

1. Notes on signaling theory

Many of the things we want to know about each other are not directly perceivable. These qualities include emotional states (are you happy?), innate abilities (are you smart?), and the likelihood of acting a particular way in the future (will you be a loyal friend?). Instead, we must rely upon signals, which are perceivable indicators of these not directly observable qualities.

Qualities can be almost anything: strength, honesty, genetic robustness, poisonousness, suitability for bookkeeping employment, etc. We rely on signals when direct evaluation of the quality is too difficult or dangerous. A bird wants to know if the butterfly it is about to eat is poisonous before it takes a bite, and relies on the signal of wing markings to decide whether to eat or move on. An employer wants to determine before making a hiring decision whether a candidate will be successful or not, and relies on signals such as a resume, references, and the candidate's actions and appearance to predict suitability for the job. A smile can be a signal of happiness, a wedding ring a signal of being married, wrinkled hands a signal of age, and a big house a signal of wealth. Our language is full of signals, both the words we say and the way we say them. Saying "yes, I would like an extra-big helping of your special Tuna-Delight" can be a signal of hunger or of politeness and the accent with which it is said can signal country of origin and social class. Indeed, much of our communication, whether it is with words, gestures, or displays of possessions, consists of signaling cues about who we are and what we are thinking.

Signals have varying degrees of reliability. Some are quite highly correlated with the quality they represent: upon seeing such a signal, one can be sure that the quality is present. Seeing someone lift a 200 lb weight is a reliable signal of strength; no matter how much a weaker person wishes to signal strength, without actually possessing that quality he or she will not be able to lift that weight. Others signals are less reliable and can be imitated by those who wish to give the impression of having the quality, without actually possessing it. Most people wearing wedding rings are indeed married, but an unmarried woman may choose to wear one to signal that she is married to forestall unwanted attention.

Signaling theory is concerned with understanding why certain signals are reliable and others are not. It looks at how the signal is related to the quality it represents and what are the elements of the signal or the surrounding community that keep it reliable. It looks at what happens when signals are not entirely reliable – how much unreliability can be tolerated before the signal simply becomes meaningless?

Signaling occurs in competitive environments. The interests of the sender and the receiver seldom align exactly, and often they are quite at odds with each other. Sometimes the competition is fierce and overt, as with prey and predators. Potential prey may signal to predators that they are poisonous or that they can run so fast or fight back so strongly that pursuing them is futile. Potential competitors may signal their strength to each other; if they are unevenly matched, the weaker may acquiesce and actual battle, which is costly for all, can be avoided. Sometimes the competition is subtle, as when the signaling is between seemingly congenial companions. But even within cooperative relationships there are conflicts of interest about how plans and identity are perceived. I wish to present myself in the best possible light while you want to know what I am really thinking and what I really can and will do.

In competitive situations, being deceptive can be quite beneficial. If a bug presents itself as poisonous when it is not, it may avoid being eaten. If I present myself as more experienced than I really am, I may get a better job. Yet if the rate of deception becomes too high, the signal loses its meaning. So, for communication to occur, for signals to maintain their significance, something must limit the rate of deception. This is the core question of signaling theory: what keeps signals reliable?

The answer is costs: a signal will be reliable if it is beneficial to produce truthfully, yet prohibitively costly to produce falsely. There are two main sources of these costs: the signal itself may be costly to produce or the punishment if caught cheating may be high.

If a signal is costly to produce *in the domain of the quality being signaled*, it will tend to be reliable. In the animal world, the prototypical example is the immense antlers that signal the strength in an elk. Carrying such antlers is very costly in terms of strength; a weaker elk cannot afford to expend so much of its strength on this display, and thus must have smaller antlers. A common example in the human domain is owning an exotic sports car as a signal of wealth. Buying and maintaining such a car is very costly in terms of money a poorer person could not afford to spend so much on this display and thus must make do with a more basic form of transportation. Such signals are relatively less costly for the honest signaler who has the quality than they are for the dishonest mimic.

