A Game-theoretic Perspective on Diego Gambetta's *Codes of the Underworld* *

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> Everything is a message, everything is full of meaning in the world of Cosa Nostra, no detail is too small to be overlooked.
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> – Judge Giovanni Falcone, quoted in Stille (1995, p. 6)

> The expressiveness of an individual (and therefore his capacity to give impressions) appears to involve two radically different kinds of sign activity: the expression that he *gives,* and the expression that he *gives off.* The first involves verbal symbols or their substitutes which he uses admittedly and solely to convey the information that he and the others are known to attach to those symbols. ... The second involves a wide range of action that the others can treat as symptomatic of the actor, the expectation being that the action was performed for reasons other than the information conveyed in this way. ... The individual does of course intentionally convey misinformation by means of both these types of communication, the first involving deceit, the second feigning.
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> – Goffman (1959, p. 2), emphases in the original

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*Paper presented at the book-launch conference for *Codes*, Oxford, June 25, 2010. I will cite Gambetta's works by the title, and other references by author-year.

Diego Gambetta is justly renowned among social scientists for his mastery of widely different modes of analysis – game-theoretic, ethnographic, and historical, to name just a few – and for combining them to great effect in studying many different social (and anti-social) institutions – the mafia, taxi drivers, and suicide bombers. This book, dealing with communication among criminals, is another outstanding contribution in this line. It brings to bear the theory of signaling and screening that was developed in game theory and information economics on many detailed observations of case studies. The result is a rich mix of improved understanding of some existing puzzles, and introduction of new intriguing puzzles that will stimulate much further thinking and research.

In the short time available, and within the limits of my own economic and game-theoretic perspective, I cannot do justice to the full scope of the work. Therefore I will select just a few themes that I found especially interesting and where I may have something to contribute.

The communication games in the world Gambetta studies are played for high stakes. For someone looking for a partner in a criminal enterprise, mistakes can be very costly. Choosing an untrustworthy partner can result in losses, not only of money but possibly also of life; choosing a police infiltrator can lead to imprisonment. Therefore strategies must be designed with great skill, and only very good strategies should be expected to survive. The signals used for communicating one's position and intentions, and the screening devices used for testing others' communication, must be clever and subtle. Indeed they are. Although they broadly conform to what we should expect from the theoretical models of signaling and screening, they climb to a level beyond that of most formal models used in game theory and its applications. The most important added feature is multidimensionality: multiple signals, multiple steps in a game of exploratory communication, and multiple different simultaneous audiences.

However, Gambetta's studies also show that not everything works all of the time. The players in these strategic games do make mistakes. This observation carries an implication for game theory: we should re-examine the neat equilibria of signaling models, where the signaler's actions are perfectly informative about the characteristic he wants to convey. I welcome this development. For a theorist, if anything is better than seeing a first-rate application of extant theory to an important real-life issue, it is feedback that stimulates development of richer or better theory. Every deficiency of the current state of a science is an opportunity in research. If current theory fails to do justice to some features of reality, that is a challenge to improve the theory. I will offer some thoughts on how this can be done for signaling theory.

Examples and Analogies

The rich and varied array of cases and anecdotes in *Codes,* and also in *Streetwise* and other Gambetta books, always make us think of other supporting anecdotes. I will exploit this opportunity of being a discussant to indulge in a few, illustrating some themes and analogies.

Strategic Ambiguity

The process of identifying potential trading partners is risky and error-prone for criminals. The recipient of a signal may be a police informer or infiltrator. Or he may be an innocent outsider who is horrified when he realizes the criminal intent of the signaler and goes to the police. The strategy for reducing these risks, in theory as well as reality, is to use a multi-stage process. The first signal is deliberately ambiguous. If the recipient reacts adversely, it can be explained away as meaning something different and innocent. If it is received favorably, a slightly less ambiguous signal is sent, and so on.

