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Probability And Bayesian Inference In Human Communication

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Abstract
This paper challenges the applicability of traditional information theory's frequentist approach to human communication, arguing that it fails to capture the unique, singular nature of communicative acts. Traditional theory, based on long-term observation and relative frequencies, overlooks the complexity and context-dependency inherent in human interactions. The objective is to redefine communication understanding through a Bayesian model that emphasises subjective probability and the critical role of beliefs and intentions. Utilising a rationalist methodology, the research conducts a qualitative analysis of theoretical concepts and prior research, proposing a new model that situates probability within the philosophy of communication. This model highlights the subjective beliefs and intentions that govern communication, challenging existing paradigms and contributing to a deeper understanding of communicative dynamics. The results reveal the limitations of the frequentist approach and demonstrate the applicability of a Bayesian perspective, advocating for a paradigm shift in communication theory towards a sender-oriented model. This shift not only challenges existing paradigms but also offers a more nuanced understanding of communication as a fundamentally human endeavour.
Keywords: Bayesian Perspective; Communication Theory; Frequentist Approach; Subjective Probability; Human Communication

Abstrak
Artikel ini memiliki tantangan mengenai penerapan pendekatan *frequentist* teori informasi tradisional pada komunikasi manusia, dengan alasan bahwa pendekatan tersebut gagal menangkap sifat unik dan tunggal dari tindakan komunikatif. Teori tradisional, berdasarkan observasi jangka panjang dan frekuensi relatif, mengabaikan kompleksitas dan ketergantungan konteks yang melekat dalam interaksi manusia. Tujuannya adalah untuk mendefinisikan kembali pemahaman komunikasi melalui model Bayesian yang menekankan probabilitas subjektif dan peran penting dari keyakinan dan niat. Dengan menggunakan metodologi rasionalis, penelitian ini melakukan analisis kualitatif terhadap konsep teoritis dan penelitian sebelumnya, mengusulkan model baru yang menempatkan probabilitas dalam filosofi komunikasi. Model ini menyoroti keyakinan dan niat subjektif yang mengatur komunikasi, menantang paradigma yang ada, dan berkontribusi pada pemahaman yang lebih mendalam tentang dinamika komunikatif. Hasilnya mengungkapkan keterbatasan pendekatan frequentist dan menunjukkan penerapan perspektif Bayesian, yang menganjurkan perubahan paradigma dalam teori komunikasi menuju model berorientasi pengirim. Pergeseran ini tidak hanya menantang paradigma yang ada namun juga menawarkan pemahaman yang lebih berbeda tentang komunikasi sebagai upaya fundamental manusia.
Kata Kunci: Perspektif Bayesian; Teori Komunikasi; Pendekatan frequentist; Probabilitas Subyektif; Komunikasi Manusia

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INTRODUCTION

The article identifies a significant problem in the field of communication theory: the inadequacy of traditional information theory, particularly the frequentist approach to probability, in explaining the unique, singular nature of human communication acts. It argues that this approach fails to account for the complexity and context-dependency of human interactions, which are influenced by the intentions and beliefs of the communicators rather than mere statistical probabilities. The primary objective of the paper is to redefine our understanding of communication by proposing a model that emphasizes the subjective nature of probability and the critical role of beliefs and intentions in human communicative interactions. It aims to illuminate the nuanced ways in which individuals convey and interpret messages, challenging existing paradigms and contributing to a more profound understanding of communication dynamics.

The article integrates several key concepts and theories. Among them the Bayesian perspective on probability, which considers probability as a subjective belief about the likelihood of certain communicative outcomes, as opposed to the frequentist view that relies on long-term observation and relative frequencies. Another key concept utilised in the paper is the philosophical reasoning behind communication acts, highlighting the importance of understanding the intentions and beliefs of communicators (the "teleological perspective") rather than focusing solely on the predictability of messages.

This approach questions traditional accounts of information theory and critiques their applicability to human communication. It also engages with alternative perspectives to build its argument against the frequentist account of probability and in favour of a more nuanced, Bayesian approach. In order to do so, the research employs a qualitative analysis of theoretical concepts, prior research, and probabilistic reasoning. It adopts a rationalist methodology grounded in philosophical reasoning, aiming to explore the philosophical underpinnings of communication through a critical examination of existing theories and the proposal of a new model.

