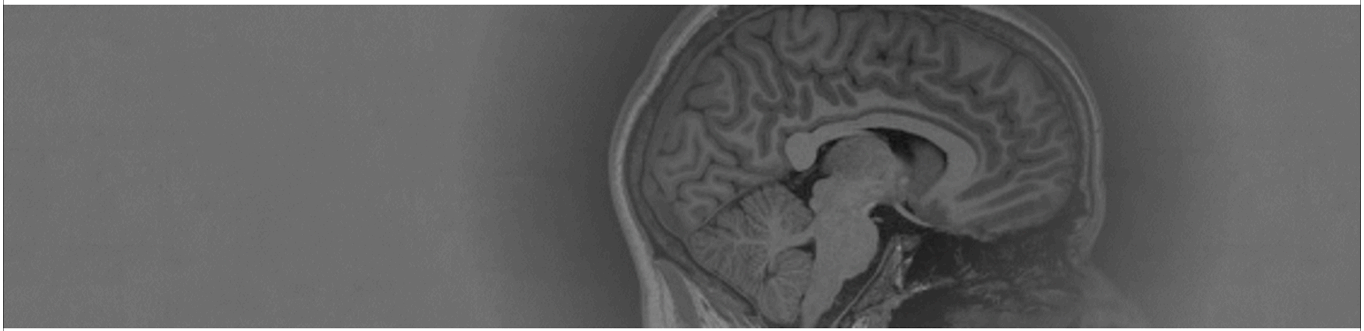
labneuroeducation.org youtube.com/stevemasson facebook.com/profstevemasson twitter.com/stevemasson



Comprendre la mémoire de travail pour mieux apprendre et enseigner

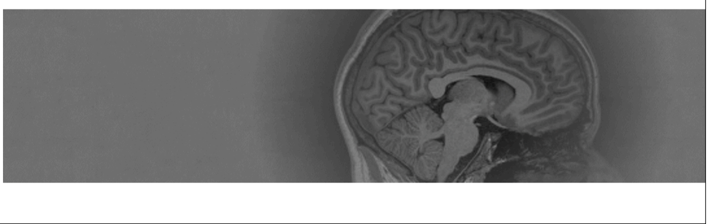
Semaine de la Chaire recherche-action 2024, Institut Villebon - 17 déc. 2024
Steve Masson, professeur à l'Université du Québec à Montréal

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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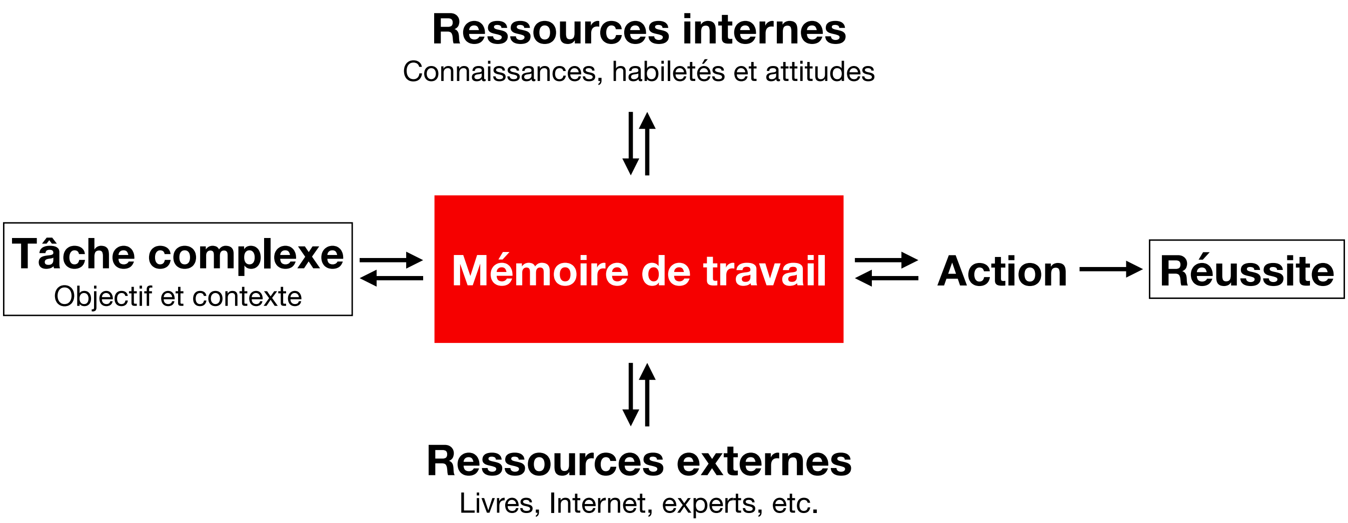