Other signals are reliable because the punishment costs if one is caught being deceptive are so high that it is seldom worth risking them. Signaling that you are a police officer with a siren in your car may be an effective way of getting quickly through a traffic jam, but most people believe the potential punishment is too high to make the convenience worthwhile. Here, the community provides punishment costs - in this case in the form of fines or jail time - which discourage this deceptive signaling.

How does the receiver of a signal know that it indicates a certain quality? This question has received little attention in previous work on signaling theory, much of which has come from theoretical biology. Most of the models of signaling behavior assume perfect communication, where what the signaler meant by the signal is the same as what the receiver interprets; the key question being the truthfulness of the signaler's claim. Yet in human communication (and presumably, at times, in animal communication) imperfections abound. **Codes** are the mappings from signals to qualities. To the extent two people share codes, the signals they exchange will be comprehensible to each other. And to the extent that they do not, a signal will be interpreted differently than it was intended to be.

1.1. *what are signals?*

What, exactly, is a signal? It is useful to define what exactly we mean by signals, especially because different authors have used the term in different ways and there has been considerable ambiguity and disagreement about terms. (see Guilford and Dawkins 1995; Maynard Smith and Harper 2003 for further discussion). (Hauser 1996)

The definition I will be using is that **a signal** is a perceivable action or structure that is intended to or has evolved to indicate an otherwise not perceivable quality about the signaler or the signaler's environment. I.e., the purpose of a signal is to indicate a certain quality.

Not everything that we use to infer hidden information is a signal. **Cues** are "any feature of the world, animate or inanimate, that can be used ... as a guide to future action" (Maynard Smith and Harper 2003). Cues need not be intentional and the information gleaned from a cue may not be beneficial to person or animal producing the cue. The smell of CO₂ that guides a mosquito to you is a cue to the insect – you did not choose to provide it with this information and indeed would preferred not to have done so. This is an unintentional cue; it is not beneficial to the producer of the cue. Signals are thus a subset of cues; all signals are cues - they can be used as a guide to future action - but not all cues are signals.

A feature may act simultaneously as a signal and as an unintentional cue. An signal displayed for one receiver may be picked up as an unintentional cue by another. One may dress in furs as a signal of success and wealth – but a robber may interpret this same clothing as a cue that waylaying the fur-wearer will net a hefty haul of fine jewelry. Or, the intended receiver may interpret a signal in unintended ways. The fur-wearer may intend to the signal wealth, taste and success to a person she hopes to impress, but this person may instead interpret the furs as a cue meaning that she is cruel to animals.

The requirement that signals must be intentional (whether conscious intent or evolved purpose) means that, for the most part, producing the signal must be beneficial to the signaler. If it is not, the signaler will cease to produce it. The time frame of this choice can vary greatly. If a person tells a joke to signal that he is wittily cool, but is met with only embarrassed stares, he can choose immediately to never tell it again. If an

insect's bright warning coloration becomes more of a lure than a warning when too many mimics appear in the area, it may take generations for this signal to evolve into a new form.

Receivers, too, must for the most part benefit from acting on a signal or they will ignore it. Heeding an honest signal is generally beneficial to the receiver, for decisions made with greater information are generally better than those made with less. But heeding a deceptive signal is usually harmful, for here decisions are made based on false information. Thus, if a signal is not reliable – if it is given sometimes by honest signalers, but sometimes by deceptive ones – receivers will not always benefit from heeding it and may indeed sometimes pay a high price for doing so. If the percentage of deceptive signals becomes sufficiently high, the receivers will eventually cease to heed it. Once this happens, the signal will no longer benefit the signalers, and eventually they will either stop producing the signal or will modify it to be more reliable. This is how deceptive signals undermine a signaling system.

Signals can be honest or deceptive, reliable or unreliable. An *honest* signal is one that is intended to indicate a particular quality and the signaler does indeed possess the quality; a *deceptive* signal is the opposite – it is intended to indicate a quality that the signaler does not actually possess. A signal is a *reliable* indicator of a quality if the presence of the signal always or almost always means that the quality is there: a reliable signal is an honest signal. An *unreliable* signal can either be honest or not.

