

Effective Visual Design and Communication Practices for Research Posters: Exemplars based on the theory and practice of multimedia learning and rhetoric^[S]

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Evidence shows that science graduates often do not have the communication skills they need to meet workplace standards and expectations. One common mode of science communication is the poster. In a review of the literature we show that poster design is historically problematic, and that the guidance provided to students as they create posters for assessment is frequently inconsistent. To address this inconsistency we provide some guiding design principles for posters that are grounded in communication theory and the fundamentals of rhetoric. We also present three

nondiscipline-specific example posters with accompanying notes that explain why the posters are examples of poor, average, and excellent poster design. The subject matter for the posters is a fabricated set of experiments on a topic that could not actually be the subject of research. Instructors may use these resources with their students, secure in the knowledge that they do not and will never represent an answer set to an extant assessment item. © 2016 by The International Union of Biochemistry and Molecular Biology, 45(3):249–261, 2017.

Keywords: Curriculum design development and implementation; teaching and learning techniques methods and approaches; using multimedia in the classroom; communication; rhetoric

Introduction

For a scientist, the ability to communicate science is crucial [1]. Recently, a proliferation of science communication training opportunities has appeared in the USA, the UK, and beyond [2–4]. These opportunities are usually for professional science communicators; however, “communication” has now become well accepted as a desired component of tertiary science education. Indeed, communication skills now feature as a core competency or key learning outcome in tertiary science curriculum statements from the Australian and American science communities [1, 5, 6]. Despite these statements, Australian Bachelor

of Science (BSc) students do not develop their communication skills to the appropriate level before going into the workplace [7] and employers consistently state that they are seeking STEM graduates with better communication skills [8]. There is evidence that communication skills are not being taught “explicitly” in the Australian tertiary science curriculum and that, instead, educators rely on “implicit” learning through doing [1, 7]. This tacit-knowledge approach to communication teaching in science education may contribute to the poor communication outcomes for graduates.

For those students who do become professional research scientists, whether in academia, industry, or another field, skills in formal science communication are vital. This includes skills in preparing technical documents, conference abstracts, journal papers, oral presentations, and conference posters. In an undergraduate context, the poster is a key communication format that allows students to practice skills related to the core learning outcome or core competency of Communication.

In this article, we offer resources, including described exemplars and marking rubrics that can be used to teach undergraduate science students about posters. To frame these resources we provide a short history of the poster

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presentation and a short review of the use of posters in undergraduate science education. We complement this with a discussion of communication theory and rhetoric as they relate to posters and offer design principles that are situated in these theories and the current literature on poster production.

The take-home for tertiary science educators is a resource, based on established communication and rhetoric theory, which they can use to teach learners about posters as a form of science communication.

The History of the Poster and Its Design

Reports place the earliest poster sessions at scientific conferences in Europe and America during the early 1970s [9–12]. It is unclear exactly how the research poster format developed, but it may have evolved from in-person or visual displays of physiology experiments called “Demonstrations” [13]. Certainly, once it appeared at conferences, the informal, flexible poster format quickly gained popularity [11, 14]; conference delegates at the International Congress of Biochemistry in 1973 voted it “a great success,” while attendees at the 1974 Biochemistry/Biophysics Meeting emphasized “the establishment of a real one-to-one communication with truly interested colleagues” [9]. As the poster became a popular medium for communicating research, however, reports of ineffective and inconsistent poster design began to appear in the literature [13, 14]. Thirty years ago, when the poster first emerged as a communication medium, researchers were constrained by the available technology (which included hand-drawn material, photographs, and rub-on letter sets) and not all poster authors used the medium successfully. Saffran [13], for example, reported text-heavy posters and poorly designed graphics at conferences but he speculated that developing technology would have a positive impact on poster design. As any attendee at a conference knows, however, technology does not always produce communication improvements, and in 2005 Fagan and Burgess [15] reported on astrophysics conference posters where the majority of authors dedicated 50% or more of the space to text.

Why do posters continue to exhibit poor formatting and style? Posters, unlike peer-reviewed journal articles, do not go through a rigorous review process [15, 16], there are discipline-specific formatting requirements [15], and in some case a poster presenter may not get quality production advice from a mentor [14]. Poster presenters are frequently more junior scientists, and they may feel that including more content on a poster establishes their credibility [16]. Doumont, has observed that junior scientists can be caught up in poor communication practices at conferences, saying “these young people logically regard current practice as the norm and consequently strive to emulate it

in their attempt to fit in.” (p. 10) [17]. We suggest that the poster assessment items given to undergraduates shape young scientists’ views of “the norm” in science communication. We also suggest that strong, consistent guidance and the use of appropriate exemplar posters can help students understand how to present a better poster.

Posters as Assessment in Undergraduate Science Courses

To understand how posters are used in undergraduate science education question we reviewed the literature in the area. We found several published examples of posters-as-assessment from chemistry classrooms [12, 18–26], with only a handful of other disciplines represented. These include biochemistry [27, 28], biological disciplines [29–34], and others [10, 35–37]. The earliest published example we found is from the mid-1980s [26], coinciding with the rise in popularity of the poster session in professional settings as described earlier.

For most of these studies the authors provided students with guidance around how to produce their poster. In many cases the authors did not publish the details of *how* they guided the students—instead they stated that they instructed students on how to make a poster and told them “what to include.” Some authors described more explicit guidance on the written and visual aspects of posters [12, 18, 24, 28, 34]. Authors also commonly mentioned providing examples [19, 24, 28, 29, 33, 36], giving instruction on using technology to make a poster [12, 23], and providing students with the marking criteria [10, 20, 30, 32]. It was rare to find an example where no explicit instruction was reported [26, 37].

This review indicates that posters have been used as assessment tasks for almost as long as posters have been used in professional settings. It also shows that there are variations in the amount and type of scaffolding given to students. Interestingly, this inconsistency mirrors the production of posters for the professional conference setting, as we have already seen.

