Brain Friendly Teaching—Reducing Learner's Cognitive Load

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Many didactic lectures induce a cognitive load in learners out of proportion to the content that they need to learn (or can learn) during that teaching session. This is due in part to the content, and in part to the way it is displayed or presented. By reducing the cognitive load on our audience, we can increase long-term retention of information. This article briefly summarizes some of the science behind cognitive load as it relates to presentations, and identifies simple steps to reduce it, while maximizing learning.

Key Words: Teaching; cognition; PowerPoint; lecturing.

During my academic career, I have lectured using transparent overheads, Diazo slides, animated PowerPoints, graphical pads, a tablet-PC and now a wireless iPad. As a self-confessed geek, I love the tools and am always looking for creative ways to make teaching more interactive and effective, while avoiding focusing on the tool rather than the teaching. For most educators, the "tool" of choice for 20 years has been either PowerPoint (Microsoft, Redmond, WA) or Keynote (Apple, Cupertino, CA). For the rest of this paper, I will only refer to PowerPoint, but the same principles apply to all digital slide software.

These programs were a huge leap forward for educators—they gave us the ability to make and edit attractive slides much faster and cheaper than previously. With traditional slide carousels, we changed from single projectors to dual projectors so we could present two carousels of slides during one lecture—often with disastrous consequences as the audience tried to follow two uncoordinated slide sets. The advent of digital projection thankfully put an end to the dual projection, but brought with it a whole new potential world of presentation excess. Now we could use an incredible array of irresistible color schemes and fonts, and add slide transitions, animations, and even sound effects. What fun!

With tools that can turn a simple lecture into a Cirque du Soleil performance, how do we start to construct lectures? Usually by looking at texts or literature and cramming everything about that topic onto the magic 60 slides that we have learnt is the "right" amount for a 1-hour lecture (that number incidently came from the maximum number of slides that could be fitted into a carousel). Then we add our images. The result of these time-consuming endeavors is frequently cognitive overload in our learners and a lack of long-term learning. There are multiple components to a successful teaching session aside from the slide content such as the development of appropriate and focused learning objectives; using active learning methods and our oral presentation skills. In this article, however, I am going to focus on the concept of "cognitive overload," and how we can change the format and content of conventional didactic lectures to reduce cognitive overload while maximizing learning.

COGNITIVE LOAD

Cognitive load is the stress put on our brain when we learn new data or skills (1). Cognitive load exists due to the limitations of our working memory. Working memory (formally called "short-term memory") is the part of our brain which enables the processing and storage of information into long-term memory. Working memory has a very small capacity—thought to be able to hold only 7 ± 2 pieces of information at any one time—and information contained in short-term memory has to be either moved to long-term memory very fast, or it is lost (2). In this way, it is similar to the Random Accessed Memory (RAM) on your computer as it processes information to be stored on the hard disc. Cognitive load is affected by what we are trying to learn (simple vs complex data); how much we try to learn in any one session; how the data are presented to us and who are the learners (is the information new to us?). *Cognitive overload* is what happens when our working memory is overloaded by too much data too fast (1). When this occurs, processing slows down, and key information is not stored. Unfortunately, PowerPoint gives us plenty of opportunity to inadvertently increase the cognitive load on our learners, reducing long-term retention of information.

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INFORMATION QUANTITY

We typically try to teach everything about the subject at hand in one session—often presenting large quantities of information in a format that might work well in a handout that could be studied at leisure, but overwhelms learners during a 45- to 60-minute lecture. We forget that for most learners, this is not their only opportunity to gain this knowledge. By overwhelming them with data, we reduce the learning of key information. We need to ask ourselves, what do we really want them to know about this condition, process, or modality? Presenting less can often result in them learning more (3). We can reduce cognitive load and improve memory retrieval by "chunking" related information together. If a single slide includes elements from multiple teaching points, it is much more difficult for learners to "chunk" together than if information from only one teaching point is included. Chunking is the process of taking long strings of information, grouping (chunking) them into smaller, more manageable bits of information, which has been shown to improve memory recall (4,5).

USING THE MODALITY EFFECT

Our working memory is able to process information down two synergistic pathways: verbal (auditory and written text) and visual (graphs, diagrams, images) (6). We can utilize this effect to our advantage by presenting information in two ways—for example, by showing an image and talking about it (7). We can also impair information storage by presenting the same information in two verbal forms—for example, by putting up a text-heavy slide and then reading it aloud. Your learners can read the information on the slide faster than you can read it, so their brains are trying to process two discordant information streams down the same pathway. Only the key words (and images) need to be on a slide, the written words will be used as memory "hooks" for the more detailed verbal information that you are speaking. Lecturers who just read the slides are also painful and boring to the audience. As John Sweller, an educational psychologist in New South Wales, said, "If your presentation can be perfectly and completely understood without your narration, then it begs the question: why are you there?" (8). Students do not attend these lectures; they read the slides at home.

