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A QUANTITATIVE MODEL OF STÖRUNG.

Abstract

In this chapter, I will introduce a method for quantifying human communication. I will try to show that Shannon's model of communication is not appropriate for modeling human communication. Instead, I will use a combination of Wiener's notion of information as the reduction of entropy and Fodors cognitivistic model of mind in order to define a quantitative framework for modeling communication between humans.

Introduction

Shannon's[1] (1948) highly influential model of communication has often been taken as a fundament for modeling human communication. Shannon himself has warned against this particular use of his model, but given the intuitive plausibility of his famous diagram, and the title of his paper – »*a mathematical model of communication*« – it is not surprising that communication scientists initially tried to apply or extend his theory to model human communication. Especially the deceptively intuitive diagram from his paper (see Figure 1 below) has contributed to the adoption of his model for psychological modeling.

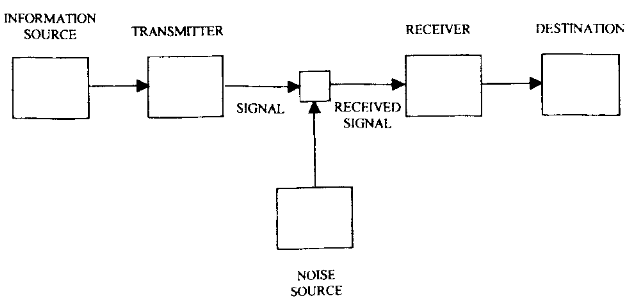

Figure 1. Shannon's famous 1948 diagramm

1 Shannon: »Mathematical Theory«.

As, among others, Frey, Kempter & Frenz[2] pointed out, Shannon's model has had a great impact on the development of the field of psycholinguistics, in which linguists and psychologists cooperate to understand linguistic communication. Research on human perception[3] was inspired by the metaphor Shannon provided. More recently, Luce & co-workers study speech perception by measuring how well human listeners can discriminate phonemes from one another, given a certain amount of noise degrading the acoustic signal[4]. For studying the human capacity to transmit phonemes to one another, Shannon's model and its corresponding theorems about entropy (uncertainty), conditional probability, and counteracting the effects of noise is entirely appropriate.

Later authors, e.g. Sperber and Wilson[5], tried to move away from the pure signal processing approach and paid more attention to the constraints and challenges of *human* communication, as opposed to (optimal) machine communication. The approach by Sperber & Wilson, however, is restricted to the domain of linguistic communication. Nonverbal communication, such as facial activity, posture, head movements etc. and also paraverbal behavior such as intonation cannot be described in their framework. Nevertheless, it is uncontroversial that these phenomena play a very important role in human communication.[6]

For a telecommunications engineer, it is possible to build pairs of encoders/decoders that are each other's perfect inverse. This is not the case in human communication. Applying Shannon's model to nonverbal communication is also difficult. With verbal communication, we at least know a lot about the signal. We know that there are phonemes, which make up morphemes, which make up words, which are ordered according to the rules of syntax. Knowing that much about the signal makes applying Shannon's model to linguistic communication more attractive than for modeling nonverbal communication. Although it is known that nonverbal communication constitutes a very important component of human communication, we don't know much about the structure of the signal. For example, Grammer et al.[7] discovered in an intriguing experiment that the difference between female soliciting and not-soliciting could not be reduced to specific behaviors. The only difference they found was the number of generated activity peaks. How these peaks were realized by these subjects was different from case to case. It was not the specific behavior that mattered, but the number of behavioral activity peaks, according to the authors. This example illustrates how little we know about human nonverbal behavior as a communicative signal and how difficult it is for scientists to decipher it.

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2 Frey/Kempter/Frenz: »Theoretische Grundlagen«.
3 See e.g. Broadbent: (1958) and Pollack et al.: »Intelligibility«.
4 Luce/Pisoni/Goldinger: »Similarity Neighborhoods«.
5 Sperber/Wilson: *Relevance*.
6 See e.g. Altorfer: *Methode zur Untersuchung*.
7 Grammar e.a.: »The communication paradox«.

