

Comprendre la mémoire de travail pour mieux apprendre et enseigner

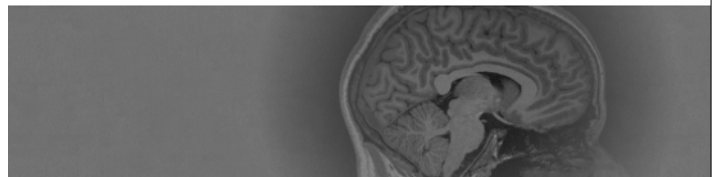
Semaine de la Chaire recherche-action 2024, Institut Villebon - 17 déc. 2024
Steve Masson, professeur à l'Université du Québec à Montréal

1

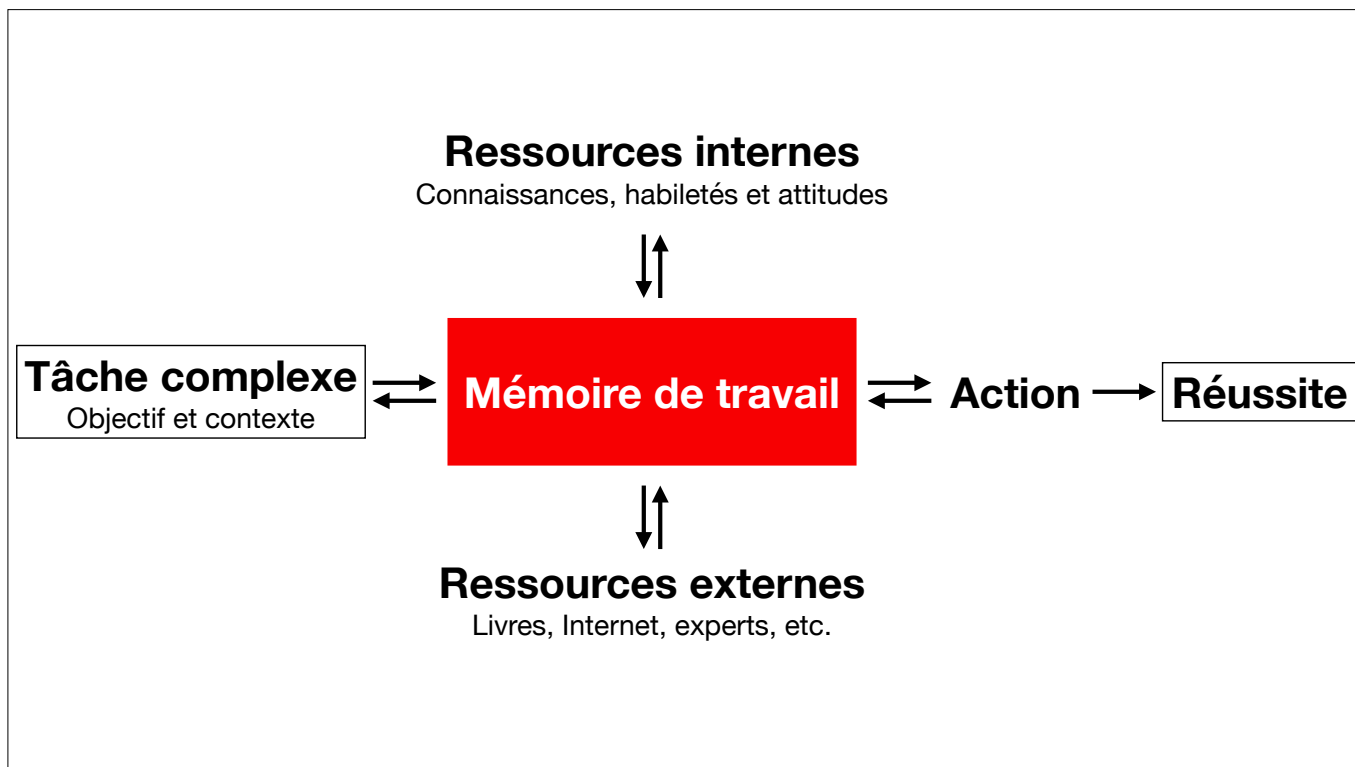
Être compétent

C'est...

1. Être capable de réussir certaines tâches
2. Posséder des connaissances et autres ressources
3. Savoir utiliser ses ressources



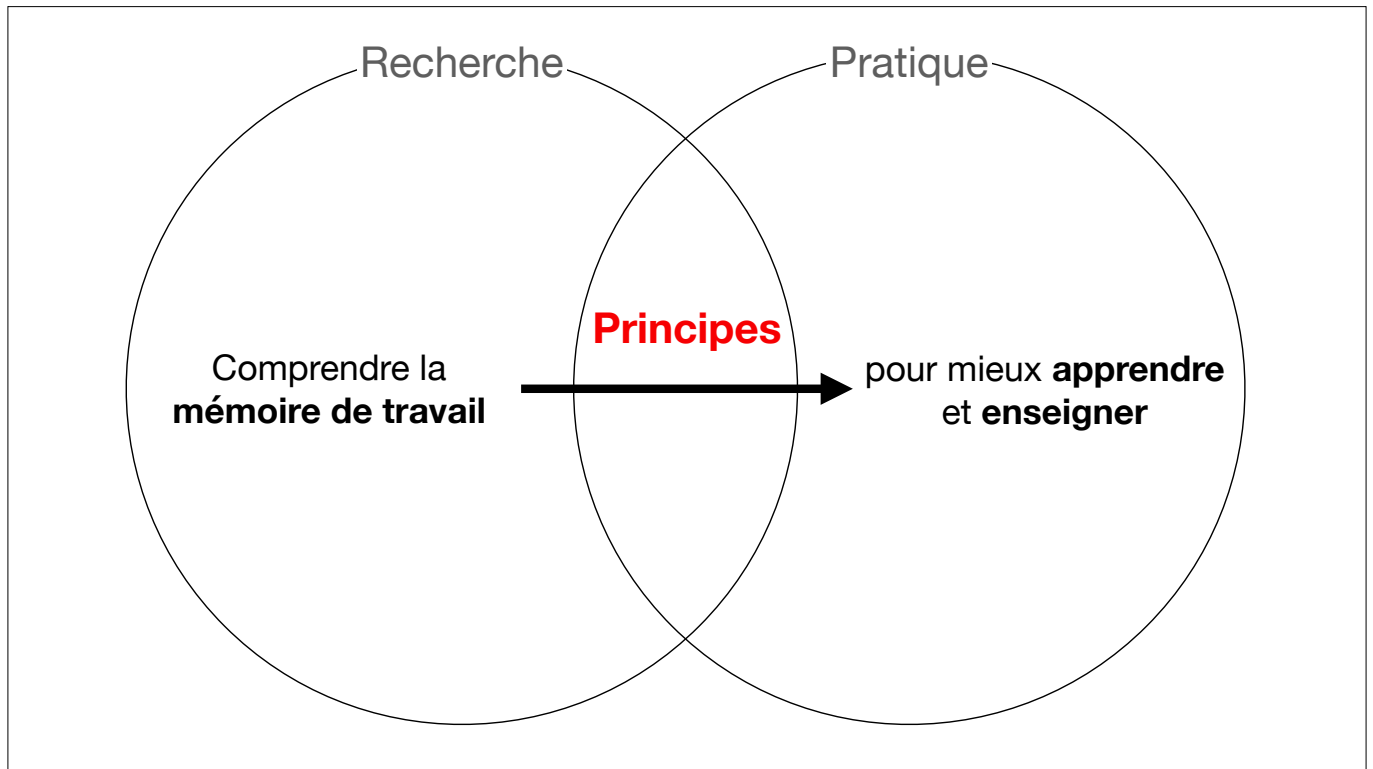
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La **mémoire de travail** est donc nécessaire à la **compétence**.

