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Personal Response Systems For Teaching Postgraduate Statistics To Small Groups

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Abstract

Technology is increasingly used to aid the teaching of statistics. Personal Response Systems (PRS) involve equipping students with a handset allowing them to send responses to questions put to them by a lecturer. PRS allows lectures to be more interactive and can help reinforce material. It can also allow the lecturer to monitor students' understanding of course content. PRS is most commonly used in large lectures where interaction from the students is particularly difficult. However, we consider its use in a small group (around 15 students) of MSc in Statistics students. Recommendations based on this experience are discussed, in particular the importance of good question design. We consider possible diagnostics for the appropriateness of questions based on response data.

1. Introduction

Technology is increasingly used in the teaching of statistics (Chance et al. 2007). Personal Response Systems (PRS) (also referred to as Electronic Voting Systems or Audience Response Systems) involve equipping students with a handset allowing them to anonymously send responses to questions put to them by the lecturer. Rudimentary versions of this type of technology have a history extending back to the 1960s (Judson and Sawada 2002), but have only become practical and affordable in their current form in the last 15 years. Modern systems use radio frequency transmitters to communicate students' answers from their handset to the lecturer's computer. The answers are then automatically collated by computer software and the frequency of responses can be displayed to the audience.

There has been an explosion in the use of PRS in the last 5-8 years. Abrahamson (2006, p.2) noted that "at almost every university in the USA, somewhere a faculty member in at least one discipline is using a response system in their teaching." Moreover, while PRS is primarily used in science-based courses, examples of use can be found throughout the spectrum of disciplines. In higher education, PRS is most commonly used in delivery of undergraduate courses to large groups. Most examples of use in smaller groups come from primary and secondary education levels (Abrahamson 2006). Use of PRS in postgraduate teaching seems to be limited to a small number of examples (Banks 2006; Eggert et al. 2004; Trapskin et al. 2005).

The degree to which use of PRS changes pedagogical practice varies considerably. At one extreme, Horowitz (2006) notes that many institutions only use PRS handsets to allow students to complete in-class tests that can be automatically marked. Conversely, some implementations have dropped the idea of lectures needing to cover course content and instead encourage students to read material beforehand. The lecture time is then a series of PRS questions to identify misconceptions and encourage discussion of the topics (Mazur 1997).

Retkute (2009) provides a recent review of the use of PRS in mathematics and statistics teaching. Existing applications of PRS in statistics have generally been in undergraduate introductory or service courses to large groups. For instance, the studies by Lass, Morzuch and Rogers (2007), McKenzie et al. (2006) and Mateo (2010) all implement PRS in lectures of over 100 undergraduates. Wit (2003) used PRS in introductory statistics for engineering tutorials involving around 210 students. A few studies have involved smaller groups, Mocko and Jacobbe (2010) used PRS in smaller introductory statistics classes of around 25 students. Koppell and Berenson (2009) used PRS for teaching introductory Business statistics to classes of around 30 students for both undergraduate and postgraduate (MBA) students. However, to our knowledge, there have been no previous studies into the use of PRS in postgraduate statistics teaching.

2. Motivation for use of PRS

There are several possible motivations for using PRS. The traditional model of higher education involving didactic delivery of courses to a passive audience is increasingly recognized to be inefficient (Larsen 2006). Moreover, changes to education delivery at high school level mean that students themselves have different expectations of higher education teaching (D'Inverno et al. 2003). Adoption of PRS has been used as a way to make learning in lectures active rather than passive.

Previous implementations of PRS in statistics teaching have mainly been in undergraduate service teaching or introductory statistics courses to large groups. Introductory courses taught to students for whom statistics is not their main subject are often unpopular and can suffer from attendance problems. PRS can stimulate increased student attendance by providing some added value to attending a lecture or tutorial. For instance, the introductory statistics tutorials in Wit (2003) had attendances that began at around 60% and fell to 10% as the course progressed. After the introduction of PRS initial attendance rose to 80% and fell to 40%, representing a marked improvement, albeit from very low levels. PRS has been found to be popular with students and to increase their enjoyment of a lecture course in a wide range of settings (Abrahamson 1998).

Another motivation for the use of PRS is through the general pedagogical principle of seeking dialogue between lecturer and student (Cutts et al. 2004; Lass et al. 2007). This motivation for PRS is particularly clear for large group teaching, where dialogue is difficult to achieve. Part of the purpose of developing dialogue is to give the lecturer an idea of whether the students understand the material and conversely to confirm to the student that they are (or are not) understanding. On a more basic level, PRS can provide a natural way of providing breaks within the lecture and provide a way of emphasizing new topics and consolidating material.