Most authors agree that Shannon's model is too limited to be applied as a framework for general human communication. In the following, I will analyze why this is the case, thereby setting the stage for a modified theoretical model of communication that will not have these limitations. Also, I will develop a measure for *semantic information*, enabling to model communication and it's opposite, which I will call ›Störung‹ (Eng: disruption), quantitatively.

2. The limitations of Shannon's model.

2.1 The source of noise.

As is immediately apparent from Shannon's diagram, there is only one source of noise, and this noise operates on the transmitted signal. However, if we see Shannon's model as a model of human communication, this would imply that the only source of imperfect communication in humans would be the noise on the transmitted signal. To put it another way, it would imply that all communication difficulties between people can be reduced by improving the quality of mobile phone transmission or by improving the quality of hearing implants or glasses. This is clearly a limitation, caused by the simple fact that Shannon did not provide a model of the sender and the receiver. It is tempting to introduce sources of noise at the sender and receiver, but as I will argue below, this is both undesired and unnecessary.

2.2 The definition of information.

The definition of information in Shannon's paper has always been a great source of confusion in the literature[8]. Shannon's definition, in short, is that information is equal to *entropy*, which he defines as

$$-k\sum_{i=1}^{N} p_i \log(p_i)$$

where k is an arbitrary constant, i is an index ranging over the possible messages that could be sent, ρ_i and is the a priori probability that message i is the actual message sent. Entropy is a measure of *uncertainty* and to equate uncertainty with information is confusing, to put it mildly. Shannon was advised to stick to the word entropy instead, but he did not want to use it because entropy is a difficult concept[9]. The paradoxical use of the word information can be understood by realizing that Shannon's goal was to study *optimal* communication in machines *constructed by us*, as opposed to *actual* communication between two *arbitrary*

8 See e.g. Sveiby: *Towards a Knowledge Perspective*.
9 Ebd.

entities (such as human beings). In search for optimal signal transmission, it makes some sense to treat entropy as information. A high degree of entropy attributed to a source means a low degree of redundancy. A low degree of redundancy in turn means that the communication efficiency is high; therefore the signal with high entropy contains more information. Nevertheless, it remains a paradoxical notion. For instance, were we to assume that extraterrestrial beings send us signals from outer space, and do so with maximal efficiency, any pure noise picked up from space, which practically means »anything picked up from space«, could represent an extraterrestrial message encoded with maximal efficiency.

Another problem with the concept of information as defined by Shannon is that it cannot be transmitted. Information according to Shannon is a property of a source, not something that can be moved around. In our common sense notion of the word, we can *provide* information to others, resulting in more knowledge »at the other side«. For a general model of communication, it is desirable to have a theoretical notion of information that corresponds more to this common sense notion.

2.3 Wiener's approach.

Wiener's[10] notion of information does provide an opportunity to develop such a definition. Wiener uses the same notion of entropy as Shannon does (inspired by Boltzmann's work on statistical physics) but sees information as the reverse of entropy. Wiener writes »The quantity that we here define as amount of information is the negative of the quantity usually defined as entropy in similar situations«[11] More important, however, is Wiener's idea to compare *a priori* entropy with *a posteriori* entropy. Although Wiener was working with continuous probability distributions and not with discrete distributions, as Shannon was, this idea can be illustrated using a discrete example. Suppose we have a discrete random process such as flipping a coin (a Bernoulli process). The probability of obtaining Head, is equal to the probability of obtaining Tails, both are 0.5. According to Shannon's formula, the entropy of this process is 1. In Wiener's terms, the a-priori entropy is thus 1. After the coin has been tossed, and landed on one side, we can now compute the *a posteriori* entropy, which is 0 – there is no more uncertainty left. The process of seeing on what side the coin landed can therefore be seen as a *reduction* of the entropy from 1 to zero by the transmission of 1 bit. In Wiener's notion information is equal to the *reduction* of entropy.

