Unit 7: INDUCTIVE REASONING IN THE SCIENCES AND EVERYDAY LFE

Introduction

In Unit 6 we studied how to test the validity of a deductive argument. You did this using a rudimentary version of symbolic logic: First you symbolized the reference and attribute classes of the premises and the conclusion to get rid of everything in the argument that was not a logical operation. You eliminatedall the semantic content (non-logical meaning) of the statements in the argument. Then you studied the logical structure or pattern (called the logical scheme) of the statements in relation to each other to see how the truth of the premises might be able to guarantee the truth of the conclusion in every case of thoughts having these shapes or structure.

Your study of validity was independent of and separate from the content or subject matter that these arguments originally carried before you took out the content and substituted letters as class variables. You paid no attention to what these statements were about. You just looked at the structures or patterns of the statements and compared them to patterns fixed and known in advance that apply as a standard to all thought sequences regardless of what the thoughts are about.

In contrast, in this unit you will study inductive reasoning in a different way altogether. The connection between the premises and the conclusion of an inductive argument does not depend solely upon the logical structure or patterns shaping the premises in relation to the conclusion. Now you have to study meaning content of the statements—you have to examine the quantity of things referred to, you have to decide whether the information called 'evidence' given in the premises really adds up to a good reason for believing the hypothesis, which is given as the conclusion, is likely to be true. An inductive argument does not provide the structure of a logicalproof; it doesn't follow a fixed pattern that holds for all thoughts. The premises provide evidence that confirms the likelihood of the conclusion of the argument— which is why it is called a hypothesis, a well-founded conjecture. There is no certainty with this kind of reasoning, only degrees of probability that the conclusion of the argument is a true conjecture. When we make predictions about the world in the sciences, we can never do so with absolute certainty. The logic of induction is the logic of qualified conjecture.

In this respect, inductive reasoning is much harder to evaluate because it is not mechanical. There is no automatic test to apply that always works for testing or evaluating all inductive arguments. You need to use common sense, general rules for evaluating evidence provided as information about a sample, or experimental results, and then you need to think about what the conclusion is claiming about a whole population or cases outside the ones that were tested in the sample.

This unit will cover the following topics:

Section 1: The contrast between verifiable premises (evidence) and confirmable conclusion (hypothesis)

Section 2: Statistical hypotheses have less predictive power than law-like hypotheses.

Section 3: Three examples of enumerative induction: CONFIRMATION IS NOT PROOF

Section 4: Uncertainty as a virtue and the principle of testability in science

Objectives

Upon completion of this unit you will be able to understand:

- why inductive reasoning never yields certainty
- why inductive premises (‘the data’) are verifiable or directly testable
- what it means to say hypotheses are confirmable or indirectly testable
- what the structure is in an enumerative induction
- the contrast between law-like and statistical hypotheses
- how statistical hypotheses can also be used as evidence
- why statements in social studies and natural science and liberal arts must be testable

SECTION 1: CONTRASTING VERIFIABLE AND CONFIRMABLE STATEMENTS

Introduction

To evaluate inductive arguments, you cannot eliminate the semantic content or the non-logical meanings of the statements involved, because it is just the semantic content or the non-logical meaning of the premises that provides the basis or support that confirms the conclusion. You have to read each argument and evaluate it separately to see if the premises provide a good reason to believe the conclusion is likely to be true.

You have to assess the quality of the data provided in the premises. You have to evaluate the quality and size of the sample, that is, you need to consider the quality and range of evidence provided in the premises and see whether in light of these findings, the conclusion seems convincing. You will learn the basic principles of this in the next Unit 8.

In this section you will learn to tell the difference between premises and conclusion, and recognise what it means for premises to confirm a conclusion. This means that to evaluate an inductive argument as good or bad, you cannot symbolize the classes involved and just look at the logical operations linking them up. You need to examine the content and size of the reference class and the attribute class of the premises and compare them to the conclusion.

Objectives

- recognise when a statement is verifiable

- recognise an inductive conclusion as confirmable
- understand how the projection of an inductiveconclusion goes
- beyond the truth of the premises

Examples of verifiable statements or data, evidence, test results, observation reports, research findings.

Recall from the last Unit 6 Section 1, Activities 1.1 and 1.2. We distinguished the finite reference class found in every particular statement from the infinite reference class that is the mark of a general statement.

Recall these examples of particular statements:

1. This copper strip expanded when it was heated to 120°F.

2. That man is the Dean of Science.

3. This person's passport has expired.

4. That table is green.

5. This stone is not a real diamond.

6. As of today, none of the students on this list have registered for this class.

7. The fourth and seventh samples of the meat consignment were infected with the lethal bacteria.

8. All the voters interviewed said they would vote for the incumbent candidate.

In the statements above, each reference class is finite (the class described by the subject is fixed or limited in number, or we might call it a closed class). So in principle a test could be run to seeif the sentence is true or false; or a specific observation whose effect could be measured, and it could be repeated to establish 'directly' in one or a few episodes, to verify that the sentence is true or false. This is what is meant by saying the statement is verifiable. It is able to be verified 'directly' through experience on one or just a few occasions.

