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Information Processing Limitations In Humans and Machines

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Introduction

❑ **Information Theory (1949)**: "Information is aimed at resolving uncertainty in complex systems." At this stage, computers as we know them today did not exist.

❑ **Problem**: the general information theory premise specifies neither the nature of « information », nor the nature of « complexity » or « uncertainty ».

❑ **Shannon-Weaver Law:** Uncertainty in information systems increases linearly with the amount or complexity (in *bit* units) of information transmitted or generated *(Shannon, Weaver. The mathematical Theory of communication, University of Illinois, Urbana III, 1949).*

❑ **Hick-Hyman Law:** Uncertainty in **psychophysical systems** is directly reflected by the time of human response to stimuli in the environment, which increases with stimulus complexity. *Hick. Quarterly Journal of Experimental Psychology. 1949;* ***4*** *(4:1): 11–26. Hyman (1953). Journal of Experimental Psychology.* ***45*** *(3): 188-196.*

❑ **Minds *vs* machines**: The concepts of **information** and **uncertainty** relate to **complexity** in physical (« machines ») and living systems (« brains »/« minds »).

❑ **Artificial Intelligence (AI):** different levels of **functional complexity** and **autonomy**

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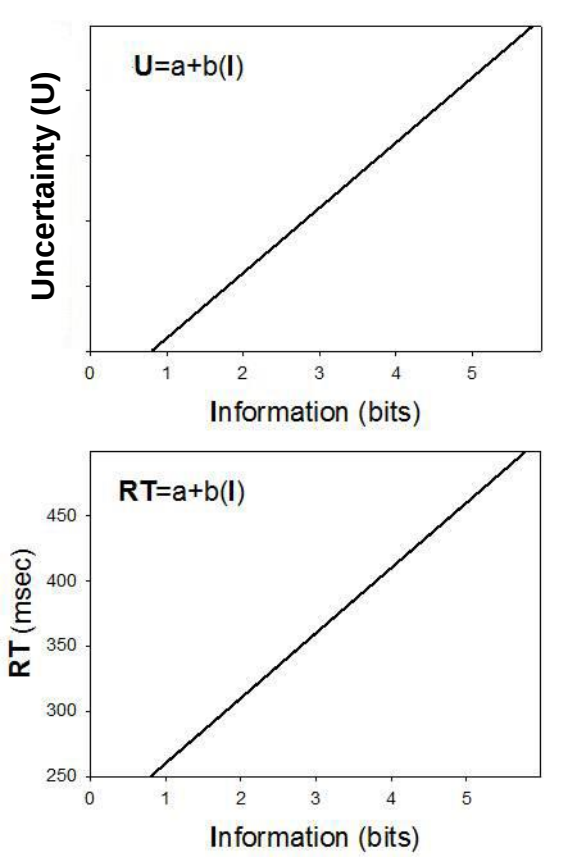
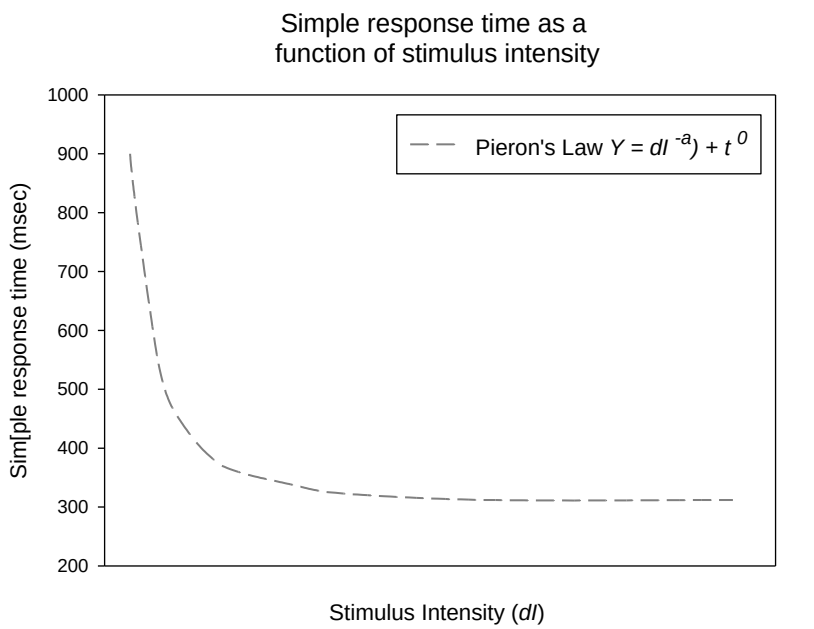
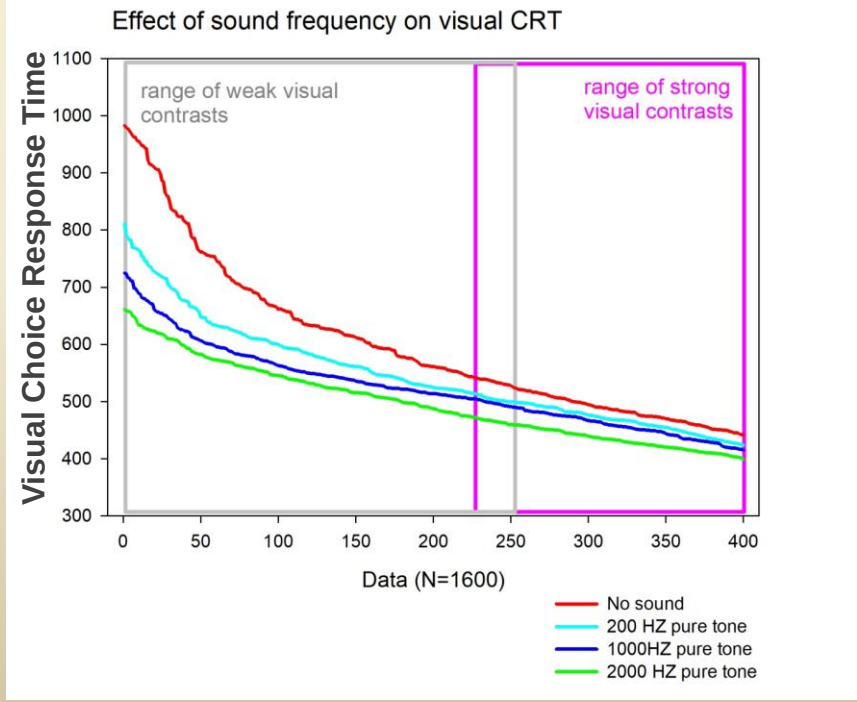
Sensory Uncertainty

