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► **To cite this version:**

Matisse Poupard, Florian Larrue, H el ene Sauz eon, Andr e Tricot. The Interplay of Cognitive Load and Intrinsic Motivation in Neuroanatomy Learning through Immersive Technologies. CLT 2024 - The 16th International Cognitive Load Theory Conference, Nov 2024, Sydney, Australia. hal-04816208

HAL Id: hal-04816208

<https://hal.science/hal-04816208v1>

Submitted on 3 Dec 2024

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The Interplay of Cognitive Load and Intrinsic Motivation in Neuroanatomy Learning through Immersive Technologies

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1 Introduction

Immersive technologies, such as virtual and augmented reality, are often regarded as effective tools for enhancing students' intrinsic motivation in educational contexts. However, recent studies suggest that this presumed positive effect may not consistently translate into improved learning performance [7].

Additionally, it is important to consider cognitive load when evaluating the impact of these tools on learning. Generally, augmented reality (AR) optimizes cognitive load, while virtual reality (VR) tends to impose additional extraneous load due to the richness of information delivered and the modes of interaction. Nevertheless, recent studies indicate that the supposed negative effect of the additional extraneous load can be beneficial with these technologies [9].

A possible explanation for these inconsistent effects with the theories of intrinsic motivation [8] and cognitive load [10] could be the interactions between these models. The literature increasingly suggests considering both of these dimensions of learning simultaneously [6, 5] and even suggests potential interactions between cognitive load and motivation [3, 2].

In this study, the relationships between cognitive load and intrinsic motivation are explored to explain the effects of virtual reality and augmented reality on learning neuroanatomy.

2 Method

The study was conducted at the French University of Bordeaux and N mes, involving second-year medical students. A total of 131 students (93 females and 38 males) participated voluntarily after being recruited via email. Participants followed a 20-minute neuroanatomy course under different technological conditions:

1. **Control Condition** consisted in following a video course in which the instructor draws and describes anatomical structures in a typical lecture style and in drawing anatomical structures (see Fig. 1a).

2. **Augmented Reality Condition:** In addition to video, a digital overlay of the structure to be drawn was projected, allowing the learner to trace the structure onto their paper (see Fig. 1b).
3. **Virtual Reality Condition:** Participants could explore the brain's vascular system by interacting with the 3D model of the brain in VR (see Fig. 1c).

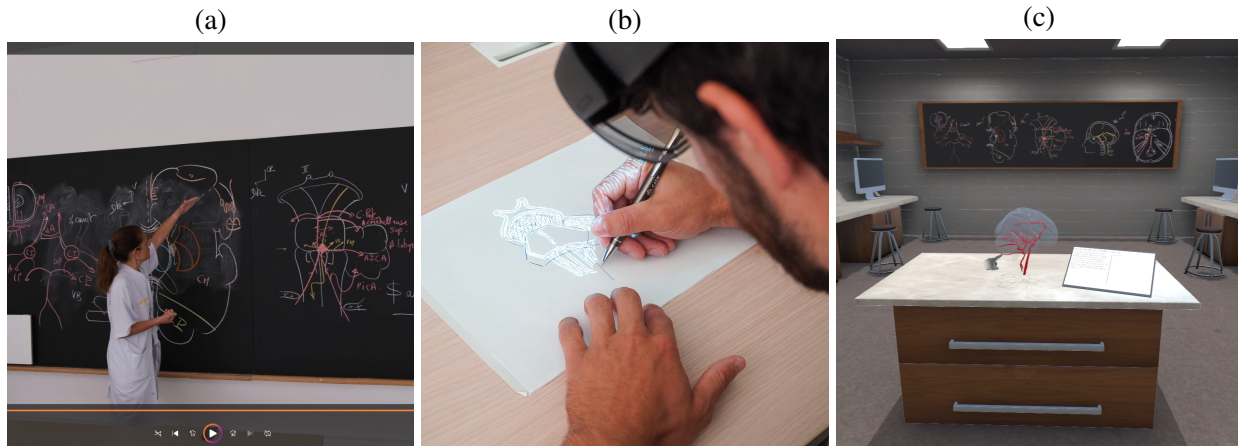


Figure 1: Illustrations of control video (a), augmented reality for drawing guidance (b) and virtual reality for neuroanatomy learning (c).

Anatomical knowledge was tested before and after the intervention. User experience, including cognitive load [1] and intrinsic motivation [4] was measured through self-reported questionnaires after the task.

3 Analysis and Results

Preliminary results show a significant but negligible negative correlation between intrinsic motivation (IM) and intrinsic load (IL), as well as a weak negative correlation between IM and extraneous load (EL). Conversely, germane load is positively correlated with IM (see Fig. 2).

Examining the mediation effects, the results show that extraneous cognitive load partially (ACME = 0.09, $p < 0.001$) but significantly mediates the effect of intrinsic motivation on learning gain (prop.mediated = 46%, $p = .006$), while the direct effect of intrinsic motivation is not significant (ADE = 0.11, $p = 0.09$) (see Fig. 3a). Similarly, germane load plays a significant and strong mediating role in the relationship between intrinsic motivation and learning (ACME = 0.15, $p < 0.001$). The proportion of the effect of intrinsic motivation on learning mediated by germane load is high (prop.mediated = 78%, $p = .002$), while the direct effect of intrinsic motivation on learning gain is not significant (see Fig. 3b). Finally, the multiple mediation analysis shows strong mediation effects, particularly through germane load, and a good overall fit to the data (Fig 3c). Nevertheless, the effect of both extraneous and germane cognitive load remains negligible.