Since a major aim in previous uses of PRS in statistics (Wit 2003; Lass et al. 2007) has been to allow the transfer of small group teaching techniques into a large lecture setting, it could be argued that PRS is not necessary in small group settings where conventional (verbal) interaction between student and lecturer should be possible without the aid of technology. Banks (2006) argues that a reluctance to participate can also be present in small groups. In our experience, many students in statistics are reluctant to admit to not understanding a particular part of a lecture. Moreover, this reluctance often extends to not admitting when they do understand. PRS also allows a much broader range of questions to be posed than is possible through a lecturer verbally posing a question and waiting for students to volunteer an answer. Wait-time, the time taken by an instructor to allow students to respond to a question, is known to be crucial to the quality of discourse (Rowe 1974). In the traditional questioning setting, the lecturer may only wait a short time for responses meaning the questions will need to be quite simple (Abrahamson 2006). Through PRS all students are able to express their knowledge beliefs, regardless of their level of anxiety about doing so in front of others. For instance, Freeman and Blayney (2005) compared lectures where PRS was used in lectures that were identical except the use of a show of hands for answering multiple choice questions and found that both students and instructors felt that PRS facilitated greater overall participation.

3. Implementation

In our study, PRS was used in the Principles of Epidemiology module of the MSc in Statistics at Lancaster University. Typically, students had recently completed a Bachelors degree in Mathematics or Statistics. The course took place in the first term and was one of the first courses students encountered. The course consisted of 5 lectures, each of two hours duration, plus additional tutorials and workshops. PRS was used in the course in both 2008 and 2009. The class sizes for each cohort were 12-15 students.

Interwrite PRS® radio frequency handsets were used. For the purpose of equipping a small group, the system is relatively inexpensive with the receiver costing in the region of $120 and each handset costing about $40. Handsets were given out and collected in at the start and end of each lecture. This was unproblematic because of the small class size. The students were each given a unique ID number, whilst retaining an element of anonymity, so that the patterns of response for individual students could be tracked. A total of 22 questions were set for the course, each lecture having between 3 and 5 questions. The complete set of questions is given in the Appendix. All the questions in the course took on a multiple choice format. Despite this the questions were quite diverse in nature. Some questions were simply testing understanding of the definition of a particular concept. In other questions students were required to apply a method to example data and then choose the correct numerical (or algebraic) answer. The use of longer questions requiring lengthier calculations seems unique among implementations of PRS in statistics teaching.

PRS allows the lecturer to assign a time limit for a particular question. However, particularly for computational questions, it was difficult to decide *a priori* upon a sensible amount of time. As a result, an ad hoc approach was used where an initial guideline time was used, but extended if necessary so that the vast majority of students had a chance to respond. While the question is running the number of responses that have been received is displayed on the screen.

In most cases the same questions were used in both years. However, two computational questions from 2008 (Q14 & Q15) proved problematic - the students took a long time and had low success rates. Q14 was deleted entirely, while Q15 was split into two questions: Q14* and Q15*.

4. Analysis and Results

Students had no problems familiarizing themselves with the handsets and logging-in. The average time taken (per question) for all responses to be collected was 3m 18s in 2008 and 2m 52s in 2009, meaning in both years over an hour of the total 10 hours of lecture time was spent waiting for responses. The time for half the students to respond was 1m 17s and 1m 09s in 2008 and 2009, respectively. Across all questions the time for all responses ranged from 45 seconds up to 8 minutes. The percentage of responses that gave the correct answer was 65% and 78% in 2008 and 2009 respectively, and by question this ranged from 33% to 100%. Individually, students ranged from 46% of correct answers to 95%.

Both cohorts of students were given an online questionnaire to complete to evaluate their PRS experience. The response rates were about 70%. Students' attitudes to PRS were predominately positive, with 81% rating their overall impression as positive compared to 9% with a negative impression. Similarly 80% said they enjoyed using PRS in the lectures. Most felt it was useful for assessing their own understanding, but were less convinced it was useful for introducing new topics. The responses to the multiple choice questions are summarised in Table 1 and Table 2. Students were also asked to give the main advantages and disadvantages of PRS. A representative selection of the responses to these questions, from both years of implementation, is shown in Table 3. The advantages listed mostly mirrored some of the aims of PRS, e.g. to provide a way to break up lectures, to consolidate their understanding of the course and to ensure they understood the course content. Some students felt that the questions provided motivation to try to pay attention during lectures.