1.2. The economics of signaling: keeping deception in check

A signal will be reliable if it is beneficial to produce truthfully, yet prohibitively costly to produce falsely. Understanding the types of signals and systems that satisfy this condition is the basis of signaling theory.

Some signals are inherently reliable. Here, the cost of simply producing the signal is prohibitive to one who does not have the quality that the signal is advertising. These are called *assessment signals* because the form of the signal itself allows the receiver to assess its reliability.

There are also many signals, especially in human communication, that are not inherently reliable. These are called *conventional signals* because it is convention, rather than any essential characteristic of the signal, that connects its form to its meaning. The reliability of these signals is externally maintained through the actions of the community: producing the signal is not itself costly, but a costly penalty is incurred if one is caught signaling deceptively.

1.2.1. Assessment signals

We hold efficiency in high esteem. Waste is bad. In the domain of new technologies, we extol a new device as time-saving, energy-saving; the ideal, it seems, is to be direct and streamlined.

Yet seemingly wasteful displays are everywhere, from the exuberant colors of a peacock's tail to the shiny chrome and deep hum of an expensive sports car. Are these simply weird anomalies, needless and heedless expenditures of energy or money? Or do these exhibitions of excess serve a useful purpose?

This is the question that Thorstein Veblen was addressing over a hundred years ago when he wrote *The Theory of the Leisure Class* (Veblen 1899). Veblen observed that to gain the esteem of one's fellow man, it is not sufficient simply to have wealth or power; it is necessary to display them. And he noted that such displays must be of actions or goods that went well beyond the practical, for if there was a utilitarian reason for having or doing something, that could explain its existence. The seemingly irrationally excessive acts and expenditures he observed functioned, he proposed, as displays of status, wealth and power. The key idea in his theory was that their "wastefulness" was an integral part of the display. In order for the display of goods or leisure to reliably indicate wealth or status, it must be wasteful – there must be some cost associated with it that is beyond what one would spend for reasons of utility. "Throughout the entire evolution of conspicuous expenditure, whether of goods or of services or human life, runs the obvious implication that in order to effectually mend the consumer's good fame it must be an expenditure of superfluities. In order to be reputable it must be wasteful." This idea, that excess cost ensures reliability, is at the heart of contemporary signaling theory. Although he did not use the terms "signal" or "quality" and

his analysis is more anecdotal than that of today's evolutionary biologists, his ideas echo in much contemporary work.

A century later, biologist Amotz Zahavi was looking at similar questions, only from the viewpoint of a biologist. He noted phenomena such the peacock's extravagantly large and colorful tail – a display that requires a great deal of energy to keep up, and that makes the bird vulnerable to predators – and the gazelle's strange reaction to seeing a lion, where it jumps up and down (stotting) rather than running off as fast as it can. Why would these displays evolve? They put their displayer at risk for predation, they wasted hard-earned energy and strength. Common sense would seem to indicate that evolution should favor the efficient. Zahavi argued that these apparently wasteful displays were signals whose cost ensured the reliability of the signal. He proposed the "Handicap principle" which stated that for signals to be reliable, they must be costly (Zahavi 1975) (Zahavi and Zahavi 1997). He argued that animals with conflicting goals would evolve costly signals of their strength and status, even though - indeed, because - they lower the animal's chance of survival. By displaying its ability to thrive even with such a handicap, the animal reliably signals its high quality. Such signals would be useful to competitors – an honest signal of fighting ability would reduce the number of actual battles, which are destructive to all participants. And they would be useful to potential mates, who wish to have best genetic advantages for their offspring.

