Lecture 4: Risky business

Learning objectives

✓ Analyse information about probabilities and risks

✓ Interpret binary classification test tables

✓ Become a critical consumer of information

Scientific examples

✓ Breast cancer

✓ HIV screening

Maths skills

✓ Calculate probabilities

Binary classification test

A *binary classification test* aims to classify objects, people or things into one of two groups. Examples include many medical tests, such as determining whether or not an individual has (or is likely to have) cancer. The table below illustrates how we can represent the possible outcomes of such as a test in tabular form.

	Disease: Yes	Disease: No
Test +	true +ve	false +ve
Test −	false −ve	true −ve

"true/false" is the test correct

"+ve/−ve" outcome of the test

Most binary classification tests are imperfect: results can be *true positives*, *false positives*, *true negatives* or *false negatives*. Identify where these terms would each sit in the table above.

We can also represent this information in a *probability flowchart* which we can use to identify the number of true/false positives/negatives for a given test in a population.

Need "gold standard" test to separate true +ve / false +ve

Accuracy, sensitivity and specificity

The terms *accuracy*, *sensitivity* and *specificity* of a binary classification test are defined mathematically below. Explain what each term means and why it is important.

Disease

	Yes	**No**
Test +	A	B
Test −	C	D

$N = A + B + C + D$

$$\text{Accuracy} = \frac{A+D}{N}$$

= no. of correct tests / all tests

= proportion of all tests that were correct

$$\text{Sensitivity} = \frac{A}{A+C}$$

= of those who have the disease, sensitivity is the proportion who test positive

$$\text{Specificity} = \frac{D}{B+D}$$

= of those who don't have the disease, specificity is the proportion who test negative

$$\text{prevalence} = \frac{A+C}{N}$$

proportion of the population who have the disease (depends on disease, not the test)

another test "gold standard"

"the test"

Question 2.2.5

A paper [14] studied the effectiveness of combined mammography and ultrasound imaging to screen for breast cancer. A total of 203 patients returned "suspicious or malignant" test results, of whom 138 were later found to have cancer (via biopsy testing). A total of 2811 patients returned "normal or probably benign" test results, of whom 12 were later found to have cancer. Find the accuracy, sensitivity and specificity of the combined procedures.

We are told

All positive tests - 203

of these 138 => true positive

A = 138

Thus 203 - 138 = 65 false positives

B = 65

Also All negative tests = 2811

of these 12 => false negatives

C = 12

Thus 2811 - 12 = 2799 true negatives

D = 2799

$\text{Accuracy} = \frac{A+D}{N} = \frac{138+2799}{3014} = 0.975$ or 97.5%.

$\text{Sensitivity} = \frac{A}{A+C} = \frac{138}{138+12} = 0.920$ 92.0%.

$\text{Specificity} = \frac{D}{B+D} = \frac{2799}{65+2799} = 0.977$ or 97.7%.

	Disease: Yes	Disease: No
Test +ve	138	65
Test -ve	12	2799

N = 3014

$\text{Prevalence} = \frac{138+12}{3014} = 0.050$ or 5.0%.

Question 2.2.6

(a) What are some characteristics of a 'good' binary classification test?

High accuracy, sensitivity, specificity
often improve one, negatively impacts others (sens / spec)

(b) Identify some negative impacts of false positive or false negative cancer test results.

False true: unnecessary treatment, stress, side effects of treatment, cost

False negative: delayed treatment, serious illness, spread of disease

(c) When might a test with a higher false positive test rate be 'better' than one with a lower rate. Give an example in which it would be worse.

→ impacts on true negatives

- minise false negatives
  catch more people with disease

- high false positive - bad if treatment is expensive or risky

(d) Are false positive results 'better' or 'worse' than false negative results?

It depends !

Question 2.2.7

A paper [20] quotes an example in which 160 gynaecologists were asked:

"Assume you conduct breast cancer screening using mammography . . . You know the following information about the women in this region:

- *The probability that a woman has breast cancer is 1% (prevalence)*
- *If a woman has breast cancer, the probability that she tests positive is 90% (sensitivity)*
- *If a woman does not have breast cancer, the probability that she nevertheless tests positive is 9% (false-positive rate)* specificity 91%.

A woman tests positive. She wants to know whether that means that she has breast cancer for sure, or what the chances are. What is the best answer?