4



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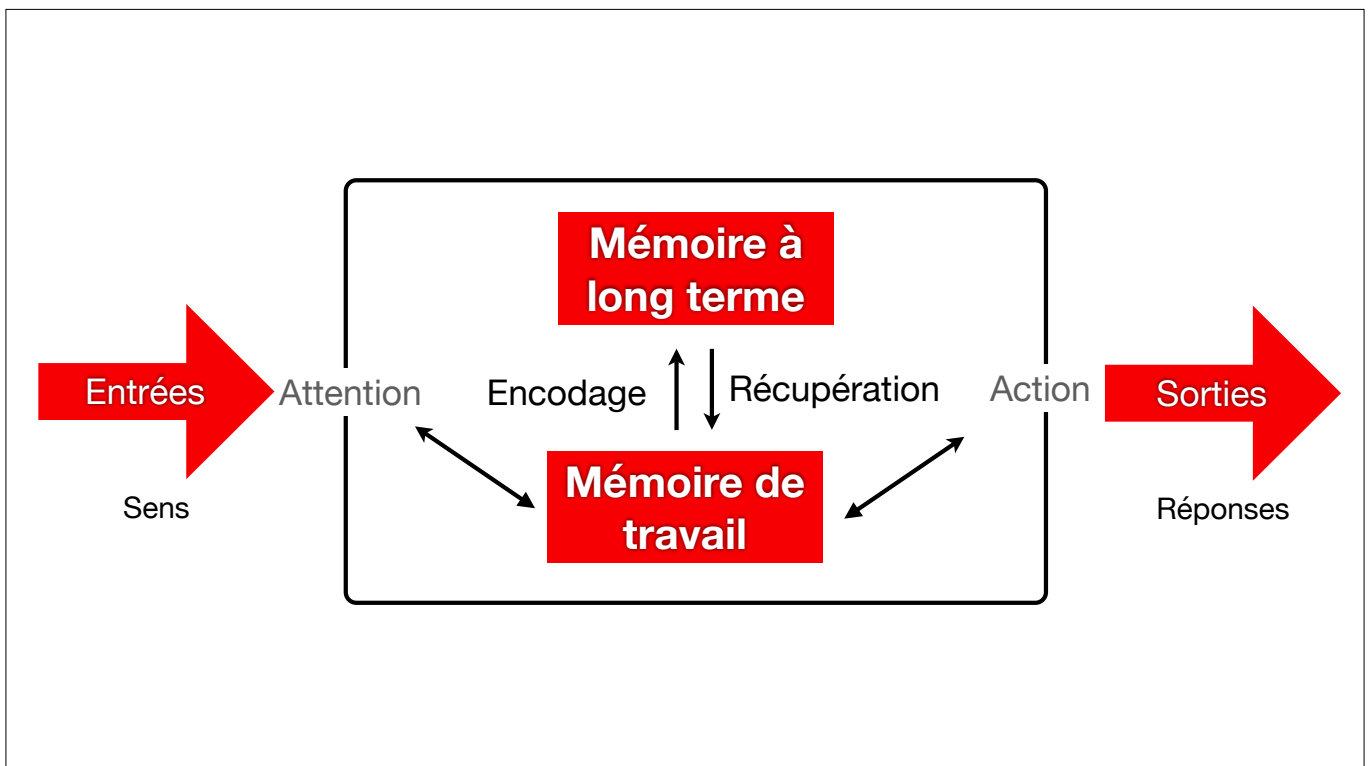
Partie 1

Qu'est-ce que la mémoire de travail ?

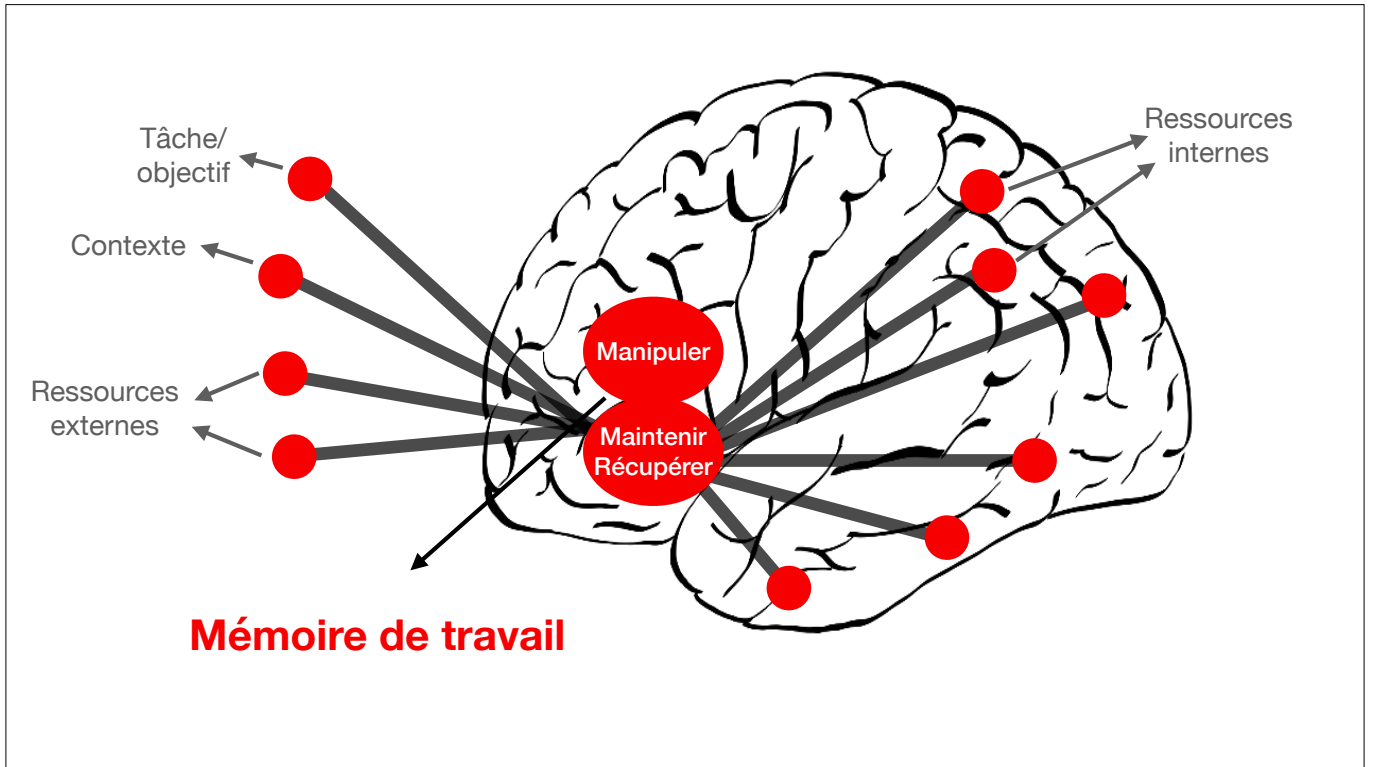
6

Mémoire de travail =
Espace de travail mental permettant
de maintenir en tête et de manipuler des informations

7



8



9

Problème

La mémoire de travail est très limitée.

10

Surcharge = État dans lequel la mémoire de travail n'arrive plus à traiter l'information

11

Étude de
Cowan

BEHAVIORAL AND BRAIN SCIENCES (2000) 24, 67-116
https://doi.org/10.1017/S000712260000511

The magical number 4 in short-term memory: A reconsideration of mental storage capacity

Nelson Cowan
Department of Psychology
University of California, Santa Barbara
cowan@psych.ucsb.edu www.psych.ucsb.edu/~pcowan

Abstract. Miller's (1956) seminal article on the capacity limit of a human short-term memory system (STM) has become the most cited work in psychology. Miller's (1956) conclusion that the capacity limit is 7 items is now regarded as a "magical number 7, plus or minus 2". This article reconsiders the evidence for Miller's (1956) conclusion, and argues that the capacity limit is 4 items, plus or minus 1. This conclusion is based on a reanalysis of Miller's (1956) data, and on new data from a series of experiments. The new data show that the capacity limit is 4 items, plus or minus 1, in a wide range of conditions. This conclusion has important implications for understanding the nature of STM, and for understanding the nature of working memory. It also has implications for understanding the nature of long-term memory, and for understanding the nature of human information processing.

Keywords: short-term memory, memory capacity, memory processing, memory organization, memory systems, memory capacity, working memory, memory systems, memory organization, memory processing.

1. Introduction to the problem of mental storage capacity

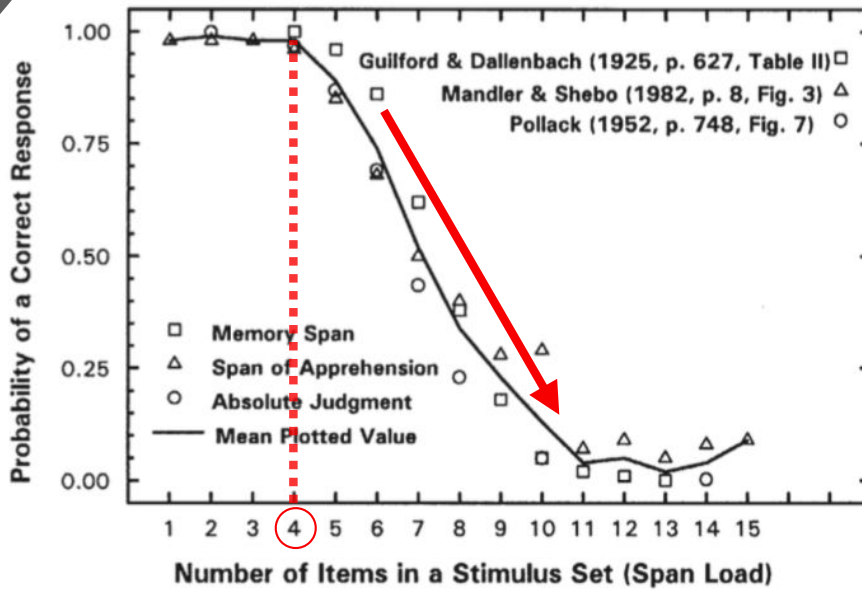
Over the past four decades, the problem of mental storage capacity has been a central issue in psychology. It has been discussed in terms of memory systems, memory organization, memory processing, and memory capacity. The problem has been discussed in terms of memory systems, memory organization, memory processing, and memory capacity. The problem has been discussed in terms of memory systems, memory organization, memory processing, and memory capacity.

In the 1950s, one possible solution to the problem of mental storage capacity was to propose that the capacity limit is 4 items, plus or minus 1. This conclusion is based on a reanalysis of Miller's (1956) data, and on new data from a series of experiments. The new data show that the capacity limit is 4 items, plus or minus 1, in a wide range of conditions. This conclusion has important implications for understanding the nature of STM, and for understanding the nature of working memory. It also has implications for understanding the nature of long-term memory, and for understanding the nature of human information processing.