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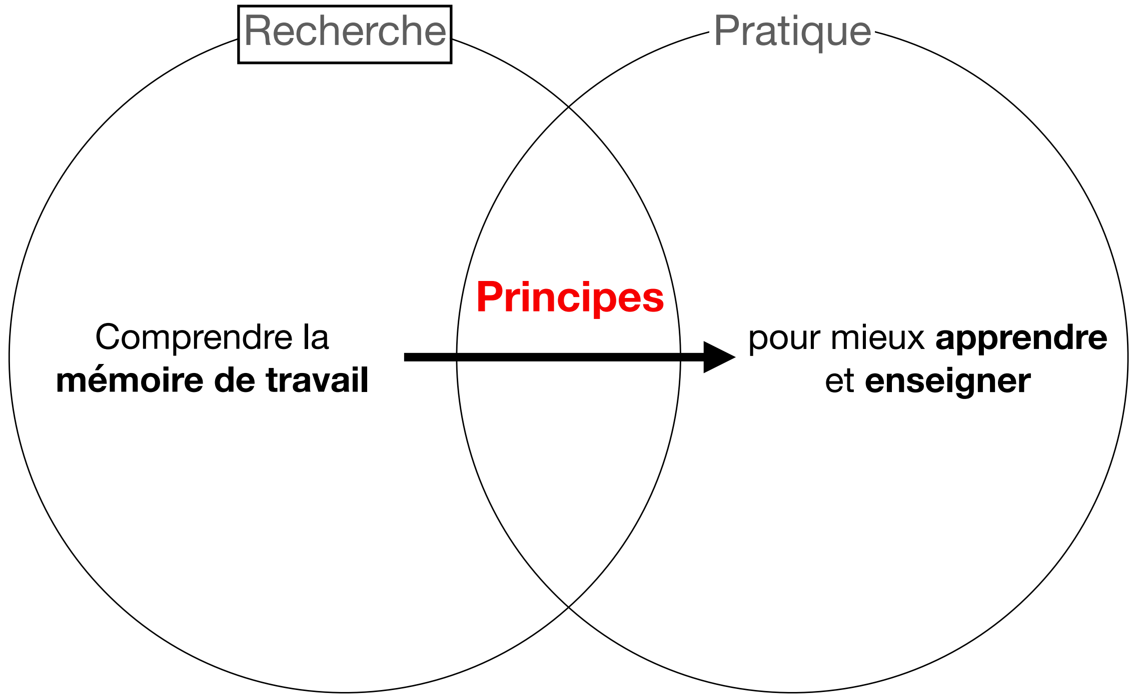
La **mémoire de travail** est donc nécessaire à la **compétence**.



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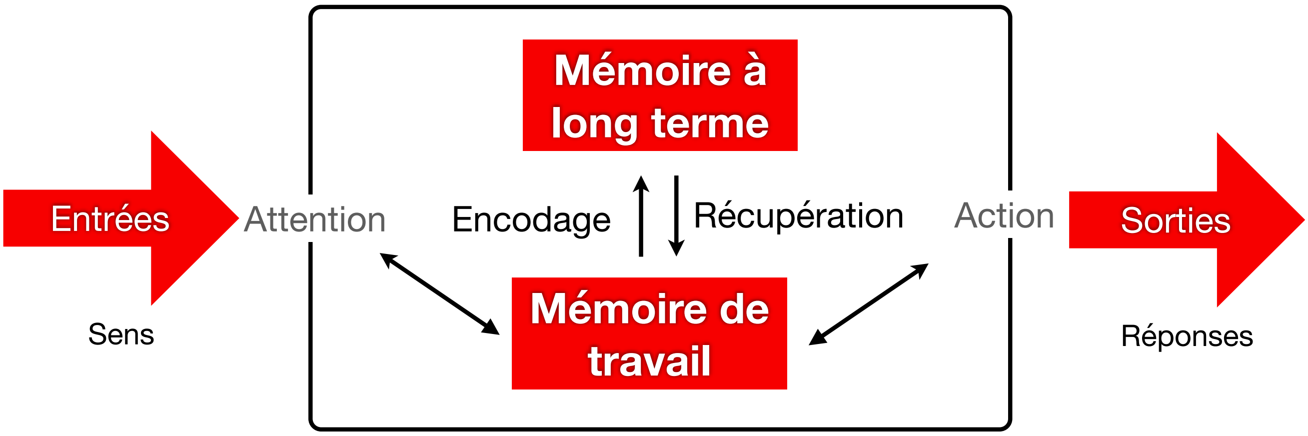
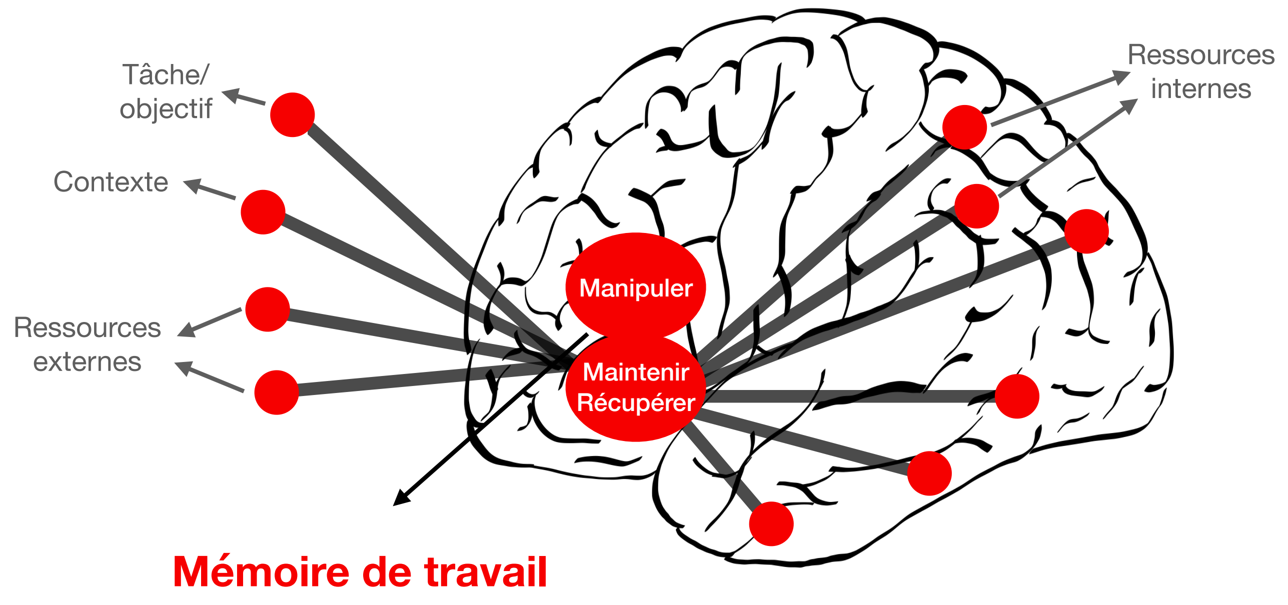
Partie 1