My favorite example of this comes from the 1951 British comedy, *The Lavender Hill Mob*. Henry "Dutch" Holland (played by Alec Guinness) is a lowly bank clerk, whose job is to supervise the transport of large quantities of gold bars from one bank to another. He dreams of stealing a consignment and living in luxury in Brazil or some such idyllic spot. But he recognizes the difficulty of getting the bullion out of the country. At his lodging, he meets Alfred Pendlebury (Stanley Holloway), who runs a foundry where lead is melted to cast Eiffel Tower replica paperweights that are exported to France and sold as souvenirs at the actual tower. Their conversation goes as follows:

Pendlebury: Must be a big responsibility.

Holland: Not really. If anyone did rob our van, it is virtually impossible to dispose of stolen bullion. In this country at any rate.

Pendlebury: Yes, oh yes, I imagine so.

Holland: Of course, if it could be smuggled abroad.

Pendlebury: What a hope.

Holland: I wouldn't say that is out of the question. If one had means of melting the stuff down.

Pendlebury: On a kitchen stove? What a job.

Holland: Of course not. It would mean taking on a partner.

Pendlebury: That's risky.

Holland: It's essential in any case. No one person could rob our van unaided.

Pendlebury: You mean he would need accomplices.

Holland: A gang.

Pendlebury: A gang? That's not so easy to come by.

Holland: Oh, I don't know. With gold selling on the Continental black market at two and a half times its standard price, quite a few people would be willing to chance an arm for half a million.

Pendlebury: Yes. But how would you get your gold across to the Continent?

Holland: Well, supposing one had the right sort of partner, in the form of, shall we say, Eiffel Tower paperweights.

Pendlebury: [laughs] By Jove, Holland, it's a good job we're both honest men.

Holland: It is indeed, Pendlebury.

Holland is clearly "sounding out" Pendlebury, and at the end vice versa, but any allegation of criminality is up to this point deniable.

Similar strategic ambiguity is used in other contexts where mistakes can be costly, for example in courtship, where too early a declaration of intention can lead to the embarrassment of a rebuff, or worse.

Related situations: War and espionage

Situations where one player wants to signal his trustworthiness credibly to another player, or wants to send a communication that must be protected from leakage to, or tampering by, a hostile third party, are ubiquitous. Nations play such games for even higher stakes than those for the criminals Gambetta studies. In wartime, countries want to communicate their plans credibly to their own soldiers and allies, and try to prevent enemy spies from discovering the truth. Of course they use their own spies, cryptanalysts etc. to try to find out the enemy's secrets. Many and varied strategies and counterstrategies are employed for this purpose, and the stories of their successes and failures are at least as rich and fascinating as those Gambetta studies.

We have some general principles, for example Churchill's famous dictum: "In wartime, truth is so precious that she should always be attended by a bodyguard of lies." Some examples of this general principle are the elaborate hoaxes perpetrated by the Allies in largely successful attempts to deceive the Germans about the locations of their landings: "the man who never was" deception about Sicily (Montagu, 1997), and many devices used to suggest that the D-day landings would be in Calais, not Normandy (Cave Brown, 2007). In the midst of all this, the Allies wanted to send truthful messages to their agents and the resistance fighters, without letting the Germans find out the meaning of the communication. The sneaky false message which U.S. Navy's cryptographic intelligence used for inducing the Japanese to reveal Midway as the target of their planned attack in June 1942 is another fascinating story (Holmes, 1998).

I do not know of any systematic attempts to examine these cases and examples through the lens of signaling theory. An attempt to use Gambetta's analytic framework of signals and signs for this purpose would be a fun and valuable research project.

Miscellany

Here is an assorted small sample of my thoughts while reading *Codes*, referenced by page numbers in the book.

p. 42: "The mobsters' henchman ... If he were too clever, he would be a menace to the boss." Luca Brasi in *The Godfather* seems an excellent example. But there is more to it. Remember Don Corleone's instruction to Michael: "There are men in this world who go about demanding to be killed. ... Such people of course to a great deal of harm to others also. Luca Brasi was such a man. ... [A] Brasi is a powerful weapon to be used. [T]he trick is to make yourself the only person in the world that he truly desires *not* to kill him. He has only that one fear, not of death, but that *you* may be the one to kill him. He is yours then." Michael follows this advice and finds Albert Neri. (Puzo, 1969, p. 423 in the 2002 Penguin Books' New American Library printing.)