Keywords: short-term memory, memory capacity, memory processing, memory organization, memory systems, memory capacity, working memory, memory systems, memory organization, memory processing.

Capacité de notre mémoire de travail

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Regional response differences within the human auditory cortex when listening to words

Cathy Price¹, Richard Wise², Stuart Remigy³, Karl Friston⁴, David Howard¹, Kathryn Patterson¹ and Richard Price¹

¹MRC Cognition and Brain Development Unit, University of Cambridge, 4, Beney Road, Cambridge CB2 3RQ, UK; ²Department of Psychology, University of Cambridge, 7, West Road, Cambridge CB3 9ET, UK; ³MRC Applied Psychology Unit, Cambridge CB2 3RQ, UK; ⁴UCL Institute of Neurology, 12, Square, London WC1N 3BG, UK

(Received 11 June 2006; Revised version received 5 August 2007; Accepted 7 August 2007)

Keywords: fMRI, auditory cortex, words, regional cerebral blood flow, stimulus rate

The relationship between activity within the human auditory cortex and the presentation rate of heard words was investigated by measuring changes in regional cerebral blood flow (rCBF) in response to words. We compared the primary auditory cortex and middle regions of the auditory cortex. There is a clear difference between the rate of presentation of heard words and local rCBF response. In contrast, the time course of rCBF in middle regions is more similar to the 'word rate' used in the study. Responses in the primary auditory cortex are more strongly correlated with the temporal envelope of the words than in middle regions. This difference is observed when the primary auditory cortex is compared to middle regions. The primary auditory cortex is more strongly correlated with the temporal envelope of the words than middle regions. This difference is observed when the primary auditory cortex is compared to middle regions. The primary auditory cortex is more strongly correlated with the temporal envelope of the words than middle regions. This difference is observed when the primary auditory cortex is compared to middle regions.

Functional anatomy can be studied by measuring changes in regional cerebral blood flow (rCBF) in response to performance on behavioral tasks [1]. The interpretation of these activation studies depends on the relationship between the rate of stimulus presentation, the regional sensitivity or inhibitory synaptic activity that underlies the processing of the stimuli and blood flow response. Only one previous study has formally assessed the relationship between stimulus rate and rCBF [2]. This looked at the response to primary visual cortex to simple repetitive photostimuli and found that rCBF increases were inversely correlated with stimulus rate between 0 and 7.8 Hz. Above 7.8 Hz, rCBF increases plateaued or even fell as stimulus rate increased suggesting that at high stimulus rates cortical response follows an activation-repetition time-out longer paradigm.

We and others are interested in language activation studies and frequently use complex auditory stimuli. Knowledge about the rCBF response to heard words in different regions of the auditory cortex is fundamental to such investigations. Several studies have shown that listening words or word-like sounds activates posterior temporal regions [4]. The present study investigates the relationship between the rate of presentation of heard words and rCBF increases in the following way.

Six right-handed, English-speaking, normal, male, volunteers, aged 24–40 years, were studied. Each subject gave informed consent to have a cross-sectional measurement of rCBF using a ¹⁵O₂ inhalation technique [5, 6] and a Siemens 3T MRI patient craniocaudal isotropic scanner [7]. During each 3.5 min dynamic scan, the subject inhaled ¹⁵O₂ at a concentration of 6 MBq/m³ and a flow rate of 50 ml/min through a standard oxygen flow mask for a period of 2 min. Intervals between scans lasted 12–18 min. Correction for attenuation was made by performing a transmission scan with an exposed ⁶⁸Ge planar external ring source at the beginning of each part of the study. Images were reconstructed by filtered back projection of the filter cut-off giving a transaxial resolution of 5 mm full width at half maximum. The reconstructed images contained 128 × 128 pixels, each having a size of 2.65 × 2.65 mm.

The behavioral rates for each stimulus were set at listening to mono presented at rates of 18, 22, 26, 30 or 36 words per minute (wpm). The subjects were instructed

Étude de

Price et al.

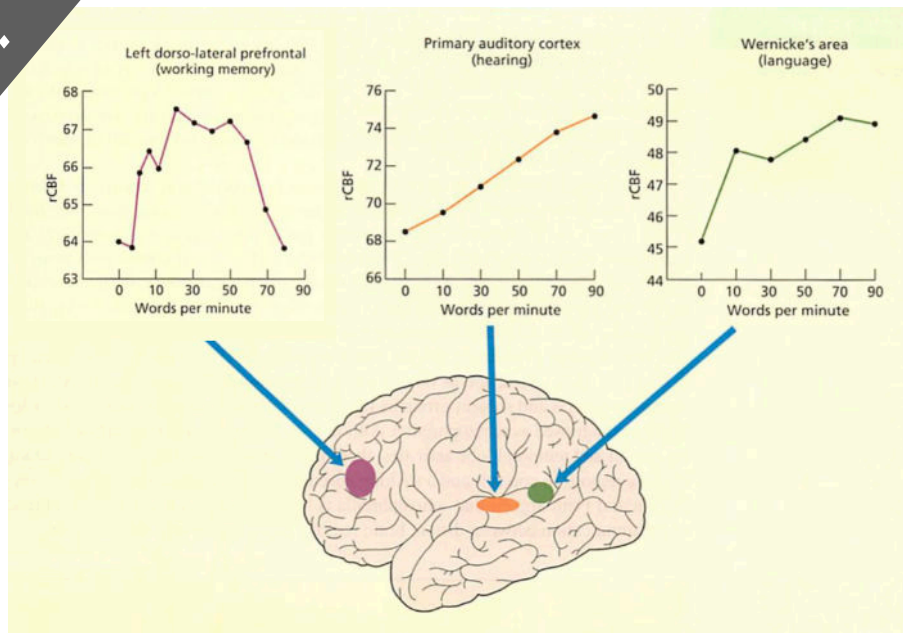


Figure tirée de Ward (2010, p. 61)

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Étude de

Price et al.

La surcharge est liée à une **désactivation** de régions cérébrales liées à la mémoire de travail.

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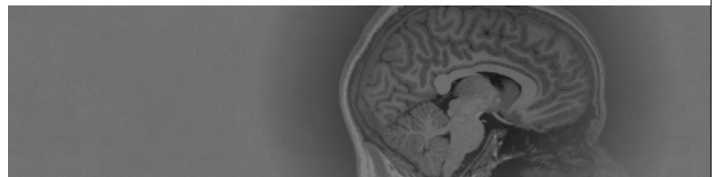
Piste de solution

Réduire la charge non nécessaire

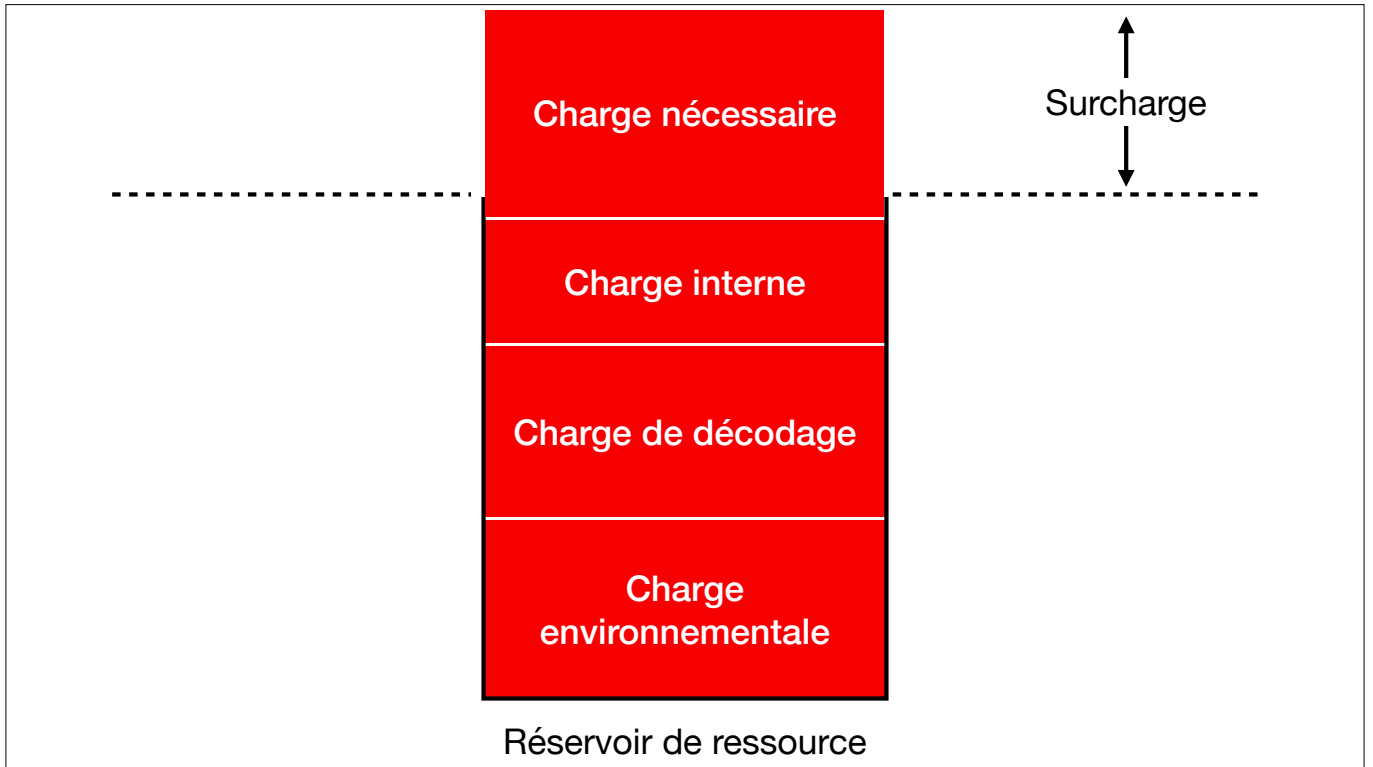
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Qu'est-ce qui contribue à la charge ?