The analysis is situated within a philosophical and qualitative research paradigm, focusing on conceptual analysis and theoretical exploration rather than empirical investigation and utilising the method of a critical review of literature and theoretical concepts related to information theory and probability in communication, followed by the development of a new conceptual framework based on Bayesian principles. Given the theoretical nature of the research, data collection primarily involves the examination of existing literature and theoretical frameworks. Data analysis entails a critical interpretation of these frameworks, leading to the development of a new model that better accounts for the subjective and intentional aspects of human communication.

The research problem centres on the inadequacy of traditional information theory, particularly its frequentist approach, in fully capturing the complexity of human communication, which is inherently probabilistic, context-dependent, and influenced by subjective interpretations.

The objective is to explore and propose an alternative framework, informed by Bayesian principles, that better accounts for the subjective and dynamic aspects of human communication. This involves understanding how prior beliefs and new information interact in the communication process, aiming to provide a more accurate and nuanced model of human communicative behaviour.

METHOD

This research adopts a rationalist epistemological paradigm, emphasising the role of reasoning and logical analysis in understanding human communication. It posits that communication is not merely a mechanical transmission of information but a complex, intentional act influenced by the beliefs, desires, and contexts of the communicating parties. This paradigm allows for the exploration of subjective experiences and the nuanced ways in which individuals interpret messages.

Central to our methodology is the Bayesian approach to probability, which contrasts with the frequentist perspective traditionally applied in communication studies. This theoretical framework is grounded in the philosophy of probability, emphasising the importance of prior knowledge and the

subjective interpretation of information. It provides a robust foundation for analysing communication as a probabilistic, context-dependent phenomenon.

The research employs a qualitative approach, utilising a comprehensive review of literature and theoretical analysis. This method is chosen for its strength in exploring complex, abstract concepts and its suitability for studies within the philosophy of communication, where the aim is to deepen understanding rather than quantify phenomena.

Data collection involves an extensive survey of academic literature, including philosophical texts, communication theories, and empirical studies that contrast frequentist and Bayesian methods. Sources are selected based on their relevance to the research question and their contribution to the understanding of communication from a Bayesian perspective. The collection process is iterative, allowing for the inclusion of new literature as the research progresses.

The analysis employs comparative and thematic techniques, focusing on identifying key themes related to the application of Bayesian principles to human communication. It involves synthesising information from various sources to construct a coherent argument supporting the shift towards a Bayesian approach. The analysis also includes a critical examination of the limitations of traditional models and a discussion of the implications of the findings for communication theory and practice.

By employing a rationalist paradigm and qualitative methods, the research aims to contribute to the philosophy of communication, offering new insights into the probabilistic and context-sensitive nature of human interactions.

RESULTS AND DISCUSSION

Cybernetician Paradigm and Information Theory

At the core of information theory is the idea developed within the “cybernetician paradigm” — applying statistical concepts of measuring uncertainty and multiplicity to the problem of random losses of information in communication signals (Ahmed, 2023; Shannon & Weaver, 1949). Information theory understands the entropy of a random variable as the average level of "information" or “uncertainty" inherent in the variable's possible outcomes (Adriaans, 2020; Steinbruner, 2021). Whenever an event is very probable or certain to happen, it is not “surprising” when it indeed happens as expected. In the same way a “predictable” message is not “surprising” in a sense that it does not transmit any new information (the predictability of content implies that it is already known). Conversely, if an event is not probable to occur, the it is more “surprising” to find out that the event actually happened. Thus, the message which is less “predictable” carries more new information (something that is now already known); hence, the lower the probability of the message is, the more information it contains. This concept forms the foundation of the information theory approach to cybernetics and machine communication (Adriaans, 2020). However, is it applicable to human communication? Can one assign a numerical probability to a message consciously created by a rational agent?