There are many extant resources available to guide poster design (see references in Table I) and we used these when designing the exemplars presented in this article. We did, however observe some contradictions in these resources, and as a rule, they draw heuristically on practice to establish their case for authority. This provenance and experience is very valuable to educators and scientists and we do not discount it in any way. It is, however, also the cause of the contradictory nature of the advice, since every discipline has slightly different norms.

We feel it will be helpful to situate poster design more firmly in communication theory, which has a single norm that should be generally and consistently applicable to educators and students in science.

TABLE 1

Design features for an "excellent" poster (see also Fig. 2 and S1 for the poster)

Design element	Poster detail	Best practice design elements	Ineffective design elements
Text Content	Title	Concise [38–42] and free from jargon [42, 43] Sentence case [40, 41, 44] Describes outcome [43]	
	Author info	Included	
	Introduction	Brief (<200 w) [40, 44] with little jargon Clear and concise, broken into two paragraphs for readability [45] Includes essential background [44], research aims, and hypothesis References used	
	Methods	Clear and concise Flowchart used [42, 44, 45]	No images
	Results (text only)	Text is concise with bullet points [40, 41] or phrases [45] Graphical summary of main finding References	
	Figure legends	Not present on graphs Brief legend included next to image result	Some repetition with methods
	Table legends	Brief	
	Conclusion	Brief (<150 w) Restates major finding [44] Describes limitations of current work and suggests future directions	
	References	Includes essential references 39	
	Acknowledgements	Included/brief [44]	
Graphic Content	Headings	Describe content of following section [43] (quasi A/E)[42] In a different colour and all-caps, numbered [38, 39, 43]	
	Diagrams	Used to graphically present methods Used to summarise major finding	
	Table	Methods - Clear (little content, formatting)	
	Graphs	Large [38, 45] Chart junk/extraneous detail removed [43, 46] No key (graph 1) – data points labeled [43] on one cluster [43, 44] Axis labels same as body text (size) [43] Title describes what graph depicts [42, 44] (quasi A/E) No legends [43] No background colour so lines and columns stand out from page [43, 45]	Graph 2 includes key

TABLE 1

(Continued)

<i>Design element</i>	<i>Poster detail</i>	<i>Best practice design elements</i>	<i>Ineffective design elements</i>
	Images/logos	Logo small and at bottom [44] Images in banner relate to content Results images large and of high quality [42], labeling clear	
Esthetics	Font Type	One sans serif and one serif font used consistently on all elements [39, 40] Sans serif font used for headings and serif for text [39, 43, 45] Body text left-justified [43, 45]	
	Font Size	Minimum 24 pt used [38, 40, 43, 45] Font size “hierarchy” consistent for body, headings, labels etc. [39–42] Title in large font, headings larger than body text	
	Colour Scheme	Cool tones [45] that relate to content [39, 40]	
	Poster background	White; all elements clear and stand out [40, 42–44]	
	Layout (flow)	All elements aligned Ample white space and margins used Poster flow clear from headings [43] and column layout [39, 40, 42, 43, 45] Use of “arena” [44] or “golden rectangle” [45] Results are the largest section [44]	
	Overall Assessment	Mainly visual with clear graphics and good flow; little text used [43] “high signal to noise ratio” [47]	

The Poster as a Communication Genre and Implications for Design

There are set conventions associated with genres that define how and what to communicate [48]. The journal paper is an example of a science genre that has these set conventions but posters are a far more flexible genre than a journal paper. Part of the looseness of the poster format comes from its “hybrid” and “multimodal” genre status; it combines visual, spoken, and written elements in a format that must communicate with equal effectiveness whether the “spoken” element is present or not [16, 49, 50]. MacIntosh-Murray [16] identifies further duality in the role—the poster must attract with artistic flair, yet present a comprehensive science message. It must also do this on a single plane for an audience with mixed knowledge and motivation [16, 51].

We propose a simple three-part framework for principles of best practice in poster design that are based on the theories of rhetoric and the findings around multimedia learning. The framework is inspired by Doumont’s three laws for professional communication [47]; however, our principles are more specific to the poster genre, and each focuses on one communication mode—written, visual, spoken—and the interaction that exists between them [15]. We discuss the key concepts from the theories of multimedia learning and of rhetoric, then list the principles.

Multimedia Learning as an Overarching Design Principle

A poster is a multimedia communication mode, because it incorporates and “integrates,” the images and words of a multimedia presentation [52–54]. The “multimedia principle” states that words along with pictures make for

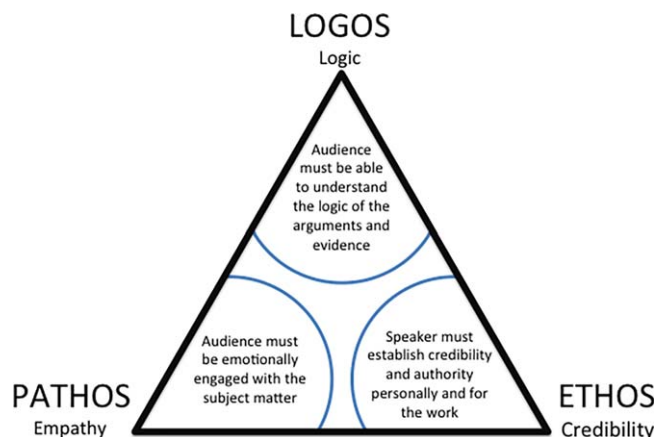


FIG 1

Aristotle's rhetorical triangle as it applies to poster design. The three principles of *ethos*, *logos*, and *pathos* are shown at the points of the triangle. The interaction between each principle, and between the communicator and the audience, are shown as the sides of the triangle. [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

more effective communication than words alone [52, 53]. Posters are meant to be primarily visual, but words—both spoken and written—are still important for conveying the message. To ensure these elements combine in the most effective way, four useful concepts from multimedia learning should be honored—these are coherence, signaling, redundancy, and contiguity. It is important to note that each of these design principles is supported by experimental evidence that addresses the learning outcomes of audiences when these principles are and are not applied [52, 54].

