Received: 16 August 2023 | Accepted: 31 January 2024
DOI: 10.1111/tct.13759

CLINICAL TEACHER'S TOOLBOX

THE CLINICAL TEACHER

The use of cognitive load theory to assist in the teaching of electrocardiogram interpretation within paramedical science education

Marc Gildas Thomas

Swansea University, Swansea, UK

Correspondence
Marc Gildas Thomas, Swansea University, Swansea, UK.
Email: m.g.thomas@swansea.ac.uk

Funding information
Swansea University

Abstract

Background: Paramedics are expected to record electrocardiograms (ECGs) as part of their clinical assessment; however, it is an extremely difficult skill to learn and understand as it has a high intrinsic cognitive load which can also be challenging to teach effectively.

Aims: This article will explore the use of cognitive load theory to assist in the teaching of ECG interpretation within the context of paramedical education.

Description: Cognitive load theory can be useful to aid teaching within complex medical and health science domains including clinical skills teaching.

Conclusions: The application of cognitive load theory to the teaching of ECG interpretation can be useful as it allows for the development of understanding, building schemata linking information currently being learned to knowledge already gained within the long-term memory, which can maximise germane load by the appropriate selection of intrinsic load, minimising extraneous load therefore not overloading the working memory.

1 | INTRODUCTION

An essential part of pre-hospital emergency care and a paramedic's duties is having the ability to understand and interpret electrocardiograms (ECGs).[1] Paramedics are expected to routinely record ECGs as part of their clinical assessment for medical emergencies such as recognition and diagnosis of a myocardial infarction (MI), so the importance of being able to confidently read and interpret an ECG accurately is essential to paramedic practice.[2] However, ECG interpretation is an extremely difficult skill to learn and understand with a high intrinsic cognitive load.[3] Any methods to assist teaching this difficult subject with a high intrinsic load can be extremely useful.

ECG interpretation is an extremely difficult skill to learn and understand with a high intrinsic cognitive load.

Clinical educators have used cognitive load theory for many years as it realises the demands on the limited capacity of the working memory in dealing with new information especially in complex domains such as health science and medical education.[4] When the working memory is overloaded, learning becomes impaired.[5] To prevent this, cognitive load theory adopts methods to reduce extraneous cognitive load (irrelevant, distracting information) therefore maximising germane cognitive load (learning that occurs), which can enhance and improve learning.[6] This article will explore the use of cognitive load theory to assist in the teaching of ECG interpretation within the context of paramedical education, offering tips on how this can be successfully integrated.

When the working memory is overloaded, learning becomes impaired.

2 | AWARENESS OF DIFFERENT TYPES OF COGNITIVE LOAD

The three types of memory that a human being has in order to process information are short-term, long-term and working memory.[7] Working memory sits in between short- and long-term memory and can only hold between five to nine pieces of information at any one time.[4] Cognitive load theory concentrates on the working memory defining the different types of cognitive load, which all take up bandwidth within this area.[6] These are named intrinsic, germane and extraneous loads.[8]

The three types of memory that a human being has in order to process information are short-term, long-term and working memory.

3 | INTRINSIC AND GERMANE LOADS

The intrinsic load focuses on the difficulty of the task at hand which is particularly pertinent to ECG understanding as this subject area is difficult to learn therefore has a high intrinsic load.[3] The germane load is the actual learning that takes place from dealing with and processing the intrinsic load by allowing it to be stored in the long-term memory so it can be accessed as and when it is required.[9] This can be achieved by constructing schemas that connect to knowledge already gained that has been stored in the long-term memory from previous learning such as adding to previously learnt physiology of the heart adding in the electrical activity recorded on an ECG.[4]

4 | EXTRANEOUS LOAD

Extraneous load comprises details that are distracting which take up storage in the limited working memory which do not play any part in the students learning, such as distracting slides on a PowerPoint slideshow that include irrelevant pictures.[10] Cognitive load theory encourages us to focus on minimising extraneous load, correctly corresponding intrinsic load to the required learning task therefore maximising the germane load.[5]