We rely on this kind of statement to report what is called evidence or data, or research findings, or experimental results or observation statements

In an enumerate inductive argument, these are the premise. We call this type of argument 'enumerative' because we are enumerating, or counting up, the instances in favour of a hypothesis which is presented as the conclusion of the argument. The evidence is said to confirm the likelihood of the conclusion. The morn instances in its favour, the stronger the confirmation **Activity 1.1**

Identify the finite reference class of verifiable statements

For statements 1-8 above, explain why each reference can be directly testable. Explain in particular for statements 6-8 how you can tell the reference class is finite.

Compare the verifiable statements 1-8 above with the following confirmable statements or hypotheses that all have reference classes which are infinite, examples 9-18 below. To say the reference class is infinite means the statement refers to uncountably many members belonging to a class that may exist at anytime and anywhere. There is no way to count them all, therefore no way to perform any observation that will eventually determine directly whether the statement is trueor false. Hypotheses are therefore not directly testable. But to be scientific, a statement should be confirmable i.e. indirectly testable—testable in the way described in the next section.

Examples of confirmable statements or hypotheses:

9. All metals expand when heated.

10. Planets move in elliptical orbits around the Sun.

11. Heavy smokers have a carbon film on their lung tissue.

12. Mammals require oxygen for life and mammary glands to feed their young after birth.

13. No student registers unless forced.

14. All voters prefer a recount of the ballots.

15. Some cow meat from England is infected with lethal bacteria.

16.80% of all retailed stones are not real diamonds.

17. Few Ghanaians are allergic to pineapple.

1 8.90% of those who contract the human equivalent of mad cow disease die from eating the infected beef.

Activity 1.2

Identify the infinite reference of confirmable statements

1. In statements 9-18, explain why the reference class cannot be directly testable.
2. Among statements 11-18 some do not include the words ‘all’, ‘each’ or ‘every’; explain how it is you can tell that the reference class is infinite.

Summary

We have observed that some statements are verifiable, that is, able to be tested directly in one or a few episodes of controlled observation and measurement. We use the word ‘Verified’ in this technical sense of the word. This requires that the sentence is an observational report, again this means that the attribute reported is measurable; it can be determined by one or a few episodes of investigation, whether the attribute applies to the individuals referred to in the reference class; the statement can be determined or verified as true or false.

Verifiable statements can function as evidence to support hypotheses.

We have observed that some other statements which are not verifiable are instead confirmable,that is, they are able to be tested indirectly. Confirmable statements are determined as likely to be true or false indirectly by other statements. Verifiable statements which are directly testable provide the information that supports or rejects those that are indirectlytestable. To be testable means the truth or falsity is determinable by anyone with appropriate training. To be testable means it is possible for someone to learn what to do to tell if the statement is true. To be testable means there is something to look out for, to tell whether or not the attribute described in the statement applies to members of the reference class.

Statements which are not testable in this way do not properly belong to natural science or social studies. They are called pseudo-scientific. We will look at these in the last section of this Unit. In the next two sections we will examine the relation between directly and indirectly testablestatements as the relation between the premises and conclusion of an enumerative inductive argument.

Section 2 Why Statistical Hypotheses Have Less Predictive Power than Law-Like Hypotheses

Introduction

The reference class of any hypothesis is infinite. But a law-like hypothesis admits of no exceptions. A statistical hypothesis always admits of some percentage of exceptions. So a statistical hypothesis is more likely to be true than a law-like hypothesis. But if true, a law-like hypothesis has more predictive power than a statistical hypothesis.

Objectives

- To contrast law-like and statistical hypotheses

Law-like Hypotheses *vs.* Statistical Hypotheses

Below are reprinted the statements in the list 9-18 that we presented in Section 1 above as confirmable statements.

9. All metals expand when heated.

10. Planets move in elliptical orbits around the Sun.

11. Heavy smokers have a carbon film on their lung tissue.

12. Mammals require oxygen for life and mammary glands to feed their young afterbirth.

13. No student registers unless forced.

14. All voters prefer a recount of the ballots.

15. Some cow meat from England is infected with lethal bacteria.

16.80% of all retailed stones are not real diamonds.

17. Few Ghanaians are allergic to pineapple.

18.90% of those who contract the human equivalent of mad cow disease die from eating the infected beef.

The first six in the list are what we call law-like hypotheses. They have the form:

All Fs are Gs (i.e. Each F is a G) or No Fs are Gs (i.e. All Fs are non-Gs)

Whereby F is the infinite reference classnamed by the grammatical subject of the sentence, and G is the attribute class, indicating the property being attributed to all members of the reference class. For example in item (12) the reference class is infinite—all mammals— and the attribute class is the requiring of oxygen and mammary glands.

This is why these statements are called law-like. Each hypothesis is a prediction that 100% (all Fs, each F, every F) have G, or that0% of the reference class F (no F, none of F) belong to the attribute class G. In other words, a law-like statement is trying to attribute the property G to every individual F without any exception whatsoever. That is to say, it is absolutely a law of nature that each and every F will have G. This means it is a regularity without any deviation at all.

Remember that in Unit 5 Section 1, when we introduced the notion of a scientific law or natural law, we said these universal negations and affirmations can be understood as disguised predictions. Restated, each of these hypotheses (9-12) can be read as follows:

9. lf x is a metal then x will expand when heated.