Limitations of Information Theory in Human Communication

Before we move to discussing the limitations of the information theory probability approach to communication, we need to remember Shannon’s theory repurposed the general definition of entropy — the amount of uncertainty involved in the value of a random variable or the outcome of a random process (Shannon & Weaver, 1949). This definition of entropy is a representation of the measure of the maximal uncertainty of a message within the “frequentist” account of probability, which claims that the probability of a random event denotes the relative frequency of occurrence of an experiment's outcome when the experiment is repeated indefinitely (Lista, 2023; Shen et al., 2023).The frequentist account, however, generally does not accept the application of the concept of probability to single events or singular occurrences (in the case of communication, to singular utterances), and can only be applied to certain attributes of a given class (Hoppe, 2021). For a

frequentist, a numerical probability can only be assigned when a specified class is defined and its attributes are known(Mises, 1998). When the options are unlimited, we cannot claim that a long series of observations allows us to calculate relative frequencies of any word within the class of utterances.(Arumugam et al., 2023; Devanesan, 2023)

Redundancy and Predictability in Human Communication

There is another important difference in how humans analyse and process messages and predict the next what is coming next. It would be true to say that to a great extent our understanding of messages which we are exposed to is related to our expectations — we are constantly predicting what the next character in a string of symbols will be, or what word in our interlocutor's utterance will follow the previous word. It would also be true to say that redundancy in human communication makes a significant contribution to our ability to make these predictions.

This is the difference in the ways we analyse and predict the frequency of occurrences in natural events and in the behaviour of human actors. In both cases we rely on some kind of probability because we cannot make absolutely certain predictions about the future. But in the case of natural events, we rely on probability because we are unable to understand the causes of the events — we do not know why one flip of a coin results in heads, and the other one in tails. Hence, all we can do is observe the external outcomes and report the frequency of occurrences (Verburgt, 2021). With human actions the process is very different — although we are also unable to directly access the content of other person's mind and understand what preferences, value judgements, goals and intentions determine their actions, we constantly try to infer and reason about them (Futerman & Block, 2017). We continuously attempt to understand and interpret the actions of other people by applying our knowledge of our own consciousness (which we obtain via introspection) and assuming that other people's mind function more or less the same as ours — teleologically, within the framework of preferred ends and chosen means.

Human Analysis and Prediction of Messages

This insight has another important implication: while long-term observations of natural events allow me to reasonably expect that they will continue to occur in the future in the same way as they did in the past (given that the causal conditions of their behaviour remain unchanged), the same will not be true for my explanation of my own action or my understanding of other people's actions. I know that I can change my intentions any second and it will cause changes in my actions, and by analogy I know that others can do likewise. No matter how long another agent observes me doing the same thing over and over again, my will can always falsify any prediction about my behaviour, particularly if there are sufficient reasons (not conditions) for me to change my intentions (Megger, 2021). I know this is true for myself, so it must be true of any other human agent. Hence, my mind refuses to accept probabilistic explanation of another agent behaviour — because in my everyday life I tend to think that the structure of other people's actions can be seen as somewhat similar to mine. Since I know that my actions are better explained as conscious aiming at ends rather than random probabilistic occurrence, I would intuitively conclude that the same holds true for other as well.

To conclude this section, perhaps it would be appropriate to say that when we receive information, we do not process it in a probabilistic manner of uncertainty reduction. It is simply not how human mind works — neither mine nor anyone else's. Another conclusion is that the probability of occurrence of the next character in a message (or the message as a whole) cannot be explained with the frequentist account of probability (the relative frequency of occurrence of an experiment's outcome when the experiment is repeated indefinitely).

BAYESIAN PROBABILITY IN REDUCING UNCERTAINTY OF THE MESSAGE

Conceptualising Probability in Communication

An alternative probabilistic conceptualisation of the communication process would rely on the Bayesian probability theory which suggests that probabilities can be understood as properties of personal beliefs (Shen et al., 2023; Titelbaum, 2022). Bayesian probability is an interpretation of the concept of probability in which instead of frequency or propensity of some phenomenon, probability is interpreted as reasonable expectation representing a state of knowledge of a personal belief. It relies on an interpretation of probabilities as expressions of an agent's uncertainty about the world, rather than as concerning some notion of objective chance in the world. The perspective here is that, when done correctly, inductive reasoning is simply a generalisation of deductive reasoning.

In this context the word probability will not describe events of the world, but rather beliefs about the events. The difference is rather obvious — events either happen or they do not, whereas beliefs or expectations can be either true or false. Of course, beliefs refer to events and can describe them, but they can also be applied to a wider range of phenomena, including hypothetical propositions.