Wiener's notion of information as something that reduces uncertainty appeals to common sense, and has inspired Gregory Bateson[12] to observe that »Information is a difference that makes a difference.«

10 Wiener: »Cybernetics«.

11 Wiener: »Cybernetics«, p 62.

12 Bateson: »Steps to an Ecology of Mind«.

2.4 What is semantic information?

As Buckley observed: »Soon after Shannon published his theory of information, it became widely recognized that it was actually a theory of signals, and he himself recognized that it did not deal with information in the semantic sense.« [13]

Shannon's definition of entropy assumes a known, finite set of possible messages. Wiener, in dealing with continuous probability distributions, also has complete knowledge of the relative probabilities of possible signals (what he calls *measurements*). Once one tries to apply the notion of information as entropy reduction to human communication, it becomes immediately apparent that we don't have complete knowledge about all possible messages. Given that we don't have a limited set of possible *meanings*, we cannot compute the changes in entropy (and therefore the information) inherent in a semantic signal. This has lead several authors to an attempt to define semantic information in ways that are related to, but not identical to Shannon's definition.

Bar-Hillel & Carnap's approach[14] was to define a logical system within which the amount of semantic information is equivalent to the number of propositions that can be excluded on the basis of the bits that are received. This, true to the spirit of the statistical physics definition of entropy, assumes a known, and finite *universe* of possible atomic propositions, from which a countably infinite set of propositions can be derived. If this set cannot be defined, the notion of semantic information becomes undefined. Another limitation of their approach is that propositions are either true or false; there is no room for uncertainty at the level of individual propositions.

In what follows, I will argue that we can have a complete model of human communication including a notion of semantic information, by integrating the concept of entropy with the cognitivistic theory of mind by Fodor[15].

3. Communication

There are quite a few definitions of communication around. What we need for a general model of communication is one that not only describes verbal communication, but also incorporates *nonverbal* communication within the same model. Thus, it is tempting to adopt the definition of Watzlawick & colleagues[16], also adopted by Graumann[17], that every form of behavior can be considered to be communication. Krämer[18] also concludes, after an extensive

13 Buckley: »Signals, Meaning, and control«, S. 601
14 Bar-Hillel/Carnap: »Semantic Information«.
15 Fodor: »The Language of Thought«.
16 Watzlawick/Beavin/Jackson: *Menschliche Kommunikation.*
17 Graumann: *Kommunikation und Interaktion.*
18 Krämer: *Bewegende Bewegung.*

review of the literature, that distinguishing between nonverbal interaction, nonverbal behavior, and nonverbal communication is rather arbitrary, and judging from the literature this distinction is in fact not being made in practice.

One possibility for distinguishing general behavior from communicative behavior is by stating that the *intentionality* of the behavior is deciding whether behavior is communicative or not. This is also problematic. As Graumann notes, we know from the work of Freud, but also from Goffmann[19] and Hall[20] how important unintentional messages can be in communication; they cannot be ignored by a theory of communication[21]. Intentionality is generally a rather murky issue. For example, the fact that I have a piece of spinach on my nose without knowing it does actually cause changes in a receiver (my dinner company) in the sense that they notice it and perhaps develop the desire to tell me about it. This communication can truly be called unintentional. On the other hand, if I have the conscious desire to ask about the time, and say »could you please tell me the time« to my interlocutor, I clearly have the intention to bring about a change in the mind of the receiver, namely a change that will bring my interlocutor to tell me the time. For these two extremes, it is not too difficult to establish the presence or absence of intentionality. An example of a »case in between« can be illustrated by the finding that the amplitude of women's lateral hip motions during walking increases once the woman is aware that she is being watched by men[22]. Women presumably do not (always) do this consciously, but it does seem to serve a biological function, namely appearing more attractive to potential partners. Invoking notions as *subconsciousness*, other agents roaming about our minds, with their own intentionality, will not help us out either, for we will never be able to tell the difference between subconscious behavior and non-conscious behavior.