A. *The probability that she has breast cancer is about 81%.*

B. *Out of 10 women who test positive, about 9 have breast cancer.* 8 of 10 sick 1000

C. *Out of 10 women who test positive, about 1 has breast cancer.*

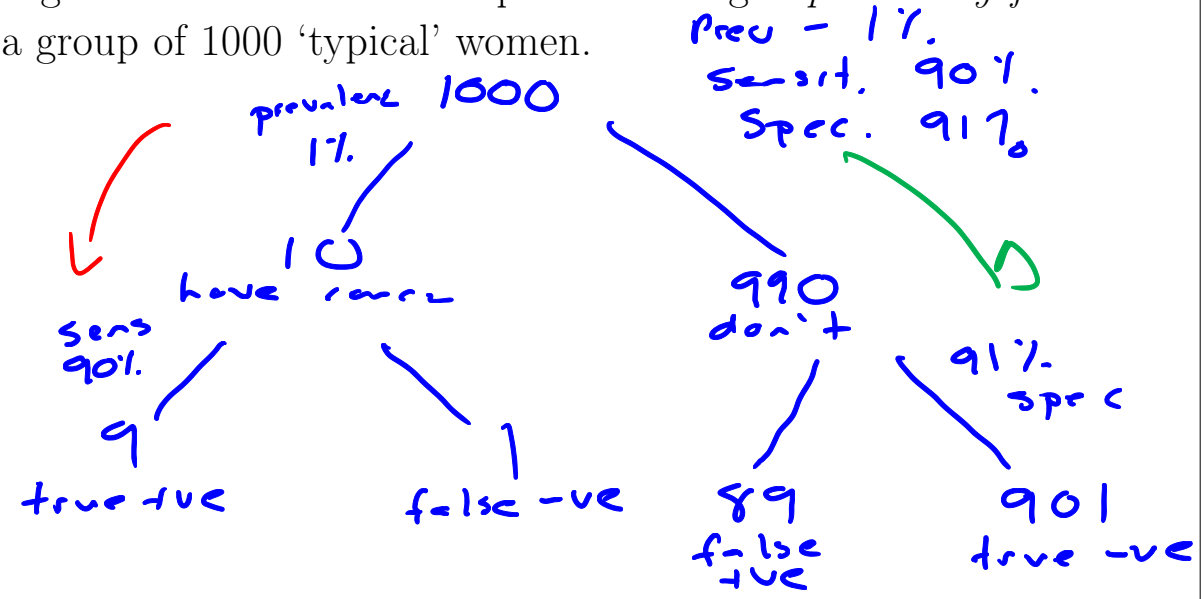
D. *The probability that she has breast cancer is about 1%."*

(a) Without doing detailed calculations, what is **your** answer?

Most common student answer is B
9 out of 10 have
breast cancer

Question 2.2.7 (continued)

(b) Investigate the answer to the question using a *probability flowchart* and a group of 1000 'typical' women.



(c) Repeat Part (b), instead using a binary classification table.

(what proportion of those who tested positive) have disease?

= have disease & +ve test / +ve test

= true positives / all positives = 9/(9+89) ≈ 0.1 or 10%.

(prev 90%)

	Disease: Yes	Disease: No
Test +ve	9	89
Test -ve	1	901
	10	990

(d) What proportion of gynaecologists do you think could answer Part (a) correctly? What are the implications for you and/or your female relatives?

21%.

after training 99% have correct

End of Case Study 1: Cancer.