5 | REDUCING THE INTRINSIC LOAD

Simple tasks without multiple elements are not likely to cause a high intrinsic load; however, tasks with multiple elements and considerations have a significantly high intrinsic load such as ECG understanding and interpretation.[5] There are a couple of ways to reduce the intrinsic load on the learner such as adopting the segmenting and pretraining effects.[10]

6 | SEGMENTING EFFECT

The segmenting effect involves breaking down the information into manageable chunks so not to overload the working memory, practicing multiple times before moving onto the next subject.[4] This allows the information to be stored in the long-term memory thus freeing up space within the working memory to absorb and process the next required piece of information or task.[10] This also allows schemas to be built linking information previously learnt stored within the long-term memory with new information currently being processed within the working memory.[11] This significantly reduces the intrinsic load preventing the learner becoming overloaded.[12] An example of this within ECG interpretation, can be first understanding the physiology of the heart including the electrical activity and how this relates to the ECG tracing.[13] This could then be built on by linking the waves seen on an ECG to the areas of the heart such as 'P' waves represent atrial depolarisation, the 'QRS' represents ventricular depolarisation with the 'T' wave showing ventricular repolarisation.[13] By constructing these schemas building on information learnt, layering the content and understanding, relating it directly to what is occurring within the heart is of real benefit to understanding ECGs. This process allows the learner to understand if there is an abnormality as they are able to pinpoint it to a specific area of the heart or electrical pathway as they have a clear understanding of the normal physiology of the heart and how it is represented on a ECG. With this progression in mind the pretraining effect further assists with this process.

Layering the content and understanding, relating it directly to what is occurring within the heart is of real benefit to understanding ECGs.

7 | PRETRAINING EFFECT

The pretraining effect allows the learner to concentrate on the knowledge of the required task before putting it into practice in a clinical environment, as when the learner is in a mock clinical environment there are distracting details which are relevant but can cause cognitive overload with the high intrinsic load, which can be overwhelming.[11] An example of this would be a practical mock scenario with an actor taking the part of a patient. The student is required to establish a history of presenting complaint and past medical history while also taking and recording observations such as respiratory rate, heart rate, blood pressure and an ECG. They then must interpret the findings within the context of the scenario, coming up with differential diagnoses, giving details of treatment plans. These extra details within this mock scenario are still essential but need to be built onto but only once the knowledge of ECG interpretation has been cemented in the long-term memory.[6] This ensures that the working memory is free to process the additional tasks such as taking an accurate patient history within the challenging, changing environment of paramedic practice, applying this knowledge including the observations using the ECG recording to assist with the differential diagnoses by looking for relevant changes within the ECG recording, for example, 'ST' elevation with reciprocal depression for cardiac chest pain (indicating an MI) or an 'S1, Q3, T3' pattern with pleuritic chest pain (indicating a possible pulmonary embolism).[13] This pretraining effect shows the importance of firstly being able to understand and interpret ECG recordings as an individual skill, before incorporating them with other elements of paramedic practice such as history taking and other clinical observations.

The pretraining effect allows the learner to concentrate on the knowledge of the required task before putting it into practice in a clinical environment.

8 | MAXIMISE GERMANE LOAD

Germane cognitive load was first added to the cognitive load framework in the 1990s as cognitive load that links to learning.[14] Recent papers suggest that as germane load closely aligns with intrinsic load, it should be included within this and now only feature two categories of cognitive load: intrinsic and extraneous.[9] Challenge this view as they state that germane cognitive load directly contributes to learning as it results from engagement in learning, which is beneficial for efficient and effective learning.[6] With this in mind, germane load is relevant to clinical education as this is the measure of learning from the correct management of the intrinsic load. In order to maximise germane load intrinsic load first needs to be appropriate so that tasks and topics learnt can be linked to the long-term memory by schemata of already learned information eventually allowing it to move permanently into long-term memory from the working memory.[11] So germane load with regard the understanding of ECGs is the measure of how well this task was learnt and applied by the learner following the use of the segmenting and pretraining effects within intrinsic load.[9] This can be assessed by formative or summative objective structured clinical examinations, applying ECG analysis to a clinical context once the students are comfortable with the understanding and interpretation of ECGs.[15] This allows learners to apply their knowledge within their long-term memory, contextualising their understanding of ECGs within a clinical case history, including a diagnosis and treatment of a condition relevant to paramedic practice such as an MI.

