2

The Act of Defining: Prediction

Dictionary definitions tend to state that a prediction is about the time ahead of the present, for example a forecast about a future event or data. Some explanations of the term also point out that Latin 'pre' actually means 'before' and that 'diction' refers to the act of talking: prediction then is talking about something before it happens. It is easy to recognize this as the ordinary language sense of what people mean when they use the word prediction. Prediction for laypeople is simply and straightforwardly about what may happen in the future. Ironically, the use of the terms 'prediction' or 'predictive' in the scientific literature is not so clear-cut. Instead, these terms are ill-defined and sometimes perhaps even confused. Nobel laureate Nils Bohr's old joke that "prediction is very difficult, especially if it's about the future" might well be a fitting description of the current science of the predictive mind.

A great number of different theories and frameworks about prediction have been proposed in recent years. These theories are very diverse in nature and scope, ranging from psychological and mathematical to neurobiological theories. They also attempt to explain the predictive foundations of human behavior in nearly all subfields of the mind sciences, including visual and auditory perception, action, attention, memory, language comprehension and production, thinking, reasoning, decision making, individual differences, social behavior and mental disorders. Given the great variety across fields and in order to consider prediction as a, or possibly the, fundamental way of how mind and brain work, it is necessary to clearly define what is meant by prediction. There is a need to be on the same page on what phenomena should be included in the definition. This may appear obvious, but the myriad of ways prediction has been considered in the scientific literature in the past highlights the need for a clear and inclusive definition.

Same phenomena, different terms?

Contemporary accounts of prediction often give the same phenomena different labels. Take, for example, the term top-down processing as already described in chapter 1, but also: expectation, anticipation, context effects, and priming in addition to 'prediction'. Some researchers in the language sciences have reserved the term prediction for the prediction of a specific word and the term expectation for the prediction of the more general meaning content that may have limited the available options but not have narrowed the choices down to a particular word. According to this distinction, the prediction of the word 'pepper' on hearing the word 'salt' is labeled a prediction. However, the prediction of the more general meaning of a plant substance used for flavoring food (the category of spices) without the prediction of a specific spice word (such as 'pepper'), is labeled an expectation only[1]. The term anticipation, especially in investigations of the effect of visual or auditory attention, is sometimes used as reflecting preparatory attention or elevated processing prior to an expected event[2]. Prediction is also often referred to as context effects, for example when upcoming words while listening or reading can be predicted in advance from sentential or discourse context[3]. Even though some researchers try to make such distinctions, most of the time the terms prediction, expectation, anticipation, and effects of context are, unfortunately, used interchangeably in the literature.

Priming vs. prediction

The distinction between priming and prediction that is often made is a notoriously problematic one, in particular because it is repeated so often and without a concise explanation about the difference between the two terms. In psycholinguistics, for example, researchers often make a distinction between 'simple priming between words' and prediction, with an intended meaning of something like 'intelligent guesses about the words they might soon encounter, based on the

message conveyed by the discourse so far'[4]. Researchers are typically relatively clear that priming is supposed to be an automatic and subconscious process such as when participants in experiments are asked to say the first word that comes to their mind when hearing the word 'salt'. Most people's response is 'pepper' without having to consciously deliberate to make this decision. It might then be sensible and reasonable to assume that the same researchers in psycholinguistics define prediction as something non-automatic and conscious to distinguish it from the process of priming, but unfortunately this is not what is typically done. As the long-winded description 'intelligent guesses about the words they might soon encounter, based on the message conveyed by the discourse so far' suggests, prediction is seen as something based on a larger amount of context. However, it is also often considered to be something that, like priming, happens automatically without conscious deliberation. If pressed, researchers will often resort to an explanation along the lines of 'priming is an implicit effect of memory that it is short-lasting and in which stimulus exposure affects the response to a later stimulus'. Prediction, in contrast, is seen as a more complex, longer lasting phenomenon. Unfortunately for this account, the literature contains plenty of examples of very long-lasting priming[5]. The fussy distinctions made between the terms priming and prediction make it very difficult to experimentally and conclusively establish whether specific effects are the consequence of presumed priming or prediction, which is little surprising given that both are assumed to affect the future.

Same term, different phenomena?

There is also the converse problem: often when using the same the same label, for example prediction, researchers situate their work within very different theoretical constructs and are not always aware that they might be attempting to explain rather different phenomena. For instance, so-called predictive coding accounts in cognitive neuroscience consider the goal of the predictive mind and brain to be to reduce the onslaught of information to small amounts of information that are behaviorally relevant and that can be processed efficiently. An influential idea within such frameworks is that only differences, termed prediction errors, are carried forward between successive processing episodes. The origin of this notion lies in work that was driven by the observation that television signals change very little across successive frames. As bandwidth was limited, researchers came up with the idea that transmitting only the difference between successive frames would be a more efficient code[6]. The coding approaches in this tradition are thus very relevant for exploring efficient techniques of computation and efficient ways of transmitting information but, even though they are often discussed in relation to prediction, they are not necessarily about predicting what will come next. This is a relevant point because the most efficient way of (predictive) coding may not necessarily be the way the human mind solves the problem. A great deal of biological evidence suggests that evolution is a tinkerer, that rather than constructing the perfect solution for a problem from scratch, mind and brain have to build on what evolutionary history has given them to work with[7]. In other words, the most efficient way of coding may not necessarily be the way the predictive mind works given evolutionary constraints.