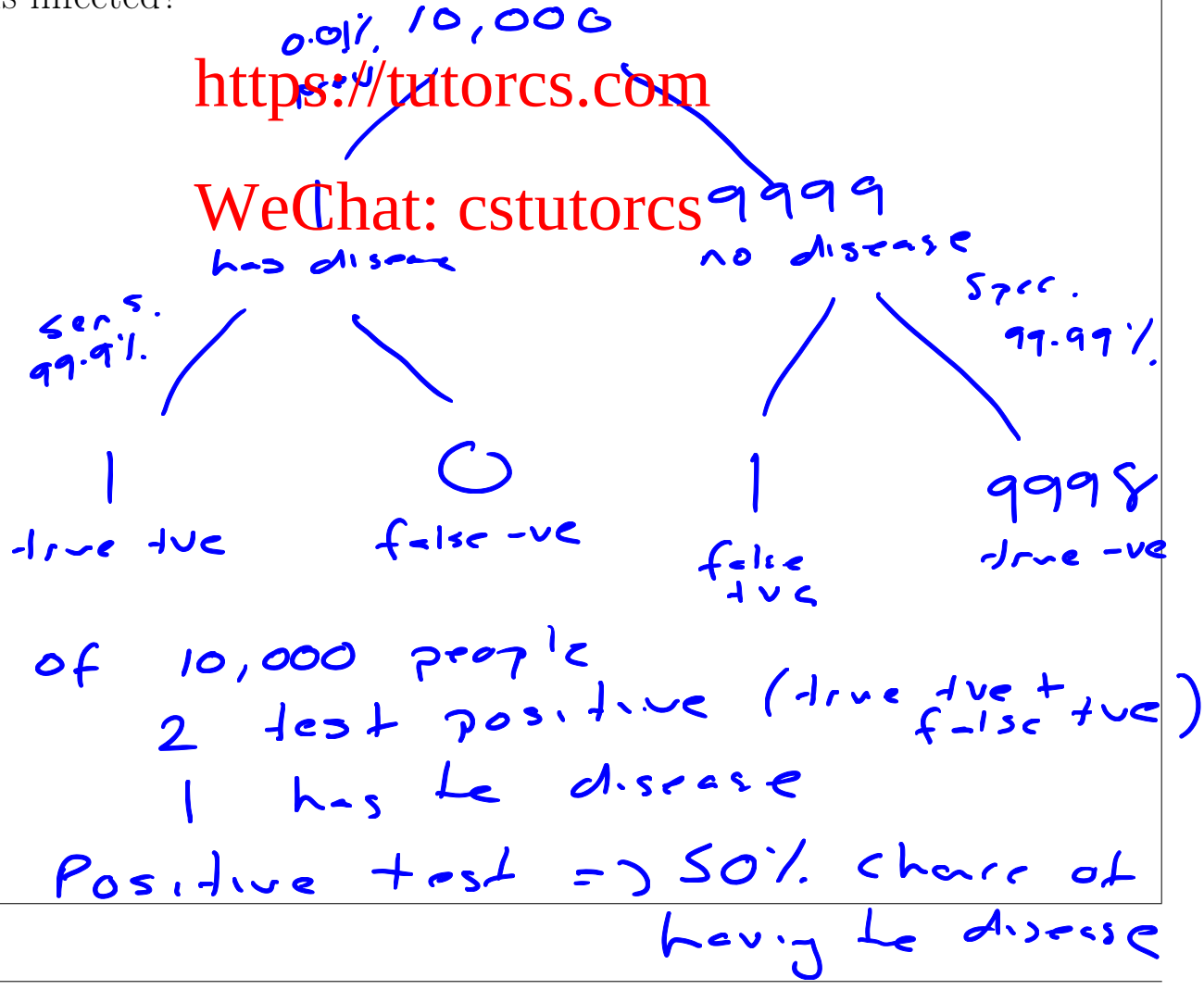
Question 2.2.8

In the 1980s, blood screening in Florida found that 22 people who had donated blood tested positive for HIV. Once notified of the test results, seven of these donors committed suicide. (At that time, HIV was not well known, and people were not regularly tested. Screening donors for the disease commenced after the discovery that transmission of HIV occurred through contact with infected blood.)

The HIV test has a very high *sensitivity* [percentage of infected individuals who correctly test positive] of about 99.9% and *specificity* [percentage of non-infected individuals who correctly test negative] of about 99.99%.

The *prevalence*, or rate of infection, for heterosexual men with low-risk behaviour, is around 1 in 10,000.

What is the (approximate) probability that someone who tests positive for HIV is infected?



Question 2.2.9

To investigate the quality of HIV counselling for heterosexual men with low-risk behaviour, an undercover client visited 20 public health centres in Germany, undergoing 20 HIV tests [20].

The client was explicit about belonging to a low risk group, as do the majority of people who take HIV tests. In the mandatory pre-test counselling session, the client asked:

'*Could I possibly test positive if I do not have the virus? And if so, how often does this happen?*'

The answers from the medical practitioners were:

No, certainly not	False positives never happen
Absolutely impossible	With absolute certainty, no
With absolute certainty, no	With absolute certainty, no
No, absolutely not	Definitely not ... extremely rare
Never	Absolutely not ... 99.7% specificity
Absolutely impossible	Absolutely not ... 99.9% specificity
Absolutely impossible	More than 99% specificity
With absolute certainty, no	More than 99.9% specificity
The test is absolutely certain	99.9% specificity
No, only in France, not here	Don't worry, trust me

(a) How would **you** answer the question?

False positives happen for 1 in 10,000 tests. A positive test doesn't mean you have the disease More tests is needed.

Question 2.2.9 (continued)

(b) Recall that the Australian Medical Association (AMA) website [2] states:

"...in order to support and enhance the collaborative nature of the doctor-patient relationship, patients must be able to make informed choices regarding their health care. An informed choice is dependent on receiving reliable, balanced health information, free from the influence of commercial considerations, that is communicated in a manner easily understood by patients."

Comment on the responses from the German doctors, relating your answer to your answers to Question 2.2.8 and the AMA statement above.

Responses either incorrect or not useful!
Poor communication!
Not easily understood by most patients.