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Introduction to experimental design: can you smell fear?

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Introduction to experimental design: can you smell fear?

Abstract: The ability to design appropriate experiments in order to interrogate a research question is an important skill for any scientist. The present article describes an interactive lecture-based activity centred around a comparison of two contrasting approaches to investigation of the question *Can you smell fear?* A poorly designed experiment (a video clip from the TV series *Brainiac Science Abuse*) is considered alongside the methods used in a peer-reviewed paper examining the same issue.

Introduction: A recent definition sees science as “*the pursuit of knowledge and understanding of the natural and social world following a systematic methodology based on evidence*” (Science Council, 2009). Implicit within the phrase “a systematic methodology based on evidence” is the need for experiments to be conducted in a manner likely to generate trustworthy data.

It is for this reason that an ability to design appropriate experiments is seen as an important component of scientific training at all levels of education (e.g. QAA, 2007; QCA, 2007). For example, the UK Quality Assurance Agency’s benchmark statements for university-level Bioscience courses note that “*students should develop competence in comparing the merits of alternative hypotheses and receive guidance in terms of how to construct experiments or to make observations to challenge them*” (QAA, 2007: p2). Despite this vital role in science education, there remains a risk that introduction of these important design principles can come across as dry (Ruxton and Colegrave, 2006), particularly in the context of a lecture or classroom tutorial in which the students are not going to perform the experiment themselves.

The following description of an introductory activity to teach about experimental design is offered both as a “ready-made” resource and as a paradigm of the use of popular science television programmes as an engaging start-point in discussion of such principles.

Activity: The 50 minute session begins with an introduction to the importance of good experimental design. If a study is badly designed then no matter how many times it is carried out the interpretation of the findings is likely to be flawed. In addition to ‘wrong’ results, a badly designed experiment may be costly in terms of time, money and even harm to participants (Ruxton and Colegrave, 2006).

Video (example of poor design): Following a brief introduction of this kind, students are invited to watch a five minute clip from UK television programme *Brainiac Science Abuse*. Popular with teenagers, *Brainiac* takes an irreverent look at science and features a disproportionate number both of explosions and of pretty female assistants; it is unashamedly at the ‘populist’ end of the science documentary spectrum. The episode used in the lecture is frequently rebroadcast (my copy was recorded from Sky1 at 07:00 on January 28th 2009) but the specific clip is also available on the YouTube channel for the series (*Brainiac Science Abuse*, 2009).

Before watching the clip, students are briefed to keep a look out for aspects of the experiment that are good and for things about the design of the experiment that are unsatisfactory. In the footage shown, presenter Richard Hammond poses the question “Can you smell fear?” To tackle this problem, three men are put through different experiences for thirty minutes, after which a blindfolded young woman is invited to smell their armpits. One man is sent jogging, one relaxes in a deckchair, and the third – alleged to have a fear of heights – is taken high into the air on a crane. At the end of the ordeal, the woman correctly identifies the man who has been terrorized on the high platform.

When the video is over, the students are given about five minutes to work with their neighbours to consider both the good aspects of design in the experiment shown, and how it might be improved. After this time their suggestions are collated by the lecturer, and then compared with a pre-prepared PowerPoint slides listing the strengths and weaknesses of the research approach (all of the slides from this lecture have been made available to colleagues to download via Slideshare, see Willmott, 2010).

Although limited, there are some features of the Brainiac experiment that are appropriate; a negative control is included (no exercise, no exposure to fearful circumstances) and all three research subjects carry out their relevant activity for the same duration of time. The same individual is employed to ‘sniff’ each of them, so variability is not introduced (in *this* aspect of the study).

Having said this, however, the list of weaknesses in the design of the experiment is rather fuller. The experiment is only performed once, with one ‘sniffer’ and only one individual representing each of the three experimental conditions (rest, exercise, fear). Furthermore, the research subject participating in each activity was not the same and no safeguard was made for differences in natural odour, use of deodorants and/or digestion of smelly foods shortly before the trial. In fact, within the video it is also clear that the proximity of the sniffer’s nose to the armpit of each subject is also very different: in one case the man is much taller than she is, leaving her nose several inches from his armpit; in a second she is about the same height; and in the third case the man does not actually raise his arm to directly expose his armpit at all. No account is made concerning the possibility of olfactory adaptation, the tendency for sensitivity to a specific odorant to decrease following repeated or prolonged exposure.

Designing a better experiment (group discussion): Armed with these observations, the students are then asked to design an experiment that would investigate the same research question in a more robust manner. They are given about 10 minutes to work in groups again, after which their suggestions are collated and discussed.

Example of a good study: Finally, the approach used in a recent study is presented. The research, by Bettina Pause and colleagues, was published in the peer-reviewed journal PLoS ONE (Prehn-Kristensen *et al.*, 2009) and serves to illustrate the thought and care required to design a more scientific consideration of whether it is possible to smell fear.

Details of the design are given in the PowerPoint slides (Willmott, 2010). In summary, the researchers used a larger number of sweat donors (n=49, of whom 28 were male). The donors were carefully screened to eliminate potential confounding factors, e.g. no smokers or individuals with known neurological disorders were involved. The donors were also given clear instructions regarding a range of lifestyle issues which may have interfered with the study; they were barred from eating spicy foods, garlic or onions for more than 24 hours prior to sweat collection, they were not permitted to use deodorant and were only allowed to wash using fragrance-free soap provided by the research team.