Qu’est-ce que la mémoire de travail ?

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





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Problème

La mémoire de travail est très limitée.

10

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

Étude de
Cowan

BEHAVIORAL AND BRAIN SCIENCES (2000) **24,** 87–185
Printed in the United States of America

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

Nelson Cowan
Department of Psychological Sciences,
University of Missouri, Columbia, MO 65211
cowanN@missouri.edu **www.missouri.edu/~psycowan**

Abstract: Miller (1956) summarized evidence that people can remember about seven chunks in short-term memory (STM) tasks. However, that number was meant more as a rough estimate and a rhetorical device than as a real capacity limit. Others have since suggested that there is a more precise capacity limit, but that it is only three to five chunks. The present target article brings together a wide variety of data on capacity limits suggesting that the smaller capacity limit is real. Capacity limits will be useful in analyses of information processing only if the *boundary conditions for observing them* can be carefully described. Four basic conditions in which chunks can be identified and capacity limits can accordingly be observed are: (1) when information overload limits chunks to individual stimulus items, (2) when other steps are taken specifically to block the recoding of stimulus items into larger chunks, (3) in performance discontinuities caused by the capacity limit, and (4) in various indirect effects of the capacity limit. Under these conditions, rehearsal and long-term memory cannot be used to combine stimulus items into chunks of an unknown size; nor can storage mechanisms that are not capacity-limited, such as sensory memory, allow the capacity-limited storage mechanism to be refilled during recall. A single, central capacity limit averaging about four chunks is implicated along with other, noncapacity-limited sources. The *pure STM capacity limit* expressed in chunks is distinguished from *compound STM limits* obtained when the number of separately held chunks is unclear. Reasons why pure capacity estimates fall within a narrow range are discussed and a capacity limit for the focus of attention is proposed.

Keywords: attention; enumeration; information chunks; memory capacity; processing capacity; processing channels; serial recall; short-term memory; storage capacity; verbal recall; working memory capacity

1. Introduction to the problem of mental storage capacity

One of the central contributions of cognitive psychology has been to explore limitations in the human capacity to store and process information. Although the distinction between a limited-capacity primary memory and an unlimited-capacity secondary memory was described by James (1890), Miller’s (1956) theoretical review of a “magical number seven, plus or minus two” is probably the most seminal paper in the literature for investigations of limits in short-term memory (STM) storage capacity. It was, in fact, heralded as one of the most influential *Psychological Review* papers ever, in a 1994 centennial issue of the journal. Miller’s reference to a magical number, however, was probably a rhetorical device. A more central focus of his article was the ability to increase the effective storage capacity through the use of intelligent grouping or “chunking” of items. He ultimately suggested that the specific limit of seven probably emerged as a coincidence.

Over 40 years later, we are still uncertain as to the nature of storage capacity limits. According to some current theories there is no limit in storage capacity per se, but a limit in the duration for which an item can remain active in STM without rehearsal (e.g., Baddeley 1986; Richman et al. 1995). This has led to a debate about whether the limitation is a “magic number or magic spell” (Schweickert & Boruff 1986) or whether rehearsal really plays a role (Brown & Hulme 1995). One possible resolution is that the focus of attention is capacity-limited, whereas various supplementary storage mechanisms, which can persist temporarily without attention, are time-limited rather than capacity-limited (Cowan 1988; 1995). Other investigators, however, have long questioned whether temporary storage concepts are necessary at all, and have suggested that the rules of learning and memory could be identical in both the short and long term (Crowder 1993; McGeoch 1932; Melton 1963; Nairne 1992; Neath 1998).