p. 55: Gambetta discusses how Russians used any available compromising material, or "kompromat," to discredit or blackmail dissenters and opponents. Why leave things to chance? Kompromat can be generated, as in the "honey traps" of James Bond and other spy fiction.

pp. 116-7: Gambetta discusses how a person threatened with torture can use apparent irrationality strategically to signal that the threat would be unproductive. This works both ways: apparent irrationality can be used by the other side also. Remember the scene from Goldfinger where Bond is strapped to a table, and a laser beam is slowly headed toward the most important part of his anatomy. He asks Goldfinger "You expect me to talk?" Goldfinger answers: "No, I expect you to die, Mr. Bond."

Next, a few somewhat less frivolous thoughts:

pp. 38-9 and elsewhere: The "family" structure of the mafia presumably helps in building and maintaining trust. This is like Greif's "community responsibility system" (2006, pp. 309–310). If a member of community A cheats in a dealing with a member of community B, then B can appeal to the head of A. If the complaint is found justified, the whole community A makes recompense to B, and then takes internal steps to punish its own member.

p. 256: "When several gangs are trying to squeeze the producers, having to deal with just one mafia can seem like a blessing." This is an example of a principle explained by Shleifer and Vishny in the context of corruption involving several bureaucrats (1998, chapter 5). The general economic issue is that of "double-marginalization" in an oligopoly selling complementary products. Each seller neglects the fact that he exerts a negative externality on the other sellers: if he raises his price, the demand facing the other sellers goes down, hurting their profits. But the seller raising the price does not bear this cost. Therefore he raises his price higher than what the group's aggregate interest warrants. All sellers do this; therefore in a non-cooperative Nash equilibrium all choose prices that are too high. A monopoly or a cartel would reduce all prices in a coordinated way, thereby making more total profit, and also benefiting the consumer.

p. 257: "Sectors that attract mobsters' protection have certain features in common – firms are small, there are low entry costs, ... they have lots of unskilled labor, and they need low technology." Garment-making is an excellent example. The same characteristics also explain why mob involvement in this industry went beyond protection and into financing (Repetto, 2004, p. 163). Industrial organization theory tells us that low entry cost also means low exit cost. An entrepreneur might easily shut shop overnight and disappear. For banks operating in the formal economy, the costs of finding and suing such an absconder were high. Therefore banks were unwilling to lend. But the mafia had better technologies for chasing down these people and punishing them, and had profits from their other activities available to invest. So the mob became a major lender to the garment industry. In *The Sicilian Mafia,* (especially pp. 85, 227) Gambetta argues that the primary business of the mafia is protection; if it engages in some of the activities it is protecting, that is merely vertical integration. However, the garment industry example shows that sometimes the same features that make an activity a prime candidate for mafia protection can also make it especially suitable for other kinds of involvement by the mafia.

Signals, Signs, and Indices

Turning from anecdotes to more systematic conceptual issues, I would like to supplement some of the analysis in *Codes*.

Gambetta draws a distinction between *signals* and *signs*. In *Codes*, p. xv, he defines these concepts as follows (emphases in the original):

> Signals are any observable features of an agent that are *intentionally displayed* for the purpose of altering the probability the receiver assigns to a certain state of affairs or "event." ... Signs ... can be anything in the environment that is perceptible and that by being perceived modifies our beliefs about something or someone. They do not require a purposive agent. But signs are also dormant or potential signals. A sign typically becomes a signal when a signaler takes steps to display it.

Gambetta calls the signals that result from display of signs "conventional" signals,[1] to be distinguished from the intentionally displayed signals of the former kind, which I will call Spencian signals (Spence, 1974).