Sweat was collected from the same set of donors (all students) on two separate occasions (and at the same time of day, in case this was relevant). On one day, sweat was collected from the participants for 60 minutes during which they undertook 3 x 10 minutes of cycling. On another day, sweat was collected from the same students for 60 minutes directly prior to the final oral examination of their degree. Sweat was pooled into one of four categories: anxious males, anxious females, males during sport, and females during sport. The researchers also took saliva samples from all participants at several time points, to enable measurement of cortisol and testosterone levels, and asked them to self-evaluate their emotions and feelings.

A separate team of 28 students (50% of whom were male) were recruited to smell the collected odours. Once again, a number of criteria such as being a smoker or having a history of neurological disorders were used to rule out participants and thus minimise the effect of confounding factors.

Two distinct approaches were employed to determine whether or not these individuals could distinguish between sweat generated during exercise and sweat generated whilst afraid (and whether the gender of donor had any bearing). Firstly, the participants were asked to rate each odour on a scale of 0 to 8 for intensity, pleasantness, unpleasantness and familiarity. They were also asked about their feelings whilst smelling each pooled odour.

Secondly, functional Magnetic Resonance Imaging (fMRI) was used to monitor brain activity stimulated by each odour, which was delivered to participants whilst within the MRI scanner via an adapted oxygen mask. fMRI is a powerful technology in which changes in blood oxygenation levels are used as an indicator of the parts of the brain that are active in response to a specific cue or stimulation (Ogawa and Sung, 2007). A small number of participants were initially exposed to a rose-smelling odour to confirm that the system was working correctly, i.e. as a positive control. A breathing belt around the chest of the participant was used to ensure that they genuinely had taken a breath, and recovery breaths were built into the scheme to guard against olfactory adaptation.

Interestingly, and in contrast to the Brainiac experiment, Prehn-Kristensen *et al.* did not detect any statistical significant differences when testing for the conscious perception of anxiety sweat versus exercise sweat. Differences were noted, however, in the subconscious detection of smell.

Evaluation: After the session, students were invited via e-mail to complete an online questionnaire regarding this activity. The survey was anonymous and no inducements (e.g. course credits) were offered for responses. The survey was made available via the virtual learning environment (Blackboard) for 14 days following the session. A total of 16 students (20% of cohort) provided feedback on the activity.

Using a Likert scale from 1 = strongly disagree through to 5 = strongly agree, students were asked to respond to the statements “*I enjoyed the session on experimental design*” and “*I found the session on experimental design useful*”; the average (mean) ratings were 4.44 and 4.25 respectively, with the lowest score in each case being given by one student who indicated that they “neither agreed nor disagreed” in relation to both statements.

Students were additionally invited to justify their evaluation with free-text comments. Examples of these qualitative answers are given in Box 1.

Conclusions the use of television clips in teaching *per se* is not particularly novel. The innovation in the current activity comes from the combined use of an extract from a popular science series with two additional phases. Firstly, having seen the weaknesses in the design of the presented experiment, students are invited to utilise their existing knowledge to design a better study. This leads, secondly, into consideration of a more robust methodology used to address the same research question and published in a peer-reviewed journal (Prehn-Kristensen *et al.*, 2009). Since this journal is an “open access” publication no subscription is required and therefore this example of primary research can be read directly by teachers or, indeed, by interested students.

Feedback suggests that the participants found this to be an enjoyable and thought-provoking exercise. Although used here with first year undergraduates, an activity of this kind could easily be conducted with upper secondary level students. In the UK, for example, the performance descriptions produced by the Qualifications and Curriculum Authority, as was, for Assessment objective 3 (How Science Works) of A level Biology specifications includes candidates being able to “*analyse, interpret, explain and evaluate the methodology, results and impact of their own and others’ experimental and investigative activities in a variety of ways*” and it is noted that good candidates characteristically can “*devise and plan experimental and investigative activities, selecting appropriate techniques*” (QCA, 2007).

The template demonstrated in this account – combining a video clip of a poorly designed experiment with discussion of a more scientific robust study – could be replicated using a different topic and/or an extract from an alternative television programme (such as *Mythbusters*). All of the resources used in this session – the video, the peer-reviewed paper and the PowerPoint slides developed for the plenary sections of the teaching – are, however, available free on the internet and as such are available “off the shelf” for use by colleagues.

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Box 1: Qualitative evaluation of the experimental design session

- The experiment presented was really entertaining. The task of coming up with a more effective experiment was stimulating.
- The set up - looking at a particular experiment, discussing among ourselves faults and then discussing as a group the experiment design was good
- It encourages me to really think about all the detail that has to go into experimental design and the variety of areas that can be explored in connection with an experiments (sic) design
- It raised an interesting discussion about something I had very little ideas about
- It described an experiment that was carried out (not the Hammond experiment but the sweat-collecting experiment) which was complex and professional. This will help to think about future experiments that us as students may like to carry out.
- It worked very well, and engaged everyone instead of just talking about how to set up a good study
- Engaging, humorous and up-to-date
- The Brainiac video was quite amusing and made the lecture interesting
- The video broke up the typical structure of a lecture so was fun
- Discussion of the elements of a good experiment/improvements to be made required active thinking, making it more interesting rather than passive absorption of information