- i. **Coherence:** The concept of “coherence” stipulates that “excess” information should be eliminated in a multimedia presentation. This concept is also encapsulated in Doumont's second law for professional communication; “maximise the signal-to-noise-ratio”, where “noise” is “anything that could distract the audience” [47] (p. 293). Mayer states, however, that if “extraneous” information cannot be removed, it is important to guide the audience by organizing the information, a method known as “signaling” [52].
- ii. **Signaling:** Signaling helps to direct an audience's attention. On slides, signaling can be achieved through the “assertion-evidence” format [53], where the title of the slide describes the main idea and the body is dedicated to evidence. This approach, as well as other signaling devices like arrows, colors, and font sizes, can also be used on panels of a poster.
- iii. **Redundancy:** The “redundancy” principle, is specific to a multimedia presentation, like a video, and the use of narration and text [46, 52]. This principle states that it is beneficial to include the same information in multiple “complementary” formats [53, 55]. This is a more

sophisticated technique than simple repetition, which is undesirable. Instead, it means that one should include the same information in multiple ways to reach as much of the audience as possible.

- iv. **Contiguity:** The contiguity principle applies spatially and temporally. In poster design the contiguity principle stipulates that (i) relevant text should be close to the graphics of interest and (ii) relevant ideas should be explained sequentially, rather than at separate times.

Rhetoric as an Overarching Design Principle

The second body of theory that we draw from to support our principles for poster design is rhetoric. First established as a formal theory by Aristotle in the 4th century BC, the fundamentals of rhetorical persuasion are still in practice today. Aristotle's *rhetorical triangle* (Fig. 1) forms an ideal underlying framework for poster design and delivery, as it focuses on (i) the interaction between the communicator, the audience, and the content and (ii) the three “appeals” of *ethos*, *pathos*, and *logos* [56].

- i. **Ethos:** First, let us consider the poster presenter, who is the “communicator”. They must demonstrate their *ethos* to an audience, where *ethos* is conceptualized as “authority” [57], qualification and credibility. In posters, *ethos* can be established in many ways, such as those that Gross [57] identifies in formal science writing; referencing past achievements, citing affiliations with research bodies, and referring to the work of others to contextualize one's own work. All can be incorporated into a poster, but a student, or any researcher, should take care not to fall into the trap of presenting *all* their work [16] in an attempt to create *ethos*. Roskelly [56] also describes how the communicator can adopt a “character”, or a certain way of presenting themselves to the audience. A well-designed poster and a professional-looking presenter can both contribute to establishing *ethos*—these are more likely to attract undivided attention and project authority than one or both that appear less prepared or less organized.
- ii. **Pathos:** A fundamental approach in effective communication is to consider one's audience. Woolsey [51] suggests there are three types of people in an audience for a conference poster session: those who know the presenter and their work personally, those who do research in the same field as the presenter (the “target” audience), and those with research interests that lie elsewhere. In a poster presentation, one of the major aims of the presenter is to capture the attention of the audience. A presenter can use *pathos* to achieve this, although the deliberate use of emotion in a formal science communication seems contrary to the nature of the discipline. Gross [57] argues that removal of emotion in formal communication is actually a method for highlighting audience-desired reason and objectivity. Certainly, such objectivity will be evident in the interpretation of the results on the poster; however, the

TABLE II

Design features for an “average” poster (see also Figs. 3 and S2 for the poster)

<i>Design element</i>	<i>Poster detail</i>	<i>Best practice design elements</i>	<i>Ineffective design elements</i>
Text Content	Title	Concise and free from jargon	Title case Describes aim and not outcomes
	Author info	Included	
	Introduction		Too long (>350 w) and not clear or concise with some jargon Too much background/detail on aim/methods Block of text Formatting errors (Latin names)
	Methods	References	Too detailed No images or flowchart Formatting errors (Latin names)
	Results (text only)	References are included elsewhere and not linked to text	Too much detail/whole sentences and paragraphs
	Figure legends	Brief legend included under graphs/with image	Some repetition with methods
	Table legends	Brief	
	Conclusion	Brief (<150 w) Restates major finding Describes limitations of current work and suggests future directions	
	References	Includes essential references	
	Acknowledgements	Included/brief	
Graphic Content	Headings	Follow IMRAD In a different color and all-caps	
	Diagrams		None
	Table	Methods - Clear (little content, formatting)	
	Graphs	Large Chart junk/extraneous detail removed Axis labels same as body text (size) Lines/columns stand out from page	Both graphs use key Data labels potentially unclear without other text Includes detailed legend White background awkward against poster background
Esthetics	Images/logos	Results images large and of high quality, labelling clear	Logo large, in banner Images in banner small/look out of place
	Font type	One sans serif and one serif font used consistently on all elements Sans serif font used for headings, serif for text	Body text justified

TABLE II

(Continued)

Design element	Poster detail	Best practice design elements	Ineffective design elements
	Font size	Title in large font, headings larger than body text	
	Color scheme	Cool tones that relate to content	
	Poster background	Blue (which is ok)	A paler color would help the text stand out more
	Layout (flow)	All elements aligned Headings Use of “arena” or “golden rectangle”	
	Overall assessment	Graphics used are clear but some “chart junk” used Visual flow is clunky, looks cluttered and text-heavy	

delivery of the content, and the content itself, can use emotion as a tool for securing attention.