Another crucial property of Spencian signals emerges in course of the analysis. The purposive act of displaying the signal is costly, and the cost differs for different underlying "events" that are known to the signaler but not directly to the recipient. This is essential if the signal is to convey the information credibly, i.e., to be an actively used strategy in a separating equilibrium. The cost of signaling must be (sufficiently) higher for a potential mimic; otherwise someone who knew a different "event" to be the true one would send a copycat signal, hoping to induce a mistaken belief in the recipient's mind and exploiting it to his own advantage. Of course a strategically aware recipient would not be fooled; therefore the signal would be useless. (See Spence (1974), especially pp. 15, 26.) Conventional signals are different; the step of displaying a sign that already exists in the environment is often

[1] There is a related category of "iconic" signals, for which the convention is so well established that "they can be understood even at the first interaction" *Codes*, p. 154.

essentially costless. How can a signal generated by costlessly displaying a dormant sign become credible communication? To understand this, I think we must distinguish between two distinct purposes of communication among Gambetta's protagonists, namely conveying private information in games with some conflict of interest, and generating common knowledge for solving coordination problems where interests are aligned.

If someone who wants to engage in a criminal enterprise wants to signal his trustworthiness to a potential partner, he must overcome the other's justifiable suspicion that he may be pretending to be trustworthy in order to exploit that trust later. That is why he must use a signal that would be too costly for an untrustworthy person to send. But if the question of trust is either absent because the parties' interests are known to be aligned, or is resolved by other means such as enforcement or reputation, and the purpose of the signal is only to locate and identify potential business opportunities and partners (*Codes* pp. 149-150), then all that is needed is a signal that tells others that you are a member of that group, or that you have the goods or services the others seek. Anything that is *common knowledge* – everyone knows, everyone knows that everyone knows, . . . – can serve the purpose. As Gambetta says, it is an "arbitrary signifier" (*Codes* p. 153). There is no need for it to be costly. Of course it is often necessary to restrict the "everyone"; criminals don't want law enforcement officials to read and interpret their signals easily and correctly. This need to restrict communication may entail its own cost,[2] but that is different from the differential cost condition of Spencian signaling. (See Chwe (2001) for an excellent discussion of methods that can bring about common knowledge.)

As usual, this distinction serves the purpose of conceptual and analytical clarity. In reality the purpose of signaling may be a combination of the different considerations, and the signal may exhibit a mixture of Spencian and conventional properties.

In this context it may be worth mentioning a third category of signs that relates to the other two. Spence (1974, pp. 10–11) calls these *indices*. An index is any observable and unalterable characteristic of an individual, such as race or gender, that may influence the beliefs of others about him. Like a Spencian signal, an index is associated with a specific individual; unlike a sign that becomes a conventional signal, it is not just "anything in the environment." However, unlike a Spencian signal, an index is not costly to send, but is freely observable like many signs.

[2]Even at a cost, it is usually impossible to eliminate all errors of both Type I and Type II; see *Codes* chapters 6, 7.

An index can be interpreted as a Spencian signal for which the cost of mimicry is infinite. Therefore it automatically meets the Spence condition. In fact if an index is truly associated with the characteristic one wishes to communicate, then it is the best possible Spencian signal.[3] For example, Ekman (2001) finds that the act of lying is accompanied by certain fleeting involuntary micro-expressions of the face and eyes. If the ability to read these expressions can be acquired by training, for example watching videos of known situations of truthtelling and lying in super-slow-motion and freeze-frame analysis, then that becomes an excellent screening device, and other costly signals (or social norms of "cross-my-heart") become unnecessary. Indeed, some of the experienced tax-drivers in *Streetwise* claim to rely on gut feelings that may have such basis (p. 217). Experienced criminals may likewise be able to detect micro-expressions in other criminals and in infiltrators from law enforcement agencies, but they do make errors as we see frequently in *Codes*.