At present, the basis for believing that there is a time

NELSON COWAN (Ph.D. 1980, University of Wisconsin–Madison) is Professor in the Department of Psychological Sciences at the University of Missouri–Columbia. He has written one book (Cowan, N. 1995. *Attention and memory: An integrated framework*. Oxford University Press) and edited another (1997. *The development of memory in childhood*. Psychology Press), and has 100 other publications on working memory, and its relation to attention. He is former Associate Editor of the *Journal of Experimental Psychology: Learning, Memory, and Cognition* (1995–1999) and current Associate Editor of the *Quarterly Journal of Experimental Psychology (section A)*. He won the 1998 University of Missouri Chancellor’s Award for Research and Creative Activities.

 0140-525X/00 $12.50

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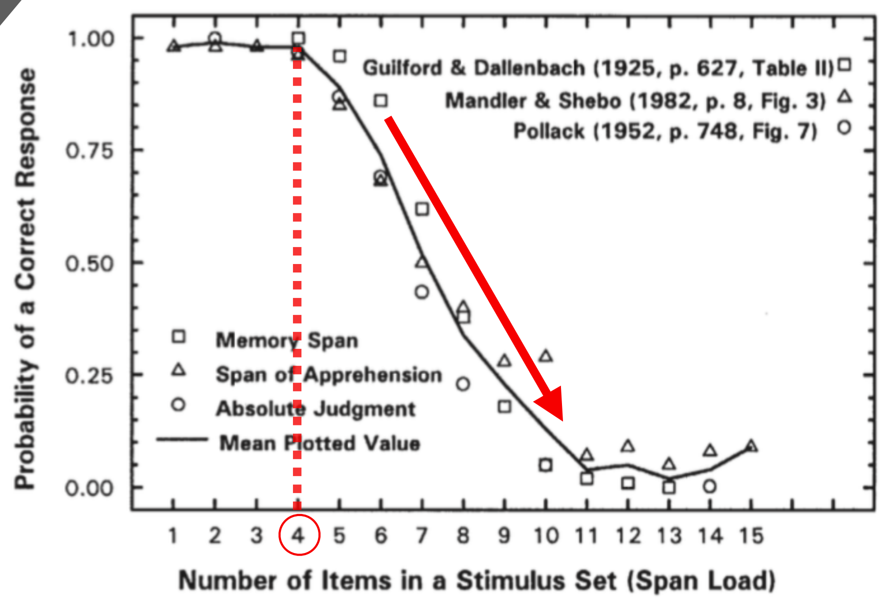
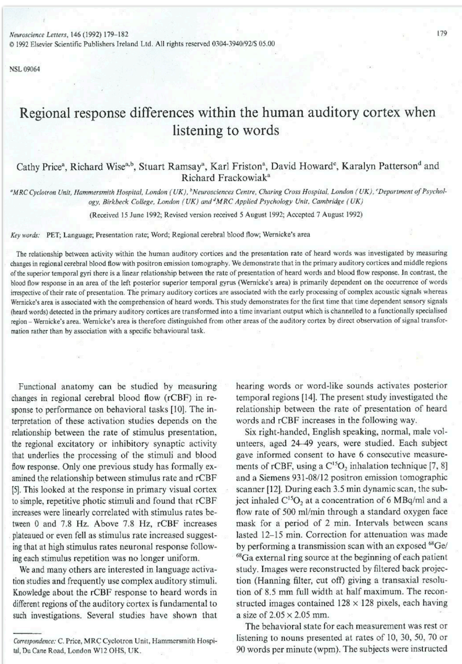
Capacité de notre mémoire de travail

Étude de Cowan



Étude de Price et al.



Neuroscience Letters, 146 (1992) 179–182

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NSL 09064

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

Cathy Price[a], Richard Wise[a,b], Stuart Ramsay[a], Karl Friston[a], David Howard[c], Karalyn Patterson[d] and Richard Frackowiak[a]

[a]*MRC Cyclotron Unit, Hammersmith Hospital, London (UK)*, [b]*Neurosciences Centre, Charing Cross Hospital, London (UK)*, [c]*Department of Psychology, Birkbeck College, London (UK) and* [d]*MRC Applied Psychology Unit, Cambridge (UK)*

(Received 15 June 1992; Revised version received 5 August 1992; Accepted 7 August 1992)

Key words: PET; Language; Presentation rate; Word; Regional cerebral blood flow; Wernicke's area

The relationship between activity within the human auditory cortices and the presentation rate of heard words was investigated by measuring changes in regional cerebral blood flow with positron emission tomography. We demonstrate that in the primary auditory cortices and middle regions of the superior temporal gyri there is a linear relationship between the rate of presentation of heard words and blood flow response. In contrast, the blood flow response in an area of the left posterior superior temporal gyrus (Wernicke's area) is primarily dependent on the occurrence of words irrespective of their rate of presentation. The primary auditory cortices are associated with the early processing of complex acoustic signals whereas Wernicke's area is associated with the comprehension of heard words. This study demonstrates for the first time that time dependent sensory signals (heard words) detected in the primary auditory cortices are transformed into a time invariant output which is channelled to a functionally specialised region – Wernicke's area. Wernicke's area is therefore distinguished from other areas of the auditory cortex by direct observation of signal transformation rather than by association with a specific behavioural task.