10. If any x is a planet then x follows an elliptical path around the Sun.

11 If x is a heavy smoker then x has a carbon film on his or her lung tissue.

12. If x is a mammal then it requires oxygen and must provide milk for its newborn.

Activity 2.1

Every hypothesis is a disguised prediction

1. Read statements 13 and 14 and translate each into a conditional, as done above for 9-12.

2. Create your own law-like statement; then translate it into a conditional to reveal its hidden predictive value.

Statements 15-18 are statistical hypotheses, such that some percentage less than 100% and more than 0% of the reference class has the property described in the attribute class. The percentage may not be mentioned explicitly, but instead referred to vaguely by the terms ‘hardly any’, ‘few’, ‘occasionally’, ‘some’, ‘most’, ‘many’, ‘typically’, etc. Restated as predictions, these could read:

15. Of all the consignments of cow meat imported here from England, some of the consignments will contain carcasses of meat infected with lethal bacteria.

16 Of any ten retailed stones, only two will be real diamonds.

17Activity 2.2

Translate statistical hypotheses as predictions

1. Do the same as above for items 17 and 18 in the list.

2. Create your own statistical hypothesis. Translate it into a condition to show the hidden prediction that it will express.

Predictive power and falsifiability

In order to appreciate the difference between the results of inductive reasoning (confirmation) and deductive reasoning (proof), we have to understand the difference in predictive power between a true law-like hypothesis which admits of no exceptions, and a true statistical hypothesis, which has exceptions built into the expectation builtinto the expectations it gives us.

Consider the contrast between

(i) All Legon Hall residents play football once a week,

(ii) Legon Hall residents play football at least once a week.

Each of these is a prediction (i)iswhat we call a law-likehypothesis, telling us that if an individual x is a Legon Hall resident then x will play football once a week.

(ii) Is a statistical hypothesis, and it tells us that for every 100 Legon Hall residents, 40 will play football at least once a week. In other words (ii) makes the prediction that if x is a Legon Hall resident then the chances are 4 out of 10 that x will play football once a week or more than once a week. Or, of any 100 Legon Hall residents, x will be in the group of 40 with the attribute of playing football at least once a week.

Now consider something very peculiar:

Which of these statements is more likely to stay true, as you encounter Legon Hall residents one at a time and check to see if they have this attribute? Clearly, (ii) is more likely to be true; because if you encounter a Legon Hall resident who does *not* play football at all, then (i) will be proven false—because (i) admits of no exception: for prediction (i) to stay true, every single Legon Hall resident must play football exactly once a week. This is a very strict condition for being true. If even one Legon Hall resident doesn't play football at all, or plays twice a week, then (i) will be false. But (ii) will stay true; because the truth conditions for (ii) are much more relaxed. Hypothesis (ii) is making a weaker prediction.

Read it again: (ii) is telling us that some L/H residents won't play football at all 60% don't, according to (ii), or any of the 40% L/H residents who do play football will play more often than once a week — hypothesis (ii) doesn't even specify how often they will play. So lots of scenarios are consistent with (ii) being true. That is, (ii) being true tells us much less than (i) does about what to expect concerning the football habits of Legon Hall residents. That is because there is far less opportunity for hypothesis (ii) to be false, than for hypothesis (i) to be false. The truth of hypothesis (i) is very restrictive: (i) will turn false provided even oneL/H resident fails to play football less often or more often than once a week. If even one L/H resident doesn't play at all, (i) will also be false, (i) is far more likely to be false than (ii): (i) is far more dependent upon the way the world is for its truth than is (ii). Therefore if (i) is true, it gives a far more detailed impression of facts that obtain in the world than does (ii).

There are fewer situations that will make (in raise than will make (i) false, but those situations could exist, (ii) will be false if less than40% L/H residents don't play football, and (ii) will be false if less40% play less than once a week. Many other situations obtaining will make (ii) false. But all these situations will also make (i) false. So we say that (i) is more falsifiable than (ii).

Indeed (i) is very likely to be false. There are students in L/H who have suffered polio and stay away from the football field altogether. Some students don't know how to play football some know how but don't care to play. Many of the women at L/H who are residents might know how to play and want to, but have no opportunity to play once a week. Given all these conditions (ii) might stay true but (i) would be false.

If (i) is actually true, then a very specific and detailed state of affairs must obtain; and so if (i) is true and you are told about it then you can make a very exact prediction about Legon Hall residents' football playing behaviour than if you are told (ii).

Both of these hypotheses may be true but law-like statement (i) is more valuable as an empirical hypothesis if it is true, because it is more vulnerable to being false. Ironically, if both these statements are true, then law-like hypothesis (i) is more valuable to us, providing us with more information about the way the world is than does the statistical hypothesis (ii), because (i) is less likely to be true than (ii).

Read the two statements (i) and (ii) again. Hypothesis (ii) can lead you to make predictions but the result is vague compared to the hypothesis suggested by (i): for instance the statistical hypothesis (ii) will be true no matter how many times over one week the Legon Hall group of footballers play. And from (ii) you know that out of any 10 or 5, how many will likely play, but you don't know which ones it will be. That is, for any individual resident, there is no way to tell from the truth of (ii) whether this individual belongs to the group that plays at least once a week or whether this individual belongs to the larger group that does not play once a week.