Table 1: Results of Yes/No questions in questionnaire

Question	Both Years		2008		2009	
	Yes	No	Yes	No	Yes	No
Have you ever used PRS before?	2	16	0	9	2	7
Was it useful to see other people's answers?	14	4	7	2	7	2
Did you enjoy using PRS?	13	4	8	0	5	4

Table 2: Levels of agreements with statements in the questionnaire

Statement		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
PRS was useful for assessing my own personal understanding and strengths and weaknesses	**Total**	**3**	**12**	**1**	**1**	**0**
	2008	1	6	1	0	0
	2009	2	6	0	1	0
PRS is useful for introducing new topics	**Total**	**5**	**5**	**4**	**2**	**2**
	2008	2	3	3	1	0
	2009	3	2	1	1	2
The use of PRS in lectures was an unnecessary distraction from learning the material	**Total**	**2**	**0**	**4**	**10**	**2**
	2008	0	0	2	6	1
	2009	2	0	2	4	1
Being able to answer questions anonymously using PRS was important to me	**Total**	**4**	**11**	**2**	**0**	**1**
	2008	1	7	1	0	0
	2009	3	4	1	0	1

When asked about the main disadvantage of PRS, despite students understanding that the results of PRS would not count towards their module mark and that their responses would be anonymous, several students said they felt the PRS questions put them under pressure. Two students felt that PRS was a waste of lecture time, particularly the time spent waiting for other students to respond, and that the time could be better spent giving additional examples. There was also a belief among some students that PRS was not a fair assessment of their understanding because they had not had enough time to reflect on the material - that the questions were introduced too soon. One student felt that PRS was not being used effectively, when the class performed badly there was not enough further explanation of why they had got it wrong. Nine students did not respond to the question on disadvantages of PRS, compared to three students for the question on advantages. All the non-respondents to the written questions rated their overall impression of PRS as positive.

Table 3: Range of responses to questions on advantages and disadvantages of PRS

In your own opinion, what was the main advantage of using PRS?

"Seeing worked examples and then finding out instantly where you have gone wrong."
"It provided an incentive to pay more attention to the lecture so that I could answer the PRS question."
"It was a good way to test my knowledge constantly."
"It encourages students to listen attentively and understand the new topic introduced by first asking them about the topic."
"It helped to break up the lecture, and was useful to shore up knowledge."
"Good method for including a short exercise in the lecture to make sure that each topic is understood. Very informal, it doesn't matter if you get it wrong!"
"It helps all students to get involved in the learning process."
"Nice to do when learning new topics as helps the understanding by having a go, especially for more complicated bits."
"Breaking up the lecture and checking understanding/doing an example."

In your own opinion, what was the main disadvantage of using PRS?

"The questions that can be asked is limited to basic questions and simple calculation, and so mostly not particularly challenging."
"I liked the PRS but felt nervous about getting the wrong answer."
"When responses by different students are displayed and you find that out of the responses only your response was incorrect. In this case, a student may be discouraged."
"Placed me under pressure and seemed to be a waste of time. More examples in this time period would have been a lot more useful."
"It is not a good method of assessing understanding of individuals."
"Sometimes, if you weren't sure what you were doing the clock counting down could get you a bit flustered."
"It wasted lecture time."
"I see no problem with it."

5. Choice and Evaluation of Questions

The success of an implementation of PRS is reliant on good question design. Beatty et al. (2006) proposed a framework for designing PRS questions. Their context was physics teaching, but many of the principles are transferable to statistics, particularly to the exercise based questions considered in our course. For instance, they suggest re-using familiar question scenarios. This is efficient because less response time needs to be set aside for the students to process the information. In the Principles of Epidemiology course, we use the same data example for more than one question (e.g. Q14 & Q15 and in Q21 & Q22 in the Appendix). They also recommend employing "compare and contrast" aspects to questions. By making the students compare different scenarios their attention is naturally drawn to differences between them. In question 13, by considering two causal diagrams, we get the students to consider what aspects make factor C a confounder. Similarly in question 9, three different schedules of events are shown and students must consider which represents a prospective cohort study.

For the formative utility of the response data, Beatty et al. (2006) suggest that questions should be designed so that answer choices reveal likely student difficulties, e.g. common errors. For instance in question 19, option a) represents the response where someone forgets that the model coefficient is on the log-scale, option b) is correct and option c) might be the response if someone thinks the intercept is the treatment effect. Wit (2003) similarly argued that all possible multiple choice answers should seem viable to avoid strategic voting through eliminating the unlikely answers.

