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REVIEW ARTICLE

The Relationship Between Cognitive Offloading and the Transient Information Effect

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Abstract

Within the Cognitive Load Theory framework, the transient information effect suggests that learning with transient information before learners can adequately process the information reduces performance, compared to learning information presented in a non-transient way. Cognitive offloading is a process whereby people externalise internal information onto the environment, making the information more accessible and so less transient, supporting task performance by reducing cognitive demands. To date, the two effects have been investigated separately but share similar underlying cognitive mechanisms, whereby both seek to reduce the cognitive load on an individual by making information more accessible and/or less transient to maximise performance. This paper discusses the similarities and differences between the two effects and proposes some new research directions by considering the two effects together.

Keywords Cognitive Load Theory · human cognitive architecture · working memory · transient information effect · cognitive offloading

Introduction

How information is encountered, and how that information relates to the environment and to the individual, has implications for cognition and for learning. This idea has underpinned research in two key areas: cognitive offloading (e.g., Risko & Gilbert, 2016), and Cognitive Load Theory (Sweller et al., 2019), both of which draw heav-

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ily on working memory research. Based on human cognitive architecture, working memory temporarily processes and stores information, and is very limited in capacity and processing time. These limits are well-established through empirical research (see e.g., Oberauer et al., 2018) and are foundational to major theoretical models in the field (e.g., Baddeley et al., 2021; Cowan et al., 2021; Barrouillet & Camos, 2021). This system operates under strict capacity constraints, limiting how much information can be held and processed at any given time (Hitch et al., 2025).

Working Memory Capacity Limitations are Important in Both Cognitive Offloading and Transient Information Effects

Due to the limited capacity of working memory, it is important to present new information in ways that minimise cognitive load. This reduction forms the basis for the transient information effect in Cognitive Load Theory, where changing the presentation of information from transient to permanent helps ease the burden on working memory (Ng et al., 2013). Similarly, cognitive offloading strategies aim to reduce cognitive demands by modifying the information processing requirements of a task (Risko & Gilbert, 2016). Both principles are concerned with improving learning through the reduction of extraneous cognitive load (e.g., by adjusting how to-be-remembered information is presented or recorded). The transient information effect does so by presenting information in a permanent manner, such as written rather than spoken information, whereas cognitive offloading reduces extraneous load through offloading information to the environment.

The transient information effect within the framework of Cognitive Load Theory states that if information disappears before it can be processed adequately, this can lead to inferior learning (Singh et al., 2012). Therefore, according to the transient information effect, learning information presented by slides and spoken by teachers is more challenging than via written information. Further, when information is transient, once that information is no longer available, students must hold that information in mind while learning, which imposes a heavy burden on limited cognitive resources.

The literature on cognitive offloading also considers the demands placed on our limited cognitive resources when completing different tasks, and how these demands can be reduced by externalising some of the information onto the environment. For example, we take notes to aid memorisation of information stored in memory, thus offloading information to the notes and so supporting improved task performance (Risko & Gilbert, 2016). In this way, the literature on cognitive offloading also considers the continued availability, or 'permanence', of information to optimise performance.

The relations between the Transient Information Effect within Cognitive Load Theory and Cognitive Offloading are summarised in Fig. 1.

Although the two effects have been investigated separately, the principles and implementation of the cognitive offloading effect may relate in part to the transient information effect, reflecting a similar underlying cognitive mechanism.