His work at first met with considerable resistance. This was, in part, because his paper was somewhat vague about why costly signals would be more reliable. But it was also counterintuitive. Many biologists felt that evolution would favor only the development of less costly signals, especially as the costs would be passed on to future generations. (Mesterton-Gibbons and Adams 1998). Yet this theory, more clearly stated and formalized, has come to be generally accepted. In 1990 Alan Grafen published a pair of papers (Grafen 1990, 1990a) that showed that costly signaling could be framed as a communication game and that within the formal models of game theoretical analysis such signaling was an evolutionarily stable communication strategy. Subsequent work has extended our understanding of this theory to incorporate receiver costs (Guilford and Dawkins 1993) and to distinguish among a variety of assessment signal types, including costly signals, indices, attenuators and amplifiers (Hasson 1997; Maynard Smith and Harper 2003). Today, it is widely accepted that extra costs in signals are not wasteful, but instead function to guarantee the reliability of the signal.

The costs that make a signal reliable must be in the domain of the quality that is being signaled. In the animal kingdom, these costs are often in the form of energy or exposure to danger. The antlers on a strong bull moose can weigh up to 60 lbs.; they are a reliable signal of strength because a weaker animal would be unable to carry this weight. Another example is the peculiar behavior of gazelles when they spot a predator. Instead of running off immediately, strong gazelles will jump up and down in place, displaying a behavior called stotting that is wasteful of time and energy. This has been interpreted as a costly signal of fitness, for only a truly fast and fit gazelle could afford this wastefulness before running off. Predators know this, and generally do not go after these bouncing creatures, choosing instead a weaker and easier prey. This display benefits both the predator and the strong gazelle, saving both a long and exhausting pursuit.

In the human world, costly signals take many forms, with money and time being among the most common.

Signaling wealth through the display of expensive possessions is an obvious one: driving an extravagantly expensive car and wearing a lot of jewelry is a costly signal of wealth – it says that the owner of these goods has so much money he can waste¹ a lot of it on these non-essential goods. A poorer person who tried

¹ Although Veblen's reputation is of a scathing social critic, it is important to note that he was quite careful in stating that he did not mean to use the term "wasteful" in its common perjorative sense, but instead as a contrast to "practical" or "useable" and that many goods and activities had both a useful and a wasteful function, but that only the costs associated with the latter served to establish one's "reputability" or status. We follow his usage here.

to emulate this display would face the prohibitive cost of either simply not having the money, or being unable to afford basic necessities.

Signaling status through the display of time-wasting pastimes is an interesting example that was raised by Veblen. He noted that displaying leisure is an important signal of status, of membership in the class of those who need not toil endlessly at some income-producing enterprise. Yet an abundance of leisure cannot be directly observed, for not very many people will watch you do nothing, day after day, year after year. Veblen proposed that the time-consuming acquisition of impractical accomplishments was a way of displaying leisure, and he listed among such accomplishments the ability to speak a dead language, knowledge of proper spelling, the occult sciences, and fashion and the breeding of fancy dogs (Veblen 1899). Someone with less financial resources would need to use much of their time in gainful employment; only someone with the leisure that comes with wealth would be able to display such accomplishments.

Not all assessment signals (signals that are inherently reliable) are costly for the honest signaler. Indices are signals whose form is directly correlated to having a particular quality². Although they are not costly to produce if one has the quality, they are impossible to produce without it. Maynard-Smith and Harper use the example of a tiger signaling its size by scratching on tree. A big tiger will scratch high up, while it is effectively impossible for a smaller tiger to reach up and scratch so high. Thus, high scratches are a reliable signal that one is in the territory of a very big tiger.

Somewhat facetiously, Maynard-Smith and Harper noted that this index would cease to be reliable if little tigers figured out how to stand on boxes. While such end-runs³ are uncommon in the animal world, they are ubiquitous in the world of humans. People are ingenious, and for most signals, there will be ways that someone, somehow, will find a way to fake a seemingly unfakeable signal. Unlike tigers, we can always find a way to stand on a box to seem taller, to bleach our hair to be blonder, to borrow an impressive car.

Although it is more costly for the deceptive signaler to make this end-run than for the honest signaler to display the cost-free index, the key equation is the balance between the deceptive signaler's perceived benefit and the cost of producing the signal. If the signaler believes that the benefit will outweigh the cost, he or she will be motivated to display the signal.