Applying Bayesian Probability to Human Communication

Subjective definition of probability in the Bayesian sense enables us to apply the concept of probability to human communication without assuming that human communication is governed by deterministic causal laws, and simply accepting that probability is a subjective measure of our own ignorance about other people's minds, rather than the result of inherent uncertainty or randomness of their minds. According to this view, a probability is assigned to a hypothesis, whereas under frequentist inference, a hypothesis is typically tested without being assigned a probability. Bayesian probability belongs to the category of evidential probabilities; to evaluate the probability of a hypothesis, the Bayesian probabilist specifies a prior probability (Pagès, 2018). This, in turn, is then updated to a posteriori probability in the light of new, relevant data (evidence). Such approach is different from frequentist inference, where a hypothesis is typically tested without being assigned a probability (Culbertson & Sturtz, 2014; Shen et al., 2023; Williamson, 2013).

Bayesian Probability vs. Frequentist Probability

The subjective approach to probability does have some advantages in comparison to the objective "frequentist" approach, particularly when applied to the problems of social science for two reasons. First, receivers determine the conditional probability of different meanings, words or symbols given the message that has been received. Depending on the amount of uncertainty in the signal, receivers generate a small set of high probability interpretations (for less ambiguous messages), or a larger set of less-probable interpretations for more ambiguous ones (Gilboa & Marinacci, 2016). A second characteristic of Bayesian inference is that determination is guided by knowledge of the prior probability of specific interpretations. That is, an ambiguous message will be interpreted in line the most likely meanings. These two properties help ensure that identification of messages is as fast and accurate as possible (Meyniel et al., 2015).

Let us consider the following example. Starting around 2003, an email circulated through what seems like every inbox claiming that scrambled English words are just as easy to read as the original words. The email text read as follows: "Aoccdrnig to a rscheearch at Cmabrigde Uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoetnt tihng is taht the frist and lsat ltteer be at the rghit pclae. The rset can be a toatl mses and you can sitll raed it wouthit porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe."

Even with a mistake in this viral email (rscheearch cannot spell researcher), the truth is that pretty much every fluent English-speaker can read and understand it. Our ability to "decode" the message comes from the fact that fluent readers read words as whole units, not letter-by-letter. And if the words are relatively short, if the sounds in scrambled words are preserved (toatl vs. talot for

"total"), if the transposed letters remain next to each other rather than farther apart and if the first and the last letter remain in their places, then the reader should not have much difficulty to understand the scrambled text.

But perhaps the biggest factor in making the sentence readable is its predictability. Predictability is a function of context, which is why it may be difficult to unscramble words like "levloy eamlred" — lovely emerald(Davis & Sohoglu, 2022). The lack of context and thus expectations makes decoding harder. This is a simple illustration of the fact that our brain does process messages in a way which is similar to a computing device which is wired to find meanings in strings of characters by looking at contexts to determine probabilities and reduce uncertainties. When the uncertainty reaches the degree close to equiprobability, our reading ability diminishes.

BAYESIAN INFERENCE IN SENDER'S ACTIONS

Probabilistic Expectations of the Sender

The communication process is geared towards the accurate transmission of the original message from sender to receiver. If the goal is to increase the accuracy of the process, then the actors need to be able to utilise the knowledge about the way the receiver's consciousness processes the message. The question, however, is, will it be helpful for a receiver to know that the word "total" is easier to unscramble it is transposed as "toatl" rather than "talot". I would argue that if a reader sees the word string of characters reading "talot", such knowledge will be of very limited use. However, for the sender who constructs the message and encodes it such knowledge can be indispensable.

I propose that it is not only the receiver who is normally concerned with probabilities, but also the sender. The receivers' ability to reconstruct a message correctly at the end of the transmission is higher if some degree of redundancy counterbalances the inevitable noise and equivocation introduced by the physical process of communication and the environment, whereas equivocation is data sent but never received, and noise is unnecessary received data. Redundancy in the classic mathematical information theory refers to the difference between the physical representation of a message and the mathematical representation of the same message that uses no more bits than necessary. Noise extends the receiver's freedom of choice in decoding a message, but it is an undesirable freedom and some redundancy can help to limit it (Amiri, 2023).