9 | MINIMISE EXTRANEOUS LOAD/ SEDUCTIVE DETAILS

Extraneous load within paramedic education can be difficult to manage as the teaching space has to be flexible, functioning as both a lecture theatre and a practical space where important clinical skills can be learned and practiced in a safe environment such as intravenous cannulation and endotracheal intubation. This poses a problem as there are several extraneous and seductive details distracting the learner from the task at hand, taking up valuable space within the working memory. The working memory can only cope with holding between five to nine pieces of information, only being able to process two to four pieces of these at any one time.[4] With this limited capacity of the working memory, it cannot afford to be occupied with other distracting, irrelevant information such as PowerPoint slides containing immaterial animations or equipment not relevant to the teaching of ECGs present around the lecture room.[6] For other non-practical lectures, including those on ECG interpretation which contain high levels of intrinsic load, the lecture room can be cleared of all distracting equipment placing them in cupboards beneath the worktops around the walls of the lecture room. Even though this is not ideal it does take away the level of distraction that this equipment poses for the students allowing them to solely focus on the topic at hand.[16] The slides to these lectures should be on a plain background, only contain relevant information with just enough information for the students to absorb with no distracting details.[17,18]

Working memory can only cope with holding between five to nine pieces of information.

10 | USE OF WORKED EXAMPLES

The use of worked examples within teaching has been proven to be useful in reducing the amount of cognitive load placed on the learner.[4] This can be achieved by breaking down the task, building it up as the learner becomes more confident with the subject matter, for example, allow students to critique parts of a treatment plan rather than write a de novo treatment plan themselves.[6] However, there appears to be less research to suggest its effectiveness within the teaching of diagnostic testing such as ECGs.[19]

Using worked examples has shown to reduce extraneous load as it demonstrates the logic regarding solving the problem.[8] This can be achieved by giving the students an example of a clinical case including the patient's presenting complaint and medical history also including an ECG recording to interpret within the clinical case content. Worked examples in this context can be extremely effective as they focus on contextualising and applying the students learning and understanding of ECGs within a clinical context discussion.[20] Agree that worked examples are an extremely effective way of reducing cognitive load on students working memory, with students becoming more knowledgeable by having studied worked examples.[6]

Using worked examples has shown to reduce extraneous load as it demonstrates the logic regarding solving the problem.

Building in completion tasks along with worked examples can also useful as these are tasks broken up into smaller more digestible pieces of information reducing the amount of extraneous load, by giving the student a partial solution to the problem, which reduces the size of the space taken in the working memory by the problem.[4] This completion principle can be achieved within the teaching of ECGs by using a similar clinical scenario to the worked example but giving the student a choice between four different answers for example.

11 | THE USE OF CONCRETE EXAMPLES

Concrete examples differ from worked examples as they focus on solid exemplars, which can help students understand and digest difficult or complicated ideas. These can be useful when trying to allow students to grasp and remember abstract ideas, as students are able to remember concrete examples better than the abstract ideas.[21] An example of this related to ECG interpretation is the analogy of 'walking back' for the interpretation of a second-degree type one atrioventricular, or Wenckebach, block. This occurs when the distance between the 'P' wave and the 'QRS' complex becomes progressively greater eventually resulting with the 'P' wave disappearing before this cycle repeats itself.[13] This way of remembering this difficult concept by imagining the 'P' wave walking back is also similar sounding to Wenckebach which reinforces this concrete example further.

Concrete examples differ from worked examples as they focus on solid exemplars which can help students understand and digest difficult or complicated ideas.

12 | APPLYING THE SPLIT-ATTENTION PRINCIPLE

Split attention can occur when students are required to divide their concentration between two or more sources of information separated by space or time.[10] This divided attention increases extraneous load substantially as the student must process separate sources of information and mentally integrate them together.[4] This is particularly pertinent to ECG learning as text separated from a diagram of the heart or of a wave on the ECG can increase the amount of extraneous load and hinder the students learning. To prevent this from occurring, the diagrams used within any slides for teaching ECG interpretation should have text integrated within them. This minimises the amount of extraneous load for the student, maximising their ability to process and absorb the information given to them.