Functional anatomy can be studied by measuring changes in regional cerebral blood flow (rCBF) in response to performance on behavioral tasks [10]. The interpretation of these activation studies depends on the relationship between the rate of stimulus presentation, the regional excitatory or inhibitory synaptic activity that underlies the processing of the stimuli and blood flow response. Only one previous study has formally examined the relationship between stimulus rate and rCBF [5]. This looked at the response in primary visual cortex to simple, repetitive photic stimuli and found that rCBF increases were linearly correlated with stimulus rates 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 neuronal response following each stimulus repetition was no longer uniform.

We and many 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 hearing words or word-like sounds activates posterior temporal regions [14]. The present study investigated 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 24–49 years, were studied. Each subject gave informed consent to have 6 consecutive measurements of rCBF, using a $C^{15}O_2$ inhalation technique [7, 8] and a Siemens 931-08/12 positron emission tomographic scanner [12]. During each 3.5 min dynamic scan, the subject inhaled $C^{15}O_2$ at a concentration of 6 MBq/ml and a flow rate of 500 ml/min through a standard oxygen face mask for a period of 2 min. Intervals between scans lasted 12–15 min. Correction for attenuation was made by performing a transmission scan with an exposed $^{68}Ge/^{68}Ga$ external ring source at the beginning of each patient study. Images were reconstructed by filtered back projection (Hanning filter, cut off) giving a transaxial resolution of 8.5 mm full width at half maximum. The reconstructed images contained 128 × 128 pixels, each having a size of 2.05 × 2.05 mm.

The behavioral state for each measurement was rest or listening to nouns presented at rates of 10, 30, 50, 70 or 90 words per minute (wpm). The subjects were instructed

Correspondence: C. Price, MRC Cyclotron Unit, Hammersmith Hospital, Du Cane Road, London W12 OHS, UK.

Effet de la **surcharge** de la mémoire de travail sur le **cerveau**

Étude de **Price et al.**

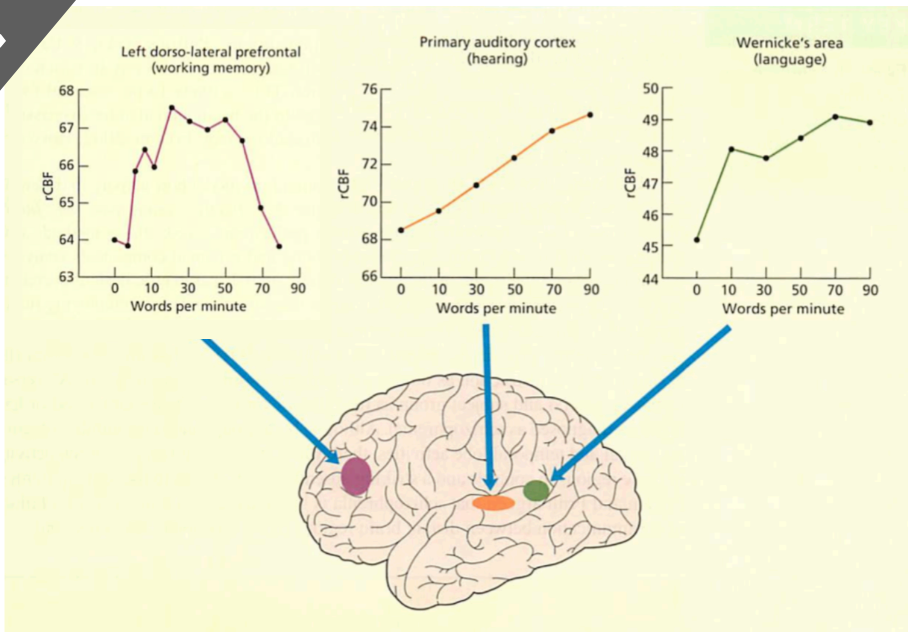


Figure tirée de Ward (2010, p. 61)

Étude de **Price et al.**

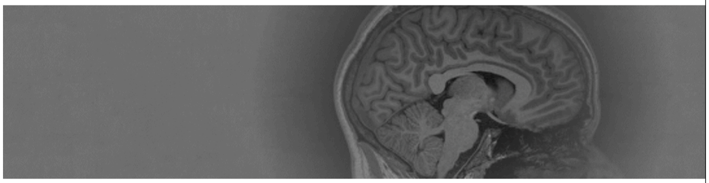
La surcharge est liée à une **désactivation**
de régions cérébrales liées à la mémoire de travail.