- iii. *Logos*: Finally, there is the content or the “subject” to consider, and how it can be enhanced with *logos*. Considering the subject means thinking about what content to include and what evidence to use in making an argument about a core message or finding. This aligns to the principle of “coherence” discussed earlier. Logic is inherent in science, but when it comes to rhetoric and communication, this refers not just to the logic of the scientific method, but also to ensuring the content is presented in a structured way that the audience can make sense of, and understand; this relates back to the “signaling” principle we described previously.

A Three-Part Model for Poster Presentations

We have selected aspects from the aforementioned work of professional communicators, multimedia learning theory, and rhetoric to create a framework for poster design and delivery. This framework echoes Doumont’s first law for professional communication—“adapt to your audience” [47]. For posters we can rephrase this as *adapt your design and delivery for audience comprehension*.

The principles we propose for best practice poster design are:

- i. Concentrate the depth and volume of content on one message
- ii. Streamline visuals and design for clarity
- iii. Plan for interaction between all elements

- iv. *Concentrate the depth and volume of content on one message*: Effective posters include only the amount of content that explains and explores the key message. The written content is therefore concise, but the scope of the poster is also constrained to one focus. The key message may be explored from more than one angle, and more than one data set may support the conclusions. The core concepts from the theory described above are coherence, redundancy, *pathos*, and *logos*.
- v. *Streamline visuals and design for clarity*: The second principle focuses on visual communication and the design of the poster, rather than the content. We align this principle to the “audience” elements of the rhetorical triangle. Effective posters take advantage of the visual format; they are engaging and attract an audience. They are also easy to read, and messages in the graphics included are unambiguous. We recommend reviewing the “esthetics” section of Tables (I–III) for some direction on how to achieve visual clarity. The core concepts from the theory described above are coherence, signaling, contiguity, and *logos*.
- vi. *Plan for interaction between all elements*: Our last principle encapsulates the interaction between the spoken, written, and visual elements of a poster presentation. This interaction is one “essential characteristic of posters” [15] (p. 40). A poster designer should consider how to communicate their message when they are and *are not* standing with the poster. This principle asks designers to consider the poster as a whole, and take care in designing a poster where each type of communication mode works in synergy with the others. This is a particularly interesting area of poster design now that new technology options are available for interactive and

TABLE III

Design features for a “horrible” poster (see also Figs. 4 and S3 for the poster)

<i>Design element</i>	<i>Poster detail</i>	<i>Ineffective design elements^a</i>
Text content	Title	Lengthy with some jargon Spelling errors All uppercase
	Author Info	Included in this case, but a truly ineffective poster would have incorrect or missing details
	Introduction	Too long (>350 w), not clear or concise with some jargon Too much background/detail on aim/methods Block of text Formatting errors (Latin names)
	Methods	No references Excessive detail/no detail No images or flowchart Formatting errors (Latin names)
	Results (text only)	Excessive detail Whole paragraphs/sentences
	Figure legends	Brief (image) with detail inadequate to understand result Too much detail with graph//describes excel axes
	Table legends	Inadequate
	Conclusion	Long (~250 w) and too detailed—restates all results and describes limitations and future directions too thoroughly
	References	None
	Acknowledgements	None
Graphic content	Headings	Follow IMRAD
	Diagrams	None
	Table	Office defaults used Too large Too detailed/presentation of results
	Graphs	Chart junk/extraneous detail included with 3D image [43] and key used Color scheme terrible Axes unlabeled Font used too small Lengthy figure legend (see above)
	Images/logos	None Results images too small and of low quality
Esthetics	Font type	Two types of sans serif font used for headings and body text but serif font used for results table (5 inconsistent fonts) “Designer” font used for title Body text justified/justification inconsistent
	Font size	Size hierarchy not consistent Title in larger font and headings not obviously larger than body of text

TABLE III

(Continued)

Design element	Poster detail	Ineffective design elements ^a
	Color scheme	There is no obvious scheme
	Poster background	Brown, dark, makes everything hard to read Background to text boxes and elements looks awkward against background
	Layout (flow)	Elements not aligned Little white space/no margin Reading flow changes from left-right to top-bottom (unintuitive) Sections are not arranged in logical flow (conclusions before some results) Methods is the largest section
	Overall assessment	Ineffective graphics and presentation, cluttered, and text-heavy, no visual flow or layout

^aThis poster was deliberately designed to combine all the different types of ineffective design—its only redeeming feature is that the graph included is large.