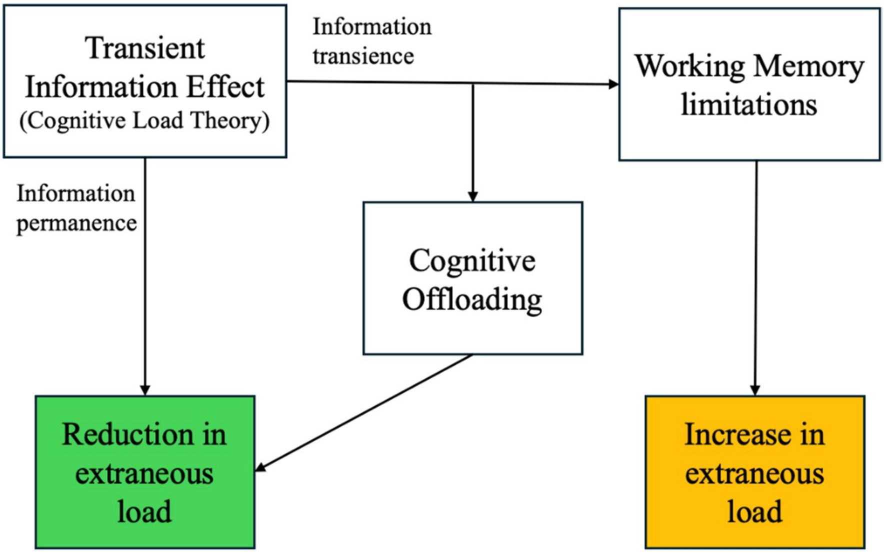

Fig. 1 Relations between transient information effect within cognitive load theory and cognitive offloading

Based on Fig. 1, the integrative model of the transient information effect and cognitive offloading indicates that cognitive offloading could be a strategy, within the transient information effect, to reduce working memory load and improve learning by externalising transient information to the external environment in permanent form such as notes. However, the effectiveness of using cognitive offloading may depend on the complexity of learning materials due to levels of element interactivity caused by either the nature of the information or differences in levels of learners' expertise, with other moderators, such as working memory capacity, delayed or immediate test and the length of transient/permanent information presented.

This paper will examine the transient information effect and cognitive offloading in tandem. We will discuss how Cognitive Load Theory provides the fundamental basis for the transient information effect, followed by empirical evidence for the effect. Next, cognitive offloading will be introduced with a sampling of relevant empirical evidence. Lastly, we will discuss the similarities and differences between the transient information effect and cognitive offloading. In doing so, we hope to encourage greater crosstalk between these perspectives on the part of researchers and practitioners.

Cognitive Load Theory

Cognitive Load Theory is an instructional theory designed to improve learning by managing cognitive load (Sweller, 1988, 2023; Sweller et al., 1998, 2019). It holds to several key principles based on our knowledge of human cognitive architecture (Sweller, 2025). (1) The theory is concerned with the acquisition of biologically secondary knowledge such as reading and writing that we have not specifically evolved to acquire automatically rather than biologically primary knowledge such as listening and speaking that we have specifically evolved to acquire (Geary, 1995, 2005, 2008; Geary & Berch, 2016; Sweller, 2022). (2) Biologically secondary information can be acquired either by generating it during problem solving or by borrowing it from others. (3) Novel information must be processed by a limited capacity and limited duration working memory system (Baddeley et al., 2021; Cowan et al., 2021). (4) Once processed in working memory, information can then be transferred to long-term memory for more permanent storage for subsequent use. Unlike when dealing with novel information, highly familiar and well-practiced information can be drawn from long-term memory without placing substantial demands on working memory.

Element Interactivity and Types of Cognitive Load

Within the framework of Cognitive Load Theory, two main types of cognitive load have been discussed: intrinsic cognitive load, concerned with the intrinsic complexity of information, and extraneous cognitive load, concerned with how information is presented to learners. The levels of intrinsic and extraneous cognitive load are both determined by the level of element interactivity (Chen et al., 2023; Sweller, 2010).

Element interactivity is a core concept of Cognitive Load Theory. It is determined by the number of interactive elements of information that must be processed simultaneously in working memory. That number can vary depending on the nature of the information and the level of expertise of the person processing the information. Identical information may be high in element interactivity for a novice to the field but low for an expert who has appropriate information stored in long-term memory (Chen et al., 2015, 2023).