Graduate students will generally have substantial experience of courses taught by traditional means, may be comfortable with the standard lecture format, and may be resistant to change. Jackson and Trees (2003) found that students who had taken many lecture courses in the past were more likely to be opposed to PRS type technology than less experienced students. It may therefore be appropriate to adopt a relatively unobtrusive form of PRS based teaching. For instance, it is generally believed that the best PRS questions are those that contain the possibility for a "common sense" misconception which can lead to a significant proportion of students confidently answering incorrectly (Judson and Sawada 2002). In our experience, graduate students are less inclined to being "tricked" in this way. Further, while it may be possible to devise many questions of that nature for an introductory statistics course, at the postgraduate level the content of course inevitably becomes more technical making the scope for memorable misconceptions more difficult.

Similarly, while we welcomed student discussions about the answers to PRS questions, little emphasis was placed on promoting student discussions. For instance, unlike Wit (2003) we did not expect students to explain to their neighbour why they chose a particular answer. While some of the potential benefits of greater student engagement are lost through not seeking discussions so vigorously, the need to avoid alienating students who are unaccustomed to engaging with each other during lectures must also be taken into account.

The results of the questionnaire show that the students see the greatest benefit of PRS as providing a way for them to confirm that they have understood the course material just covered. We believe the most useful questions are those that require application of a new concept or method, but can be completed in a relatively short space of time, e.g. 2 to 3 minutes. Longer questions, such as question 14 on Mantel-Haenzael estimates, should be avoided because students are reluctant to spend several minutes applying a method which they are not confident they understand correctly. Often, these longer problems involve several steps and it can be better to partially work the students through a problem and set a PRS question on one part only, or else to set the problem as two or more PRS questions. For instance, the original Q15 on standardization was split into two questions Q14* and Q15* corresponding to the two main steps to the answer.

The PRS software reports the time to response for each student. These can be exported to standard statistical software to give Kaplan-Meier estimates of response times. In Figure 1, the response times for three selected questions in the course are shown. Q19 involved simple interpretation of model output, where around 40% of students were able to respond quickly. Q6 was a short computational question, where some responses were very quick but ranged up to 3 minutes. Q14 required more extensive computation. Here we see that no responses were received for 3 minutes and required 6 minutes for all responses to be received.

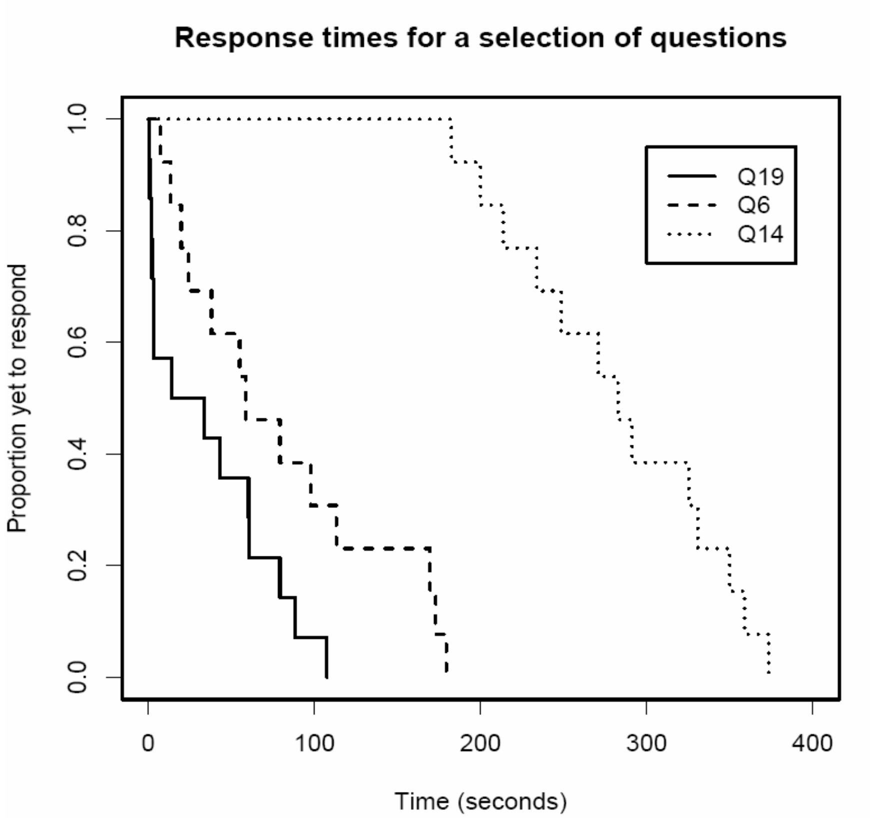


Figure 1: Response times for three selected PRS questions.