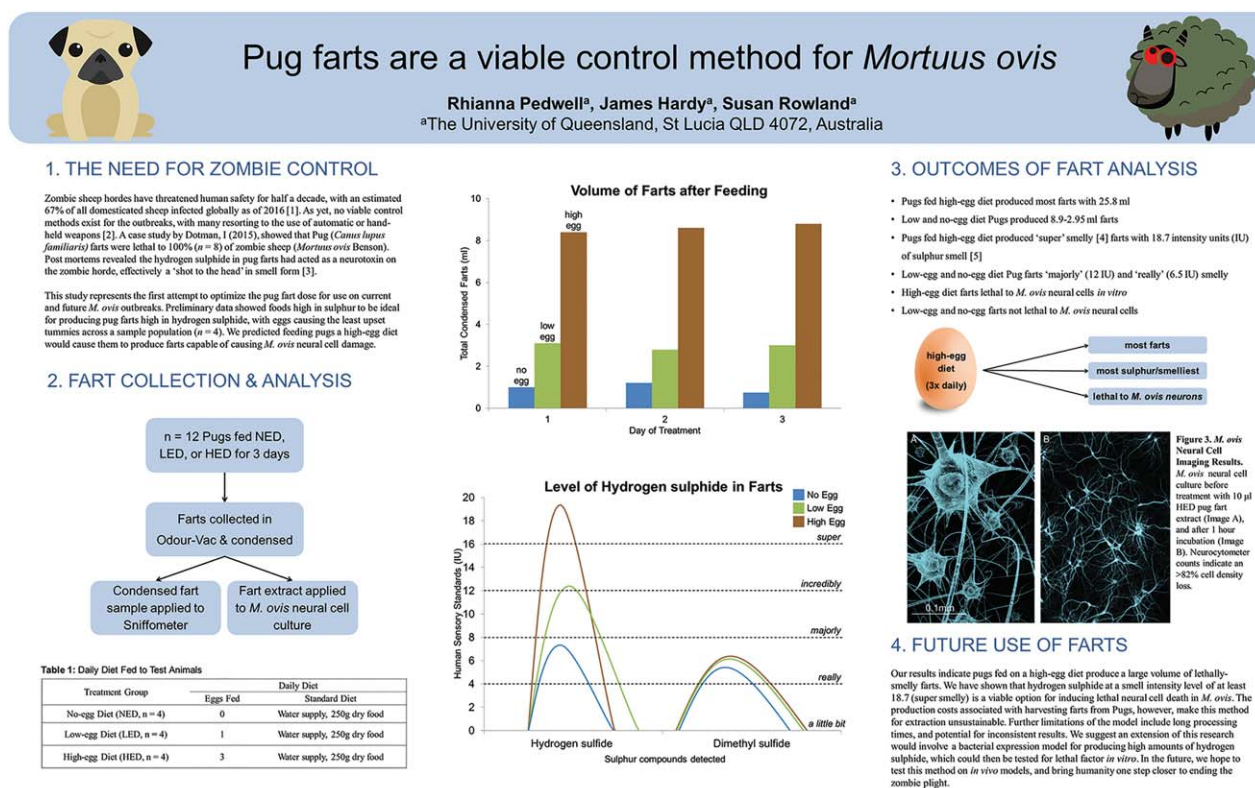


FIG 2

An excellent poster. [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]



Efficacy of Pug Farts as a Control Method for *Mortuus Ovis*

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BACKGROUND

For human safety, zombie sheep herds have been a threat for the last 5 years, and it is estimated that more than 67% of all domesticated sheep on the planet have been infected. There are no effective management strategies for the zombie threat, and many humans under in outbreak areas have resorted to using physical violence against the zombies to kill the population. This includes both the use of hand-held weapons such as knives and machetes, as well as automatic weapons such as rifles and machine guns. In 2015, Dotman reported his experience in dealing with zombie sheep (*Mortuus Ovis*) created by his neighbour, Benon, by employing his pet Pug (*Canis lupus familiaris*) as a means of defence. Specifically, the Pug's farts were lethal to all of the zombie sheep on Grandma's farm, with none of the eight left 'alive'. Extensive post-mortems were conducted on the zombie remains, with tissue samples of the brain, muscle, digestive tract, eyes, and skin collected and stored for research by the Centre for Research into Unnatural Phenomena (CRUP). These post-mortems revealed the farts from the Pug acted as a neurotoxin against the sheep, that is they caused wide-spread tissue damage and rapid cell death. Like those who had used hand-held and automatic weapons, this further confirmed the theory that targeting the head is the most effective strategy for controlling zombie sheep. This study is the first to optimize the use of farts from pugs as a method for controlling *M. ovis*. Our laboratory conducted preliminary testing into the generation of farts in Pugs, by feeding them high-meat, high-sulphur, and high-fibre diets. The high-sulphur diet was the most effective in producing Pug farts, and it was also least likely to cause the dogs gastrointestinal distress (other than extra gas). Eggs, from chickens, are known to be high in sulphur. Therefore, we fed a group of Pugs a no-egg, low-egg, or high-egg diet and measured fart production. We predicted feeding pugs a high-egg diet would cause them to produce farts capable of causing *M. ovis* neural cell damage. Standard equipment was used to measure fart production. We took samples of the farts and sprayed them over neural cell cultures from *M. ovis*, to test if the farts from each diet had enough potency to induce neural cell death.

MATERIALS & METHODS

Pug Feeding and Fart Collection

We fed 12 healthy pugs three types of diet for three days in a large enclosure with outside access. We obtained ethics approval for this study. Each group was fed a diet specified in Table 1 each day for three days. We used an Odour-Vac™ system in each enclosure to capture farts every 2 minutes for 12 hours after feeding for each day. Captured farts were converted to liquid form in a standard condenser, and the volume measured.

Sniffometer Rating

Aliquots of 2 ml pure fart extract were made for each treatment group and analysed using an MQ-2000 Sniffometer calibrated for sulphur. The Sniffometer measured the amount of sulphur-containing compounds in a sample, then used advanced synthetic olfactory software to quantify the smell intensity against Human Sensory Standards. [4] The results were expressed qualitatively using the Nasal Malodour Scale (NMS) [5].

M. ovis Neural Cell Death Assay

Remaining condensed fart was diluted to a 1:1000 solution with purified water. Cell cultures grown from an *M. ovis* brain tissue sample were mixed with 10 µl of fart extract from each group and incubated at 37°C for 1 hour. Cell density was measured before and after the treatment using a neurocytometer. The percentage of affected neurons must be above 80% to be considered lethal.

Table 1: Daily Diet Fed to Test Animals

Treatment Group	Daily Diet
No-egg Diet (NED, n = 4)	0 Eggs Water supply, 250g dry food
Low-egg Diet (LED, n = 4)	1 Egg Water supply, 250g dry food
High-egg Diet (HED, n = 4)	3 Eggs Water supply, 250g dry food

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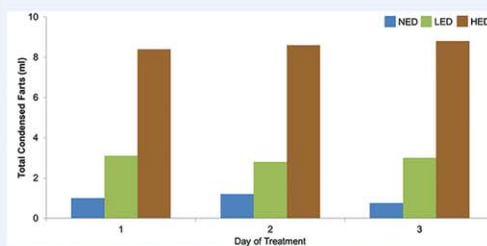


Figure 1: Volume of Condensed Pug Farts during Feeding period. Volume of condensed farts was measured using an Odour-Vac™ system in the Pug enclosures. Samples were taken at 2 minute intervals for 12 hours post-feeding for three days.