Diagrams used within any slides for teaching ECG interpretation should have text integrated within them.

13 | EXPERTISE REVERSAL EFFECT (REMOVAL OF SCAFFOLDING): NOVICE TO EXPERT

Students are able to slowly remove the scaffolding, which supports their learning once they have completed the learning tasks over a period of time. As they have built on knowledge gained by linking schemata from the working memory to the long-term memory and are able to apply and contextualise this knowledge gained of ECG interpretation to clinical paramedic practice they are now ready to have this supporting structure of their learning slowly removed.[4]

This transition of learning supported by educators shares the vision that[22] believed in as zones of proximal development, with the learner being scaffolded between these levels with the scaffolding only being removed once the learning had been fully absorbed and retained. This novice to expert journey of a clinician gaining knowledge, continually building on it through their career not just in university but as part of lifelong learning and evidence-based education and practice is shared by.[23] This is especially important for ECG interpretation as by the continuation of building on knowledge gained, applying it to current evidence-based practice guidelines allows for the maintenance of competency and confidence of this essential paramedic diagnostic investigation and skill.

By the continuation of building on knowledge gained, applying it to current evidence-based practice guidelines allows for the maintenance of competency and confidence.

14 | CONCLUSION

The application of cognitive load theory to paramedic education, particularly with the teaching of ECG interpretation, can be extremely useful. The subject of ECG interpretation is one of the most important and difficult diagnostic tests to learn, which is also equally as challenging to teach.[24] Cognitive load theory allows the development of understanding, building schemata linking information currently being learned to knowledge already gained within the long-term memory.[9] These processes within cognitive load theory can maximise germane load by the appropriate selection of intrinsic load, minimising extraneous load and therefore not overloading the working memory. By applying worked and concrete examples of ECG interpretation within the context of paramedic practice this can further expand and contextualise learning without increasing extraneous load.

ECG interpretation is one of the most important and difficult diagnostic tests to learn which is also equally as challenging to teach.

By continually supporting learning with scaffolding, only removing it when it is appropriate to, linking learning with evidence-based healthcare and education practice allows for the learner to develop a deep understanding of ECG interpretation which can be applied during their challenging frontline pre-hospital emergency roles.[25–27]

AUTHOR CONTRIBUTIONS

Marc Gildas Thomas: Writing—original draft; writing—review and editing

ACKNOWLEDGEMENTS

The author has no acknowledgement to disclose.

CONFLICT OF INTEREST STATEMENT

None.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

ETHICAL APPROVAL

The author has no ethical statement to declare.