Multiple Signals

One of the strongest lessons for game theory contained in *Codes* is the importance of multiple signals. A single signal is rarely definitive. Some signals are harder for an imposter to mimic and therefore more reliable. For example, having been in prison is a robust signal of criminality (*Codes* pp. 11–12, 20, 109–110), as is the screening device used by the mafia that a potential recruit must 'make his bones' by killing someone (*Codes* p. 24). But almost always, the recipient will look for multiple mutually consistent and reinforcing signals. Thus, Joseph Pistone was able to pass off as the mafia hanger-on Donnie Brasco because "it just was very hard for mobsters to think that, *taken together*, all the things he did and did not do were not near-perfect discriminating signals." (*Codes* p. 22, emphasis added.) His friend and mentor Benjamin "Lefty Guns" Ruggiero pointed out to him multiple subtle signs to look for in others: "how a person acts, carries himself, talks; what deference is paid to him" (*Codes* p. x). Similarly, the taxi drivers in *Streetwise* (p. 210) look for multiple signals: "the cost of mimicry increases with the amount of information the customer is required to reveal. Each property must be credible and consistent with the other properties. Drivers place their confidence more in a sequence of signals than in any one of them".

In sharp contrast, models of signaling games allow just one signal. The few exceptions include Milgrom and Roberts (1986) and Wilson (1985). The reason is easy to see from these

[3]But if an index is used to infer something about a person on the basis of an erroneous belief that has become self-sustained, or otherwise for reasons of social policy, such use may be prohibited. Laws against the use of race in hiring, or the use of gender in calculation of annuity payments, are instances of this.

papers – the conditions required for multiple signals to prevail simultaneously in the equilibria of these models are quite stringent. But the reality of multiple signals is so compelling that another effort to enrich the theory seems justified. Here I offer some suggestions for such an extension.

Suppose there are two types, A and B. The value to being accepted as type A (for example the profit from business that will result) is V_A, and that to being regarded as type B is V_B. Choose labels so that $V_A > V_B$; therefore type B would like to be mistaken for type A. Suppose signals $x_1, x_2, \ldots x_n$ are available. The costs of signaling for the respective types are $C_A(x_1, x_2, \ldots x_n)$ and $C_B(x_1, x_2, \ldots x_n)$. Mimicking is costly:

$$C_A(x_1, x_2, \ldots x_n) < C_B(x_1, x_2, \ldots x_n) \quad \text{for all } (x_1, x_2, \ldots x_n) > (0, 0, \ldots 0)\,,$$

and

$$C_B(0, 0, \ldots 0) = 0.$$

Then to reveal his type credibly and optimally,[4] A will choose $(x_1, x_2, \ldots x_n)$ to maximize

$$V_A - C_A(x_1, x_2, \ldots x_n)$$

subject to the constraint that type B should find it optimal not to mimic:

$$V_A - C_B(x_1, x_2, \ldots x_n) \leq V_B\,.$$

This is equivalent to minimizing A's cost of signaling

$$C_A(x_1, x_2, \ldots x_n)$$

subject to keeping B's cost of signaling prohibitively high:[5]

$$C_B(x_1, x_2, \ldots x_n) \geq V_A - V_B\,.$$

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[4]I am ignoring all details of selection among multiple equilibria of the signaling game; see Milgrom and Roberts (1986) for a discussion of these.

[5]A case emphasized by Milgrom and Roberts (1986) makes the point quite dramatically. Suppose there is a wasteful signal that is available at equal cost k to both types, and the cost functions are

$$C_A(x_1, x_2, \ldots x_n) + k, \qquad C_B(x_1, x_2, \ldots x_n) - k,$$

respectively. Then k can be eliminated using the constraint, and he problem becomes one of maximizing

$$V_B + C_B(x_1, x_2, \ldots x_n) - C_A(x_1, x_2, \ldots x_n)\,.$$

In this case the best set of discriminating signals maximizes the difference in signaling costs. It does not matter how costly it is for the true type A to send all these signals, so long as it would be maximally more costly for the mimic B!

The difficulty of having multiple signals coexist can be seen by considering linear signaling costs:

$$\begin{aligned} C_A(x_1, x_2, \ldots x_n) &= a_1\, x_1 + a_2\, x_2 + \ldots + a_n\, x_n\,, \\ C_B(x_1, x_2, \ldots x_n) &= b_1\, x_1 + b_2\, x_2 + \ldots + b_n\, x_n\,, \end{aligned}$$

where $a_i < b_i$ for all i (the Mirrlees-Spence single-crossing condition). Now A's optimization problem is one of linear programming, and the solution is extreme: only that signal i for which the ratio a_i/b_i is smallest is chosen. Note that it is not the absolute advantage (smallest a_i or biggest b_i) that matters, but the comparative advantage captured by the ratio. Even if a_i is high for the lowest-ratio signal, b_i is so high that a small x_i serves to separate types credibly. This makes good intuitive sense once we recognize the intuition, but it precludes coexistence of multiple signals.