What I propose is to define communication not from the sender-perspective, but from the receiver's[23]. If a scratch my head in despair now, and nobody sees it, my behavior is not communicative, because nobody picks up on it. As soon as my neighbor peeks through my window and sees me scratching my head, some form of communication can be assumed to take place, supposing the perception of my scratching will change something in the observer's mind. The definition of communication I propose is therefore:

Communication is any behavior of a sender that results in changes in the mind of a receiver.

If a sender displays behavior, and this results in changes in a receiver, communication has taken place. This corresponds well to what I believe is the general *function* of communicative behavior, namely, *causing changes in the mind of (a) receiver(s).* Note that I do not adopt the *systemic* assumption[24] that communi-

19 Goffmann: *Interaction Ritual.*
20 Hall: *The silent language.*
21 Krämer: *Bewegende Bewegung.*
22 Grammar: *Signale der Liebe.*
23 Cf. Altorfer: »Methode«.
24 Maturana/Varela: *Der Baum der Erkenntnis.*

cation necessarily involves feedback. Both one-way communication and communication with feedback loops can be captured under this definition. This is important, for it allows non-interactive communication media, such as television, to be modeled too.

4. Modeling the communicator's mind

As mentioned before, I propose to define communication as *behavior of a sender resulting in changes in the mind of the receiver*. But what is the mind of a receiver, or more specifically, how can we model the mind of the receiver formally?

4.1 Extending the Language Of Thought model.

I propose to adopt and adapt parts of Fodor's Language Of Thought (LOT) hypothesis for this purpose. In short, Fodor's[25] view is that our mind (or brain) contains representations of propositions, and has *attitudes* toward these propositions (predictably called *propositional attitudes*). These attitudes are *desire that P, believe that P, hope that P*, etc. The advantage of this approach is that inferences, voluntary or automatic chains of logical reasoning, can be modeled in a way similar to how cognition appears to operate in practice. For example, suppose I have represented the proposition P=[the ambient temperature is 12 degrees] in my mind, and have the attitude towards P that I *dislike* P. Also, there is another propositional *rule* that specifies that I will try to make propositions towards which I have the attitude *dislike* false. This will cause me to generate behavior aimed at making P untrue, i.e. towards raising the ambient temperature. One of the things I can do is to generate behavior such that the mind of a receiver near the window is changed in such a way that she will close it. In order to bring about this change, I could say (communicate) »close the window« (ignoring issues of politeness for the moment). This in turn will activate propositional attitudes in the receiver and could lead the receiver to close the window. Note that in order to communicate effectively (i.e. bring about the desired changes in the receiver) the sender needs a model of the receiver, in able to predict the effect of the communication attempt. Ideally, the sender has a *copy* available of the relevant propositions in the receiver. The better the match is between this *copy* and the actual list of relevant propositions in the receiver, the more effective communication can be performed by the sender.

The explanatory power of the theory of propositional attitudes is very high, and appeals to common sense. There is a long-standing debate about how and even whether these propositions are represented in the brain[26] but this discussion is not relevant to the present discussion. The only assumption I want to make here is that

25 Fodor: »The Language of Thought«.
26 See e.g. Smolensky, »Proper Treatment«, Fodor/Pylyshyn: »Connectionism«

the mind *functionally* contains representations of propositions, and attitudes towards them. How this functionality is implemented in the brain, and even the question what the ontological status of these hypothesized propositional attitudes is, is beyond the scope of this paper, and not essential for the model under consideration.

4.2 Semantic information.

Extending the LOT model with subjective probabilities enables the quantitative modeling of semantic information in communication. Suppose the mind represents not only propositions, but also, for every proposition P, the (subjective) probability that P is true. For propositions like »it rains« this probability will usually be 1 or close to 1. However, in many other situations, most notably *social* situations, we are usually faced with high degrees of uncertainty.