The response times are able to provide different information about the difficulty of the question than the proportion of correct answers. This can have some use for assessing the appropriateness of a question for future use. For instance, if the vast majority of students are able to quickly respond correctly to a knowledge-based question, that question may not be necessary, unless perhaps it relates to something particularly worth emphasizing. In contrast, if a significant proportion of students require some time to respond, perhaps because they need to refer back to their lecture notes, this would suggest the question was of use in reinforcing a particular concept. The response times can also indicate a suitable time limit to be used in future implementations of the question (e.g. one could take the time for 90% of students to respond). Finally, the response time graphs can identify questions that are inappropriate due to being overly time consuming, such as question 14.

6. Discussion

In our experience, PRS was used with very few technical problems. Moreover, PRS was popular with the majority of students. It was considered less successful for introducing new topics and some students felt there was not enough action taken when students were unsuccessful at answering a question. It may be possible to improve this aspect of PRS by incorporating a much greater degree of contingent teaching within the questions. For instance, Wit (2003) suggested that ideally one should have a sequence of branching questions, chosen dynamically depending on the responses to previous questions. However, it is difficult to prepare for all possible contingencies in advance and will inevitably lead to unused material. Having a variable number of PRS questions in a session will also tend to increase the possibility of timing issues. Cutts (2006) successfully applied a contingent teaching approach to a computer science course through honing the use over several years to find the consistently problematic topics.

In our implementation, students' responses remained anonymous and did not count to the final module mark. In some implementations the results of PRS have counted towards the final mark (Butler & Butler 2006, Lass et al. 2007). Alternatively, some institutions have produced anonymous rankings of students based on their PRS answers, allowing them to know their relative performance compared to their peers (Robins 2009). However, such measures don't seem appropriate in the small group setting as it would be difficult to maintain anonymity and would place greater pressure on the students who already feel some pressure by the use of PRS.

We found that a minority of students were opposed to the use of PRS in lectures. One explanation for their opposition is that these students have developed a passive mentality where they essentially switch off during lectures. In other studies this has lead to a minority of students deliberately answering questions incorrectly (D'Inverno et al. 2003), although there was no evidence of this in our study.

It does not seem appropriate to set complicated computational or algebraic questions within a lecture as these cannot be completed in an acceptable time (e.g., five minutes). When explaining procedures that involve multiple steps, it may be more appropriate to set a PRS question on one step of the procedure, or a series of questions leading the student through the steps. Alternatively, PRS could be used to obtain answers to complex questions in a tutorial/workshop setting after the students have spent sufficient time on the problem. Time seems to be the main constraint to including PRS within lectures. Distributing handsets, posing questions, waiting for responses and explaining answers all require time. The course within which we used PRS was fortunate in having a fairly flexible allocation of lecture time allowing the lectures to have a more tutorial style to them. More often this will not be the case and the inclusion of PRS may be at the expense of covering material. The choice and design of questions becomes even more important if lecture time is limited.

The full benefit of PRS may not have been achieved in our implementation as discussions surrounding the PRS answers were limited since the students were not used to interacting with each other in discussions during lectures. Additionally, there was quite a wide ability range within the group. Some students said they found the PRS questions too easy and this is borne out by the student who got 95% correct. An added challenge is to develop questions which can engage the full range of abilities.

A limitation of PRS in its current form is that the balance of the dialogue exchange is heavily in the lecturer's favor. The interaction from the students occurs only after prompting by the lecturer at a time of their choosing and the responses the students are able to make are restricted. Cutts et al. (2004) have developed additional software to allow a greater range of ways in which PRS signals can be interpreted. As a result, PRS can be made into a "clapometer", so that at any time students can indicate if they are confused or bored by the current topic. More advanced technology of a similar nature to PRS is also available, such as Tablet PCs which students are able to draw on and send their working on a problem to the lecturer who may then show the whole group a particular solution (Reba and Weaver 2007). Judson and Sawada (2002) argued that to realize the full potential of PRS it needs to engender collaborative learning between students. Students learn more by explaining to a peer their rationale for a solution to a problem than through only being told the solution by the lecturer. Wit (2003) attempted to nurture such peer-instruction by encouraging students to discuss their PRS choices with their neighbor in the lecture hall, and allowing second rounds of voting after these discussions. Future development of our own implementation of PRS would look to incorporate a greater level of co-operative learning.

