# Introduction to the theory of cognitive communication

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## How language, information, energy, internet, brain, and the mind are related to one another

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Translated by Werner Lange (nee Schmidt), Ireland.
He graduated in Informatik, received his Dr.-Ing. degree in 1979 at TU Kaiserslautern, and then worked on simulation and design of analogue and digital mobile communication systems. He was deeply involved in the process leading up to the implementation and worldwide adoption of the GSM standard and has co-authored a number of essential patents in the field. He has chaired the System Review Group in Germany from industry experts feeding into the bulk of the European specifications 1987-88. From the early 1990s he has been advising on the implementation of mobile networks across Europe and into Asia. He has been (mainly) living in Ireland for well over 30 years. In hindsight it can be said that if the teams he was involved in had not formed how, where and when they did, the development of mobile communication would have taken a very different path.

*Remarks concerning the translation*

Part 3 covers the third chapter of Werner Rupprechts's extraordinary German book resulting from a lifetime of researching, teaching and condensing results into precise form, yet making knowledge accessible to anyone interested, as generations of students will attest. It is probably the best book on information theory, from its very origins through to its present frontiers where new ground awaits to be uncovered. After a recap about energy in its various embodiments, the mystery of entropy is being unravelled, the limits on speed and complexity in electronics are explored, and, last not least, Maxwell's demon is examined. As in Parts 1 and 2, here also included are the introduction on the background of the book, the "Epilogue and Acknowledgements", and the complete table of contents (greyed out what is not covered here), plus the untranslated list of references.

I hope this translation of W. Rupprecht's book will help to attract the audience that this fascinating work of a lifetime deserves. As the translator, my particular thanks go to D. Thum of DTS-law in Munich in securing the contractual framework for the translation. Thanks also to the makers of DeepL for their very helpful translation tool under non-trivial demands, and to bookmundo and partners for publication of the result.

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*by Werner Rupprecht*
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## Part 3 Energy, Entropy, and Information level

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# Background and conception of this book

The theory of cognitive communication covers a huge field. As indicated in the subtitle, it is about language, information, the Internet, the brain and other objects and especially about the relationships between these objects. The present treatise is comparable to a physics textbook, in which the different topics of mechanics, optics, electricity and still other topics and their relations to each other are dealt with.

The general process of communication is rather simple: A sending communication partner assigns a signal to a meaning that he or she would like or should communicate. A receiving communication partner perceives the signal. If the communication is error-free, the interpretation of the received signal provides the receiving communication partner with the meaning that the sending communication partner wished or ought to communicate. The problems and difficulties can be seen in the details:

What is a meaning? How is a meaning created? Is the sender of a signal concerned at all with communicating something? Does she or he always expect a reaction? Or is it sometimes just the receiver's own concern to discover a meaning in a signal sent by a sender for some reason or other that is not necessarily intended?

What happens if the signal with which a transmitter wants to communicate something arrives defective at the receiver? What must be present so that the receiver can correctly interpret the received signal as intended by the transmitter? Does the meaning of the message conveyed provide the receiver with information? What is information anyway? How does the recipient evaluate the meaning of the information? Are they satisfied with the information or is a reaction in the form of an answer deemed to be necessary? Does a dialogue arise in the form of a mutual exchange of signals? Does the dialogue converge to a common understanding? Is the dialogue escalating? These and many other questions need to be examined.

## *Where communication takes place and what kind of structures it may have*

Communication takes place almost everywhere: between people, with animals, with machines. Within organisms and more complex machines, various sub-areas also communicate with each other. Without communication, our biotic existence would not even exist, because the evolution of all life is also based on communication[0.1]. The cultural evolution of mankind, which resulted from passing on knowledge, would certainly not have taken place without communication.

[0.1] Genetic tools use molecular communication to alter the architecture of their own genome (Bauer, J. 2008 and Dingel, J. Milenkovic, O. 2008).

Communication between machines is relatively simple because it has been constructed by people. Machines, unlike humans, have no consciousness and therefore do not think about the meaning that humans assign to the signals exchanged by machines. Machine communication is usually based on binary logic and (usually) uses so-called "formal" languages. Machines that communicate are systems that are formally algorithmic and are "incomplete", as the mathematician K. Gödel proved. There are statements which humans recognize as "true", but the truth of which a machine cannot prove (and in the opposite case cannot disprove either). Nevertheless, machines do excellent work, as can be seen on translation computers and search engines on the Internet.