A principled and inclusive definition

What is needed then is to define prediction in a principled way. It is essential to be conceptually clear about what predictions are, one simple reason being that this is needed to establish what experimental evidence can be considered relevant and what not. First, prediction must be defined in such a way that what is called prediction is clearly about the future; environmental input which is likely to be upcoming or encountered soon. This means that phenomena and processes that are retrospective or retrodictive, that is utilize information to explain the past, should not more or less arbitrarily be called prediction[8,9]. Predictive and retrodictive processes and mechanisms are of course likely to interact very closely. A theory which includes both predictive and retrodictive processing principles, however, is more of a general theory of how mind and brain work and should not simply be called prediction. Prediction may be an important part of such a theory, but forward-looking does not explain all of the functioning of the mind in such a

framework. This issue is worth stressing here because confounding prediction and retrodiction has resulted in some very muddled theoretical thinking and interpretation of experimental evidence, and a lack of systematicity in parts of the literature on the predictive mind[10].

Second, prediction must be defined in an inclusive way such that phenomena and approaches that are clearly about the future are not more or less arbitrarily excluded from the discussion. This means, for example, that even subconscious and short-lasting priming is part of the predictive mind and brain because it affects what happens in the future. In a similar manner, the definition should apply to predictions that are about the more distant future and are conscious, effortful, and more akin to active reasoning or decision-making. A discussion of short-cuts, predictive heuristics and biases, and predictive social understanding, must also be included in a comprehensive account of the predictive mind. Finally, the definition should equally apply to different candidate approaches and levels of description including psychological, mathematical, and neurobiological theories of prediction.

In consideration of these requirements, prediction in the present book is defined as the *conscious or subconscious use of information from previous experiences for the conscious or subconscious processing of information about future states of the body and environment*. This way of thinking about prediction is simple and straightforward, inclusive but principled, and also corresponds closely to the ordinary language sense that prediction is about what may happen in the future. Before discussing the strengths and weaknesses of the various major approaches to prediction in the mind and brain sciences, it is necessary to consider the criteria that should be fulfilled by both a plausible and a comprehensive theory of the predictive mind.

The term "prediction" is commonly understood as foreseeing future events.
In scientific literature, the definition of prediction can be less clear and sometimes confused.
Various fields propose different theories of prediction to explain human behavior.
Different terms like top-down processing, expectation, anticipation, context effects, and priming are often used interchangeably.
The distinction between priming and prediction is not always clear, and both may be considered automatic processes.
The same term "prediction" can be used to describe various phenomena and approaches.
It's crucial to have a clear and inclusive definition of prediction to guide research in the mind and brain sciences.
Prediction is defined as the conscious or subconscious use of information from past experiences to process information about future states of the body and environment.
This definition is simple, inclusive, and aligns with the ordinary language understanding of prediction.
Defining prediction helps in determining the criteria for a comprehensive theory of the predictive mind.

prediction is based on context
priming vs prediction: prediction is like the input based on previous knowledge

References

[1] Van Petten, C., & Luka, B. J. (2012). Prediction during language comprehension: Benefits, costs, and ERP components. *International Journal of Psychophysiology*, *83*(2), 176-190.

[2] LaBerge, D., Auclair, L., & Sieroff, E. (2000). Preparatory attention: Experiment and theory. *Consciousness and Cognition*, *9*(3), 396-434.

[3] Kutas, M., DeLong, K. A., & Smith, N. J. (2011). A look around at what lies ahead: Prediction and predictability in language processing. In M. Bar (Ed.), *Predictions in the brain: Using our past to generate a future* (pp. 190–207). Oxford University Press.

[4] Otten, M., & Van Berkum, J. J. (2008). Discourse-based word anticipation during language processing: Prediction or priming? *Discourse Processes*, *45*(6), 464-496.

[5] Cave, C. B. (1997). Very long-lasting priming in picture naming. *Psychological Science*, *8*(4), 322-325.

[6] Harrison, C. W. (1952). Experiments with linear prediction in television. *Bell System Technical Journal*, *31*, 764–783.

[7] Jacob, F. (1977). Evolution and tinkering. *Science*, *196*(4295), 1161-1166.

[8] Ferreira, F., & Chantavarin, S. (2018). Integration and prediction in language processing: A synthesis of old and new. *Current Directions in Psychological Science*, *27*(6), 443-448.

[9] Onnis, L., & Huettig, F. (2021). Can prediction and retrodiction explain whether frequent multi-word phrases are accessed 'precompiled' from memory or compositionally constructed on the fly? *Brain Research*, *1772*, 147674.

[10] Pickering, M. J., & Gambi, C. (2018). Predicting while comprehending language: A theory and review. *Psychological Bulletin*, *144*(10), 1002-1044.