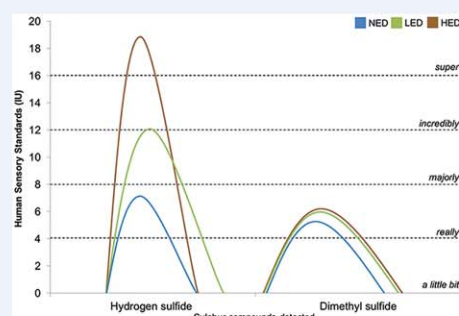


Figure 2: Sniffometer reading for Pug fart samples. Peaks show level of sulphur-containing compounds in 2ml aliquots of condensed pug farts. Farts are measured on the Human Sensory Standards scale for 'smell intensity'. Nasal Malodour Scale ratings overlay the figure.

RESULTS

Pugs fed the high-egg diet produced the most volume of farts, and the most intensely smelly farts (Figure 1). HED fed pug farts were also the most lethal *in vitro* against *M. ovis* neural cell cultures. A total of 25.8 ml of condensed farts were collected from this group. This was nearly three times as many as the low-egg diet with a total 8.9 ml, and 16 times more than the no-egg diet at 2.95 ml.

The Sniffometer reading shows a peak for all three treatment groups at the Human Sensory Standards level for hydrogen sulphide. Farts extracted from the high-egg diet group showed a reading of 18.7 intensity units for hydrogen sulphide. This indicates a 'super' smell rating for the condensed farts on the NMS. Pugs fed the low-egg diet also produced 'majorly' smelly farts, with hydrogen sulphide measured at 12 intensity units. Farts from the no-egg diet group had a hydrogen sulphide intensity unit rating of 6.5, making these farts 'really' smelly.

M. ovis neural cell killing assays showed fart extract produced from HED fed pugs was lethal to >82% of all cell cultures (Figure 3). LED fed pugs produced farts that produced >65% cell death. Fart extract from NED fed pugs failed to affect the neural cell culture.

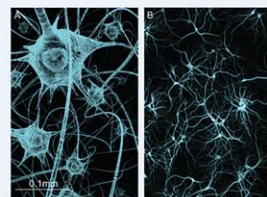


Figure 3: *M. ovis* Neural Cell Imaging Results. *M. ovis* neural cell culture before treatment with 10 µl HED pug fart extract (Image A) and after 1 hour incubation (Image B). Neurocytometer counts indicate an >82% cell density loss.

CONCLUSIONS & FUTURE DIRECTIONS

Our results indicate pugs fed on a high-egg diet produce a large volume of lethally-smelly farts. We have shown that hydrogen sulphide at a smell intensity level of at least 18.7 (super smelly) is a viable option for inducing lethal neural cell death in *M. ovis*. The production costs associated with harvesting farts from Pugs, however, make this method for extraction unsustainable. Further limitations of the model include long processing times, and potential for inconsistent results. We suggest an extension of this research would involve a bacterial expression model for producing high amounts of hydrogen sulphide, which could then be tested for lethal factor *in vitro*. In the future, we hope to test this method on *in vivo* models, and bring humanity one step closer to ending the zombie plight.

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FIG 3

An average poster. [Color figure can be viewed at wileyonlinelibrary.com]

digital poster delivery; apps such as Aurasma [58] and QR code reader [59] now allow posters to be linked to online resources, and a digital poster can become "a kind of automated, self-discovery learning" [60]. Applicable theoretical concepts include signalling, redundancy, contiguity, *pathos*, and *ethos*.

Poster Resource Design

To develop the three exemplar posters (Figs. 2 and 3, and Supporting Information) we used the principles laid out above and also accessed both published and unpublished resources on poster design and presentation. To create the high-quality poster we used the principles of design described above. To create the less effective posters we variously drew on the resources cited in Table 1 and (i) deliberately followed "bad" advice, (ii) did the opposite of the "good" advice, and (iii) discarded the framework described above. Much of the detailed formatting advice from the earlier resources (~1980–1990s) was out-dated, due to rapid changes in technology. The information on the website resources, in general, was still current.

When planning these exemplar posters we had initially thought to use pre-existing science posters as the focus of critique. We reconsidered, however, after evaluating the risks around (i) causing personal offence, and (ii) alienating some students and educators by using discipline-specific material. Our solution was to create our own posters with an invented storyline and data.

The "experiments" reported in these resources relate to the use of dog flatulence to kill mutant zombie sheep. The contemporary theme of the zombies and the light-hearted humour woven throughout the mock scientific study is designed to appeal to and engage students. This takes the focus from theory-heavy content in one discipline and shifts it onto best practices for poster design. It also means that when students and educators consider the quality of the posters they are not drawn to critiquing the experimental methods or the study itself.

