CHAPTER 2

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.

A reason for this state of affairs might be that a great number of different theories and frameworks about prediction have been proposed. 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.

2.1 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, prospection, preparation, foresight, context effects, and priming in addition to 'prediction.'

Some researchers in psycholinguistics for instance 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 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

In linguistics, researchers may refer to the prediction of upcoming words while listening or reading as context effects, for example when upcoming words can be predicted in advance from sentential or discourse context.² In the fields of visual or auditory attention, some researchers refer to prediction by using the term anticipation as reflecting preparatory attention or elevated processing prior to an expected event.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.

2.2 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 nonautomatic 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 effect of implicit 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.

The state of affairs then that priming and prediction are often kept separate, though there are no precise theoretical criteria for doing so, though they cannot be easily distinguished experimentally, and though both are assumed to affect the future, is very unsatisfactory.

2.3 Same Term, Different Phenomena?

There is also the converse problem: Often when using 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 brain to be to reduce the onslaught of information to small amounts of information that are relevant for behavior: amounts of information that can be processed with efficiency. 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, the brain has to build on what evolutionary history has given it '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.

What is needed is to define prediction in a principled way given the diversity of ways prediction has been defined and conceptualized in the scientific literature.

2.4 A Principled and Inclusive Definition

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

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 the mind works and should not simply be called a theory of 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.⁹

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 shortcuts, predictive heuristics and biases, and predictive social understanding, for example, 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 framing 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.

2.5 Minds and Brains

Another philosophical minefield and potentially confusing terminology to get out of the way at the beginning of this book concerns the distinction between mind and brain. This relationship is sometimes called the mind– body problem and has been discussed by philosophers, behavioral and brain scientists, and others, for centuries, and in some cases millennia.

The well-known dualistic proposal of Descartes, Cartesianism, for instance is that the mind can interact with the body but mind and brain are separate entities and "substances essentially distinct from one another."¹⁰ Dualism has failed to put forward plausible explanations of how an immaterial mind and physical brain could interact.

The majority of contemporary scientists reject the Cartesian notion of an immaterial mind or soul: It is assumed that brains are made of physical matter and that brains control our lives, though interestingly a substantial minority of scientists continues to deny the physicality of mind believing that a 'spiritual part' survives death.¹¹

Mind and brain in the materialistic view, also called physicalism, are just different levels of description; there is no physical organ in the human body called mind: Mental processes arise from biological processes in the brain. Neuroscientists admit nevertheless that there are still aspects of the mind-brain relationship that are unknown such as how biological processes in the brain give rise to consciousness and subjective experiences.

Functionalism is a version of materialism that focuses on a functional role of the mind-body relationship: Mental phenomena, including cognitive states such as beliefs, arise from brain states. In this view, minds can potentially arise from other physical systems, not just brains, and artificial minds may in future become conscious. The present book does not address this question.

In this book, the materialistic view is taken that the human mind is the product of the human brain: Brains cause minds. The term 'predictive mind' is used interchangeably with the term 'predictive brain,' though for convenience the 'predictive mind' is referred to in the chapters about psychological and mathematical theories whereas in the chapters about neurobiological theories of prediction the focus is on the 'predictive brain.'

A final imperative and the topic of Chapter 3, before describing the various major approaches to prediction in the remainder of the book, is to consider the criteria that should be fulfilled by a plausible theory of the predictive mind.