Further, from (ii) you know that 40% of the residents play at least once a week, but (ii) does not tell you exactly how often in fact they play, (ii) doesn't tell you about any one particular individual at all, actually.

So (ii) gives you much less information, if it is true, than would hypothesis (i). If hypothesis (i) is true, then it gives you n specific bit of information about every single Legon Hail resident. So (i) has more empirical content thanhypothesis (ii). Hypothesis (i) has more predictive powerthan hypothesis (ii). But this is precisely because hypothesis (i) is less likely to be true than is hypothesis (ii). More things could happen that would undermine the truth of (i) than of (ii). (ii) is more certain to be true than (i). The conditions that make (ii) true are far more liberal and varied than the conditions required for (i) to be true. The truth of (ii) is more impervious than (i). We say (i) is more falsifiable than (ii), and therefore it has more empirical content and more predictive power than (ii). And for that reason (ii) is also less valuable than (i) as anempirical hypothesis. In the natural sciences, in social studies, and in creative liberal arts scholarship, uncertainty is a virtue.

Summary of this section

Statistical hypotheses are more likely to be true than law-like hypotheses, but law-like hypotheses, if true, have more empirical content than statistical ones. Particular, verifiable statements are less likely to be false than hypotheses, but they tell us far less about the world generally; particular observation statements are verifiable and their truth can be tested directly, but they carry no predictive power at all.

Hypotheses are disguised or implicit predictions. This is because every hypothesis, be it statistical or law-like, can be framed as aconditional [if ____ then ____] statement. So empiricalcontent can be understood as predictive power.The more likely a statement is to be false, the more predictive power it has. In Section 5 of this Unit we will explore this in even more depth.

In the next section we will consider the relation of evidence to these hypotheses as the relation between the premises and the conclusion of an inductive argument where the more evidence accumulated in favour of a hypothesis, the more the premises confirm the probability of the conclusion's being true.

SECTION 3: THREE EXAMPLES OF ENUMERATIVE INDUCTION: CONFIRMATION IS NOT PROOF

Introduction

Hypotheses are constructed in relation to evidence. To appreciate the support that evidence provides for an hypothesis, we need to understand the type of reasoning called 'enumerative induction'.

Objectives

- To appreciate that the type of support given by evidence to an empirical hypothesis is not the same as the support of premises that prove a conclusion deductively, thanks to rules

  of inference and independent of the statements' contents. Thus we speak of inductive reasoning.

- To understand the way an hypothesis 'goes beyond' the evidence. Thus we speak of inductive reasoning.

- To see why supporting evidence confirms but does not prove the truth of a hypothesis. This is the key distinction between deductive and inductive reasoning, as introduced in Unit 6.

- To recognise that an inductive argument based on a statistical hypothesis confirms but cannot prove the conclusion

Here is an illustration of Enumerative Induction where the conclusion is a Law-like Hypothesis.

Consider the basis for conjecturing statement (9) in Section 1.

In the following argument, the premises (i-vii) are directly testable or verifiable.

Premises (i-vii) are called data, evidence, findings, research results, observation reports, experimental outcome, and in this argument, these premises do support the conclusion. So the conclusion is said to be confirmed by the premises. Recall that another name for a conclusion in an inductive argument is the hypothesis.

Because theconclusion is going ‘beyond’ the sample of individuals where tests can be conducted (either it is referring to a future case or an infinite class of cases) we say thatthe conclusion is indirectly testable. Premises (evidence):

i) This silver spoon was heated to 400°F and expanded.

ii) This copper wire was heated to 120°F and expanded,

iii) This iron bar was heated to 800°F and expanded, iv)

This mercury was heated to 100°F and expanded,

v) This aluminium pot was heated to 350°F and expanded.

vi) This gold ring was heated to 500°F and expanded.vii)This tin strip was heated

to 275°F and expanded. viii)Summary of data: All the metals that were tested

expanded when heated.

Conclusion (hypothesis): All metals expand when heated.

Statements (i-vii) constitute individual observation reports or test results. The statement (viii) is a summary generalisation of all these observation reports. Notice that above the solid line all the statements have reference classes that are finite (in summary generalisation (viii) as well: ‘all the metals tested is a finite collection of metals) and they are all verifiable. The conclusion beneath the solid line is a hypothesis: notice its reference class is infinite (it refers to all metals for all time, past and present and future, anywhere). And so it can only be confirmed (never proven) by the evidence presented in the premises above the solid line.To prove the conclusion we would have to know it must always be true without any exception. And although this may be the case, we cannot know this from the premises given. The data or the evidence provided only gives us a very good reason to believe that this conclusion is very likely to be true. And there is no evidence to the contrary, according to this argument. So if we assume this evidence is complete, in that it leaves out no relevant data, then we have evidence that confirms the hypothesis to a very high degree of probability.

It is worth reviewing intuitively why confirmation does not provide an absolute proof of the truth of this conclusion, but rather provides a degree of certainty of the likelihood that the conclusion is true. Getting any number of metallic substances to expand by heating them certainly cannot provein the sense of providing a guarantee that all metals everywhere at any time must expand when heated. Thousands of successful trials cannot rule out the logical possibility that some future test result will yield evidence of a metal somewhere at sometime in future that fails to expand no matter how much it gets heated. This is why empirical test results are not treated as deductive proofs of the hypotheses that they confirm.