Educators can use these posters as examples of poor, acceptable, and excellent practice without the risk of revealing the answers to a current assessment item. Since the posters are built around a fanciful and unique subject it

EFICACY OF POG FARTS AS A LETHAL TREATMENT AGAINST POPULATIONS OF *MORTUUS OVIS*: PRELIMINARY FINDINGS

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Introduction

For human safety, zombie sheep herds have been a threat for the last 5 years, and it is estimated that more than 67% of all domesticated sheep on the planet have been infected. There are no effective management strategies for the zombie threat, and many humans under in outbreak areas have resorted to using physical violence against the zombies to cull the population. This includes both the use of hand-held weapons such as knives and machetes, as well as automatic weapons such as rifles and machine guns. In 2015, Dotman reported his experience in dealing with zombie sheep (*Mortuus ovis* Benson) created by his neighbour, Benson, by employing his pet Pug (*Canis lupus familiaris*) as a means of defence. Specifically, the Pug's farts were lethal to all of the zombie sheep on Grandma's farm, with none of the eight left 'alive'. Extensive post-mortems were conducted on the zombie remains, with tissue samples of the brain, muscle, digestive tract, eyes, and skin collected and stored for research by the Centre for Research into Unnatural Phenomena (CRUP). These post-mortems revealed the farts from the Pug acted as a neurotoxin against the sheep, that is they caused wide-spread tissue damage and rapid cell death. Like those who had used hand-held and automatic weapons, this further confirmed the theory that targeting the head is the most effective strategy for controlling zombie sheep. This study is the first to optimize the use of farts from pugs as a method for controlling *M. ovis*. Our laboratory conducted preliminary testing into the generation of farts in Pugs, by feeding them high-meat, high-sulphur, and high-fibre diets. The high-sulphur diet was the most effective in producing Pug farts, and it was also least likely to cause the dogs gastrointestinal distress (other than extra gas). Eggs, from chickens, are known to be high in sulphur. Therefore, we fed a group of Pugs a no-egg, low-egg, or high-egg diet and measured fart production. We predicted feeding pugs a high-egg diet would cause them to produce farts capable of causing *M. ovis* neural cell damage. Standard equipment was used to measure fart production. We took samples of the farts and sprayed them over neural cell cultures from *M. ovis*, to test if the farts from each diet had enough potency to induce neural cell death.

Materials and Methods

Treatment Group	Daily Diet	
	Eggs Fed	Standard Diet
No-egg Diet (NED, n = 4)	0	Water supply; 250g dry food
Low-egg Diet (LED, n = 4)	1	Water supply; 250g dry food
High-egg Diet (HED, n = 4)	3	Water supply; 250g dry food

Pugs
Our sample for this study were 12 adult Pugs who passed a health check and had no known gastro-intestinal diseases or conditions. Ethics approval for the use of these animals, the feeding of the diets, and the testing of the farts was obtained for this study. The Pugs were healthy, and from two litters of the same parents, with n = 7 pugs from the first litter aged 4 years and n = 5 pugs from the second litter aged 3 years. All animals were spayed. We fed each dog 250g of Pet Appetite Premium dry-food, and all animals had constant access to fresh filtered water. Animals were also fed free-range organic eggs sources from a near-by supermarket (name withheld). The eggs were boiled for 8 minutes on the day of feeding and allowed to cool completely before being fed to the test animals. Pugs were fed twice a day, receiving dry food in the morning at approximately 7 AM AEST, and the cooled eggs at approximately 7 PM AEST. Pugs in the no-egg diet received more dry-food at the second feeding. Pugs in the low-egg diet were fed 1 egg per day, and Pugs in the high-egg diet were fed three. After the feeding period, Pugs were assessed for general health once again and returned to their owners after a 24 hour period.

Fart Collection
Pugs were kept overnight in large enclosures to collect farts produced. Enclosures were fitted with an Odour-VacTM system that collects all farts produced post the second feed. The system works by extracting gas at 2-minute intervals and feeding this into a converter that condensed all gas that was 'scented' into liquid form. The volume of this condensed material was measured by the system and fed into a database for each enclosure.

Sniffometer Reading
After the three-day feeding period, total collected fart extract for each diet group was retrieved and labelled. Aliquots (2ml) of the fart extract for each group were prepared. An MG-2000 Sniffometer was calibrated for detecting sulphur using melted elemental sulphur. Aliquots of fart extract were applied to the highly sensitive Whiff-Pad and measured. The Sniffometer measured the amount of sulphur-containing compound in the samples using mass-spectrometry and then sending data through to its advanced olfactory software to be quantified against Human Sensory Standards. Level of fart smell was expressed using the Nasal Malodour Scale.

Neural Cell Killing Assay
Remainings samples of condensed fart were diluted to a 1:100 solution with purified water. *M. ovis* neural cell cultures were obtained from CRUP and grown at 37°C for 24 hours on media enriched with pig blood. Each plate was misted with 10µl of fart extract from each group and incubated at 37°C for 1 hour. Cell density was measured before and after the treatment using a neurocytometer. Based on *M. ovis* post mortem studies, the percentage of affected neurons must be above 80% to prove lethal.

Results

Pugs fed the no-egg diet produced a total volume of 3.215863 ml of farts over the three day feeding period. Pugs fed the low-egg diet produced a total volume of 5.114625 ml of farts over the three day feeding period. Pugs fed the high-egg diet produced the most farts, with a total of 26.01495 ml produced. Table 1 shows the 12-hour total readings for each pug in each diet group. These totals were summed, to produce a daily total for each pug in each diet group. The total amount of farts for each pug over the three-day feeding period was also recorded.

The Sniffometer reading (Figure 1) shows a peak for all three treatment groups at the sniff-level for hydrogen sulphide. A small, constant level of dimethyl sulphide was also detected in each of the three samples. Farts extracted from the high-egg diet group showed hydrogen sulphide reading of 18.7 intensity units on the Human Sensory Standards scale (0-20). When converted to the Nasal Malodour Scale, this is indicative of a human being finding the farts from the HED group 'super' smelly. Pugs fed the low-egg diet also produced farts with a hydrogen sulphide smell intensity score of 12 units, which translates to an NSM rating indicating 'majorly' smelly farts. Farts from the no-egg diet group had a hydrogen sulphide intensity unit rating of 6.5, and when translated using the NSM scale this indicates the farts were 'really' smelly. None of the hydrogen sulphide peaks fell within the NSM scale ratings for 'a little bit' or 'incredibly' smelly.