In contrast to the formal language of machines, the natural everyday language of humans is characterized by "uncertainty". This is probably related to the functioning of the neural network in the cerebral cortex, in which the firing neurons indicate "vague quantities" of stimulus patterns that are perceived by the human sensory organs. Remarkably, the rather vague everyday language, which contains numerous ambiguities of words and sentences and which often pays little attention to a supposedly important grammar, fully satisfies the usual needs of humans. An important help may be the special gift of the human being to put oneself into the world of thoughts of the other communicating person.

The evolutionary origin of communication between individuals might be found in symbiotic relationships of the first living organisms. Symbiosis is characterised by the fact that it is beneficial to all participating. In order for a symbiosis of different beings to come about, some form of communication must precede it. The merits of communication can also be seen in the behaviour of social insects[0.2]: the single honeybee has a tiny brain. Communication with other bees in the hive results in the colony behaving more intelligently than the individual bee. Social networks on the Internet (like Facebook, Blogs, Twitter and others) may eventually lead to comparably positive effects.

## *Ambivalence of communication and cognitive and emotional needs*

The more highly developed communication is, the more its ambivalence becomes apparent: it does not only deliver advantages, but sometimes also entails disadvantages. It is well known that an unthinkingly uttered improper word can lead to a long-lasting rift between people. Mass media (newspapers, television) not only inform people, but sometimes deceive and manipulate them. Limitless communication via the Internet prevents local malpractice from being concealed, but also creates the danger that intelligence services and other organisations might permanently monitor people's behaviour.

Generally speaking, communication serves to satisfy needs: On the one hand, direct face-to-face verbal communication between people serves an emotional need for human interaction, e.g. to share joy or grief or just to pass the time. On the other hand, communication also serves a cognitive need, which is about increasing knowledge. This

[0.2] see D. Fox (2012)

increase in knowledge results from information[0.3], i.e. from learning new facts[0.4]. The same applies to non-verbal communication using gestures and facial expressions.

The communication between higher animals also serves cognitive and emotional needs. The need for information, e.g. where to find food, shelter, help etc., is the driving force for communication. Communication between machines consists of the exchange of commands and status messages and is solely cognitive or informational in nature.

Emotional and cognitive needs cannot always be clearly separated from each other, because, for example, an unsuccessful attempt to make emotional contact also has a cognitive component. In all cases, information is therefore an essential element of communication.

Looking at public life and the behaviour of individuals, one can get the impression that the emotional aspect of communication has a more significant impact on current events and, in the short term (in connection with advertising, television viewing figures, etc.), a greater economic impact than the cognitive element of communication. Behaviour of individuals is often guided more by their frame of mind than by unemotional rational considerations.

In this study, however, the cognitive aspect of communication is at the centre of attention. The emotional aspect, which is mainly dealt with by psychologists (and not to a small extent by marketing experts), is touched upon only in passing. The cognitive component is of vital importance in the long term, especially because it determines the extent by which mankind increases its knowledge and thus ensures continued existence and further development of civilization.

## *Cognitive communication applies to all disciplines of science*

The theory of cognitive communication is a multi-disciplinary theory. It serves, uses and connects practically all sciences[0.5]:

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0.3 In this study, the term "information", the meaning of which in everyday language is usually somewhat vague, is used in the sense of Shannon's theory of information, which is described in detail in Part 2. Shannon's theory of information has led to great advances in telecommunications technology and to new insights in astrophysics.

0.4 Even if one has not learned "something new" during a conversation, this is already information if it was uncertain before the conversation whether one will learn "anything new" or not.

0.5 The following classification of the sciences reflects the view of the author. This classification is based on the type of primary questions and tasks and does not take into account the manifold interrelations between the sciences. The Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) uses a slightly different classification, which takes more into account the extent of current cooperation between the various individual sciences. It distinguishes between "*humanities and social sciences*", "*life sciences*", "*natural sciences*" and "*engineering sciences*". At the DFG, for example, the field of mathematics is included in the natural sciences and not, as here, in the humanities. The American National Science Foundation (NSF) even distinguishes between seven major areas. A different view (v. Weizsäcker) distinguishes only two scientific disciplines, the *structural sciences* and the *empirical sciences*.

- the ***humanities***, which as primary core areas deal with *abstract* topics about existence, meaning, logic, justice, etc. and include the fields of philosophy, theology, mathematics, law, linguistics, social and cultural sciences and others,
- the ***natural sciences*****,** which are primarily concerned with the analysis of *physically* existing nature and the laws governing it, and include the fields of physics, chemistry, biology, medicine and others,
- the ***engineering sciences***, which are primarily concerned with the concrete synthesis of artificial objects that are not found in nature, and include the fields of civil engineering, mechanical engineering, electrical engineering and others.