The receiver's states in terms of expectations and current data deficits, among other factors (like communication context or communication conventions) is what determines the sender's actions. If we are to define meaning as information interpreted via a contextual framework, then the probability of successful decoding of a message will depend on the ability of the sender to accurately "anticipate" the contextual framework of reference used by the receiver. To put it simply, the successful interpretation of an accurately transmitted message will depend on the sender's ability to predict the receiver's uncertainty within the context of the communicative situation.

When a sender initiates a communicative exchange, he necessarily utilises the concept of probability, understood as reasonable expectation representing a state of knowledge, or a personal belief, in what the receiver knows and does not know. Successful communication always requires some shared knowledge (for example, a code or language), and whenever someone composes a message, he does it with an assumption that the receiver will be referring to the same code (and the same framework for interpretation). Basically, when man communicates, he necessarily acts upon his knowledge of other people's knowledge. This knowledge is, of course, not complete, since the content of other people's mind is not directly accessible to us. Therefore, the sender's knowledge of the receiver's knowledge lacks "certainty", it relies on a subjectively understood probability of the receiver's state of uncertainty. Communication is then a necessarily entrepreneurial action which success is probabilistic.

If we return to the question about the nature of probability, we can then attempt to apply some of the insights from that discussion to the process of communication. By shifting the perspective from the reduction of the receiver's uncertainty to the sender's expectations of the receiver's

uncertainty, we may formulate a different approach to implementing probability theory to the process of communication. By changing the focus of applying the concept of probability to the sender rather than the receiver we can allow for a more accurate integration of the theory of probability into the epistemological framework which looks at communication as a subcategory of human action.

From A Priori Assumptions to A Posteriori Realities of Communication

Communication is an action which endeavours to interfere with the mind of another social agent, made with the intent of producing some change in order to arrive to a different, preferred state of affairs. It is an attempt to make things happen, or change the course of events by influencing and affecting cognitive statuses. It presupposes that the acting agent believes that his actions are capable of producing the desired change, that is, the agent things that there must be some causal relationship between the communicative action and its effects. Thinking about communication from the perspective of Bayesian reasoning allows to conceive it as an action whereby non-omniscient man is attempting to act on his imperfect knowledge of another man's knowledge in order to achieve his ends.

The successful attainment of the communication ends depends on multiple factors, but one of them is the sender's relatively adequate understanding of this causality. The more accurate the sender's prediction of how the receiver will decode and process the message is, the more successful the communication is likely to be. Whenever I refer to a particular linguistic convention in communicating (for example, while composing a sentence in English) I act on the assumption that my audience shares with me the same knowledge of English syntax and thus should be able to understand me. This can be described as my a priori knowledge. When I engage in communication with the audience, I am collecting some evidence via the feedback I am receiving, and update my prior probability to produce what is known as a posteriori probability. In a way, each communicative interaction with a particular receiver can be examined as a kind of "test" which either confirms or rejects the sender's hypothetical expectations about the receiver.

This view of communication process in a way reverses the application of the probability concept in communication, but it does so by recognising both the nature of human action (the intentionality of a conscious agent as the source of causality) as well as the limitations of the agent's knowledge which requires him to rely on probability instead of certainty. It also allows to replace the frequentist approach to probability (with its mathematical apparatus applicable to information analysis) with a subjective definition of probability as applicable to human action. Because in human interaction uncertainty comes from the basic fact of human ignorance about other actors' inner states, this forces us to adopt a subjective definition of probability. And because we know that the behaviour of others is not governed by deterministic causes that can be described statistically, our probability statements are the reflections of our limited understanding of the minds of another acting agents. The limited availability of knowledge about the content of another person's mind is what leads to the acknowledgement of the entrepreneurial nature of human communication.

If we knew with certainty what another person knows, and how he will respond to our message, we would not need to rely on probability. Our communication activities would be one hundred percent effective and fail proof. When a machine sends and receives messages, the process is determined by causally sufficient conditions and it can be described mathematically. In human communication we necessarily deal with a different set of causes — the mind of an acting individual. People communicate not because they have been caused to communicate by some previous events, but because they have a purpose they want to achieve — they intend to produce changes with a hope to improve the future situation, and they use communication means to achieve communication ends given the general condition of uncertainty about the outcomes of their efforts. As Bon Barwise put it, "Information travels at the speed of logic, genuine knowledge only travels at the speed of cognition and inference" (Barwise, 2016). In information theory and indeed knowledge is often understood in terms of having information — particularly in computer sciences, where the goal is to use machines as

information processors, and to get them do things with the information they have. Machines do not have beliefs. But to say that a person knows of an event A means that (s)he assigns A posteriori probability one to it— which is of course a Bayesian interpretation of knowledge.