Two of the three fart samples produced by the different diet groups were successful at inducing *M. ovis* neural cell death, shown in Figures 2-4. The fart sample produced by the no-egg diet group was able to induce cell death in more than 20% of the tissue sample. This indicates non-lethality for this level of hydrogen sulphide. The fart sample produced by the low-egg diet group was also unable to induce a lethal amount of cell death in the tissue sample, with <65% of cells lost, based on neurocytometer readings. The sample from the high-egg diet group induced neural cell death in >82% of the tissue sample, and this is indicative of a lethal dose.

Table 1				
Test Subject	Day 1	Day 2	Day 3	Total
NED1	0.10418229	0.10418209	0.05355678	0.261448
NED2	0.25994683	0.66666667	0.25003568	1.176619
NED3	0.45685059	0.15162168	0.45663134	1.064543
NED4	0.27777778	0.26542587	0.05000001	0.593204
Total	1.09311749	1.12810781	0.79523263	3.016448
LED1	0.69327485	0.50893547	0.50893543	1.711146
LED2	0.92975536	0.69565617	0.71111111	2.336523
LED3	1	0.95	1	2.95
LED4	0.71523595	0.72685485	0.81326791	2.255388
Total	3.33858266	2.84218662	3.03425566	9.214935
HED1	2.11211017	2.19888889	2	6.412007
HED2	2.31113265	2.40140145	2.25857492	6.971089
HED3	2	2	2.32222229	6.322223
HED4	2	1.97995692	2.26788099	6.247837
Total	8.42226442	8.72117797	8.84978499	26.001341

Conclusions

Our results indicate pugs fed on low, or no-egg diets are not capable of producing farts that have a hydrogen sulphide smell intensity that equates to a lethal dose in *M. ovis* with neurons. Further our findings indicate that feeding pugs a high-egg diet causes them to produce a large volume of farts, with a hydrogen sulphide level of 18.7 smell intensity units and that this level of hydrogen sulphide is capable of inducing lethal neural death in *M. ovis*. It has been 5 years since the advent of *M. ovis* outbreaks, with more than 60% of the population of domesticated sheep now infected (1). Research attempts at developing a control mechanism have so far failed to produce adequate results. Our findings are the first indication of a viable method. However, there are limitations to these methods. First, it cost AUD \$500 to cover the veterinary, enclosure building, and feeding costs of each pug. The equipment we used is also highly specialised, and none of the art, so this was also a huge cost for the project. Further limitations of the model include long processing time, in each pug took roughly 4 hours to digest the eggs completely, although this varied among individuals and therefore there is the potential for inconsistent results. We suggest an extension of this research would involve a bacterial expression model for producing high amounts of hydrogen sulphide, which could then be tested in vitro on captured *M. ovis* specimens and eventually lead to a solution.

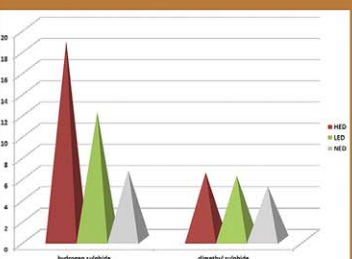


Figure 1. Sniffometer Reading. Farts collected from pugs in each diet group during the feeding period, using an Odour-Vac system in the enclosure. These were condensed and 2 ml aliquots taken. The samples were applied to the Whiff-Pad of an Sniffometer (MG-2000) that had been calibrated for sulphur containing compounds. The readings are then quantified using the Human Sensory Standards scale. Dark-red peaks indicate the reading for the high-egg diet group, greenish, reddish peaks indicate those for the low-egg diet. The light pink/red peaks indicate the reading for the no-egg diet. A similar level of dimethyl sulphide was found along with the hydrogen sulphide.

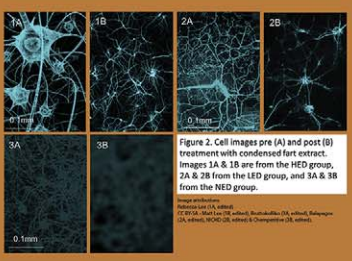


Figure 2. Cell images pre (A) and post (B) treatment with condensed fart extract. Images 1A & 1B are from the HED group, 2A & 2B from the LED group, and 3A & 3B from the NED group.

FIG 4

A terrible poster. [Color figure can be viewed at wileyonlinelibrary.com]

will also be immediately obvious if students copy material from these resources and submit it as their own for assessment.

The first (Figs. 2 and S1, Supporting Information) is an example of an ideal poster, one that follows almost every best-practice design principle or advice. The second example (Figs. 3 and S2, Supporting Information) is passable, but it has several flaws that can be considered typical of professionally made science posters. The final poster (Fig. 4 and S3, Supporting Information) is the example of what can go wrong when every design principle is ignored. It is exaggerated, and it is unlikely such a poster exists. The different ineffective design elements have, however, been observed in actual posters. We have included all three posters as Supporting Information so that educators can download the files for their own use.

We elaborate on the design elements of each poster in Tables (I-III). The list of elements has been categorized into what we see as the three broad considerations in poster design: text content, graphics content, and esthetics. The "best practice" or "ineffective" design elements for each

poster are detailed and the publications that address these elements are referenced.

Using the Resources

Educators are able to use the three posters and the accompanying Tables (I-III) as teaching tools to exemplify best practices for poster design, and to show where common design errors can add up to an ineffective poster. The posters are deliberately nondiscipline specific and use a contemporary theme, so they are appealing and engaging for students of any field. We envision educators using the resources to prompt discussion around poster design, in the context of the poster as assessment. Tables (I-III) give a detailed breakdown of what has and has not been designed well for each poster. Educators may find use in these as marking criteria for students, or as marking rubrics. The three principles for poster design are better suited for use as guiding points by students or by experienced researchers. We realize, however, that not everyone will agree with these principles, or the other design practices we have used. We welcome feedback from the community,



particularly from those with expertise and experience in communication, visual design, and education.

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