Similar end-runs can erode the reliability of costly signals, too. A winter tan is a costly signal of wealth and leisure: it is a signal that one has bountiful time and money, enough to vacation somewhere warm, sunny and far away. For a while, it was a fairly reliable signal. Then tanning parlors came along, and people with far less time and money could sport a winter tan⁴. Humans are inventors, and inventing cheaper and easier ways to signal a desirable quality – often in the absence of that quality – is a driving force behind much creative design.

² The distinction between indices and costly signals is often ambiguous, so I will use the term “assessment signal” to refer to all signals where ability to honestly signal a quality is related in some way to actually possessing the quality and where there is some cost to deceptively producing the signal. I will use the terms “index” and “costly signal” on the occasions where it is necessary to distinguish between signals that were free to honestly produce because they are causally related to the quality (indices) and signals that are costly to produce in the domain of the quality and relatively costlier for the deceptive signaler (costly signals).

³ end-run is defined in the American Heritage dictionary as “A maneuver in which impediments are bypassed, often by deceit or trickery”. Although it is considered a colloquialism, it is the best phrase I can find for this phenomenon.

⁴ tanning is an excellent and complex example of signaling and will be examined in depth either here or in the chapter on status and fashion.

1.3. *Conventional signals*

Not all signals are costly or inherently tied to the quality they are indicating. Many signals are arbitrary, indicating a particular quality through convention rather than because of any causal or cost relationship.

In the animal kingdom, certain sparrows signal their place in the hierarchy with badges of status – black markings on their chests. These non-costly signals, often termed *conventional signals*, are very common in the realm of human communication. I may, for instance, choose to indicate that I am a serious bike rider by wearing a full outfit of cycling gear; but buying these clothes, while financially a bit pricey, does not require paying any costs in the domain being signaled, in this case of cycling prowess. Such conventional signals are not inherently reliable – and indeed there are novice cyclists and non-athletes who sport a full Tour de France outfit. Yet the signals must be sufficiently reliable that they remain meaningful: if sparrows with status badges were no more likely to be of high status than those without, or cycling gear only occasionally correlated with biking ability, the signals would not convey information about the underlying quality. Since they have no inherent cost to keep them honest, if giving such a signal is advantageous for those without the underlying quality, what prevents there from being so many deceptive signalers that the signal becomes meaningless?

By themselves, conventional signals are open to deception. If no external force keep this in check, they can quickly become meaningless. However, conventional signals can be quite reliable - if there is a penalty imposed on deceptive signalers who are detected.

The reliability of conventional signals is externally determined, by the punitive actions of the receiver or others who are harmed by the deceptive signal. These include honest signalers who are defending the reliability and validity of their signal, other potential receivers of the signal, and the receiver's network of ties, who may feel personally affected by harm done to the receiver.

If the signaler is not identifiable, any punishment must be made immediately. Otherwise, the receiver's memory, community and communicative ability determine the temporal and social extent of the penalty. We can demarcate the types of penalties by these features:

- Immediate penalty: the deception is recognized immediately. Here, the receiver must simply be capable of punishing the deceptive signaler
- Subsequent penalty: the deception is discovered later. Here, the receiver must be able to recognize and be capable of punishing the deceptive signaler
- Communal penalty (reputation): the deception is penalized by others. Here the receiver must be able to communicate with others to indicate that the signal is not to be trusted. It must be possible to communicate the identity of the signaler, and the community must be motivated and capable of imposing a punishment.

Given their unreliability, why have conventional signals?

Handicaps are costly. They are costly for the signaler, who is paying a high cost to indicate honesty. They can also be costly for the receiver, who may need to spend quite a lot of time assessing the signal. Sometimes, it is beneficial for the receiver to avoid these costs and rely instead on less costly, but less reliable, conventional signals (Guilford and Dawkins 1993)

Conventional signals are very common in human communication (Farrell and Rabin 1996). Wearing a cross to signify Catholicism, using the word "cow" to signify a domesticated, female bovine, turning on a siren to indicate you are an official emergency service person in a hurry – all these are conventional signals. This does not mean they are cost-free; it means that the costs that keep these signals reliable exist within the community rather than in the signal itself.