Shannon, Weaver, 1949, top; Hick, 1949; Hyman, 1953, bottom





(Piéron H. The Sensations. 1952; Yale University Press)



Dresp-Langley B, Monfouga M. Combining Visual Contrast Information with Sound Can Produce Faster Decisions. Information. 2019; 10(11):346.

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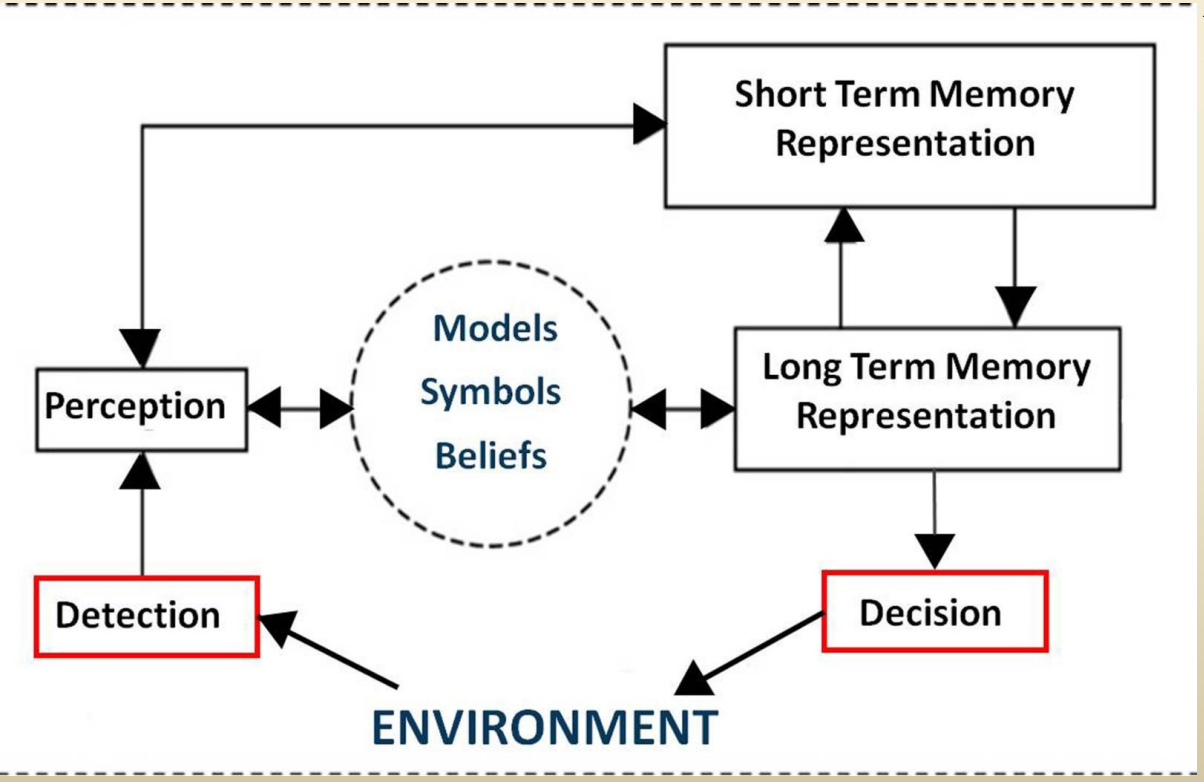
Cognitive Uncertainty

Cognitive uncertainty corresponds to system states that require regulation of representations of the environment in order to obtain better prediction and adaptation

Mushtaq F, Bland AR, Schaefer A. Uncertainty and cognitive control. Front Psychol. 2011;2:249.

In **humans**, functional interaction between conscious and non-conscious cognitive workspaces enables decision making

Dresp-Langley, B. Why the Brain Knows More than We Do: Non-Conscious Representations and Their Role in the Construction of Conscious Experience. Brain Sci. 2012; 2: 1-21.