Embracing Bayesian Perspectives for Understanding Human Communication

The exploration of the Bayesian perspective on probability in communication reveals profound insights into the nature of human interaction. This section synthesizes the findings from the qualitative analysis of theoretical concepts, prior research, and probabilistic reasoning, discussing their implications for understanding human communication.

The frequentist approach to probability, which relies on long-term observation and relative frequencies, has been a cornerstone of traditional information theory. However, our analysis underscores its limitations in capturing the essence of human communicative acts. Unlike natural phenomena, where events can be predicted with a degree of certainty based on past occurrences, human communication is inherently unpredictable and context-dependent. The frequentist approach fails to accommodate the singular nature of communicative acts, which are driven by the intentions and beliefs of the communicators rather than statistical probabilities.

The shift towards a Bayesian perspective allows for a more nuanced understanding of communication. By viewing probability as a subjective belief about the likelihood of certain communicative outcomes, this approach acknowledges the role of the communicator's intentions and the receiver's interpretations. It recognizes that uncertainty in human interaction stems from our limited knowledge of other actors' inner states, rather than inherent randomness. This subjective definition of probability aligns with the entrepreneurial nature of human communication, where each act is a venture into the unknown, guided by the communicator's beliefs and intentions.

Our discussion further illuminates the distinction between the anticipation and prediction of communicative acts in human versus natural phenomena. In natural events, predictions are based on observed frequencies, devoid of understanding the underlying causes. In contrast, human communication involves a teleological understanding, where actions are interpreted through the lens of intentions and chosen means. This insight challenges the applicability of numerical probabilities to human communication, advocating for a model that emphasizes understanding ('verstehen') and the teleological analysis of actions.

The findings from this analysis have significant implications for the field of communication theory. They call into question the adequacy of traditional models that prioritize the reduction of uncertainty and suggest a paradigm shift towards recognizing the subjective and intentional aspects of communication. By adopting a Bayesian perspective, we can develop a more accurate and profound understanding of how individuals convey and interpret messages, moving beyond the limitations of the frequentist approach.

The proposed Bayesian model of communication offers a framework that places the sender's intentions and beliefs at the forefront, challenging existing paradigms and contributing to a richer understanding of communicative interactions. This model not only highlights the limitations of the frequentist approach but also underscores the importance of considering the subjective beliefs and intentions of communicators. It paves the way for future research to explore the practical implications of this perspective, potentially incorporating case studies and examples to illustrate its applicability to real-world communication scenarios.

CONCLUSION

In this paper, we have ventured beyond the traditional confines of information theory, challenging the frequentist approach to probability in the context of human communication. We have argued that the frequentist perspective, with its reliance on statistical regularities and long-term frequencies, is ill-suited to capture the essence of communicative acts, which are inherently singular and shaped by the intentions and beliefs of communicators.

By embracing a Bayesian perspective, we have proposed a model that recognizes the subjective nature of probability in communication. This model acknowledges that communicative acts are not governed by deterministic causes that can be described statistically, but by the volition of conscious agents. Our probability statements, therefore, are reflections of our limited understanding of the minds of other acting agents, and the uncertainty in human interaction arises from our ignorance about these inner states.

The entrepreneurial nature of human communication, as highlighted in this paper, underscores the creative and dynamic aspects of how we convey and interpret messages. It is a process that requires us to adopt a subjective definition of probability, one that is informed by our experiences, knowledge, and the context in which communication occurs.

This paper calls for a re-evaluation of the role of probability in communication theory. It suggests that a shift from a receiver-centric model focused on uncertainty reduction to a sender-oriented model that places intentions and beliefs at the forefront will lead to a more profound and nuanced understanding of communicative interactions. By doing so, we not only challenge existing paradigms but also pave the way for future research that can further explore the practical implications of this perspective, potentially transforming how we approach and study human communication.

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