As an example, if students who have just been introduced to algebra are presented with the problem "*(a + b)/c = d, solve for a"*, the number of elements that they must manipulate in order to make a single valid move may vastly exceed working memory limits resulting in solution failure. They must consider each component of the problem along with the rules of algebra to determine what constitutes a legal move. There are 9 elements to the equation along with 2 elements associated with the statement, *"solve for a"*, along with a large array of relevant algebraic rules that need to be simultaneously manipulated in working memory.

It might be noted at this point that mathematical problems and their solutions are almost never presented orally because they are likely to overwhelm working memory. The contrast with permanent, written, static information is stark. A problem and its solution presented in oral form to novices may be unintelligible. The same information presented in written form may be far simpler.

In contrast to novices, for more well-practiced individuals, the entire problem and possible moves can be effortlessly retrieved from long-term memory and equally accepted or rejected before considering another move. For a more experienced mathematician, this problem and its solution have been stored in long-term memory as a single element resulting in a minimal working memory load.

Transient Information Effect

The transient information effect refers to the reduction in learning that occurs when information disappears before it can be adequately processed (Leahy & Sweller, 2011; Singh et al., 2012). For instance, when a teacher presents a sequence of slides where each replaces the previous one, learners may struggle to integrate new content with earlier material, particularly when the content involves high element interactivity. In such cases, learners must retain prior information in working memory to make meaningful connections, which imposes a substantial extraneous cognitive load. In contrast, presenting information in a non-transient format such as permanently available written instructions allows learners to revisit content as needed. Permanence reduces the demands on working memory and mitigates extraneous cognitive load (Ng et al., 2013).

Cognitive Offloading

Risko and Gilbert (2016, p.676) define cognitive offloading as “the use of physical action to alter the information processing requirements of a task so as to reduce cognitive demand”. The principle of cognitive offloading can be applied in different ways. One category of offloading involves environmental adjustments or ‘external normalisation’. This might involve rotating a map or organizing objects to better align with task demands (e.g., Armitage et al., 2020; Armitage & Redshaw, 2022; Berry et al., 2019; Risko et al., 2014; Dunn & Risko, 2016), thus serving to offload mental transformations that would otherwise be cognitively costly. However, this form of cognitive offloading is not directly related to or interchangeable with the concept of information transience. A second form of offloading refers to when we directly externalise aspects of the to-be remembered or processed information to the environment. This is likely the form of offloading that most people would think of when they consider how it might be applied in everyday life. It is also the form that more directly relates to the issue of transience within Cognitive Load Theory. For example, we often write down information (e.g., for a grocery list or as notes in class) or use a smartphone to set reminders to carry out a task at later time. This can help overcome the limitations and fallibilities of working memory and long-term memory and can enhance the ability to manage multiple pieces of information simultaneously. As such, it offers a way of reducing cognitive load and ensuring task-relevant information is not forgotten.

Research shows that shifting information to external aids enhances task performance - adults and children benefit from strategies like note-taking, setting reminders, or marking locations, with greater gains under high cognitive load (Bulley et al., 2020; Burnett & Richmond, 2023, 2024; Gilbert et al., 2023; Risko & Dunn, 2015). Offloading can also improve memory for non-offloaded items by freeing cognitive resources, a phenomenon termed “saving-enhanced memory” or “cognitive spillover” (Storm & Stone, 2015; Dupont et al., 2023). Individual differences, such as working memory capacity, influence offloading behavior (Ball et al., 2022), and metacognitive judgments about importance, confidence, and effort also play a role (Scott & Gilbert, 2024; Sachdeva & Gilbert, 2020).

Transient Information Effect and Cognitive Offloading: Implications for Research and Practice

To summarise, cognitive offloading captures how learners intentionally use external tools or representations to reduce memory and processing demands. The learner is active and drives the offloading behaviour. In contrast, the transient information effect is about how instructional information is provided in a way that determines whether it can be fully processed and retained, which has an impact on cognitive load. In delivering the information, the instructor is typically more responsible for the extent of information transience. How might these concepts link in principle and practice?