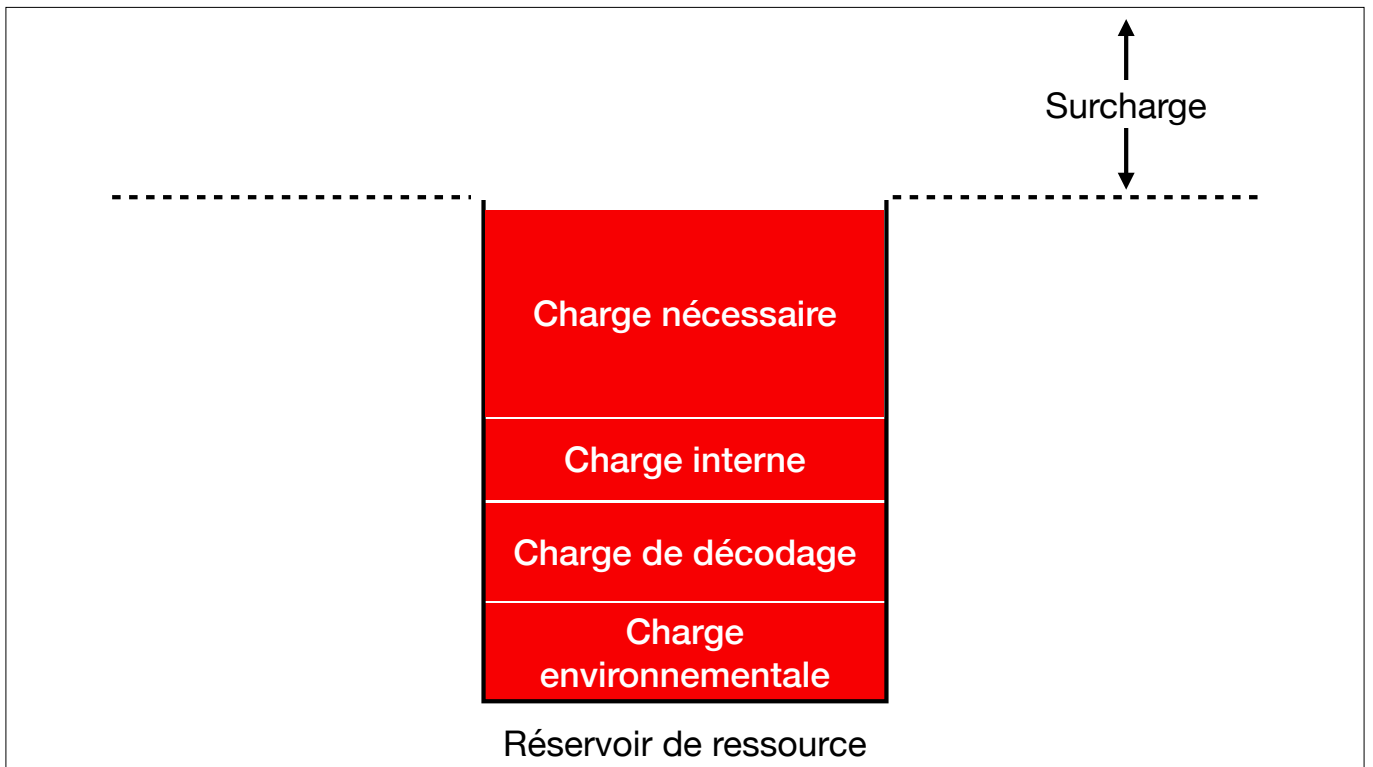
1. Charge interne : liée au niveau d'**expertise**
2. Charge de décodage : liée aux modalités de **présentation**
3. Charge environnementale : liée aux **distractions**
4. Charge nécessaire : liée au **contenu** à apprendre



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20

Il faut :

charge **interne** ↓ + charge **de décodage** ↓ + charge **environnementale** ↓

—> charge **nécessaire**

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Partie 2

Comment réduire le risque de surcharge ?

22

Principe 1

Automatiser les préalables

(diminue la charge interne)

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Principe 1

Automatiser les préalables
(diminue la charge interne)

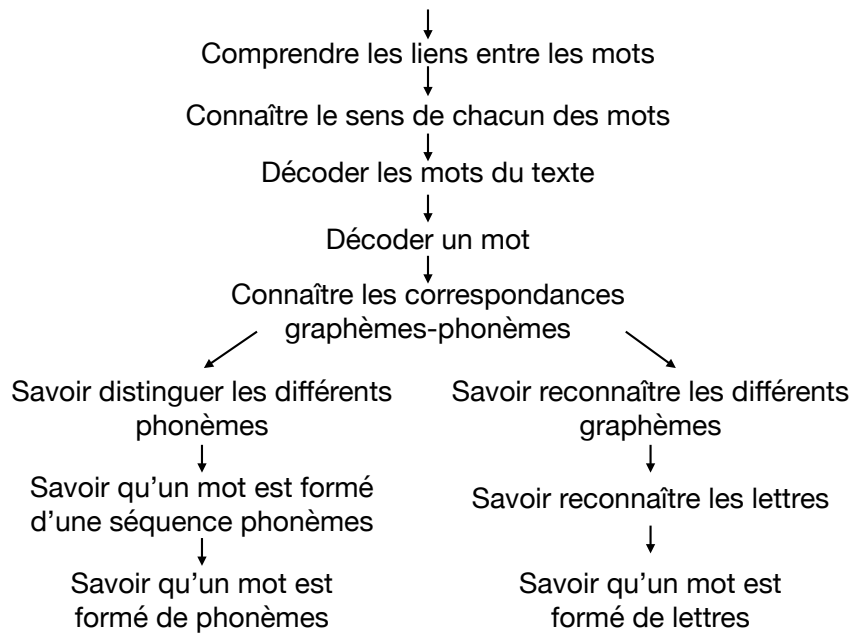
Comment ?

Étape 1
Identifier les préalables

24

Comprendre un texte

Exemple



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Principe 1

Automatiser les préalables

Comment ?

Étape 1

Identifier les préalables

Étape 2

Vérifier si les préalables sont acquis et automatisés

Étape 3

Acquérir et automatiser les préalables qui ne le sont pas

26

Principe 1

Automatiser les préalables

Pour réduire la charge cognitive interne

Comment ?

Stratégie 1

Activer les préalables à plusieurs reprises

Stratégie 2

Entraîner la récupération en mémoire des préalables

Stratégie 3

Élaborer des explications liées aux préalables

Stratégie 4

Espacer l'activation des préalables

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Principe 2

Optimiser les modalités de présentation

(diminue la charge de décodage)

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Principe 2

Optimiser les modalités de présentation (diminue la charge de décodage)

Comment ?

Stratégie 1

Catégoriser l'information

Étude de Bor et al.

Bor, D., & Gilmore, C. (2010). Encoding Strategies Dissociate Prefrontal Activity from Working Memory Demand. *Journal of Experimental Psychology: Applied*, 16(1), 1-11.

Encoding Strategies Dissociate Prefrontal Activity from Working Memory Demand

Daniel Bor,¹ John Duncan,¹ Richard J. Wiseheart,¹ and Adrian M. Owen¹

¹Medical Research Council Cognition and Brain Sciences Unit, 15 Chaucer Road, Cambridge CB2 3EF, United Kingdom; ²Department of Psychology, University of Hertfordshire, Hatfield, United Kingdom; ³Wolfson Brain Imaging Centre, University of Cambridge, Cambridge, United Kingdom

Summary

It is often proposed that prefrontal cortex is important in organization and control of working memory systems. In some cases, effective reorganization can decrease task difficulty, implying a dissociation between frontal activity and loads memory demand. In a spatial working memory task, we studied the improvement of performance that occurs when materials can be reorganized into higher level groups or chunks. Structured sequences, encouraging reorganization and chunking, were compared with unstructured sequences. Though structured sequences were easier to remember, event-related functional magnetic resonance imaging (fMRI) showed increased activation of lateral frontal cortex, in particular during memory encoding. The results show that, even when memory demand decreases, organization of working memory contents into higher level chunks is associated with increased prefrontal activity.

Introduction

Neurocognitive studies suggest that the prefrontal cortex plays a key role in task organization and control. In complex tasks, for example, learners with prefrontal damage use poor strategies and exhibit behavioral impairments (Buckley and Guggisberg, 1991). Here we investigate the role of prefrontal cortex in reorganizational strategies used to decrease working memory demand.