EXTRANEOUS INFORMATION

Extraneous information is visual or verbal information that is not needed to teach the learning objective. By adding extraneous information, we are increasing the cognitive processing that our learners are required to do (9). This extra cognitive work (load) impairs the processing of the important information. The temptation to inadvertently include extraneous information on slides is huge—we frequently add icons, extra images, and figures that are not needed to convey the teaching. How often has your conscious attention (let alone unconscious) been drawn to looking at the icons or pretty pictures on the slide rather than listening to the speaker? On the other hand, images used appropriately can be very impactful as we remember images better than written words. They can also provide a useful "mental pause" between different topics. We can distract learners further by using slide transitions, complex animations (simple animations can aid learning such as arrows that appear and disappear), or sound effects.

READABILITY IS MEMORABILITY

The more difficult a slide is to read, the more difficult it is to learn. Small and fancy fonts, low contrast color schemes, small and poor quality images, complex graphs, and large tables all challenge the learner and add nothing to the presentation (Fig 1). The audience should never remember your slide design when they leave the room, only your lecture. Light-colored backgrounds, although helpful to show text in a brighter room, reduce the visibility of imaging abnormalities as the audience's pupils will be constricted. Changing from light to dark backgrounds is similarly challenging to viewer's ciliary muscles and results in eye strain. Remember that whereas you are making slides 30 cm from your computer, your audience may be (and usually is) reading them from the back of the room. Keep font sizes to 28 or more, preferably larger.

SPLIT ATTENTION

By splitting the attention of our audience, we increase cognitive load and decrease the learning. There are several ways this can happen. We may have multiple teaching points, images, or graphs on a single slide so that they are focusing on a different component than we are discussing. Taking notes, especially in a high cognitive load lecture, is as mentally challenging as playing chess (10). A learner is trying to listen to the lecturer, identify the important points, read the slide, and get notes written, often while the next slide is being presented (and additionally trying to remember the new slide).

EXPERTS VERSUS NOVICES

Experts and novices learn differently. This can be challenging as our audience frequently includes mixed learner groups, for example, first to fourth year residents, fellows, and faculty. Novices need a framework of information built before they can add the details, whereas experts assimilate information in a much more complex manner. Experts have pre-existing patterns or schema in their long-term memories which they can retrieve and add information to (4,11). We need to be aware of the expertise level(s) of our audience and adjust how we present the information. Junior residents may need to be given some form of pre-learning to provide that "framework" for them to avoid cognitive overload during a lecture that is more geared to senior residents.

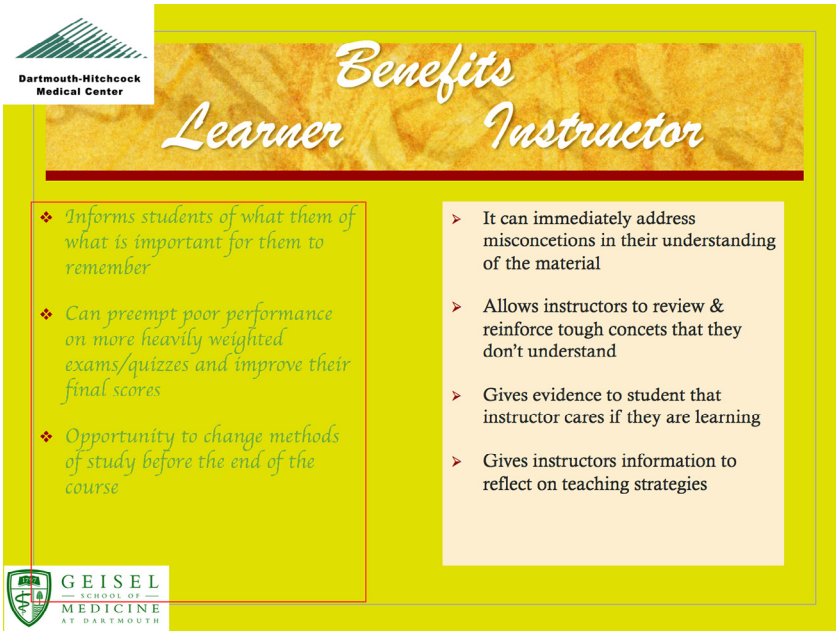

Figure 1. An example of a "brain unfriendly" slide with high cognitive load from a talk on formative assessment. The color scheme, bullets, typos, and icons are distracting. The font is difficult to read (small, poor contrast). Too much text and more than one teaching point included (instructor benefits, student benefits).