Transience vs. Permanence

Within Cognitive Load Theory, transience and permanence refer to the extent to which information has a relatively lasting presence in the environment. Information in capacity-limited working memory is by its nature transient and ephemeral, only becoming more permanent when integrated and consolidated into long-term memory. Given this, rendering information less transient through offloading can reduce pressure on the limited capacity of working memory and help minimise loss due to decay and interference, to which newly encoded representations are vulnerable. In this way, reducing information transience helps mitigate against representational transience and limited cognitive capacity within working memory, both for offloaded information (by providing an available and accessible external record) and also for non-offloaded information (by freeing up cognitive resources).

Thus, information transience creates the need for cognitive offloading, and offloading can mitigate against transience information effects that might result. In other words, information transience is a design problem, and cognitive offloading is a learner-driven solution to this problem. Thus, while these are distinct research fields and principles, they are highly likely to overlap and interact in real-world learning contexts. Understanding these distinctions and overlaps is important, both to better characterise the research fields and their implications, and to identify how to best link instructional design and practice with productive offloading for the purposes of enhancing learning.

It is important to note that cognitive offloading does not offer a surefire way of avoiding transience-based loss. Memory and later use of offloaded information can suffer if the external record of the offloaded information becomes unavailable before it is successfully integrated into long-term memory, or where participants are not expecting to need to retain that information over longer time-periods (Eskritt & Ma, 2014; Sparrow et al., 2011). Thus, increasing information permanence, that is, making it more available and accessible by externalising to the environment, can aid cognitive performance but does not necessarily always result in representational permanence. This contrasts with the general assumption in Cognitive Load Theory that increasing 'permanence' and reducing transience is uniformly positive for learning, provided cognitive load is not increased by doing so.

Future Research

However, in an education context, students generally do not have access to materials at the point of test and therefore need to have formed reliable internal representations by then. The potentially different assumptions about the benefit of 'permanence' could be explored in future research by manipulating factors such as the length of time that information is available (i.e., is externally permanent) during the learning phase, how much information is made available during learning, and the delay between learning and test. This could be investigated over longer time frames than have generally been utilised to date in the literature, to more closely align with real-world learning environments.

For example, when learning with transient information, a 2 (length of time: short vs. long) x 2 (offloading: yes vs. no) experiment with immediate and delayed tests could be designed. The transient information effect hypothesis might expect increased availability during learning, e.g., across multiple lessons, would always lead to improved learning and therefore should translate into better performance at test. In comparison, cognitive offloading might predict some potentially negative effects on test performance if learners become too reliant on having information externally available and do not form robust and accessible internal representations.

Expertise and Individual Differences Moderating Cognitive Offloading and Transient Information Effects

Offloading can also become problematic if it is overused or if it distracts from learning, and poor instructional design might increase information transience and force learners to offload excessively. The act of offloading may sometimes come with a time or resource cost, and indeed this is often incorporated into offloading paradigms (Gilbert, 2015). In this context, research has shown that people may over-rely on making information more permanent, even if that does not always *optimise* performance (Gilbert et al., 2020). Offloading approaches are also likely to vary between individuals and groups. For example, younger children's offloading tends to be less selective and spontaneous (Armitage & Gilbert, 2025), whereas greater prior knowledge of a subject area can help the individual prepare for a task by proactively offloading information in an effective way (Martin & Schwartz, 2009). In contrast, there has only been limited examination of choice and control on the part of the learner regarding the transient information effect (e.g., Ng et al., 2013), although the self-managed effect within Cognitive Load Theory suggests that learners are able to manage their own cognitive load when learning (e.g., Gordon et al., 2016; Sithole et al., 2017).

Future Research

Future work should explore the benefits of allowing an active role for the individual in choosing how and when to reduce transience during complex learning tasks, either through direct offloading, or through avoiding transience, for example by asking the instructor to revisit content or (within e-learning platforms) allowing interaction with play controls and rewatching of content.