I will define a set of *relevant propositions* (RPs) in a receiver[27]. These relevant propositions are those propositions that are important to the receiver in the specific communicational context. That is, those propositions that the receiver has a strong attitude towards in a certain communicational context. In a flirt situation, this could be the proposition [he likes me], in solving a mathematical problem it could be [x is linear in y].

At this point it is important to point out that the proposed model by itself does not specify how we can find out about which propositions are relevant. Communication research adopting the proposed model would have as a first task to find out about the RPs that exist in a certain context or domain, for instance by using interview techniques and/or questionnaires to assess which propositions are relevant in a subject, and which subjective probabilities are assigned to them. In fact, this is already what happens in the use of questionnaires to assess the effect (German: *Wirkung*) on the receiver. In order to assess the socio-emotional effects of certain signals/cues (such as head movements or general physical activity) on a receiver, one often uses questionnaires where subjects fill in how much a number of (often bipolar) adjectives they believe apply to their interlocutor (see e.g. Bente et al., 2001). The interpretation of these results is necessarily on the level of propositions, i.e. language. As Fodor (1981) points out, we can hardly expect to be able to explain mental states (and having a certain attitude towards or opinion about our communication partner *is* a mental state) at the neurobiological level, without referring to a propositional level of representation. In that sense, defining sets of RPs is something we already do in social psychological research.

Once we have identified a set of RPs, this will enable us to define what happens with the entropy (uncertainty) in the receivers mind upon communication, and therefore how much information has been transmitted. To illustrate this with a

27 The notion of ›relevance‹ here is not the same as the one used in Sperber & Wilson's well-known book *Relevance* (1995).

simplified example: suppose person A wants to marry person B. Person A has a number of RPs about B in his mind.
1. [B wants to marry me] {0.7}[28]

It follows from this that there is also
2. [B does not want to marry me] {1 – 0.7 = 0.3}

We can now compute the entropy over these probabilities, which is 0.88. Suppose A now tries to reduce the uncertainty about B's desire by asking B »do you want to marry me?«. Let's assume there are three possible answers of B: »yes«, »no«, and »I have to think about it«.

a) yes
Resulting change in receiver:
1. [B wants to marry me] {1}
2. [B does not want to marry me] {0}

b) no
1. [B wants to marry me] {0.1} (A retains some hope)
2. [B does not want to marry me] {0.9}

c) think about it
1. [B wants to marry me] {0.5}
2. [B does not want to marry me] {0.5}

The respective entropies after receiving these answers are:
a) 0
b) 0.47
c) 1

As we can see, answers a and b both have reduced the entropy in A's mind, while answer c has *increased* it. It is important that a model of communication is able to model *disinformation* as well. It is this disinformation, or *Störung*, that I consider to be an appropriate model of semantic noise in human communication.

As Grammar et al.[29] have noted, human communicators often send mixed signals, for instance in order to get what they want, but to hide their true intentions at the same time. The notion of entropy applied to a set of RPs in the receiver's mind enables us to model both the increase and decrease of entropy in a receiver. This is especially important for modeling *nonverbal* behavior. Suppose

28 For purposes of clarity and brevity, a rather loose notation of propositions is used throughout this paper. In the calculus of desires and belief, the proposition [B wants to marry A] is much more formal, along the lines of »B has the propositional attitude »desire« towards the proposition [A and B are married].

29 Grammar e.a.: »The communication paradox«.

in the above example that the answer to the marriage proposal is a silent smile, loud laughter, or crying. That would create a high number of RPs with low probabilities and will significantly increase the entropy in A.