MAKING YOUR SLIDES BRAIN FRIENDLY (12)

1. Include your learning objectives (using active verbs from Bloom's Taxonomy (13)) so that the audience can focus on what they need to learn from this session. This has been shown to increase learning.
2. Stop worrying about the number of slides. The talk length is dependent on the words you will say, not the number of slides. Slides cost nothing, and it is much better that you have less information (hence less time) on each slide.
3. Make your slide format as boring as possible. Remove all icons from all but the title slide. Remove images that are not adding to the teaching (unless using as a short mental pause between topics). Use a standard font—a sans serif font such as Helvetica or Arial is more readable when projected than a serif font such as Times Roman. Never capitalize all text—the audience hears this as shouting! Simplify the bulleting, bullets are not needed on every indent level.
4. *No* slide transitions. Remove unnecessary animations—having one line appearing at a time is annoying to the audience and requires you to click slide advance so repetitively that it defocuses your attention from what you are saying.
5. Pick a high contrast, dark background color scheme (eg, white or pale shade text on deep blue, brown, gray, or black). This will show abnormalities in radiology images better.
6. Put each image, diagram, or graph on its own slide where possible. Images can be paired if you need the pre- and post-contrast or two different magnetic resonance sequences, but if you are thinking of more than two images, consider if that is really necessary. Enlarge them to use all the screen real estate. Crop down to the area of interest when possible.
7. Reduce the amount of text overall and markedly reduce the number of words per slide. In my experience, most lecturers need to cut out at least 50% of text. Remember, you do not need to have every word that you want to say on each slide—only the *key* information. Put any additional text in your speaker notes and use "presentation mode" (to edit an old talk, copy and paste the current text into the speaker note area). Use 36 or 40 font, which will limit how many words you can put on each slide. Ensure spelling is correct.
8. Summarize tables—huge tables are cognitively overwhelming and unreadable. A lecture is not a paper. Pull out the key information, put into a Powerpoint table and highlight (color, font) the data you will focus on. Try to keep tables to 4×4 (plus headers) or less.
9. Only one learning point per slide. Have the audience focus on that before you move on. This helps with chunking for memory retrieval (Fig 2).
10. Remove acronyms and abbreviations unless they are very familiar with the audience. It is frustrating for the audience if they cannot decode the slide.
11. *Signal* key content either verbally ("this is key" or "don't forget this") or with highlighting on the slide with color, underlining, or bold. This reduces the cognitive load for note takers (14).
12. Replace some text slides with images—radiographic, clinical, pathological, or other. We remember images better than we do words, particularly if the images are emotionally impactful. This utilizes the modality effect as you talk about the slide.
13. Provide a summary at the end to reinforce the major learning points.

Finally, always practice your talk out loud and then edit. Practicing in your head will not show you how smoothly it will flow, and if it makes sense.

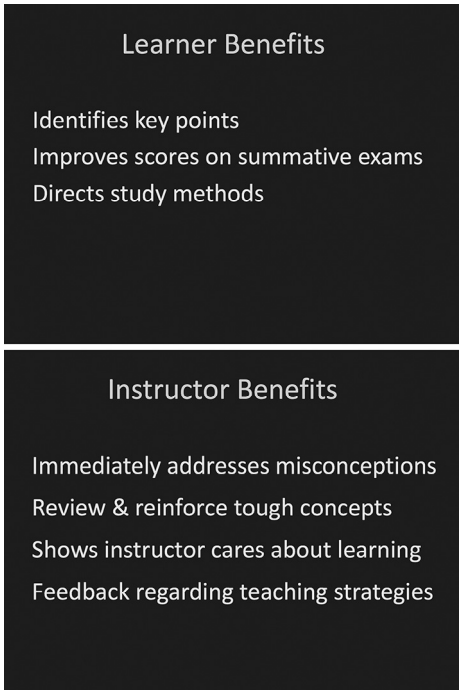

Figure 2. Same content made "brain friendly." The text has been reduced to the important points, and the slide scheme was simplified and separated into two slides, each focusing on one teaching point.

SUMMARY

Revising your lectures to reduce cognitive overload is a highly worthwhile task which will pay dividends for your learners. This article briefly summarizes some of the science behind this concept as well as providing the steps to achieve Brain Friendly Teaching.

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