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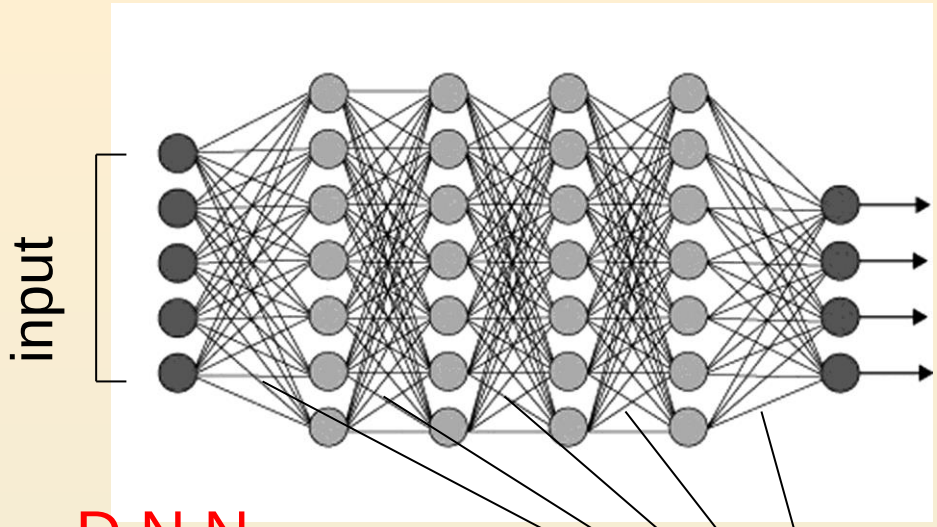
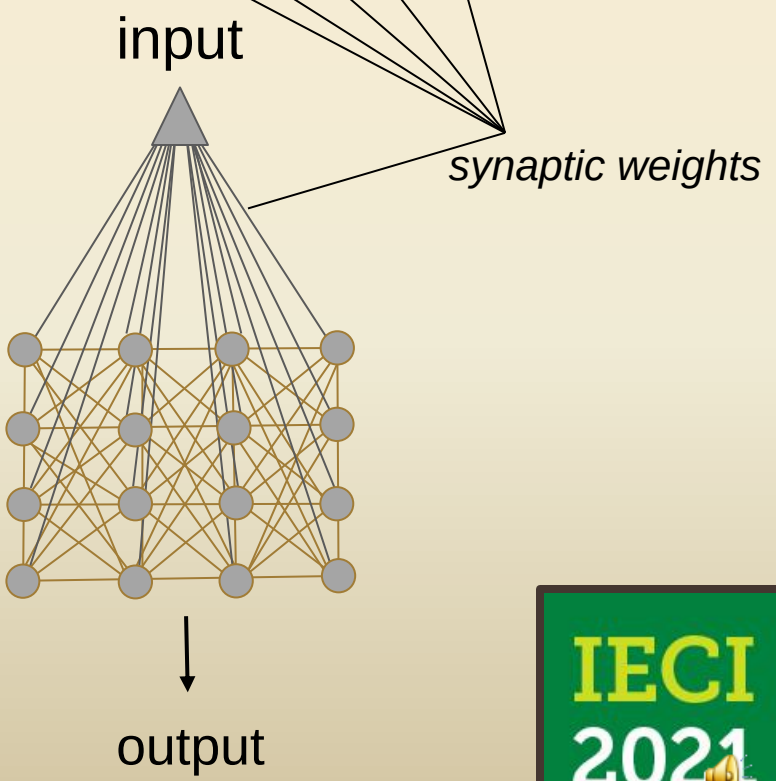
Uncertainty in Neural Networks

- complexity of the data
- complexity of functional architecture
- complexity of learning algorithms
- complexity of input and output dimensionality





Example: SOM represents a distribution of input data vectors using a finite set of models. The quantization error (QE) of an input vector can be expressed as the Euclidean norm of the difference between input vector and best-matching model.

Kohonen , Nieminen, Honkela T. On the Quantization Error in SOM. Lecture Notes in Computer Science. 2009; 5629. Springer, Berlin, Heidelberg

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Uncertainty In Artificial Intelligence

Level 1 AI: Human controlled - *'human on the loop'*: human agent initiates and controls all steps in the process

Level 2 AI: Semi-autonomous - *'human in the loop'*: human has control over some of the steps in the process

Level 3 AI: Fully autonomous AI - *'no human in the loop'*: human has no control over any step in the process

Boulanin , Verbruggen. Mapping the development of autonomy in weapon systems. 2017; Stockholm International Peace Research Institute.

- **Level 1** and **Level 2** AI combine sensory and cognitive uncertainty in the human with the design specific uncertainty of the AI system

- This does not straightforwardly imply that **Level 3** AI is more reliable or « trustworthy »

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Conclusions

- Shannon & Weaver's post-war Information Theory is challenged by contemporary cognitive neuroscience and the rise of neural network learning and AI

- A novel conceptual framework for what is to be understood by « information », « complexity », and « uncertainty » needs to be carved out

- The processing constraints and limitations of human brains and machines need to be studied in domain and application specific contexts

- The conscious processing limitations of a human agent in any context are compensated for by non-conscious processes that run in massively parallel, dedicated resonant networks of the human brain

- Interactions between « conscious » and « non-conscious » cognitive workspaces cannot (yet?) be implemented in current AI

- Under conditions of critically high uncertainty, the human expert can resort to decisions on the basis of **intuition**, the machine (AI) can not

Acknowledgments

Thank you