I can think of two ways around this problem. One is that A's cost function C_A is more convex than B's. Then a combination of multiple signals each in small quantity becomes less costly to A but not equally less costly to B. That makes separation easier to achieve. This is basically what happens in the central case of interest in Milgrom and Roberts (1986). Using the examples in *Codes*, a combination of signals of previous imprisonment (*Codes* p. 20, 106) and self-harm (*Codes* Chapter 5) may be easier for a true criminal than a mimic, because the former's experience of imprisonment may have included episodes of self-harm, making it less costly to use it again. Therefore the two may be used together, and come to be regarded as mutually consistent and reinforcing. Observe that a condition on the relative *curvatures* of the two types' signaling cost functions goes beyond the single-crossing property, which is to do with the relative *slopes* of the two functions.

The other way for multiple signals to coexist is that the scale of each signal cannot be freely chosen, but has an upper limit. Then the best signal (the one with the lowest a_i/b_i) cannot be scaled up sufficiently to achieve separation on its own, and additional signals must be used. As the most simple instance of this, suppose each x_i must be either 0 or 1. That is probably close to reality; for example Donnie Brasco has list of things to do and not do (*Codes*, pp. 20–21). The resulting integer programming optimization with zero-one variables can be problematic because of discreteness, but ignoring this, the solution is to rank the signals by increasing order of the ratios, say

$$a_1/b_1 < a_2/b_2 < \ldots < a_n/b_n\,,$$

and then use the signals in this order (1 first, then 2, etc.) until the constraint is met. Sometimes just one signal may do the job (if $b_1 > V_A - V_B$), but typically more signals will be required.

The underlying characteristics that are being signaled (or screened for) can also be multidimensional; transactors may be interested in a potential partner's competence as well as his trustworthiness. Signaling and screening with multiple types is a hard problem in information economics, and only limited success has been achieved in special contexts such as nonlinear pricing (Wilson, 1993). This is another area of theory that requires further work, and Gambetta's examples may provide a useful starting point for thinking.

Unavoidable Ambiguity

Even with one of the above generalizations to allow coexistence of multiple signals, signaling theory retains an unrealistic precision. Credibility is either present or absent; signals are either fully revealing (in a separating equilibrium) or reveal nothing (in a pooling equilibrium). Semi-separating equilibria are often an exceptional case or are ignored altogether. But in reality people are aware that they can rarely be 100% sure. And recipients of signals will find it optimal for to accept the signaler on a basis less than total certainty. Even though the consequences to the mob of accepting a police or FBI infiltrator were very serious, Donnie Brasco needed to give only "*near*-perfect discriminating signals" (*Codes* p. 22, emphasis added). How can we extend signaling theory to cope with such ambiguity in signals and their interpretation?

Here I offer a mere beginning of a possible approach. This is highly incomplete in that it leaves too many loose ends and exogenous stipulations that should be endogenized, but I hope it proves a useful starting point. Suppose there are two types, A and B, and the prior probability of type A is α. There are many available signals x_i, for $i = 1$ to n, each of which can take just two values, 0 or 1. Type A is more likely to give signals 1 than type B is. Specifically,

$$\begin{aligned} \Pr\{\, x_i = 1 \mid A \,\} &= p_i \,, \\ \Pr\{\, x_i = 1 \mid B \,\} &= q_i < p_i \,. \end{aligned}$$

The reasons for this remain to be modeled, but it could be that each type has unobserved heterogeneity of the cost of giving signal 1 as opposed to giving signal 0, but the distribution of type B's cost exceeds that of type A's cost in the sense of first-order stochastic dominance.

