and (4) the expected joint interests or cooperativeness of the sender and receiver as important factors influencing a sender's decision to reveal or withhold a piece of vicarious information.

In contrast to the approach used by others, examining information transfer in the context of cooperation and conflict, our model assigns a probability of shared communal interest, rather than firmly placing others in the role of cooperator or competitor. In the case of pure cooperators ($c = 1$) and competitors ($c = 0$), the results from the presented model here are at odds with some predictions by Krebs & Dawkins (1984) and Noble (1999). Noble argues that communication only evolves under conditions of shared interests between sender and receiver when cooperation and conflict characterize potential relations between sender and receiver. Similarly, Krebs and Dawkins (1984) argue that (vicarious) information concerning fitness-enhancing opportunities ($B > C$) or fitness-endangering opportunities ($C > B$) will only be shared with competitive receivers when the communicative signal is costly to produce. Both of these results are special cases of our model, and not generalizable across all contexts. For example, the sharing of fitness-promoting vicarious information with competitors requires a high degree of exclusivity, and hence personal reputational benefits, for the sender under conditions of high believability, and limits on exclusivity under conditions of low believability, as in some forms of second-hand or third-hand information (Table 4). Personal benefits can therefore outweigh net costs of aiding competitors or harming non-rivals (potential cooperators) with shared interests.

Our model does not agree with Krebs & Dawkins (1984) concerning the sharing of fitness-endangering ($C > B$) vicarious information with competitors. In cases of warning others about strategies that can have fatal consequences, where the costs of ignoring outweigh the benefits of believing, our model predicts that these stories will always be shared with receivers with whom the sender has no degrees of common interest ($c = 0$), and believability is less than certain (Table 4). Under the condition of certainty, the model does predict, consistent with Krebs & Dawkins, that an additional cost of exclusiveness needs to be present.

Although no empirical data have yet been gathered specifically to test the presented model, we highlight some results from published studies that support some of the predictions and underlying assumptions of our model.

First, more credible information ($b > 0.5$) is generally assigned higher prestige while unbelievable information can potentially harm a sender's reputation. A sender is more likely to be credited for information that is confirmed to be true than for information that is doubtful (Hess & Hagen, 2002; Jaeger, Anthony, & Rosnow 1980; Kuttler, Parker, & La Greca, 2002; Wilson, Wilczynski, Wells, & Weiser, 2000). People are also less likely to spread information of dubious reliability (Jaeger et al., 1980, p. 476).

Second, it is a demonstrated fact that we converse most with and about our relatives and friends and less to and about foes or strangers (Emler, 1994). In a similar vein, McAndrew and Milenkovic (2002) showed that reputation-enhancing gossip about others is more

likely to be shared when the subjects of gossip are family or friends, and that reputation-damaging gossip is spread more widely when the subjects are foes. An experiment similar in design to theirs could be set up to investigate the difference in sharing true and false vicarious information, in terms of the targeted receivers' degree of cooperativeness towards the sender. It would be relevant to test the variable conditions of exclusivity under which highly credible vicarious information is shared with both cooperators and competitors.

Lastly, the model offers potential directions for exploring aspects of frugal decision-making for cognitively-limited or information-limited senders (De Backer, 2005). While we obviously do not assume that senders cognitively estimate the parameters of our model and solve optimality conditions to select the best context-specific choice, it may be the case that people estimate some critical components of our model and navigate different decision paths based on heuristics. For example, a decision tree outlining the decision of sharing truthful fitness-promoting vicarious information would, according to our model, incorporate the following steps: First, if a sender has directly experienced or witnessed an event or circumstance, she will know whether or not a piece of information is true ($t = 1$). If the sender did not witness the situation, she can rely on the next criterion: "Do I believe the information is true or false?", based on whether the sender has any clues or suspicions about the truth content of the information. The next step is to determine whether the receiver is currently engaged in, or likely to engage in future cooperative exchanges or alliances. The last step is to determine whether exclusivity is high enough to tell the information to a competitor. With the first telling of self-disclosure information, it is likely that a sender will have exclusive information. If the information is second-hand, the degree of exclusivity may be unknown or quite low. Having identified the credibility, cooperative status of the receiver, and exclusiveness of the information, the sender can then assess the expected impact (costs and benefits) of the vicarious information on the receiver, using a simple heuristics. A similar line up of simple heuristics can be construed for initiating the sharing of false information.

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