# Cognitive Load in Mastoidectomy Skills Training: Virtual Reality Simulation and Traditional Dissection Compared

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**OBJECTIVE:** The cognitive load (CL) theoretical framework suggests that working memory is limited, which has implications for learning and skills acquisition. Complex learning situations such as surgical skills training can potentially induce a cognitive overload, inhibiting learning. This study aims to compare CL in traditional cadaveric dissection training and virtual reality (VR) simulation training of mastoidectomy.

**DESIGN:** A prospective, crossover study. Participants performed cadaveric dissection before VR simulation of the procedure or vice versa. CL was estimated by secondary-task reaction time testing at baseline and during the procedure in both training modalities.

**SETTING:** The national Danish temporal bone course.

**PARTICIPANTS:** A total of 40 novice otorhinolaryngology residents.

**RESULTS:** Reaction time was increased by 20% in VR simulation training and 55% in cadaveric dissection training of mastoidectomy compared with baseline measurements. Traditional dissection training increased CL significantly more than VR simulation training ($p < 0.001$).

**CONCLUSIONS:** VR simulation training imposed a lower CL than traditional cadaveric dissection training of mastoidectomy. Learning complex surgical skills can be a challenge for the novice and mastoidectomy skills training could potentially be optimized by employing VR simulation training first because of the lower CL. Traditional dissection training could then be used to supplement skills training after basic competencies have been acquired in the VR simulation. (J Surg Ed 73:45-50. 

**KEY WORDS:** cognitive load, temporal bone dissection, mastoidectomy, virtual reality simulation, surgical skills training

**COMPETENCIES:** Medical Knowledge, Practice-Based Learning and Improvement, Patient Care

## INTRODUCTION

Complex skills are needed in temporal bone surgery and need to be taught to residents: (1) precise motor skills in handling drill, suction/irrigation, and the operating microscope and (2) a deep knowledge and understanding of the anatomy and surgical relations of the temporal bone. This has traditionally been taught through cadaveric temporal bone dissection followed by supervised surgery. For the novice, novel and unorganized information and technical skills represent a complex learning task and surgical skills training should be organized to provide efficient learning.

During the last decade, simulation training has been increasingly employed in health professional education and also in surgical education supported by the development of virtual reality (VR) surgical simulators. Maintaining facilities for traditional cadaveric dissection training is very costly especially if trainees are provided access to "open lab" facilities, where surgical procedures can be trained at the convenience and needs of the individual trainees. However, optimal from a surgical educational point, such facilities require constant care and supervision, including sanitization of equipment, disposal of biological waste, acquisition, and

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maintenance of necessary equipment. In addition, cadaveric temporal bones are becoming increasingly difficult to obtain owing to regulation and safety issues. VR simulation training of mastoidectomy[1-4] can provide the opportunity for novices to acquire some of the necessary basic competencies in a safe environment before proceeding to other training modalities such as cadaveric dissection.

In complex learning tasks such as learning the mastoidectomy procedure, the learners' cognitive load (CL) in the learning situation should be considered because this could have implications for the organization of skills training. It could be hypothesized that because VR simulation is less complex it reduces the CL of the learner, in turn leading to better learning and making VR simulation training well suited for the initial training of novices. However, the haptic interaction and different visual cues in VR simulation could impose additional CL compared with other training modalities. This knowledge could instigate relevant changes in both the specific training modalities (i.e., virtual and cadaveric dissection training) and in the organization of temporal bone surgical skills training in general.

Cognitive load theory (CL theory) is one of the leading theories of learning and provides a theoretical framework of the cognitive architecture with the basic assumption that working memory and information processing is limited.[5] The theory suggests 3 sources of CL in any learning situation: (1) the intrinsic load of the learning task, (2) the extraneous load provided by the learning situation, and (3) the germane load of the learning process itself.[6] Actual learning and skills acquisition can, according to the theory, be impeded if the total CL in the learning situation results in a cognitive overload, i.e., the limits in working memory and information processing are exceeded. Learning tasks can impose an extraneous CL resulting in a cognitive overload, e.g., when the learner needs to integrate complex multisource information and psychomotor skills. This can be managed by employing instructional strategies and design principles to lower the extraneous load and optimize intrinsic and germane loads,[6] leading to more efficient learning.

CL can be measured by a variety of methods including self-reported invested mental effort or difficulty, or by objective measures such as functional magnetic resonance imaging or the dual-task paradigm.[7] In the dual-task paradigm, performance in a secondary-task estimates CL, e.g., by measuring reaction time in response to a visual, auditory, or tactile stimulus. Secondary-task reaction time performance has been demonstrated to detect changes in CL in surgical skills training of novices.[8]

In this study, we wanted to compare CL in traditional dissection and VR simulation training of mastoidectomy using the dual-task paradigm with reaction time measurement for CL estimation.

## MATERIAL AND METHODS

A total of 40 otorhinolaryngology residents (postgraduate year 2-5) participating in the national Danish temporal bone courses in January 2014 and 2015 were recruited for a study on cadaveric dissection and VR simulation training of mastoidectomy in a crossover study design, with participants receiving cadaveric dissection first in the 2015 course and VR simulation first in the 2014 course. During this study, we also performed the reaction time measurements during VR simulation and cadaveric dissection training presented here. Participants signed informed consent for participation.

Participants were novices regarding the mastoidectomy procedure with only limited mastoidectomy experience because participation in a temporal bone course is a prerequisite before beginning supervised temporal bone surgery.

Cadaveric dissection was set up with a cadaver head in a dissection tray, an operating microscope, an otosurgical drill, and irrigation device operated by a pedal and a continuous vacuum suction (Fig. 1A). Participants were given 60 minutes to complete a mastoidectomy up until the point of posterior tympanotomy without feedback or instructions by staff but guided by printed instructions.

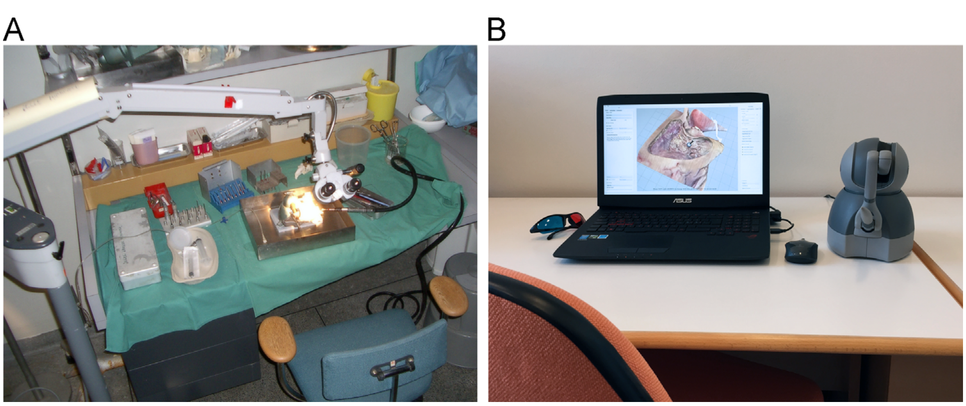


**FIGURE 1.** (A) An example of a set-up for traditional cadaveric temporal bone dissection training and (B) the set-up for VR temporal bone simulation on a laptop with the Visible Ear Simulator and the Geomagic Touch haptic device.