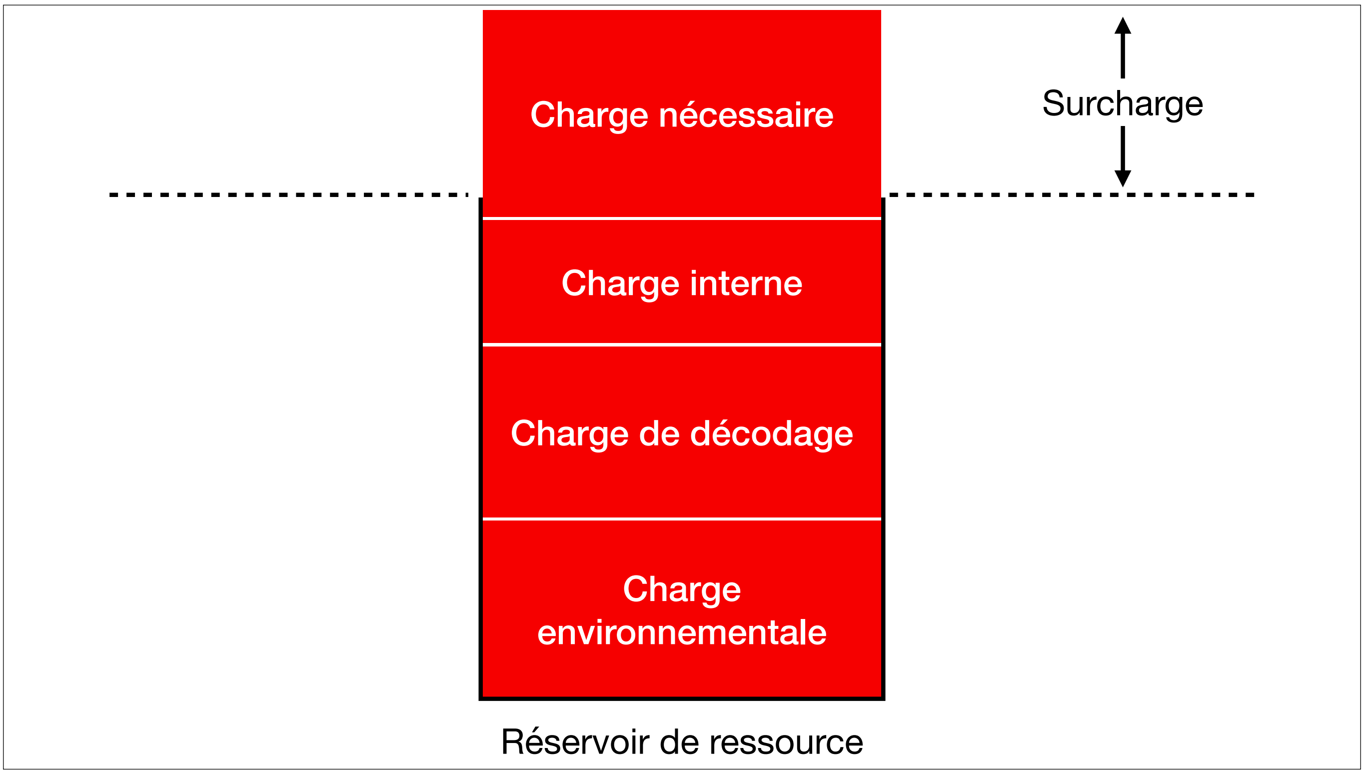
Piste de solution

Réduire la charge non nécessaire

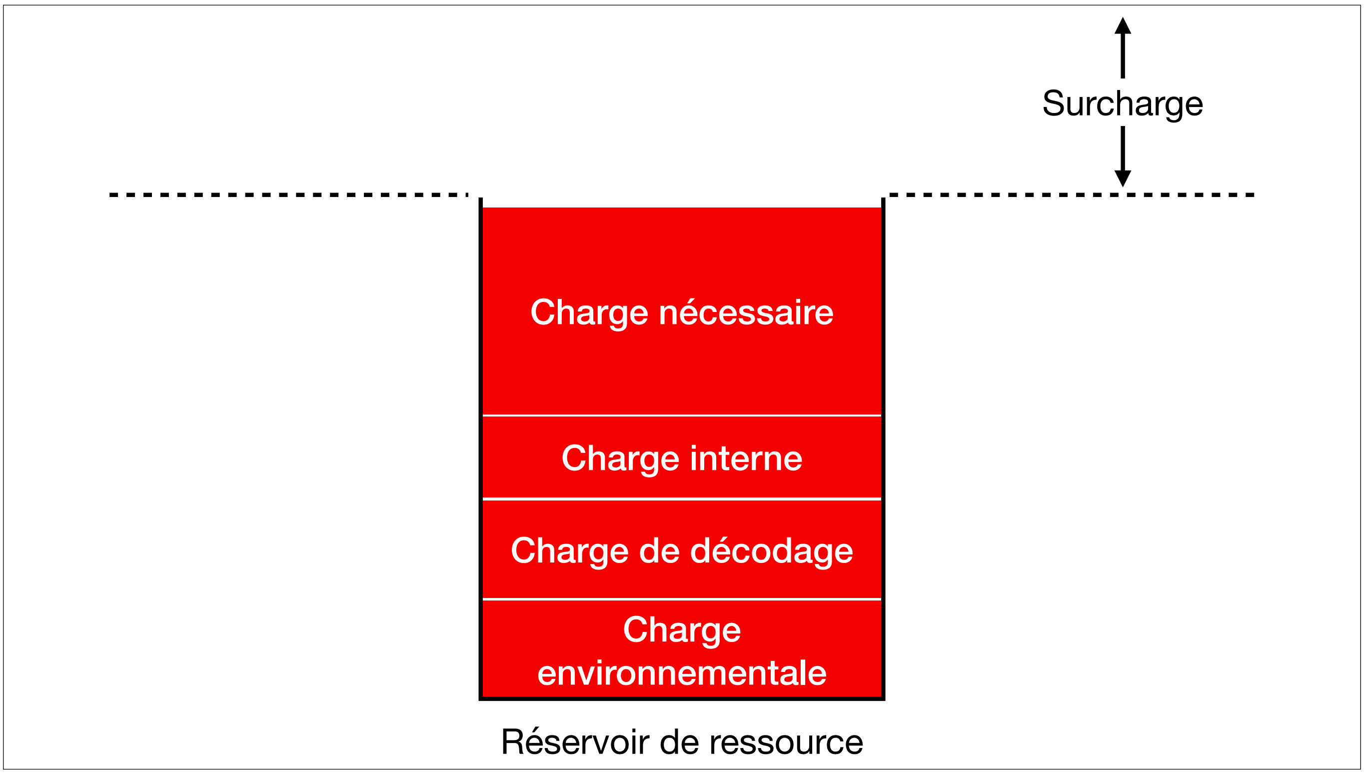
Qu’est-ce qui contribue à la charge ?