ORCID

Marc Gildas Thomas https://orcid.org/0000-0003-1775-0150

REFERENCES

1. Harris AY. Assessment skills for paramedics Maidenhead: Open University Press; 2011.

2. Caroline NL. Emergency care in the streets 7th ed. Burlington: Jones & Bartlett Learning; 2014.
3. Blissett S, Cavalcanti R, Sibbald M. ECG rhythm analysis with expert and learner-generated schemas in novice learners. Advances in health. Sci Educ. 2015;20(4):915–33. https://doi.org/10.1007/s10459-014-9572-y
4. Van Merrienboer JJ, Sweller J. Cognitive load theory in health professional education: design principles and strategies. Med Educ. 2010;44(1):85–93. https://doi.org/10.1111/j.1365-2923.2009.03498.x
5. Young J, Sewell J. Applying cognitive load theory to medical education: construct and measurement challenges. Med Educ. 2015;4(1): 107–9. https://doi.org/10.1007/s40037-015-0193-9
6. Tindall-Ford S, Agostinho S, Sweller J. Advances in cognitive load theory rethinking teaching London: Routledge, Taylor & Francis; 2020.
7. Kumar P, Clark M. Kumar and Clark's clinical medicine 9th ed. London: Elsevier; 2016.
8. Qiao Y, Shen J, Liang X, Ding S, Chen F, Shao L, et al. Using cognitive theory to facilitate medical education. BMC Med Educ. 2014;14(79): 79. https://doi.org/10.1186/1472-6920-14-79
9. Leppink J, Van Gog T, Paas F, Sweller J. Cognitive load theory: researching and planning teaching to maximise learning. Res Med Educ. 2015;1(18):207–18. https://doi.org/10.1002/9781118838983.ch18
10. Fraser K, Ayres P, Sweller J. Cognitive load theory for the design of medical simulations. Soc Stimul Healthcare. 2015;10(5):295–307. https://doi.org/10.1097/SIH.0000000000000097
11. Mayer R. Applying the science of learning to medical education. Med Educ. 2010;44(1):543–9. https://doi.org/10.1111/j.1365-2923.2010.03624.x
12. Leppink J, Duvivier R. Twelve tips for medical curriculum design from a cognitive load theory perspective. Med Teach. 2016;38(7):669–74. https://doi.org/10.3109/0142159X.2015.1132829
13. Garcia T. 12-Lead ECG the art of interpretation 2nd ed. Burlington: Jones & Bartlett Learning; 2015.
14. Paas F, Van Merrienboer J. Variability of worked examples and transfer of geometrical problem-solving skills: a cognitive based approach. J Educ Psychol. 1994;86(1):122–33. https://doi.org/10.1037/0022-0663.86.1.122
15. Daniels V, Pugh D. Twelve tips for developing an OSCE that measures what you want. Med Teach. 2018;40(12):1208–13. https://doi.org/10.1080/0142159X.2017.1390214
16. Mayer R. How seductive details do their damage: a theory of cognitive Interest in science learning. J Educ Psychol. 1998;90(3):414–34. https://doi.org/10.1037/0022-0663.90.3.414
17. Cantillon P, Hutchinson L, Wood D. ABC of Learning and Teaching in Medicine 3rd ed. London: BMJ Publishing Group; 2017.
18. Chandler P, Sweller J. The split-attention effect as a factor in the design of instruction. Br J Educ Psychol. 1992;62(2):233–46. https://doi.org/10.1111/j.2044-8279.1992.tb01017.x
19. Thach T, Blissett S, Sibbald M. Worked examples for teaching ECG interpretation: salient features or discriminating features? Medical Education. 2020;54(8):720–6. https://doi.org/10.1111/medu.14066
20. Antiperovich P, Zareba W, Steinberg J, Bacharova L, Tereshchenko L, Farre J, et al. Proposed in-training electrocardiogram interpretation competencies for undergraduate and postgraduate trainees. J Hosp Med. 2018;13(3):185–93. https://doi.org/10.12788/jhm.2876
21. Weinstein Y, Sumeracki M, Caviglioli O. Understanding how we learn a visual guide London: Routledge, Taylor & Francis; 2019.
22. Vygotsky L. Mind in society: the development of higher mental processes Cambridge: Harvard University Press; 1978.
23. Benner P. From novice to expert: excellence and power in clinical nursing practice Upper Saddle River, N.J: Prentice Hall; 2001.
24. Zeng R, Yue R, Tan C, Wang Q, Kuang P, Tian P, et al. New ideas for teaching electrocardiogram interpretation and improving classroom teaching content. Adv Med Educ Pract. 2015;6:99–104. https://doi.org/10.2147/AMEP.S75316
25. College of Paramedics Paramedic (COP). (2019). Curriculum guidance 5th ed. Retrieved from https://www.collegeofparamedics.co.uk/publications/professional-standards
26. Davies P. What is evidence-based education? Br J Educ Stud. 1999; 47(2):108–21. https://doi.org/10.1111/1467-8527.00106
27. Swanwick T. Understanding medical education, evidence, theory and practice 2nd ed. London: Wiley Blackwell; 2014.

How to cite this article: Thomas MG. The use of cognitive load theory to assist in the teaching of electrocardiogram interpretation within paramedical science education. Clin Teach. 2024. e13759. https://doi.org/10.1111/tct.13759