Research could contrast direct offloading on the part of the learner versus indirect offloading via transience reduction by the presenter, and examine impacts on learning of otherwise transient information. The contributory roles of task context, working memory capacity, prior knowledge, and metacognitive ability would be interesting dimensions to examine on this context.

Indeed, prior knowledge and expertise are also likely to influence the importance and usefulness of avoiding transience and encouraging offloading. Novices without well-developed prior knowledge structures and relevant experience may be overloaded more quickly by transient information and find offloading more helpful to mitigate against this. In contrast, individuals with more internalised knowledge structures and experience are likely to be less vulnerable to transience, and less likely to need or benefit from offloading. In this case, more instructional support and offloading might prove to be harmful to learning. Examining these interactions, and how we might adaptively 'fade' support as expertise develops could be a useful direction for future research.

Distinct Task Complexity and Task Types Used by Cognitive Offloading and Transient Information Effect Experiments

It is also useful to consider the extent to which offloading paradigms such as intention offloading and reminder setting (e.g., Gilbert et al., 2023) are directly analogous to the learning tasks that are typically examined in Cognitive Load Theory. The latter perspective has typically been explored within the context of education, focusing on how educators present information to learners as recipients of this information. Thus, studies have tended to look at instructions for completing a learning task, where the materials are complex and focus more on understanding and comprehension. In contrast, cognitive offloading studies often involve relatively simple instructions (e.g., in the context of intention offloading, *any circle containing the number 7 needs to be dragged right*) and use more basic memory recall paradigms such as remembering letters, words, or spatial locations. So, whilst there are clear similarities in principle between these two paradigms, type of information and task complexity typically vary between these two areas.

In one recent exception, Burnett and Richmond (2024) examined cognitive offloading behaviours and effects in a more complex naturalistic task, in which participants were asked to learn health-related information about selected medical conditions. Having the option to make notes during encoding enhanced memory for both younger and older adults. There are few cognitive offloading studies that have been carried out within an explicitly educational context (Scaife & Rogers, 1996). Martin and Schwartz (2005) found that interacting with the physical environment improved the development of fraction concepts with 9- and 10-year-old children, and that being able to adapt the environment to support the task was important for transfer of learned skills.

Future Research

Within the cognitive load theory framework, all effects including the transient information effect are more likely to be found when materials are high in element interactivity (Chen et al., 2015; Sweller, 2010). Accordingly, the effectiveness of cognitive offloading should be moderated by the level of element interactivity which in turn is affected by learners' expertise. Therefore, we can predict that for a 2 (element interactivity: low vs. high) x 2 (offloading: yes vs. no) experiment involving transient information, the cognitive offloading group would perform better than the no cognitive offloading group when materials are high in element interactivity (due to learners being less knowledgeable), whereas, when materials are low in element interactivity (due to learners being more knowledgeable), the advantage of cognitive offloading may be reduced.

In summary, exporting cognitive offloading methodology and principles into the sorts of complex and educationally relevant learning tasks that are often examined in work on Cognitive Load Theory and the transient information effect should be a goal for future research.

Conclusions

Failures in learning tasks due to cognitive overload and forgetting are likely to increase when information is transient and reduce when information 'permanence' is introduced by the educator, an observation that forms a key assumption of Cognitive Load Theory. Analogously, reducing informational transience and increasing its availability and accessibility by offloading to the environment has become a recent focus of research in memory and cognition. The two literatures have so far been somewhat separate with surprisingly little crosstalk, and empirical explorations have tended to emphasise different research questions, methods, and possible applications. We see the transient information effect as an important dimension of cognitive offloading, in that transience is part of the complex interplay of variables and factors that will need to be considered when looking at how well individuals can engage in and perform a task, from the point of view of cognitive load and offloading. Continuing to consider how the literatures on cognitive offloading and Cognitive Load Theory can be mutually informative, and how offloading might be explored in the kind of learning contexts that are the focus of Cognitive Load Theory, should prove fruitful in enhancing our understanding of how to optimise learning through the prisms of educational and cognitive psychology.

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