Pragmatics, Synchronics and Energetics in Spoken Language – an Information Theoretic Perspective

Roger K. Moore
Speech and Hearing Research Group, University of Sheffield, UK
r.k.moore@sheffield.ac.uk

A prime concern in speech-based interaction is *what* people say, and considerable research resources have been devoted to characterising such behaviour at the traditional acoustic, phonetic, phonological, morphological, lexical, syntactic and semantic levels of description [1]. Such studies involve a multitude of approaches to characterising the complexity of spoken language [2], but 'information theory' [3] provides a particularly powerful paradigm for a single unified approach to measurement. For example, Coupé et al. have recently shown that *all* languages have an information rate of ∼39 bps [4].

Of course, in reality, spoken language is not a fixed code with a constant information rate; what people say is conditioned on critical causal factors such as …

a) their situated and embodied context (i.e. *pragmatics*),
b) the temporal evolution of events (i.e. *synchronics*), and
c) the level of effort that they are prepared to devote to their behaviour (i.e. *energetics*).

In other words, a key question in spoken language interaction is not just *what* people say, but *why*, *when* and *how* they say it?

This paper will address these issues and speculate as to how these conditioning factors – the pragmatic, synchronic and energetic 'priors' – impact on the subsequent active management of 'information' leading to the dynamic adaptation of behaviour in an ongoing interaction/dialogue [5]. Examples of relevant behaviours will be presented, and how such behaviours might be characterised from an information theoretic perspective will be discussed. In particular, each factor will be analysed with respect to three behavioural domains [6]:

a) the *physical* domain of objects and actions,
b) the *abstract* domain of knowledge and data, and
c) the *social* domain of agents and relations.

Interaction in the physical and abstract domains typically involves *formulaic* speech acts – 'command-and-control' or 'question-and-answer' respectively – which usually conform to a strict 'turn-taking' protocol for dialogue [7, 8, 9]. Interaction in the social domain involves more fluid *conversational* behaviour with considerable overlap between speakers [10, 11, 12]. These domains are not only non-mutually-exclusive, but they also point to the potential for *multimodal* interaction [13]; i.e. they emphasise the active and dynamic (re)distribution of information across different behavioural channels as a function of the communicative context.

Finally, these issues will be addressed from the perspective of matched/mismatched interlocutors, where not all of the participants are necessarily human beings [14, 15]. It will also be emphasised that speaking and listening are not independent behaviours. Hence, there are significant conditional dependencies influencing efficient interaction and communications which may be usefully characterised from an information theoretic point of view, e.g. as in 'predictive coding/processing' [16, 17] and closed-loop control [18, 19, 20, 21].

It will be concluded that information theoretic measures such as 'mutual information', coupled with a decomposition into pragmatic, synchronic and energetic priors, have the potential to provide powerful tools for unravelling the rich complexity of spoken language behaviour.

[1] P. B. Denes and E. N. Pinson, *The Speech Chain: The Physics and Biology of Spoken Language*. New York: Anchor Press, 1973.

[2] D. Gibbon, R. K. Moore, and R. Winski, *Handbook of Standards and Resources for Spoken Language Systems*, D. Gibbon, R. K. Moore, and R. Winski, Eds. Berlin, New York: Mouton de Gruyter, 1997.

[3] C. Shannon, "Communication in the presence of noise," *Proceedings of the IRE*, vol. 37, no. 1, pp. 10–21, jan 1949.

[4] C. Coupé, Y. Oh, D. Dediu, and F. Pellegrino, "Different languages, similar encoding efficiency: Comparable information rates across the human communicative niche," *Science Advances*, vol. 5, no. 9, 2019.

[5] C. V. Goldman and S. Zilberstein, "Optimizing information exchange in cooperative multi-agent systems," in *AAMAS '03: Proceedings of the Second International Joint Conference on Autonomous Agents and Multiagent Systems*, 2003, pp. 137–144.

[6] R. K. Moore, "Talking with Robots: Opportunities and Challenges," in *Proceedings of the International Conference on Language Technologies for All (LT4All)*. Paris, France: UNESCO, 2019.

[7] A. Gravano and J. Hirschberg, "Turn-taking cues in task-oriented dialogue," *Computer Speech & Language*, vol. 25, no. 3, pp. 601–634, 2011.

[8] S. C. Levinson, "Turn-taking in human communication – origins and implications for language processing," *Trends in Cognitive Sciences*, vol. 20, no. 1, pp. 6–14, 2015.

[9] G. Skantze, "Turn-taking in conversational systems and human-robot interaction: a review," *Computer Speech & Language*, vol. 67, p. 101178, 2021.

[10] S. J. Cowley, "Of timing, turn-taking, and conversations," *Journal of Psycholinguistic Research*, vol. 27, no. 5, pp. 541–571, 1998.

[11] E. Schegloff, "Overlapping talk and the organization of turn-taking for conversation," *Language in Society*, vol. 29, pp. 1–63, 2000.

[12] M. Heldner and J. Edlund, "Pauses, gaps and overlaps in conversations," *Journal of Phonetics*, vol. 38, no. 4, pp. 555–568, 2010.

[13] C. Alviar, C. T. Kello, and R. Dale, "Multimodal coordination and pragmatic modes in conversation," *Language Sciences*, vol. 97, no. 101524, 2023.

[14] R. K. Moore, "Is spoken language all-or-nothing? Implications for future speech-based human-machine interaction," in *Dialogues with Social Robots – Enablements, Analyses, and Evaluation*, K. Jokinen and G. Wilcock, Eds. Springer Lecture Notes in Electrical Engineering (LNEE), 2016, pp. 281–291.

[15] G. Huang and R. K. Moore, "Better Curious Than Smart?: Enhance Inclusiveness Between Mismatched Conversational Partners: An Opinion Paper," in *CUI@CHI: Inclusive Design of CUIs Across Modalities and Mobilities*, Hamburg, Germany, 2023.

[16] K. Friston and S. Kiebel, "Predictive coding under the free-energy principle," *Phil. Trans. R. Soc. B*, vol. 364, no. 1521, pp. 1211–1221, 2009.

[17] A. Clark, *Surfing Uncertainty: Prediction, Action, and the Embodied Mind*. Oxford University Press, 2016.

[18] W. T. Powers, *Behavior: The Control of Perception*. NY: Aldine: Hawthorne, 1973.

[19] P. Capdepuy, D. Polani, and C. L. Nehaniv, "Constructing the Basic Umwelt of Artificial Agents: An Information-Theoretic Approach," in *Advances in Artificial Life SE - 38*, ser. Lecture Notes in Computer Science, F. Almeida e Costa, L. Rocha, E. Costa, I. Harvey, and A. Coutinho, Eds. Springer Berlin Heidelberg, 2007, vol. 4648, pp. 375–383.

[20] R. K. Moore, "PCT and Beyond: Towards a Computational Framework for 'Intelligent' Systems," in *The Interdisciplinary Handbook of Perceptual Control Theory: Living Control Systems IV*, W. Mansell, Ed. Elsevier, 2020, ch. 15, pp. 557–582.

[21] ——, "Local minima drive communications in cooperative interaction," in *Proceeding of the AISB Convention*, Swansea, 2023.