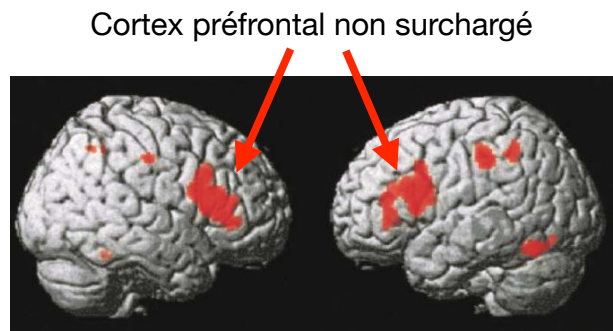
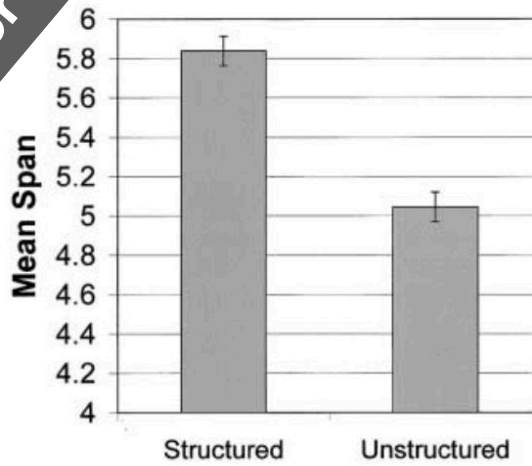
Undoubtedly prefrontal cortex makes an important contribution to working memory. Though some studies emphasize a role in attention and executive functioning, data have also suggested that the prefrontal cortex—specifically the dorsolateral prefrontal cortex (DLPFC)—plays a role in the monitoring, control, and organization of working memory systems (D'Esposito et al., 1980; Owen, 1987, 2006; Petrides, 1984). Such terms, however, can be hard to interpret precisely, and interpretations of a controlling role have been made difficult by studies that show that DLPFC is recruited, for example, after the contents of a working memory list must be reorganized in memory (Duncan et al., 2000) or a prefrontal cortex at all, 2000) or a prefrontal cortex at all, 2000) or a prefrontal cortex at all, 2000). Other studies have shown that reorganization can be used to reduce working memory demand (Bor et al., 2009). In such cases, the reorganization of working memory contents into higher level chunks is associated with increased prefrontal activity.

Behavioral Study

Working memory for spatial sequences was tested using a modified spatial working task in which participants were required to remember sequences of locations on a 4 × 4 grid (Figure 1). Each participant's spatial span was calculated as the mean number of locations that could be recalled successfully following a single presentation. For any one participant, the mean span was either 4, 5, or 6, and in some cases, the mean span was 7 or 8. In order to compare the effects of structured and unstructured sequences, we used two different sequences: a high level chunked sequence (HLC) and a low level unchunked sequence (LLU). The HLC sequence was presented with the structured sequence presentation (Figure 1B), and the LLU sequence was presented with the unstructured sequence presentation (Figure 1C). The HLC sequence was presented with the structured sequence presentation (Figure 1B), and the LLU sequence was presented with the unstructured sequence presentation (Figure 1C). The HLC sequence was presented with the structured sequence presentation (Figure 1B), and the LLU sequence was presented with the unstructured sequence presentation (Figure 1C).

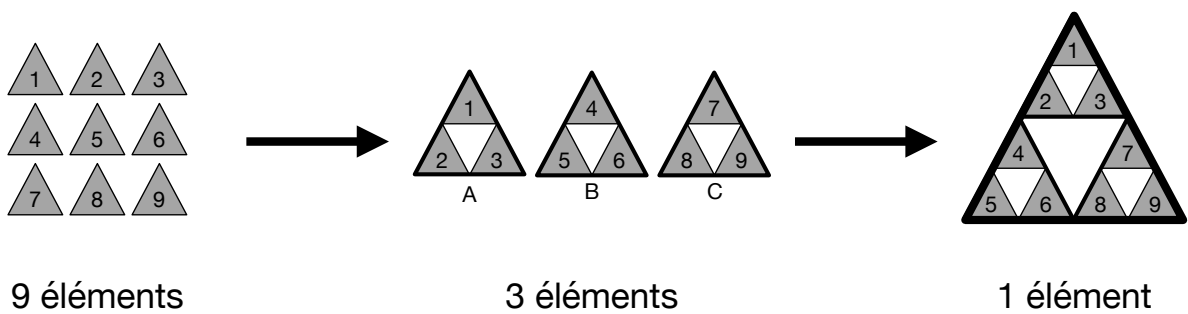
Effet de la structuration sur la surcharge cérébrale

Étude de
Bor et al.



Structuré >
non structuré

Quand l'information est structurée,
le cortex préfrontal s'active davantage (**pas de surcharge** de la mémoire de travail).



11 éléments

1 5 1 4 9 8 7 3 0 0 0

4 éléments

1 514 987 3000



Canada



Montréal



UQAM



Poste spécifique

Principe 2

Optimiser les modalités de présentation

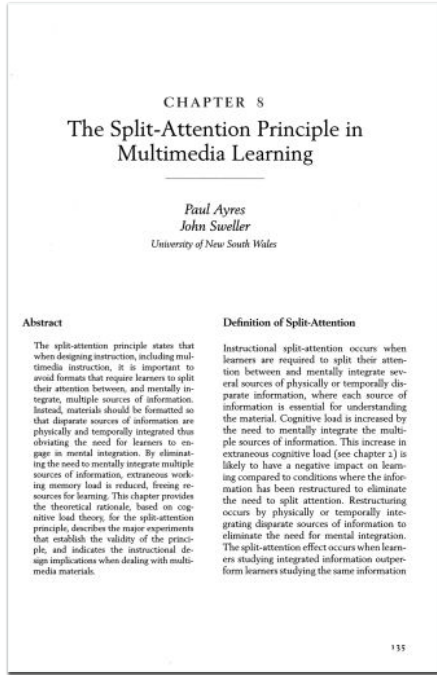
Comment ?

Stratégie 1

Catégoriser l'information

Stratégie 2

Rassembler l'information



Synthèse sur l'attention partagée

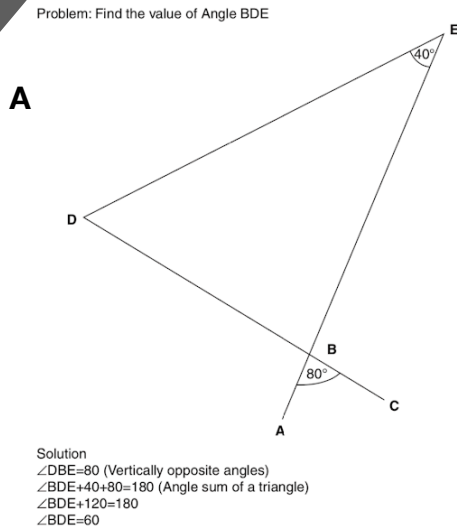


Figure 8.1. Split-attention format.

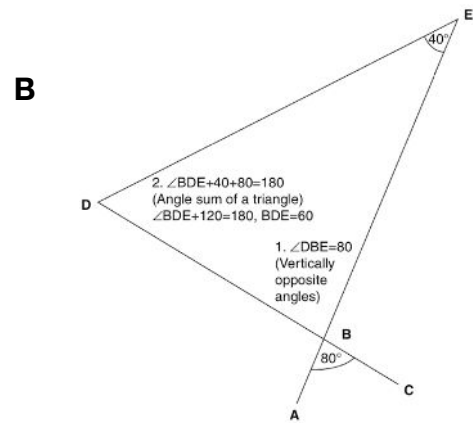


Figure 8.2. Integrated format.

Principe 2

Optimiser les modalités de présentation

Comment ?

Stratégie 1
Catégoriser l'information

Stratégie 2
Rassembler l'information

Stratégie 3
Éviter la redondance

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Étude de

Chandler et Sweller

COGNITION AND INSTRUCTION, 1991, 8(4), 293-332
Copyright © 1991, Lawrence Erlbaum Associates, Inc.

Cognitive Load Theory and the Format of Instruction

Paul Chandler and John Sweller
University of New South Wales

Cognitive load theory suggests that effective instructional material facilitates learning by directing cognitive resources toward activities that are relevant to learning rather than toward preliminaries to learning. One example of ineffective instruction occurs if learners unnecessarily are required to mentally integrate disparate sources of mutually referring information such as separate text and diagrams. Such split source information may generate a heavy cognitive load, because material must be mentally integrated before learning can commence. This article reports findings from six experiments testing the consequences of split source and integrated information using electrical engineering and biology instructional materials. Experiment 1 was designed to compare conventional instructions with integrated instructions over a period of several months in an industrial training setting. The materials chosen were unintelligible without mental integration. Results favored integrated instructions throughout the 3-month study. Experiment 2 was designed to investigate the possible differences between conventional and integrated instructions in areas in which it was not essential for sources of information to be integrated to be understood. The results suggest that integrated instructions were no better than split-source information in such areas. Experiments 3, 4, and 5 indicate that the introduction of seemingly useful but nonessential explanatory material (e.g., a commentary on a diagram) could have deleterious effects even when presented in integrated format. Experiment 6 found that the need for physical integration was reduced if the material was organized in such a manner that individual units could not be understood alone. In light of these results and previous findings, suggestions are made for cognitively optimal instructional packages.