As it happens, there are synthetic metals that have been produced which are called superconductors and never absorb energy, so they remain at absolute zero when energy is introduced; they never expand. So in fact this hypothesis is false. But it is confirmed by this evidence. According to this data, the hypothesis is in fact likely to be true, although in fact (as we can learn later, or as states of affairs change) it is in fact false. For a good inductive argument, therefore, there is no logical contradiction between the premises being true and the conclusion being false. Inductive reasoning is quite different from deductive reasoning.

Enumerative induction will confirm a statistical hypothesis more often than a law-like hypothesis.

Recall the list of statements-9-18 appearing in Section 1 of this Unit and earlier in Section 4. The statements 15-18 on that list are statistical hypotheses, such that some percentage less than 100% and more than 0% of the reference class is claimed to have the property described in the attribute class.

Examples of confirmable statements which are statistical hypotheses:

15. Some cow meat from England is infected with lethal bacteria.

16. 80% of all retailed stones are not real diamonds.

17. Few Ghanaians are allergic to pineapple.

18. 90% of those who contract the human equivalent of mad cow disease die from eating the infected beef.

Statistical hypotheses can also be the conclusions of enumerative inductive arguments following the same form of argument as you just observed in this section. Statistical hypotheses more regularly reflect the prediction that is supported by a body of evidence.

Consider two examples where statistical hypotheses are morefaithful to the data than a law-like hypothesis:

Two further illustrations of enumerative induction where the conclusion is a statistical hypothesis.

First example of evidence supporting a statistical hypothesis—

Premises:

1. The first rat fed with charcoal-burnt cow meat developed a brain tumour in 200 days.
2. The second rat fed with charcoal-burnt cow meat did not develop a brain tumour.
3. The third rat fed with charcoal-burnt goat meat developed a brain tumour in 215 days.
4. The fourth rat fed with charcoal burnt pork did not develop a brain tumour.
5. The fifth rat that ate the charcoal burnt-pork developed a tumour in 180 days.
6. The sixth rat ate the charcoal burnt cow meat and got a tumour in 63 days.
7. The seventh rat ate the charcoal burnt chicken meat and got a tumour in less than two weeks.
8. The eighth rat got a tumour in 250 days after starting on the charcoal-burnt cow meat.
9. The ninth rat eating charcoal-burnt mutton had a brain tumour after 90 days.
10. The tenth rat fed with charcoal-bun it bush meat developed a Drain tumour in one year.

Summary of data: Eight of the ten rats studied developed brain Sumours.

Conclusion: 80% of all rats fed on charcoal-burnt meat develop brain tumours, (that is, charcoalburnt meat is carcinogenic in rats.)

Second example of evidence supporting astatistical hypothesis

Premise:

In a sample of 20 patients who ate cow-meat infected with the lethal bacterium and who contracted thehuman equivalent of mad cow disease, 18 of the patients died shortly after eating the infected beef.

Conclusion: 90% of people contracting the human equivalent ofmad cow disease will die of eating infected meat, (that is, the human equivalent of mad cow disease usually is fatal.)

In the second example, the premise above the solid line is a summary generalisation of observation reports; it is verifiedby cross-checking each of the test results or repeating the experiments that it summarises. In both examples, the conclusions below the solid line are statistical hypotheses referring to any group (of rats and of people, respectively) under the specified conditions, and attributing a property that will be found in a high percentage of cases (cancer and death, respectively). These hypotheses are said to be confirmed bythe evidence reported in the premises above the solid lines. They are not proven in the sense that deductive proofs provide a guarantee of mathematical theorems.

Arguments based on statistical hypotheses

It is not always that inductive reasoning starts with particular statements and ends with a general statement. We observed this in a general way in the first section of Unit 6. In section 1 and 2 we focussed on the structure of enumerative inductive reasoning, where you add up from an accumulating collection of individual observation reports describing data; the more verifiable observation reports provided in the premises that support the conclusion, the likelier the concluding hypothesis is of being true.

However sometimes arguments include hypotheses in the premises. You can project from a statistical hypothesis to draw an inductive conclusion about a particular future case.

Consider the following argument where the evidence cited in the premise is itself a statistical hypothesis.

Premise 1: 90% of Legon Hall residents play football at least once a week.

Premise 2: Jonathan is a LegonHall resident.

Conclusion: Jonathan plays football at least once a week. Notice that these premises do not guarantee the conclusion will be true. This is because Jonathan might be in the 10% for whom the attribute of playing football at least once a week does not apply.

But because of the very high percentage of Legon Hall residents who do have this attribute, we have a good reason to believe that the conclusion is likely to be true. This is therefore an inductive argument. The conclusion is a prediction that goes beyond the premises.

Contrast this argument with the modus ponnes deduction that emerges if the hypothesis in the first premises were to be law-like:

Premise 1: All Legon Hall residents play football at least once a week.

Premise 2: Jonathan is a Legon Hall resident

Conclusion: Jonathan plays football at least once a week.