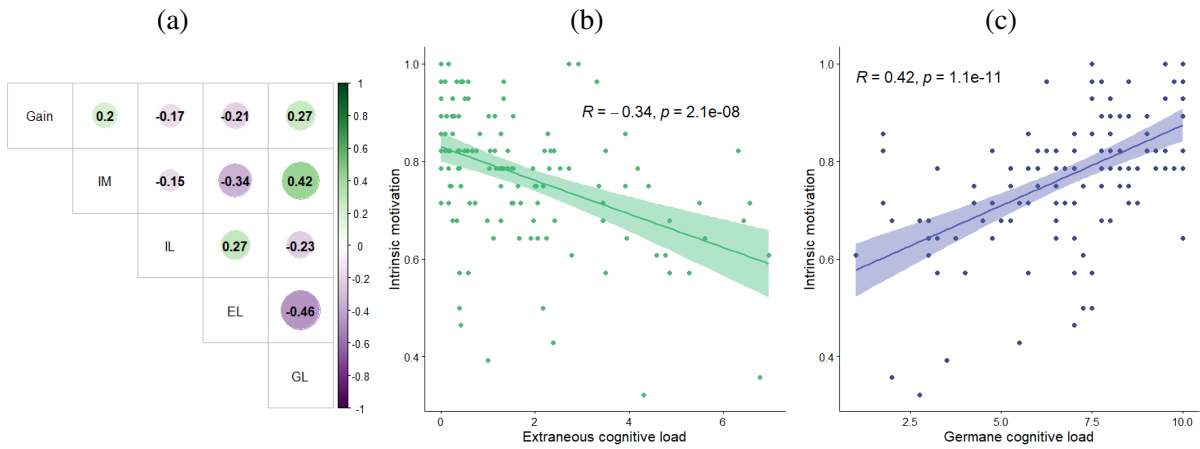


Figure 2: Correlation matrix (a) and linear regression between intrinsic motivation and extraneous (b) and germane (c) cognitive load

4 Discussion and Implications

These preliminary results show a significant interaction between cognitive load and intrinsic motivation. In particular, it appears that the most motivated learners reported a higher germane load and a lower extraneous load compared to less motivated students. These findings align with recent studies suggesting that increased motivation is associated with reduced extraneous load and increased germane load [3].

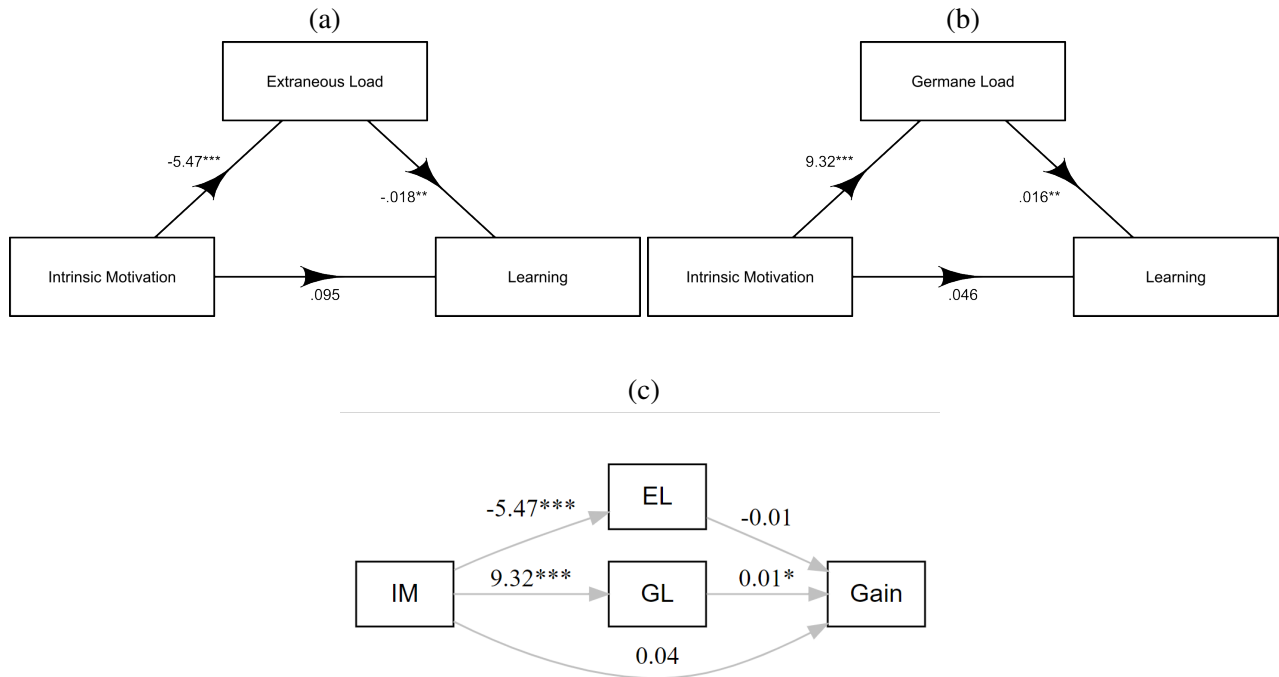


Figure 3: Mediation analysis : simple mediation of extraneous (a) and germane (b) cognitive load, and multiple mediation on intrinsic motivation effect on learning

Furthermore, the analysis indicate that the effect of intrinsic motivation on learning is mediated by cognitive

load. This strong mediation by both extraneous and germane load could explain some inconsistent results highlighted in the study of the effects of immersive technologies on motivation. Indeed, many studies reveal a positive effect of these technologies on intrinsic motivation without a corresponding positive impact on learning (see [7] for a review). Based on these results, considering cognitive load in the evaluation of VR/AR for learning and their effects on motivation is essential.

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