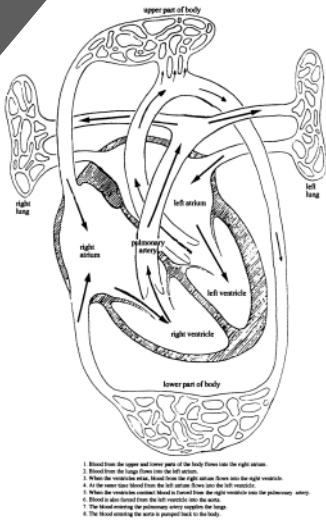
Over the last decade, there have been considerable interest and debate in areas of cognition and education. Nevertheless, until recently, our knowledge of the cognitive processes involved in understanding instructional material has been somewhat limited. In the last few years, however, cognitive science has progressed to a point where it is becoming obvious that traditional methods of instructional

Requests for reprints should be sent to John Sweller, School of Education, University of New South Wales, P.O. Box 1, Kensington, New South Wales, Australia 2033.

Effets de la **redondance** de l'information

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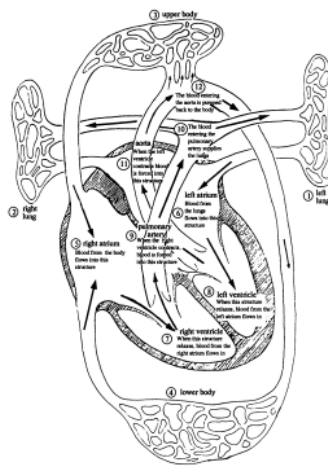
Diagram indicating flow of blood through the heart, lungs and body



1. Blood from the upper and lower parts of the body flows into the right atrium.
2. Blood from the right flows into the left atrium.
3. When the ventricle atria, blood from the right atrium flows into the right ventricle.
4. As the upper and lower parts of the body flow into the left ventricle.
5. When the ventricle atria, blood is forced from the right ventricle into the pulmonary artery.
6. Blood is pumped from the left ventricle into the aorta.
7. The blood entering the pulmonary artery supplies the lungs.
8. The blood entering the aorta is transported to the body.

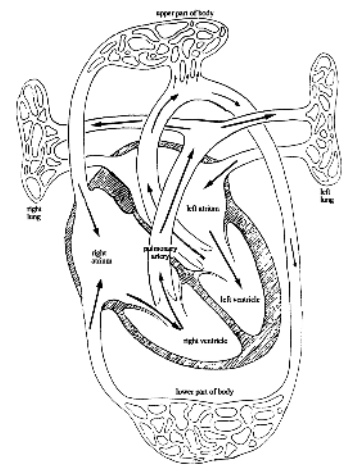
A

Diagram indicating flow of blood through the heart, lungs and body



B

Diagram indicating flow of blood through the heart, lungs and body



C

Instruction Times (in Seconds) and Test Scores on the Problems of Experiment 5

Group	Instruction Time	Problem					
		1	2	3	4	5	6
Diagram only M	69.1	5.3	4.9	3.7	3.5	14.9	1.8
	12.0	1.2	1.5	2.1	2.8	1.4	1.5
Modified M	105.7	4.5	2.8	1.7	1.4	7.8	0.9
	9.6	1.2	2.4	1.6	2.1	4.5	1.1
Conventional M	158.8	3.5	1.7	0.8	1.1	7.6	0.9
	38.5	1.2	1.3	0.8	1.5	4.1	0.9

Diagramme seulement (C)

Redondant (B)

Redondante +
attention partagée
(A)

Diagramme seulement = plus efficace et plus rapide

Principe 3

Réduire les distractions

(diminue la charge environnementale)

41

Principe 3

Réduire les distractions

(diminue la charge environnementale)

Comment ?

Bruit
Conversation
Musique
Décoration

Stratégie 1
Réduire les distractions
sonores et visuelles

Stratégie 2
Réduire les distractions
technologiques + multitâche

Téléphone
Médias sociaux
Multitâche

Anxiété
Meilleure préparation aux examens
Méditation

Stratégie 3
Favoriser le bien-être

42



youtube.com/stevemasson

Principe 4

Complexifier progressivement
(assure que la charge nécessaire n'est ni trop grande ni trop faible)

Il faut :

charge **interne** ↓ + charge **de décodage** ↓ + charge **environnementale** ↓

—> charge **nécessaire** pour apprendre

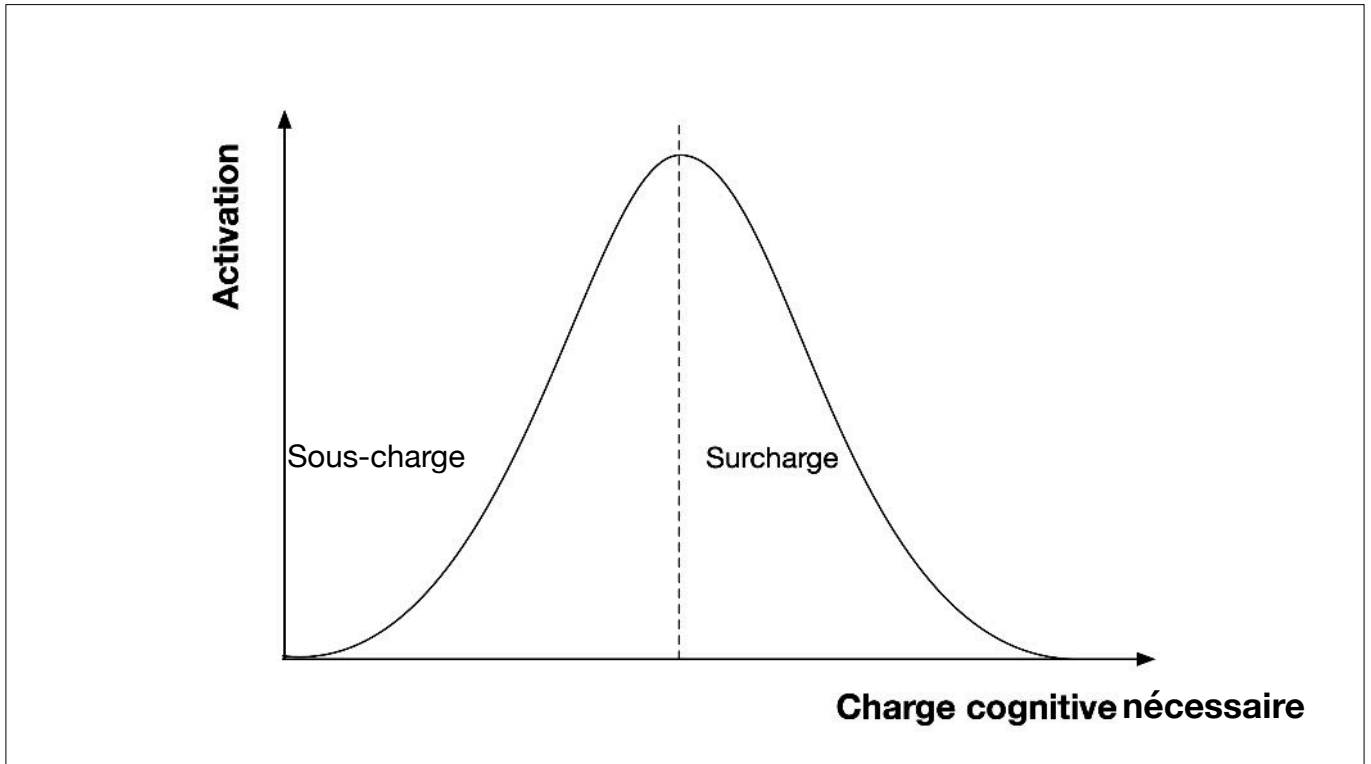
45

Principe 4

Complexifier progressivement

(assure que la charge nécessaire n'est ni trop grande ni trop faible)