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




Charge nécessaire
Surcharge
Charge interne
Charge de décodage
Charge
environnementale
Réservoir de ressource

19


Surcharge
Charge nécessaire
Charge interne
Charge de décodage
Charge
environnementale
Réservoir de ressource

20

Il faut :

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

—> charge **nécessaire**

Partie 2

Comment réduire le risque de surcharge ?

Principe 1
Automatiser les préalables
(diminue la charge interne)

Principe 1
Automatiser les préalables
(diminue la charge interne)

Comment ?

Étape 1
Identifier les préalables

Comprendre un texte

Exemple

↓
Comprendre les liens entre les mots
↓
Connaître le sens de chacun des mots
↓
Décoder les mots du texte
↓
Décoder un mot
↓
Connaître les correspondances graphèmes-phonèmes

↙ Savoir distinguer les différents phonèmes
↓
Savoir qu'un mot est formé d'une séquence phonèmes
↓
Savoir qu'un mot est formé de phonèmes

↘ Savoir reconnaître les différents graphèmes
↓
Savoir reconnaître les lettres
↓
Savoir qu'un mot est formé de lettres

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

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

Principe 2
Optimiser les modalités de présentation
(diminue la charge de décodage)

Principe 2

Optimiser les modalités de présentation

(diminue la charge de décodage)

Comment ?

Stratégie 1

Catégoriser l'information

Étude de

Bor et al.

Neuron, Vol. 37, 361–367, January 23, 2003, Copyright ©2003 by Cell Press

Encoding Strategies Dissociate Prefrontal Activity from Working Memory Demand

Daniel Bor,[1,*] John Duncan,[1] Richard J. Wiseman,[2] and Adrian M. Owen[1,3]
[1]Medical Research Council Cognition and Brain Sciences Unit
15 Chaucer Road
Cambridge CB2 2EF
United Kingdom
[2]Department of Psychology
University of Hertfordshire
Hatfield
United Kingdom
[3]Wolfson 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 contents. In some cases, effective reorganization can decrease task difficulty, implying a dissociation between frontal activity and basic 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

Neuropsychological data suggest that the prefrontal cortex plays a key role in behavioral organization and control. In complex tasks, for example, patients with prefrontal damage use poor strategies and exhibit behavioral incoherence (Shallice and Burgess, 1991). Here we investigate the role of prefrontal cortex in organizational strategies used to decrease working memory demand.

Undoubtedly prefrontal cortex makes an important contribution to working memory. Though some studies emphasize simple working memory storage, neuroimaging data have also suggested that the prefrontal cortex—especially the dorsolateral prefrontal cortex (DLPFC)—plays a role in the monitoring, control, and organization of working memory contents (D'Esposito et al., 1998; Owen, 1997, 2000; Petrides, 1994). Such terms, however, can be hard to define operationally, and in previous studies, a complicating factor has been simple task difficulty. The DLPFC is recruited, for example, when the contents of a working memory list must be rearranged in reverse (Owen et al., 2000) or alphabetical (Postle et al., 1999) order prior to making a response. Evidently, in such cases the task is substantially harder when reorganization is required. This confound is important because increasing task difficulty is itself associated with DLPFC activation in many different cognitive domains (Duncan and Owen, 2000).

In the present study we sought direct evidence for a role of prefrontal cortex in a well-defined working memory strategy. In the working memory literature, the best-studied strategy is perhaps performance improvement through chunking. An opportunity to reorganize materials into familiar or regular structures can increase working memory capacity, sometimes very substantially (Ericcson et al., 1980). In domains from sending and receiving Morse code (Bryan and Harter, 1899) to chess (Chase and Simon, 1973), chunking has been proposed as the major basis for increasing expertise through learning. We investigated chunking in a standard spatial working memory task by manipulating the extent to which sequences of stimuli could be encoded into memory as simple configural representations. We predicted that trials that allowed such chunking would be less difficult to remember than trials that did not allow chunking. Despite this decrease in task difficulty, we predicted increased recruitment of the lateral prefrontal cortex.