Here you have a valid deductive syllogism! From the law-like hypothesis in the first premise, if it were true, then necessarily the conclusion must follow. So you can see that the predictive power of a law-like hypothesis is quite different from that of a statistical hypothesis. The lawlike hypothesis is more likely to be false, as we discussed in Section 1 of this unit. But if it is true, then we can know much more about the sporting habits of Legon Hall residents than we can learn from a statiscal hypothesis on the same topic.

The contrast between using a statistical hypothesis as premises of an argument and a law-like hypothesis as the premise of an argument marks thedifference between confirming a conclusion inductively and providing a statistical hypothesis on the same topic.

Contrast the difference neatly using syllogistic form:

If the *X* percent stands for all (100 percent) or none (o percent) Fs are Gs then the conclusion is called a universal generalisation or law-like hypothesis. When xpercent stands for more than 0% and less than 100%, F's (for instance some, few, many, most) then we call the conclusion a statistical hypothesis or a statistical generalisation. It follows that we can show schematically two examples of general hypotheses functioning as premises to draw particular inductive conclusions.

In the two argument schema below, F stands for the reference class of the statement; G stands for the attribute class of the statement; *a* denotes some particular person, entity, event, or class:

(i) Statistical argument form:80% of all Fs are Gs.A is an F. So A is G.

(ii) Law-like argument form:100% Fs are Gs.A is an F. So A is G.

Summary

Recall we considered in Unit 4 that in social studies, we rarely are able to arrive at law-like hypotheses that are not trivial. It may be noted that the human sciences pursue particular statements based on evidence or upon statistical hypotheses. So the results are not very steady or certain as they can be in physics or other statements that can operate on law-like hypotheses as their first principles. But that is not a drawback of social studies. Sweeping generalities tend to be uninformative about human behaviour.

Arguably, social studies researchers are in most cases looking for explanations of differences between societies, between cultures, between historical cases of revolution for example. Social scientists rarely seek law-like statements at all, for they are not interested in the uniformities and absolute regularities of human experience—these are largely truistic and commonplace. Law-like generalities that hold true of human beings are banal. Rather, it is the uniqueness of distinct human situations, the peculiar features of this revolution, not what is true of ail revolutions, for instance, that are of interest. This may be another way of accounting for the differences we witness in the methods and the models of explanation that distinguish the human from the natural sciences, as we began to survey in Unit 4.

SECTION 4: UNCERTAINTY AS A VIRTUE AND THE **PRINCIPLE OF TESTABILITY IN** SCIENCE

Introduction

We saw in Section 4 that, in general, the more falsifiable a statement is, the more predictivepower it has, and the more empirical content ithas, so the more valuable it is in giving us a picture of how the world is. The more likely a statement is to be false, the more information its truth provides us about the world, if in fact it is true. We saw this in Section 4 by comparing two statements: one was a law-like hypothesis, the other a statistical hypothesis.

But this is a counter-intuitive and very peculiar fact about empirical knowledge so we will spend this section spelling it out.

The ideas in this section of the Unit are amazing. They are perhaps the most unexpected features of knowledge that you will encounter in this whole course. If you don't get it right away, read it again. Read it again tomorrow. Expect really interesting ideas to take a while to understand.

Objectives

- To recognise the connection between a statement's being falsifiable and its having empirical content and predictive power
- To appreciate that a statement which can never be false is empty of empirical content
- To understand what it means to call a statement a pseudo-hypothesis

The relationship we just witnessed in Section4 between degree of falsifiability and predictive power leads to a very unexpected feature of empirical knowledge in the humanities and in social studies and in the natural sciences, but this does not mean as scholars and scientists that we seek absolute security that everything we claim to know can never be contradicted and must never be questioned.

It means rather that as a critical thinker you should never be shy of controversy. You should question and challenge what people say, especially people presented to you as experts and authorities. If someone is incapable of robust controversy over something they take to be true, then their knowledge base is not resilient and unlikely to be worthy of your serious consideration as an intellectual in any walk of life.

Surprisingly, the more certainty we can claim about a statement, the more we have no reason to wonder if the statement is true, the less useful it is in telling us about the world encountered through our systematic, carefully recorded experience and inquiry.

That is to say, as we just saw in the last section, for any statements you compare that describe the way the world is, the one that is providing the most information about the world (the one that has the most ‘empirical content’ and the most ‘predictive power’) will be the statement that is the most vulnerable to being false. This is because a statement that provides a lot of detail about the way the world is will be a statement whose truth requires that the world be a certain way—the more detail the statement describes, the less its truth can admit of deviation from a particular state of affairs. If this is puzzling or hard to understand, don’t be surprised! It is not at all what you would expect. We will witness this odd feature of truth through examples in the next exercise.

Certainty about our descriptions of the world as scholars and scientists is an odd sort of virtue. Although desirable, certainty is not actually a direct goal of research in any empirical science or social studies subject area or liberal arts discipline that you will pursue in university.

As scholars and scientists, we try to formulate hypotheses and claims about the world, hoping these claims will be true, but we must ensure that the claims we make are able to be false: otherwise the empirical hypotheses or statements we produce will not be not saying anything about the world.

If we propose a thesis about human society or human personality or economics or cultural geography or geography or an exegesis of sacred scripture, or an interpretation of a poem, which is certain to be true and about which there is nothing that anyone would disagree, your supervisor is likely to tell you that the thesis is uninteresting. The way the world is must make some differenceto the truth or falsity of an interesting thesis that you propose.