46

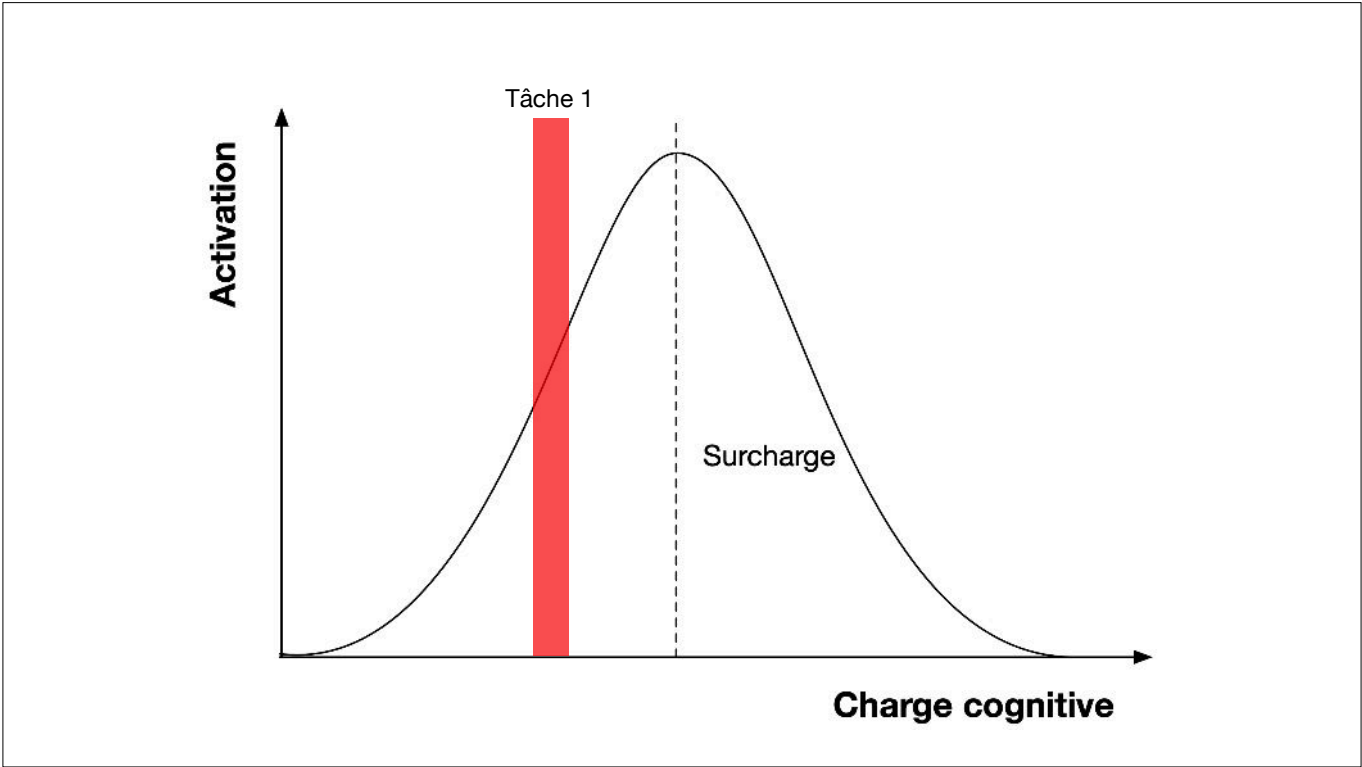


47

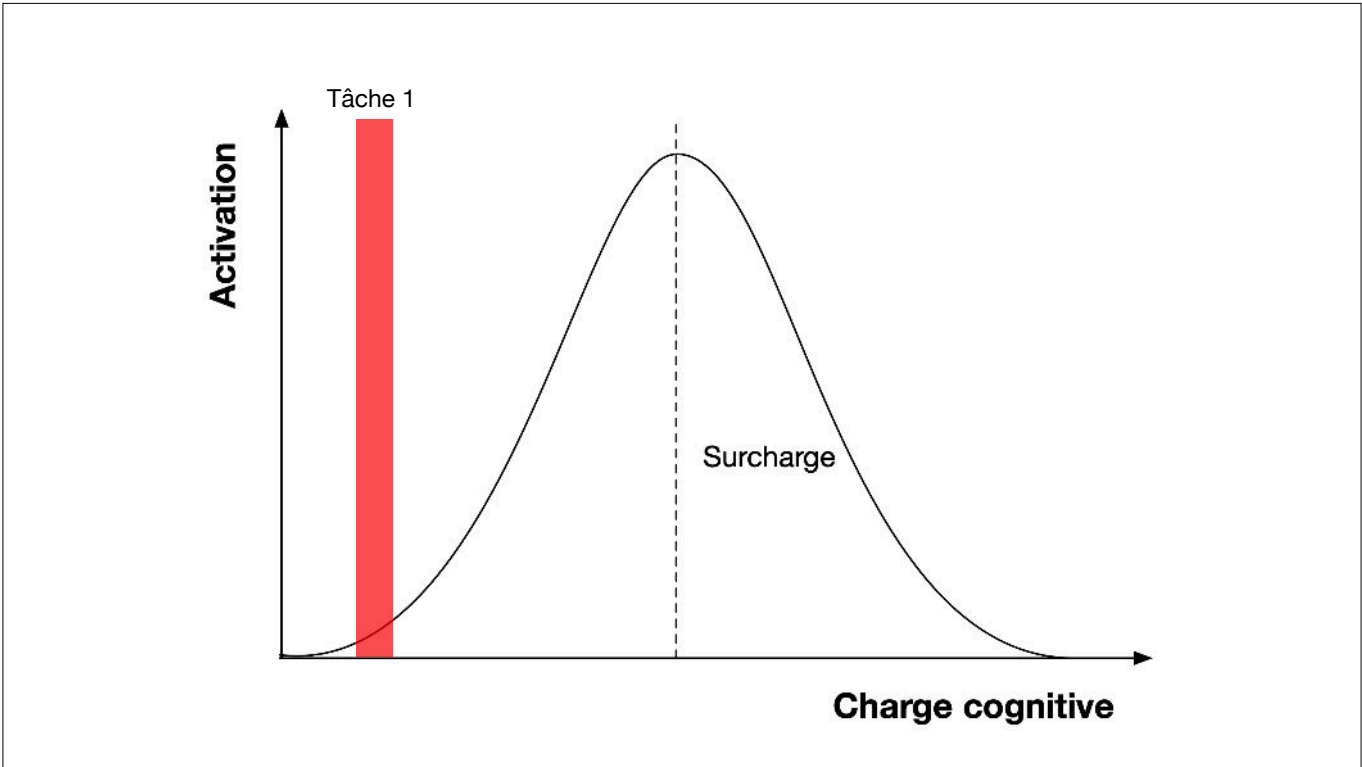
La charge d'une tâche dépend du **niveau d'expertise**.

La charge d'une tâche **se déplace** donc au cours de l'apprentissage.

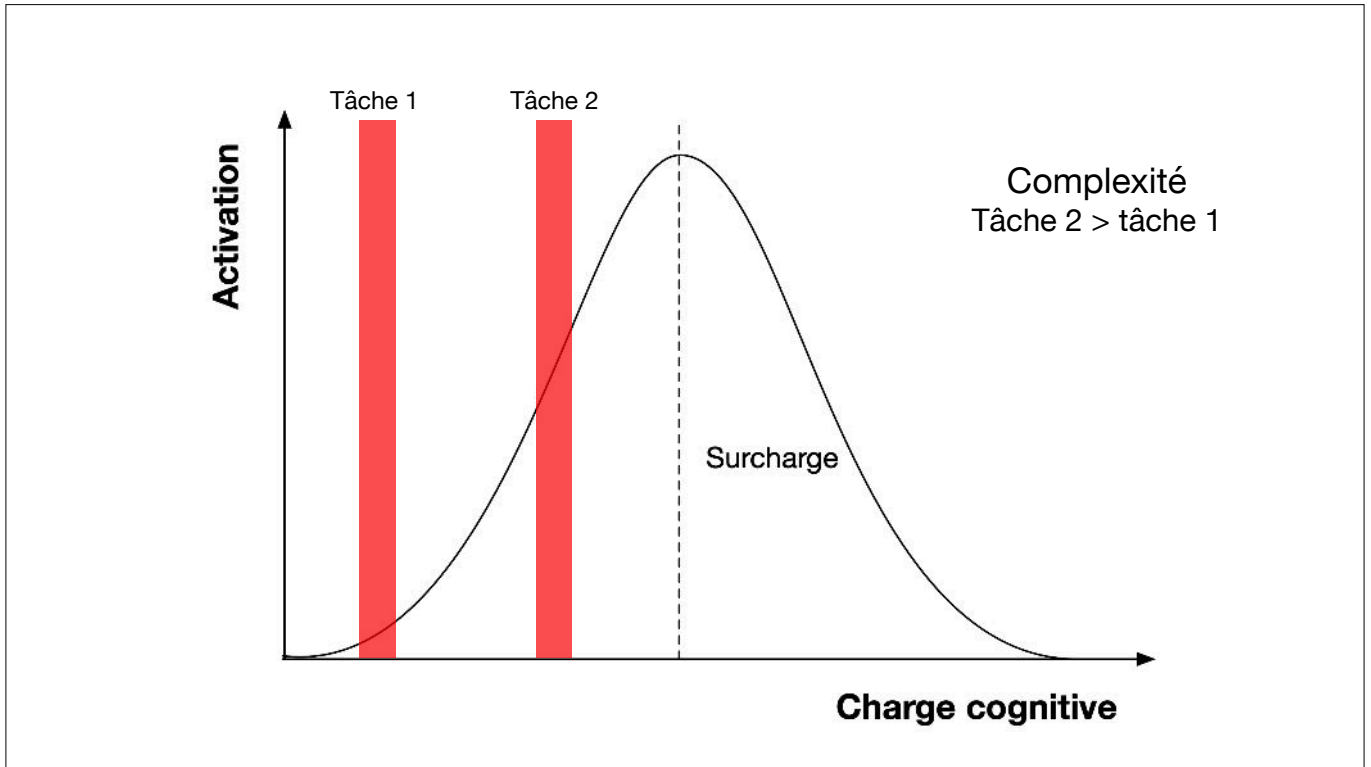
48



49



50



51

Il faut constamment **adapter** les tâches en fonction du niveau d'**expertise** des apprenants.