Let's look at the example of candidates for a job. Here, the candidates' hidden quality is how well they will do this job. While future performance is not directly perceivable, a potential employer can look for a variety of signals to indicate ability, some of which are more reliable than others. When the job has many responsibilities and where it will be very costly for the employer should the chosen employee turn out to be unqualified, it is likely that the application process will itself be costly – for both applicant and employer. For instance, in academia, a typical application process includes giving a talk about your work, being interviewed by multiple members of the department, and providing detailed reference letters from other academics who know your work. For the applicants, these are very costly signals to produce. It took a great deal of effort to acquire the expertise they are displaying in their talk and in their conversations about their work. These signals are reliable, for they would be quite difficult to produce well without the requisite knowledge in your field, the ability to lecture well and the history of getting on well with your colleagues. Thus, they do provide a good sense of the candidate's ability. While certainly not every hire works out perfectly (and many that do not may well have been cases where the initial signals did indicate the likelihood of some problem – the production of a reliable signal does not guarantee its accurate interpretation or good use of that information) outright dishonesty is quite rare, for the ability to discourse fluently on crystalline polymer fabrication or critical signification in 16th century odes is hard to fake⁵. As a process, it is quite reliable.

Yet, it is also very costly, not only for the signaler, but also for the receiver, who must invest considerable time and energy listening to the talk, interviewing the candidate, reading letters, following up on references. When choosing the right applicant is crucial, these evaluation costs (which Guilford and Dawkins called receiver costs) are worthwhile. But when it is less important, it may be a better investment for the employer to use signals that are less expensive to evaluate. If the job has fewer responsibilities – the cost of making a poor hiring decision is lower – then it will not be worth spending so much time and energy evaluating the applicants. At a fast food restaurant, where turn-over is high and job skills needed are low, potential applicants may be asked only to fill out a standard form, listing their education and previous experience. The manager is likely to look quickly at the application form, checking that some previous experience is indicated, but making no effort to ascertain the veracity of the claim. Here, the list of references is effectively a conventional signal: the act of writing down some random names and numbers is not much more difficult than filling in honest answers. And, indeed, there is widespread deception in employment applications, especially for such high-turnover jobs. However, the application is not meaningless: there are still sufficient costs to dishonesty to keep them reliable enough⁶. [if people believe that there will be consequences to lying, they will be more honest; there are general societal constraints about lying that keep many people generally honest; the manager can adjust the amount of time and money she spends evaluating applications if cheating becomes too widespread or if the job gains responsibilities].

Online, nearly all signals are conventional signals. In face to face situations, I can simply see that you are tall; online, I must rely on signals – a photograph or your self-description - in order to ascertain your height

⁵ Somewhere, perhaps in language, or here, or in section on deception, need to mention the case of alan sokol and social text.

⁶ There are two costs here that for the sake of simplicity I am omitting, but which will be discussed later [cross ref]. There is what we can call the invention cost of deception: telling the truth is generally cognitively easier than creating a falsehood. This is particularly noticeable in face to face interaction, where the extra effort of inventing a story can be seen in the timing of a person's replies, their eye movements, etc.(Ekman 1997). There is also the cultural (moral? guilt?) cost of deception: people are taught not to lie, that it is wrong, that it will lead to bad results. There are thus, for many people, strong internal costs to lying and in most or all circumstances, these costs are high enough that they will not engage in outright deception. This can be quite context dependent and subjective – what seems like a lie to one person may seem like a legitimate exaggeration to another, and for many people, there are circumstances where they can find lying morally justified (e.g. if their family was desperate for food and shelter, they might feel that the cost of not getting work overcame their compunction against lying in order to get a job)..

- [TO BE CONTINUED]

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