As an empirical scientist or humanities scholar you need to propose hypotheses or theses that are testable,that is, there should be something to look for, some experiment that can be conducted or an investigation to pursue, or a debate to engage inwhose results will indicate whether your thesis is likely to be true or likely to be false. If there is no way at all for the thesis to be false, then there is nothing in particular about the world that we can learn from its being true. If a statement remains unassailable no matter what happens, then its being true is not revealing anything about the way the world actually is, rather than how it might be. Such a statement contributes nothing to explain or predict the occurrences and states of affairs that we are likely to observe. It has no explanatory nor predictive power. We call such a claim a pseudo-hypothesis.

Let’s look at examples of this oddity, that an empirical description which can never be false, which can be embraced with complete certainty, fails to tell us anything about the way the world is in fact.

(Notice when we make this demand that a statement must be falsifiable to be useful, we are talking only about descriptive statements referring to the empirical world, not about statements of mathematics or rules of logic or principles of morals.)

For example, suppose that when you ask me what the weather is like outside, I tell you:

(i) ‘Either it is raining or it is not raining.’

Although what I have said is unassailably true, true no matter what is happening with the weather, it is thereby vacuously true, empty of empirical content, because it doesn’t give you any anticipation of what the weather will be like when you get outside. Similarly if I reply to your query:

(ii) ‘If it is raining, then something outside this building will got wet;’

Then again I have told you something which is empty of empirical content, in the sense that whether or not it is raining outside, my statement will be true. My statement will be true if it is raining here and not raining over there; it is true if the sky is sunny; it’s true if it is snowing, if we are in a drought. No matter what the weather is like, my statement will be true.

It is not able to be false. So again I haven’t given you any information in answer to your query, although what I have said in reply is unassailably true. Indeed for that very reason, what I have said is useless to you because you wanted to know about the weather outside now, and what I have told you could never be contradicted by any experience you might have under any weather conditions. So what I have told you gives you no reason to expect the weather to be one way rather than another; my statement (ii) has no predictive power.

To satisfy your query, the sort of reply that is required will be true only under certain weather conditions and false under all others, e.g.

(iii) ‘It is raining directly outside this building now.’

Then by accepting this statement as true, the report (iii) supplies you with a set of expectations about the weather outside now—if those conditions do not prevail, (iii) is false. So if (iii) is true, your believing it provides you with expectations which amount to information about the weather conditions that do in fact prevail. In contrast, (i) and (ii) are not able to be false; so their being true gives you no expectations about the weather now because their truth is not dependent upon any particular conditions prevailing.

So knowing (i) and (ii) to be absolutely true is to know nothing about the weather as it is now. This is why (i) and (ii) are said to be empty of empirical content. An unfalsifiable descriptive hypothesis of this kind is useless in science; it is called a pseudo-hypothesis(‘pseudo’ means ‘fake’ in Greek).

The capacity or abilityof a true descriptive or explanatory statement to be false is so crucial to its value in any empirical science that falsifiability has been used as the central standard for a statement to be suitable for scientific discourse or for entry into rigorous social studies. This was a principle recognised by the logical empiricists known as the Vienna Circle in the 1930s and was later popularised by Karl Popper in the mid-twentieth century.

We can take the point a step further and appreciate that there are degrees of predictive power that can be discerned by comparing the degree of falsifiability between statements. That is, the more falsifiable a statement is the more empirical content it provides.

Contrast (iii) above with the following statement:

(iv) Every third Friday it rains outside this building.

Now, consider that the reference class of (iv) is infinite (it refers to an unlimited number of Fridays). If (iv) were true it would tell us a great deal more about the weather than does (iii). But (iv) is very likely to be false. It would take only one future episode to contradict (iv). If we wait three weeks from Friday; then if it does not rain, (iv) will be false. But (iii) would be true, insofar as the statement made by (iii) refers to the weather outside this building at the time it is uttered, that is, today.

What happens three weeks from now is of no significance to the truth of this particular statement. We can see therefore that (iv) is more falsifiable than (iii). Therefore (iv) provides more predictive power than (iii), exactly because (iv) ismore vulnerable to being shown false. Therefore so long as it is true, it is more valuable as an empirical statement than (iii).

Contrasting degrees of empirical content

Activity 5.1

Compare the scope of reference of these statements and see how the greater the scope, the greater the falsifiability, and therefore the greater the empirical content (or predictive power) of the statement.

1. The Earth's orbit around the sun is elliptical.

2. All the planets that were discovered by Kepler before 1620 AD have elliptical orbits.

3. All planets have elliptical orbits.

Activity 5.2

Examining degrees of falsifiability

1. Which of the following statements is the most falsifiable?

2. Which is not falsifiable at all?

3. Which gives the most precise information if it remains true in light of tests or new evidence?

4. Which is the least able to be false (which remains true in the face of the widest range of experience)?

A. 80% of the seedlings planted in the laboratory last month have developed mould around the pistil and stamen.

B 80% of seedlings planted in sandy soil treated with 'ROTRAID' pesticide will develop mould around the stamen and pistil

C. The seedling I placed in the last row of this plothas*no* mould around the stamen.

D. The insecticide 'ROTRAID' causes mould in flowering plants.

E. Either 'ROTRAID' causes mould in flowering plants or it does not.

F. 'ROTRAID' causes mould in flowering plants only if it has mycotic (i.e. mould-producing) properties.

G. 'ROTRAID' will produce mould within ten weeks of germination of seedlings, somewhere on the stamen, pistil, root or stem of the plant.