4.3 Calculating receiver entropy over sets of RPs.

Suppose a communicator entertains N Sets of Mutually Exclusive Relevant Propositions (*SMERPs*). *SMERPs* have at least a size of 2, for a simple proposition such as [it rains] always is accompanied by its negation, [it does not rain]. However, larger sets are of course possible, for instance
[he is younger than 16] {0.1}
[he is between 16 and 21] {0.8}
[he is older than 21] {0.1}[30]

Each RP i has associated with it a probability ρ_i. The receiver-entropy *RE* is defined to be:

$$RE = \sum_{j=1}^{N} entropy(SMERP_j)$$

Where, following Shannon and Wiener,

$$entropy(S) = -\sum_{i=1}^{|S|} p_i \log(p_i)$$

The semantic information *I* that is transmitted can be computed simply by following Wiener's approach:

$$I = \Delta RE$$

that is, the difference between the entropy before and after the communication took place. As mentioned before, this can be a negative value, indicating that there is more uncertainty after the communication took place then before.

30 It is also possible to calculate the entropy over continuous distributions. If my expectation of the outside temperature follows a normal distribution with mean m and standard deviation s, and I receive a weather report stating that the actual temperature is T, with a measurement error of E, Wiener shows a method to compare the entropy before and after my reception of the weather report. In cases where numeric quantities play an important role, such as in financial negotiations or the communication in the stock exchange, the framework can be easily extended to incorporate numerical quantities with continuous probability distributions in a way that is quantitatively still directly comparable to the discrete approach.

4.4 On the appropriateness of modeling using propositions

The use of propositions and their subjective probabilities in the model presumes that both are accessible to human subjects. Many nonverbal phenomena are suspected to occur at a subconscious level, so how is it possible to translate attitudes that are supposedly operating below the level of consciousness to straightforward propositions? My answer is: by trying anyway. This implies that we ask subjects in experiments to describe the propositions they feel are relevant, and what subjective probabilities they assign to them for themselves. This is not very different from asking subjects to rate on a scale from 1 to 7 how »warm« or »cold« they felt their interlocutor was, which constitutes standard practice in social psychological research.

4.5 The nature of noise.

The signals we receive are always deteriorated by noise. However, as mentioned above, there is also something we could call noise operating at the message level between sender and receiver. Communication is never perfect, in the sense that the change in the receiver is never exactly that change that the sender intended. From the model it follows that there are two principal ways in which communication »fails«: one can activate[31] propositions in the receiver that were not intended to be activated, and one can not activate propositions in the receiver that were intended to be activated. It is, however, impossible to tell »whose fault it is«. Communication errors are a property of the system, of the *difference* between the intended change of the sender and the actual effect on the receiver.

There is one way in which it appears that we *can* make the distinction between »errors« at the sender and at the receiver, and that is when communicators share a *protocol*, a set of rules that both communicators have to observe. Examples of these protocols are the famous Gricean maxims of effective communication[32], or from Brown & Levinson's[33] theory of politeness. Note that most protocols are culturally specific. There are cultures in which eye contact is forbidden in most social situations, which clearly differs from German culture, where avoiding all eye contact is considered to be highly impolite, or at least aberrant. However, this still does not help in deciding at which side the »error« is. There are two situations: either the two communicators share the same protocol, or they don't. If they don't, the communication failure can be attributed to the difference in protocol. If they do have the same protocol, and one of them violates the protocol, one might be tempted to say that the violator is the source of the miscommunication. However, if the violator *knows* the protocol, he must be violating it on purpose, which means that in that sense he is not making an »error« in his communication.

31 By ›activate‹ I mean changing the associated probability in the receiver.
32 Grice: »Logic and conversation«.
33 Brown/Lewinson: »Universals«.

4.6 The new model

If we were to draw a diagram analogous to Shannon's famous flow chart, it would look very simplistic. As with Shannon's model, it is not a diagram but the mathematics behind the diagram that defines the model. The relationship between the model of Shannon and the model proposed in this paper is that for any identified *physical* communication channel (e.g. speech) between an identified sender and receiver, Shannon's model is an appropriate description of the signal transmission that takes place, provided that we know what the sender intended to transmit.