More radical departures from the standard lecture format towards group discussion based teaching may be suitable for graduate students, who are able to work well independently. However, this approach might be most effective if used in all modules of a course rather than in a single module in isolation and with students who have had some exposure to discussion-based teaching as undergraduates.

PRS has definite benefits as a teaching tool for statistics. The benefits for large group teaching of service or introductory courses are transferable to postgraduate teaching to a small group. Indeed, some of the practical issues associated with distribution of handsets are less problematic for small groups. As with other emerging technologies, care is necessary to ensure that teaching objectives remain central. The main benefits of PRS are not necessarily inherent to the technology, but stem from the pedagogical shift from passive to active learning that they encourage.

Appendix

Full list of questions used in the course

1. What do you understand by the term "epidemiology"?
    a) Study of skin conditions of the epidermis in humans.
    b) Study of the distribution of disease and its determinants.
    c) Don't really know.

2. In a population of 10,000 persons at risk at the beginning of the year, 23 people contract malaria within a one year period. What is the risk of developing malaria for the population at risk?
    a) 23%
    b) 0.0023%
    c) 0.23%

3. In epidemiology studies, censoring occurs when:
    a) A person in a study is no longer at risk although they have not developed the disease.
    b) A person in a study is no longer at risk because they have developed the disease.
    c) A person in a study has died as a result of the disease under study.

4. Consider whether the following statements are true or false.
    i) Prevalence is a measure of frequency but incidence is a rate.
    ii) The incidence rate can be estimated as the ratio of the total number of people who have the disease at a specific time by the total observation time.
    iii) The estimated disease prevalence is the number of people with the disease at a specific time divided by the number of people in the population at risk at the specific time.

    a) i) T ii) T iii) F
    b) i) T ii) F iii) T
    c) i) F ii) F iii) T

5. We can estimate the prevalence/risk of disease using the (i) likelihood and the incidence rate of disease using the (ii) likelihood.
    a) i) normal, ii) Poisson
    b) i) binomial, ii) Poisson
    c) i) binomial, ii) exponential
    d) i) Poisson, ii) binomial
    e) i) Poisson, ii) normal

6. A backtransformation to the original λ scale, using the antilog function, gives the confidence interval defined by:
    a) $[\exp(D/T - 1.645/\sqrt{D}), \exp(D/T + 1.645/\sqrt{D})]$
    b) $[(D/T)/\exp(1.645/\sqrt{D}),(D/T) \exp(1.645/\sqrt{D})]$
    c) $[(D/T)/\exp(1.645\sqrt{D}),(D/T) \exp(1.645\sqrt{D})]$

7. For Example 3.1, calculate the 90% confidence interval using the second approximate method based on re-parameterization. Choose the correct answer from the options below.

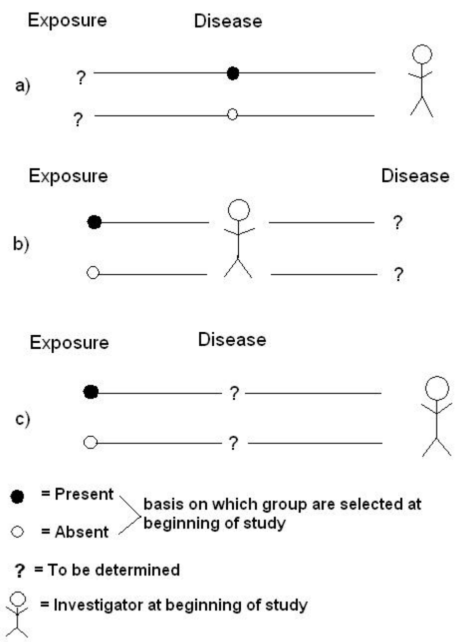
a) (0.00018,1.087)
b) (0.0071,0.0245)
c) (0.0075,0.0261)

8. In which of the following cases has an observational study been used;

i) In a study into the link between radiation exposure and cancer, a cohort of survivors of the atomic bombings of Japan in 1945 was followed over time.
ii) Research into the effects of taking vitamins on the influenza virus have shown that participants that were randomised to take vitamins had significantly less chance of developing the virus.
iii) A study into the risk of coronary heart disease (CHD) in women based on the amount of dietary fat they consumed concluded that there was no association between the amount of fat intake and the risk of developing CHD.