H. 'ROTRAID' will produce mould between the 56^{th} and the 63rd day after germination, and then only on the stamen of any plant's flower to which it has been applied.

For another, non-trivial, illustration of the contrast between a pseudo-hypothesis and a falsifiable hypothesis, compare Darwin's theory of evolution (D) with the following expression of the Creationist account of our origins (C).

(C): The universe as we perceive it now was created in 168 hours,6,066 years ago.

(D): The origin of life occurred in the oceans millions of years ago in such a way that:

i. The many species we witness today developed from very few types of single-cell marine organisms.

ii. The different species developed very gradually in a seamless continuum of incremental change accumulating over millennia.

iii. Species continue to develop always in response toenvironmental pressures that affect genetic mutations. So if an individual is able to survive long enough to reproduce its genetic endowment, then it produces offspring with characteristics similar to those that allowed the parent to compete successfully in changing environmental conditions.

A point should be made about the contrast between Darwin's evolutionary theory and the Creationist paraphrase from Scripture. Recall what we learned from Unit 1 that different statements serve different purposes: observation reports and empirical hypotheses describing and explaining the world as it appears through rigorous and systematic investigation are serving a different purpose than statements aimed at expressing value judgements or statements intended to provide spiritual inspiration or instruction or guidance. Not all important discourse in our lives is susceptible to the same type of logical analysis. Not all statements should be regarded on a par; some statements are not suited to compete with empirical hypotheses because they serve a different, equally important purpose in our lives.

We do many things with language besides report the way the world appears and build explanations about why it is the way it seems to be. The mistake some people make — sometimes very learned and highly prestigious people with influential jobs — is to confuse statements as theoretical or empirical claims when in fact they are not standing in contradiction at all with theoretical or empirical claims — because they are not falsifiable, they do not count as scientific in the first place. So they cannot contradict scientific claims. In other words by defending (D) in this exercise, we have not invalidated nor have we undermined or belittled the significance of (C).

A statement such as (C) above is susceptible to varied interpretations — it may be an allegory, a metaphor; it may express the ultimacy in value of the Divine as that which came before everything else and without which nothing else could come to pass. (C) surely is an example of a statement with multiple implicit as well as explicit meanings.

This is the domain of humanities imaginative speculation, literary theory and scriptural interpretation. This domain is governed by varied points of view, each of which is defensible with more or less success by appeal to competing first principles, to varied evidence, and careful deductive reasoning. Even when we stop parading (C) as a pseudo-hypothesis, it need not be treated as an inert, fixed and immutable component of dogma. When we cut off from the many layers of meaning a statement might have, we lose our capacity to access our own insights available through deeper reflection on our own experiences; and we lose the great opportunity to learn from other people with experiences different from our own.

Summary

Scientific and empirical knowledge generally has to be vulnerable to being false; it must be susceptible to constant revision in the light of new evidence. This is what makes it possible for knowledge to grow. This is where the metaphor of a Tree of Knowledge comes from. We have very little use for a statement that can never befalse when building a faithful and informative picturesof the world. The pictures we paint with descriptions and explanations in the natural sciences and social studies must be always in the process of updating.

In social studies as well as the natural sciences, we are always ready to revise or reject an hypothesis in the light of new evidence that snows us our initial expectation was wrong. As students of the natural sciences and social studies, we must constantly challengeand test the theories we are presented by authorities against our first hand experience and against contrary views we gain in the course of life outside the classroom. This is the only way to make substantive contributions to our favourite discipline. This is the making of world-class scholarship and scientific discovery.

And this is the way we should live our personal lives. To be sealed mentally inside a dogma, or to be dependent upon a single leader or group or fixed tradition by which we learn what to believe, means to be stuck with prejudices and limitations that we are never free to change. It means to give up the ability to grow by thinking critically and reasoning practically on one's own.

Assignment 7—Thinking exercise

Look for non-falsifiable claims that are presented as scientific hypothesis. These might turn up anywhere (in radio call-in discussions, newspaper editorials, and in your textbooks!) Explain in terms of their invulnerability to being false why these claims have no predictive and no explanatory power.

Unit summary

In the study of logic, it is important to keep separate in your mind the truth of a conclusion from the strength of an argument. Bad or weak arguments may turn out to have true conclusions, and good or strong arguments may turn out to have false conclusions. In inductive logic, the standards for strong arguments are designed to make it probablethat if the premises of the argument are true, the 'conclusion will be true as well, if we adhere to these standards, conclusions that are based on true premises will usually, but not always, be true.

In this unit you learned:

- The difference between verifiable and confirmable statements
- The way evidence supports a hypothesis in an enumerative induction.
- The way a statistical hypothesis can be relied upon as evidence.
- The way law-like statements are more valuable because they are more vulnerable to being false than statistical hypotheses.
- The reason why descriptive statements that are always true are regarded as pseudoscientific.
- The contrast between inductive confirmation and deductive proof.
- The value of uncertainty in building an accurate representation of the world.