This listing is made, on the one hand, because the details of communication form a complicated network of relationships in which all these sciences are involved in one way or another, and, on the other hand, in order to illustrate from which particular scientific background the topic is approached in the present treatise: the description of communication processes presented here is based on an engineering/technological point of view.

The engineering sciences make extensive use of insights from the natural sciences and humanities and, on this basis, develop independent theories and views which, in return, do not remain without influence on the other sciences. An engineering-technical perspective has on many occasions contributed to a better understanding of interrelationships in non-technical fields. According to S. Wendt (2008), however, the actual field of competence of engineers lies in the mastery of complex technical systems in which many different objects and influences interact, as is the case, for example, in the mass production of automobiles, global energy supply and mobile communications. In all these ventures, not only aspects of technology must be taken into account, but also economic, legal, ecological, social and other conditions. It is unavoidable that engineers get bogged down in matters of detail, because, as we all know, the devil is often in the details.

As communication is also a system of complex dependencies of many objects and effects, which becomes clear in this treatise, the author himself being an engineer feels entitled to examine the huge field of communication in all its ramifications in great detail. The author has dealt with telecommunications technology throughout his professional life. He therefore does not consider it unreasonable to speak about communication also without the prefix "tele". Various models that have proven themselves in telecommunications can be largely applied to natural communication with some adaptations.

**A cognitive communication theory, which, ideally, represents all fundamental components that play a role in communication in a unified way and describes the dependencies between the components also quantitatively as far as possible, is certainly desirable, because many processes in nature and in social interaction can be explained in this way**.

### *Relationships between the spiritually abstract and the physically material world*

Meaning and information are both abstract entities, whereas a signal is something physically real. Information not only increases the recipient's knowledge, information is also quantifiable. The expected value of the amount of information calculated with the help of probability theory is called "entropy" and is described by a mathematical formula which has the same form as the formula for entropy in statistical thermodynamics. Because of this fact one may ask whether there are connections and interactions between the intellectually abstract world of the philosopher Plato and the real physical material world, and if so, what these connections are. The abstract thinking about meanings in the human brain and the associated firing of material neurons also points towards this question.

The emergence of meanings and notions in the human being is a process that develops over time and which (according to the philosopher I. Kant) is fed from two different sources, on the one hand from what the human being perceives through its sensory organs and on the other hand from what stems from one's own inner being or what is otherwise experienced somehow outside of the senses. Both sources need not be active at the same time.

There are good reasons to suggest, for example, that the stimulus patterns coming from the eyes to the brain are stored there for a certain period of time and by correlation checked with each other for similarity or resemblance. As a result, certain types of matching and similar patterns are formed, which then remain memorized for a longer period of time and enable the recognition of recurring identical or similar patterns[0.6]. The same happens with the stimulus patterns that are perceived by ears and other sensory organs. These representations of visual, auditory and other stimulus patterns with their sequence of events and changes over time can be named or coded and thus form different meanings and notions in the brain. The ideas acquired in this way can be refined by observing reactions of the surroundings to specific actions of one's own articulation organs and limbs. The limbs (especially the hands) can be used to produce tools and experimental settings that allow to investigate nature as it is done in the natural sciences.

Some of the notions that derive from inner feelings and experiences can also be explained biologically/scientifically, e.g. the basic emotions "well-being" and "indisposition", which are usually associated with the state of one's own bodily functions. The situation seems to be different with concepts that develop through pure contemplation about abstract objects. Examples are discoveries of mathematical principles and concepts[0.7], artistic ideas, philosophical conceptions about existence, ethics and related questions. Conceptions that

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[0.6] The human brain with its approximately one hundred billion ($10^{11}$) brain cells (neurons) and about 1000 times more synapses (these are the switching points between the neurons) can hold almost any amount of information. It is also said that a human being has the highest number of brain cells at birth.

[0.7] A simple example is given by Pythagoras's theorem for a planar right-angled triangle. This theorem is valid regardless of whether humans exist or not. The same is true for other mathematical theorems such as the "Integral Theorems of Cauchy" in the function theory of complex variables. Such theorems are discovered, and not invented, by humans, just as the natural laws of physics are discovered and not invented. These phenomena imply the real existence of a Platonic world, see the book "Computer Thinking" by the mathematician R. Penrose (1991).