a) Study i)
b) Study i) and iii)
c) Study ii)

9. Which of the diagrams, a), b) or c) is characteristic of the timing of events in a prospective cohort study?



[Diagrams based on p.24, Hennekens and Buring (1987)]

10. In a study into the link between birth-weight and infant mortality, a researcher used birth registry records to obtain the weight of babies. The associated outcome (infant mortality) was determined using national death records. It was found that for children between the ages of 1 and

5, those with birth weights below 2.5kg had twice the risk of childhood mortality compared to those with birth weights > 2.5kg. What type of study has been used here?

a) Retrospective cohort study
b) Prospective cohort study
c) Case control study

11. Calculate the estimated (incidence) rate of IHD for each cohort, per 1000 person years, based on the maximum likelihood estimate for the rate parameter.

a) Rate for the exposed group is 0.015 and the rate for the unexposed group is 0.006.
b) Rate for the exposed group is 15.1 and the rate for the unexposed group is 6.1
c) Rate for the exposed group is 0.083 and the rate for the unexposed group is 0.05

12. Average annual incidence rates for breast cancer in Iceland in 1910-1972, per 100,000 population:

Year of birth	Age				
	40-59	50-59	60-69	70-79	80-89
1880-1909	65.9	95.1	129.5	140.1	227.9
1840-1879	38.7	53.8	71.7	81.1	136.9
Difference	27.2	41.3	57.8	59.0	91.0
Ratio	1.70	1.78	1.81	1.73	1.66

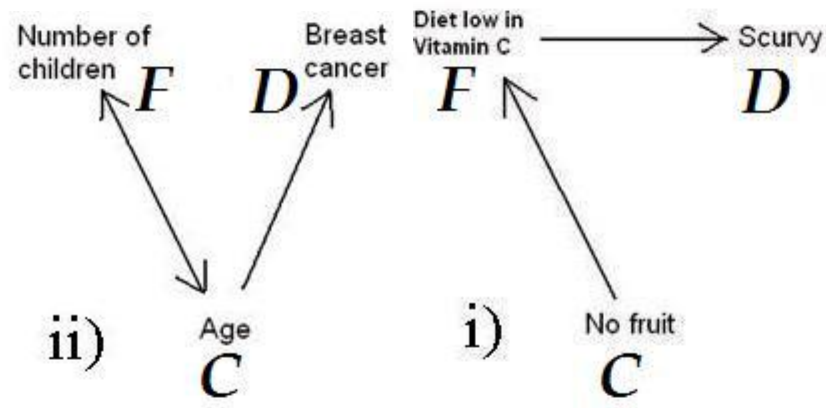
For the Iceland breast cancer example, decide whether the following statements are true or false.

i) The rate ratios are stable within the range 1.66-1.81
ii) The rate ratios of incidence of breast cancer are increasing over the 50-year age span.
iii) The rate differences triple over the 50-year age span

a) i) T ii) T iii) F
b) i) F ii) F iii) T
c) i) T ii) F iii) T

[Data in table taken from p.50, Breslow and Day (1980)]

13. In the Figure below, identify whether C is a confounder or not and choose the correct answer from the options below.



a) i) Confounder ii) Confounder
b) i) Confounder ii) Not a confounder
c) i) Not a confounder ii) Not a confounder
d) i) Not a confounder ii) Confounder

14. Table: IHD data, stratified by age:

	Exposed		Unexposed	
Age	D1	Y1	D0	Y0
40-49	2	311.9	4	607.9
50-59	12	878.1	5	1272.1
60-69	14	667.5	8	888.9
Total	28	1857.5	17	2768.9

For the IHD data, calculate the Mantel Haenszel estimate of the rate ratio. It is equal to
a) 2.40
b) 2.39
c) 2.51

[Data taken from Table 14.1, p137, Clayton and Hills (1993)]

14*. For the IHD data, calculate the overall reference rates for each age group (across exposed and unexposed groups)
a) 0.0066 for 40-49, 0.0039 for 50-59, 0.009 for 60-69.
b) 0.0065 for 40-49, 0.0079 for 50-59, 0.014 for 60-69.
c) 0.0082 for 40-49, 0.0053 for 50-59, 0.011 for 60-69.

15. For the IHD data, calculate the expected number of cases for the exposed and unexposed group for the IHD data using the indirect method of standardisation.

a) 13.67 in the exposed group; 6.5 in the unexposed group.
b) 11.51 in the exposed group; 39.29 in the unexposed group.
c) 18.39 in the exposed group; 26.56 in the unexposed group.