Suppose it is observed that signals x_1, x_2, ... x_k are each equal to 1, while signals x_{k+1}, ... x_n are each equal to 0. Call this event E. Using Bayes' Theorem, the odds ratio of the posterior probabilities of the types is

$$\frac{\Pr\{ A \mid E \}}{\Pr\{ B \mid E \}} = \frac{\alpha}{1-\alpha} \left(\prod_{i=1}^{k} \frac{p_i}{q_i} \right) \left(\prod_{i=k+1}^{n} \frac{1-p_i}{1-q_i} \right) .$$

If for any of $i = 1$ to k we have $q_i \approx 0$, then the posterior probability $\Pr\{ A \mid E \} \approx 1$, so i is on its own definitive for type A. If for any of $j = k+1$ to n we have $p_i \approx 1$, then the posterior probability $\Pr\{ B \mid E \} \approx 1$, so j on its own is definitive for type B. More generally, any signal that is unlikely to arise when the type is B is a surer indicator that the type is A, and vice versa. We can understand some of the observations in *Codes* in this light. For example, Joseph Pistone says: "Cops always buy, never sell." (*Codes* p. 22) Thus, if selling is $x_1 = 1$, and type B is Cop, then $q_1 = 0$, so a mobster would believe that selling is a sure indicator that the person doing the selling is not a cop. Of course this belief can be exploited by a cop who is willing to sell, as indeed Donnie Brasco was.

This is merely a possible start for a model of signaling where signals remain ambiguous and less-than-perfect separation is the normal kind of equilibrium. Much remains to be done, especially the specification of the distributions of costs of signaling for the types.

Multiple Recipients

When sending a signal to a potential partner in a criminal business, the signaler cannot be sure who receives it – whether the intended recipient is friendly or hostile, whether he is an infiltrator from a law enforcement agency – or indeed, whether there are any unintended recipients – eavesdroppers from law enforcement, or members of the general public who may raise an alarm. Therefore the sender must allow for the possibility that his communication goes to multiple audiences, who may interpret it differently and respond differently. There is some theory of this in the literature on cheap-talk games, starting with Farrell and Gibbons (1989). But the context requires some extension of that theory.

Suppose there are two states of the world or events, 1 and 2. In the context of *Codes*, they may be 1: the sender is engaged in a criminal enterprise and 2: the sender is a law-abiding citizen. Denote the prior probabilities of these by p_1 and p_2. There are two possible signals, labeled 1 and 2. Let q_{ij} denote the conditional probability that the sender uses signal j when the state is i. Then Bayes' theorem yields

$$\Pr\{ \text{State} = 1 \,|\, \text{Signal} = 1 \} = \frac{p_1 \, q_{11}}{p_1 \, q_{11} + p_2 \, q_{21}} .$$

Suppose there are two recipients or audiences, called A and B, for the signal. The signaling occurs in public, in the sense that both recipients get the same signal. In this context A may be a potential partner in crime, and B may be an eavesdropping law-enforcement agent. The sender would like A to interpret signal 1 to indicate a high probability of the state being 1, but B to interpret the same signal as indicating a low probability of the state being 1. In other words, the sender would like a situation where, denoting beliefs of the two recipients about the various probabilities by the corresponding superscripts,

$p_1^A \; q_{11}^A$ is as high as possible (close to 1), but $p_1^B \; q_{11}^B$ is as low as possible (close to 0).

This is difficult to achieve.

First consider the conditional probabilities of the signal being sent. If everything about the game is common knowledge and the parties are fully rational, they can each solve the game and find the equilibrium. This includes calculating the sender's equilibrium strategy, that is, the probabilities with which he uses in the two signals in the two states. Therefore A and B should have the same q_{ij}. If the q_{ij}'s are to differ, therefore, common knowledge of the game or rationality should fail in some appropriate way, or the signal (at least some part of it) should not be publicly equally observable by both recipients.