Complexité ni trop grande ni trop faible

52

Principe 4

Complexifier progressivement

(assure que la charge nécessaire n'est ni trop grande ni trop faible)

Comment ?

Stratégie 1

Complexifier progressivement
les tâches

Stratégie 2

Fournir un exemple de
solution

Étude de

Sweller et Cooper

COGNITION AND INSTRUCTION, 1985, 2 (1) 59-89
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The Use of Worked Examples as a Substitute for Problem Solving in Learning Algebra

John Sweller and Graham A. Cooper
*University of New South Wales
Sydney, Australia*

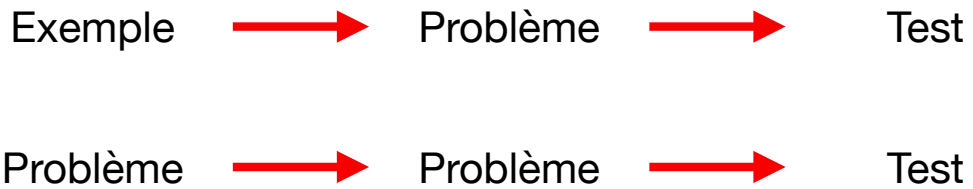
The knowledge required to solve algebra manipulation problems and procedures designed to hasten knowledge acquisition were studied in a series of five experiments. It was hypothesized that, as occurs in other domains, algebra problem-solving skill requires a large number of schemas and that schema acquisition is retarded by conventional problem-solving search techniques. Experiment 1, using Year 9, Year 11, and university mathematics students, found that the more experienced students had a better cognitive representation of algebraic equations than less experienced students as measured by their ability to (a) recall equations, and (b) distinguish between perceptually similar equations on the basis of solution mode. Experiments 2 through 5 studied the use of worked examples as a means of facilitating the acquisition of knowledge needed for effective problem solving. It was found that not only did worked examples, as expected, require considerably less time to process than conventional problems, but that subsequent problems similar to the initial ones also were solved more rapidly. Furthermore, decreased solution time was accompanied by a decrease in the number of mathematical errors. Both of these findings were specific to problems identical in structure to the initial ones. It was concluded that for novice problem solvers, general algebra rules are reflected in only a limited number of schemas. Abstraction of general rules from schemas may occur only with considerable practice and exposure to a wider range of schemas.

In certain respects the teaching of mathematics and mathematically-based curriculum material is stereotyped. There are usually three steps followed: (1) Relevant information consisting of principles and relations, frequently in the form of equations, is introduced to students; (2) A relatively small number of

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Effets de fournir un **exemple de solution**

Meilleure séquence ?



Exemple = charge ↓

Mean Seconds and Errors Per Problem on Initial and Repeat Problem Presentation During Acquisition, and on Test Problems in Experiment 3

Group	Acquisition		Test
	Initial Presentation	Repeat Presentation	
Worked Example	32.0 (—)	53.2 (0.45)	43.6 (0.18)
Conventional Problem	185.5 (2.73)	59.5 (0.36)	78.1 (1.64)

Note: Mean errors appear in parentheses.

Moins d'erreurs et plus rapide si exemple de solution avant

Principe 4
Complexifier progressivement
(assure que la charge nécessaire n'est ni trop grande ni trop faible)

Comment ?

Stratégie 1
Complexifier progressivement les tâches

Stratégie 2
Fournir un exemple de solution

Stratégie 3
Diminuer progressivement la guidance

Étude de
Van Merr. et al.

INSTRUCTIONAL TECHNOLOGY, Vol. 4 (1)
 Copyright © 2001, Lawrence Erlbaum Associates, Inc.

**Taking the Load Off a Learner's Mind:
 Instructional Design for Complex Learning**

Jerren J. G. van Merriënboer, Paul A. Kirschner, and Liesbeth Kosters
*Instructional Technology Expertise Center
 Open University of the Netherlands, Heerlen*

Over the last decade, the integration of knowledge, skills, and attitudes, the coordination of cognitively different constituent skills, and the transfer of what is learned to daily life or work settings. Realistic, situated tasks may stimulate transfer of learning more than the domain-based tasks that are used in traditional learning. Learning may be supported by the task design, the content, and the nature of the interaction. Learning may be supported by the task design, the content, and the nature of the interaction. Learning may be supported by the task design, the content, and the nature of the interaction. Learning may be supported by the task design, the content, and the nature of the interaction.

Recent instructional theories tend to focus on authentic learning tasks that are based on real-life tasks as the driving force for learning (Merrill, 2002; Rogalski, 1996; van Merriënboer & Kirschner, 2001). The general assumption is that real tasks help learners to link the knowledge, skills, and attitudes necessary for effective task performance; give them the opportunity to learn to coordinate constituent skills that make up complex task performance; and eventually enable them to transfer what is learned to their daily life or work settings. This focus on authentic, whole tasks can be found in practical instructional approaches, such as the job-aided task, "near-transfer," problem-based learning, and workplace-based learning, and in theoretical models, such as Collins, Brown, and Newman's (1989) theory of cognitive apprenticeship learning, Johnson's (1990) theory of cooperative learning environments, Nelson's (1990) theory of collaborative problem solving, and Schwab, Bertram, and MacPeters's (1999) theory of goal-based learning.

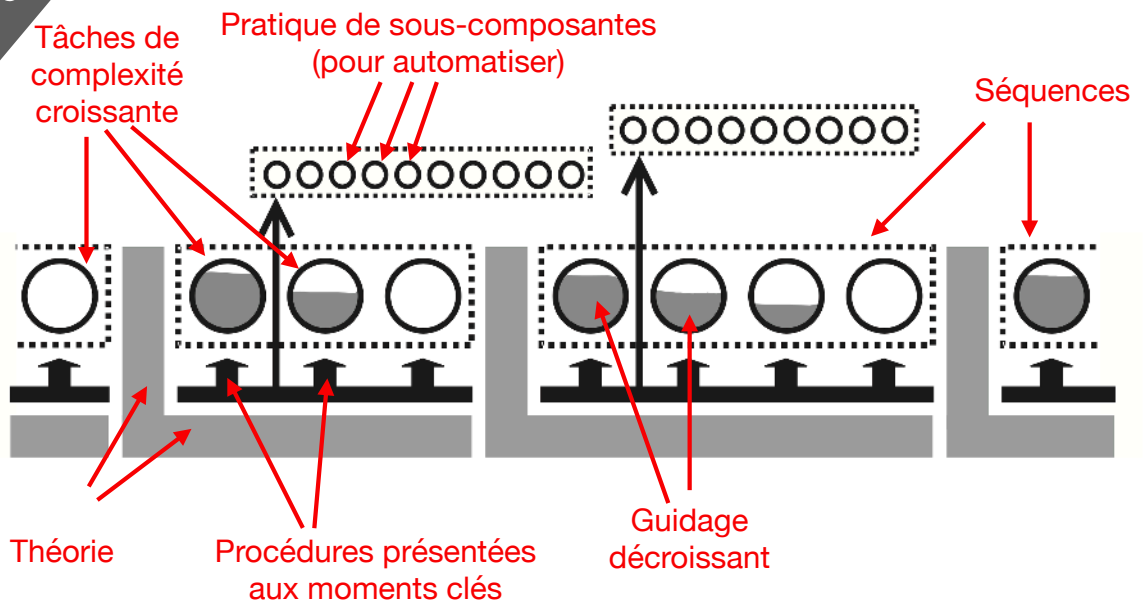
A severe case of all these approaches is that learners have difficulties learning because they are overwhelmed by the task complexity. The aim of this article is to discuss managing cognitive load when rich learning tasks are used in education. First, methods for scaffolding whole task practice are discussed, including sample to complete sequencing of learning tasks and the use of alternative tasks, such as worked-out examples and completion tasks. Second, methods for just-in-time information presentation are discussed, including timely presentation of information to support practice on learning tasks and the direct, step-by-step presentation of procedural information. Third, we sketch an instructional design model for complex learning fully consistent with cognitive load theory (CLT). We conclude that CLT offers useful guidelines for designing learning and extensive cognitive load, so that sufficient processing capacity is left for genuine learning.

SCAFFOLDING WHOLE-TASK PRACTICE

Goal-based learning or their original meaning within contextual psychology, include all devices or strategies that support problem-solving. Learning theory (van Merriënboer, 1992) holds cognitive apprenticeship learning and the framework, and scaffolding explicitly presents to a combination of performance support and fading. In fully the support services however achieve a goal of a learner is achievable without that support. When the learner achieves the desired goal, support gradually diminishes until it is no longer needed. Because extensive or continuous support can hamper the learning process, it is crucial to determine the right type and amount of support and the fade at the appropriate time and rate. Many types of support share the common characteristic that they do not direct the learner, or even control teaching, or just provide (e.g., procedural support), but rather guide the learner during his or her work on complex learning tasks (i.e., problem-solving support).

Correspondence should be addressed to Jerren J. G. van Merriënboer, Department of Instructional Technology, Open University of the Netherlands, Sorbonnelaan 1, Postbus 30.602, 6525 EA Heerlen, The Netherlands. E-mail: j.j.vanmerri@open.nl

Modèle d'enseignement prenant en compte les limites de la mémoire de travail



Synthèse