5. Applications

Using this model to study communication studying the relation of the physical signal and the effect it has on a receiver. A number of communicational phenomena can be explained elegantly within the proposed framework. To give a few examples, suppose a message in the speech channel conflicts with another – simultaneous – message in the gesture channel. For example, one could say »go right« and point to the sky. This induces at least two extra and partly conflicting RPs in the receiver. In the framework, this means that two extra RPs will add to the current entropy value. In case the message in speech is »right« and the pointing is to the left, only one RP is added, for the speech and the gesture signals induce propositions that are each other's negation. This corresponds to the intuition that pointing upward while saying »right« is more confusing than pointing to the left and saying »right«.

Also, nonverbal signals that modulate socio-emotional communication can be understood in the light of the model. A good example is smiling to indicate irony, either in email or face-to-face conversation. The smiling activates the additional proposition [truth value of statement is intended to be opposite] {p} that modifies the uncertainty level caused by the ironic remark.

At this point it is important to point out that the entropy defined as above only tells us about differences in uncertainty, not about the emotional effects of messages. Some messages are more pleasant or unpleasant to receive than others, and this is reflected in the *attitudes* towards these propositions. Incorporating the attitudes towards the RPs into this model could even lead to a definition of so-called *pragmatic* information, indicating how valuable certain information is for the receiver. Although potentially interesting, this extension is beyond the scope of the present paper.

The model is not limited to human face-to-face communication. In the study of medial communication, the model could be applied to provide a formal definition of »communication medium«. A communication medium is then to be defined as *a (group of) physically defined communication channel(s) (in the sense of Shannon) that produce(s) changes in the semantic entropy in a receiver.* This definition does not only apply to person-to-person communication systems such as telephone or video conferencing systems, but also to media in the more traditional sense of the term, e.g. television or newspapers.

All these different media can be explored qualitatively and quantitatively within the same framework. Every medium has a number of p-channels, and the effect of these physical channels on the semantic information flow can be studied, by studying both the physical signals that are transmitted over these channels as well as the effect these signals have on the receiver's entropy RE. For example, in email or electronic chatting people often communicate with others while lacking reliable knowledge about certain relevant propositions (e.g. gender, age, physical appearance). The model can be used to explore how people reduce these uncertainties in different media. For example, one can systematically reduce the number of channels that is available to the communicators, and assess not only what their evaluation of their communication partner was, but also what they believe is the evaluation of themselves by their interlocutor. The model would predict that when fewer channels are available, more signals should be exchanged in the still available channels to reduce the uncertainty in the communicators[34], although this will probably vary with the specific characteristics of the channels that are available. When this compensation is not possible (for instance in electronic chatting, due to physical limitations such as typing speed) the average uncertainty is then predicted to be higher, relative to for instance face-to-face communication or telephone.

Another application of the model is in Artificial Intelligence, for instance in human machine interaction. A machine can be built that keeps track of a number of suspected RPs active in the human with which it communicates ([user is paying attention] {0.7}, [user understands X]« {0.4} etc.) and uses as a general strategy to decrease the estimated entropy in itself and the user.

The highly general formulation of the model also allows for its application in other communicational situations than human-to-human communication. Diplomatic communication, for instance, also involves the reduction of uncertainty about the beliefs and desires of (the representatives of) other nations, and at the same time the increase of uncertainty in (representatives of) hostile nations. The list of relevant propositions can in this case be found in official documents and reports of diplomats or by interviewing diplomats about them.

6. Summary

The central thesis of this paper is that communication can be modeled quantitatively using the notion of entropy. Communication reduces or increases uncertainty in a receiver. By combining Fodor's cognitivistic model of the human mind, and applying Wieners notion of entropy reduction to sets of mutually exclusive propositions, one arrives at a notion of information that a) corresponds largely to our

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34 Cf. Walther: »Interpersonal effects«.

common sense notion, and b) is quantifiable. The resulting theoretical framework is very general and can be applied to a wide range of communication phenomena, including nonverbal communication, medial communication, human-machine communication, and diplomatic communication.

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