15*. Using the overall reference rates, calculate the expected number of cases for the exposed and unexposed group for the IHD data using the indirect method of standardisation.

a) 13.67 in the exposed group; 6.5 in the unexposed group
b) 11.51 in the exposed group; 39.29 in the unexposed group
c) 18.39 in the exposed group; 26.56 in the unexposed group

16. Which of the following statements about case-control studies is true?

a) the outcome is unknown at the beginning of the study.
b) the groups are defined by the level of exposure.
c) follow-up is eliminated.

17. Decide whether the following statements about the exposure odds and odds ratio are true or false:

i) The exposure odds for a case of oesophageal cancer are 0.923.
ii) The exposure odds for a control are 0.532.
iii) The exposure odds ratio is 1.73.

a) i) T ii) F iii) F
b) i) T ii) T iii) F
c) i) F ii) F iii) F
d) i) F ii) T iii) T

18. A study investigating the relationship between tonsillectomy history and the incidence of Hodgkin's disease gave the following frequencies of 85 matched case-control pairs:

History of case	History of control	
	Exposed	Unexposed
Exposed	26	15
Unexposed	7	37

Calculate the odds ratio of the matched case-control study. Also calculate the odds ratio estimate if matching had been ignored. *Hint: First draw up a 2 x 2 table relevant for a case-control study with no matching.*

Decide whether the following statements are true or false.

i) The odds ratio ignoring matching is equal to 1.468.
ii) The exposure odds for a case are 0.48.
iii) The odds ratio for the matched study is greater than the odds ratio ignoring matching.

a) i) T ii) F iii) F
b) i) F ii) T iii) F
c) i) T ii) F iii) T

[Data taken from Table 1 of Newell and Henderson (1974)]

19. Model fitted in R:

```
D <- c(3,2,1,1,3,2,2)
E <- c(6.2,1.0,2.2,1.8,1.5,1.0,0.4)
z <- c(0:6)
loglinearmodel <- glm(D ~ offset(log(E)) + z, family=poisson)
summary.glm(loglinearmodel)
```

Results:

```
Coefficients:     Estimate Std. Error z value Pr(>|z|)
(Intercept)       -0.7445      0.4780   -1.557   0.1194
    Z              0.3194      0.1353    2.360   0.0183
```

In the example above, how would you interpret the coefficient of the dose variable?
a) For an increase in dose of one unit, the disease rate increases by 0.3194.
b) For an increase in dose of one unit, the disease rate increases by 1.376.
c) For an increase in dose of one unit, the disease rate decreases by 0.7445.

20. Model fitted in R:

```
z <- c(0,1,2,3)
cases <- c(29,22,3,3)
controls <- c(99,122,40,24)
logisticmodel <- glm(cbind(cases,controls) ~ z,
     family=binomial)
summary.glm(logisticmodel)
```

Results:

```
Coefficients:  Estimate Std. Error z value Pr(>|z|)
(Intercept)    -1.2583   0.1950    -6.453  1.09e-10 ***
Z              -0.4411   0.1867    -2.363  0.0181   *
```

How would you interpret the coefficient of the number of negative screening test results variable?

a) The disease odds decreases by a factor of 0.64 for each additional negative screening result.
b) The disease odds decreases by a factor of 0.4411 for each additional negative screening result.
c) The disease odds increases by a factor of 0.4411 for each additional negative screening result.
d) The disease odds increases by a factor of 0.64 for each additional negative screening result.

21. In a group of patients presenting to a hospital casualty department with abdominal pain, 30% of patients have acute appendicitis. 70% of patients with appendicitis have a temperature greater than 37.5C, whereas 40% of patients without appendicitis have a temperature greater than 37.5C. For each of the following statements, say whether the statement is true or false.

i) The sensitivity of temperature greater than 37.5 C as a marker for appendicitis is 21/49.
ii) The specificity of temperature greater than 37.5 C as a marker for appendicitis is 42/70.
iii) The predictive value of temperature greater than 37.5 C as a marker for appendicitis is 21/30.

a) i) T ii) F iii) T
b) i) T ii) T iii) T
c) i) F ii) F iii) F
d) i) F ii) T iii) F

22. In the appendicitis example above, are the following statements true or false? i) The predictive value of the test might be different in another population. ii) The specificity of the test will depend upon the prevalence of appendicitis in the population to which it is applied.

a) i) T ii) F
b) i) T ii) T
c) i) F ii) F
d) i) F ii) T

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