Next consider the prior probabilities p_i. It was long an article of faith in game theory that all players have the same priors. Actually it was only a simplifying assumption to "enable one to zero in on purely informational issues" (Aumann, 1976). In recent years game theorists have liberated themselves from this straightjacket, following the lead of Morris (1995) and others. In the present context, the two recipients may have different priors in this game as the result of some previous communication or interaction.

By making a signal is sufficiently complex or multidimensional, and revealing the details to the intended recipients in a piecemeal way, the sender can hope that eavesdroppers will miss at least some part of the signal, or misinterpret what they do observe. Some of the private understandings and conventions described in Part II of *Codes* seem to serve such purposes. So do many of the devices in situations of espionage and counterespionage, for example the "Moscow rules" of meetings in John Le Carré's George Smiley novels. A related tactic is to conceal the truth in a bodyguard of lies or irrelevancies. In baseball, coaches signal to batters whether to take a pitch or hit, and runners whether to try to steal bases, and catchers signal to pitchers to call for particular pitches, using many quickly flashed signs, only one of which is for real, and the recipients have been informed beforehand which number in the sequence that is.

Congratulations and Thanks

In *Codes,* as in his other books, Diego Gambetta has given us a cornucopia of facts, ideas, applications of theory, and material for new theory. Congratulations and thanks, Diego, and get to work on your next book!

References

Aumann, Robert J. 1976. "Agreeing to Disagree." *Annals of Statistics* 4(6), 1236–1239.

Cave Brown, Anthony. 2007. *Bodyguard of Lies: The Extraordinary True Story Behind D-Day.* Guilford, UK: Lyons Press.

Chwe, Michael. 2001. *Rational Ritual: Culture, Coordination, and Common Knowledge.* Princeton, NJ: Princeton University Press.

Ekman, Paul. 2001. *Telling Lies: Clues to Deceit in the Marketplace, Politics, and Marriage.* New York: W. W. Norton.

Farrell, Joseph, and Robert Gibbons. 1989. "Cheap Talk with Two Audiences." *American Economic Review* 79(5), December, 1214–1223.

Gambetta, Diego. 1993. *The Sicilian Mafia: The Business of Private Protection.* Cambridge, MA: Harvard University Press.

Gambetta, Diego. 2009. *Codes of the Underworld.* Princeton, NJ: Princeton University Press.

Gambetta, Diego, and Heather Hamill. 2005. *Streetwise: How Taxi Drivers Establish Their Customers' Trustworthiness.* New York: Russell Sage Foundation.

Goffman, Erving. 1959. *The Presentation of Self In Everyday Life.* New York: Doubleday.

Greif, Avner. 2006. *Institutions and the Path to the Modern Economy: Lessons from Medieval Trade.* Cambridge, UK and New York: Cambridge University Press.

Holmes, W. Jasper. 1998. *Double-Edged Secrets: U.S. Naval Intelligence Operations in the Pacific During World War II.* Annapolis, MD: Naval Institute Press, Bluejacket Books.

Milgrom, Paul, and John Roberts. 1986. "Price and Advertising Signals of Product Quality." *Journal of Political Economy* 94(4), August, 796–821.

Montagu, Ewen. 1997. *The Man Who Never Was.* London: Globe Pequot Press.

Morris, Stephen J. 1995. "The Common Prior Assumption in Economic Theory." *Economics and Philosophy* 11(2), October, 227–253.

Puzo, Mario. 1969. *The Godfather.* New York: Putnam.

Repetto, Thomas. 2004. *American Mafia: A History of Its Rise to Power.* New York: Henry Holt.

Shleifer, Andrei, and Robert W. Vishny. 1998. *The Grabbing Hand: Government Pathologies and Their Cures.* Cambridge, MA: Harvard University Press.

Spence, A. Michael. 1974. *Market Signaling: Information Transfer in Hiring and Related Screening Processes.* Cambridge, MA: Harvard University Press.

Stille, Alexnder. 1995. *Excellent Cadavers.* New York: Random House.

Wilson, Robert. 1985. "Multi-dimensional Signalling." *Economics Letters* 19(1), 17-21.

Wilson, Robert. 1993. *Nonlinear Pricing.* New York, NY and Oxford, UK: Oxford University Press.