In an initial, large-scale behavioral study, we acquired direct evidence that reorganization of structured sequences into higher level chunks is an effective strategy in spatial working memory. In a second study, we used event-related functional magnetic resonance imaging (fMRI) to compare brain activity during structured and unstructured sequences. A control fMRI study shows that the difference between structured and unstructured sequences is specifically associated with their role in the working memory task.

Results

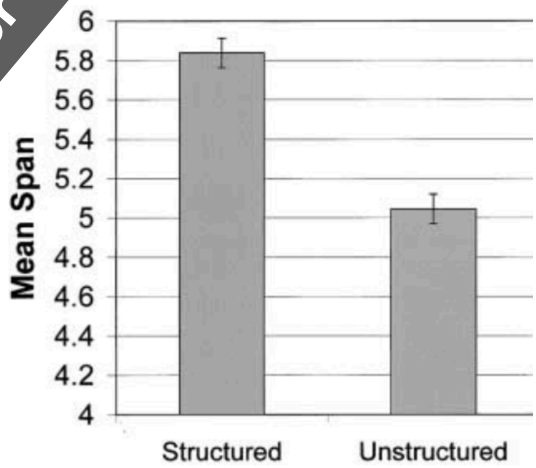
Behavioral Study

Working memory for spatial sequences was tested using a modified spatial span 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 sequences were either all structured, using an algorithm which tended to produce sequences containing familiar shapes, such as right angled triangles and parallelograms (Figure 1A), or all unstructured, using an alternative algorithm that produced sequences with less symmetry and fewer parallel sides (Figure 1B). The group that was presented with the structured sequences performed significantly better than the group that was presented with the unstructured sequences (mean span = 5.84 versus 5.05, $F[1, 210] = 56.79$, $p < 0.001$, see Figure 2).

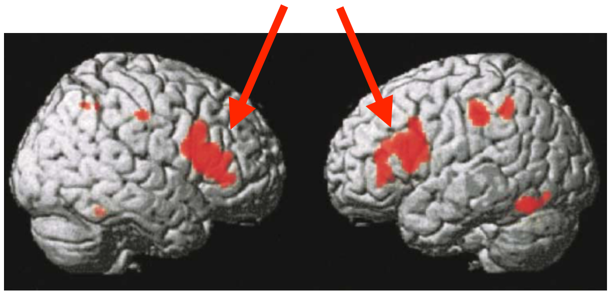
*Correspondence: daniel.bor@mrc-cbu.cam.ac.uk

Effet de la **structuration** sur la surcharge cérébrale

Étude de Bor et al.

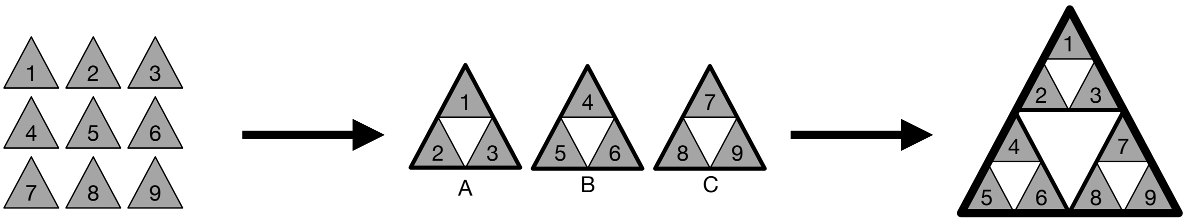


Cortex préfrontal non surchargé



Structuré >
non structuré

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



9 éléments | 3 éléments | 1 élément

11 éléments: 1 | 5 | 1 | 4 | 9 | 8 | 7 | 3 | 0 | 0 | 0

4 éléments: 1 | 514 | 987 | 3000

1 → Canada
514 → Montréal
987 → UQAM
3000 → Poste spécifique

Principe 2
Optimiser les modalités de présentation

Comment ?

Stratégie 1
Catégoriser l'information

Stratégie 2
Rassembler l'information

Étude de

Ayres et Sweller

CHAPTER 8

The Split-Attention Principle in Multimedia Learning

Paul Ayres
John Sweller
University of New South Wales

Abstract

The split-attention principle states that when designing instruction, including multimedia instruction, it is important to avoid formats that require learners to split their attention between, and mentally integrate, multiple sources of information. Instead, materials should be formatted so that disparate sources of information are physically and temporally integrated thus obviating the need for learners to engage in mental integration. By eliminating the need to mentally integrate multiple sources of information, extraneous working memory load is reduced, freeing resources for learning. This chapter provides the theoretical rationale, based on cognitive load theory, for the split-attention principle, describes the major experiments that establish the validity of the principle, and indicates the instructional design implications when dealing with multimedia materials.

Definition of Split-Attention

Instructional split-attention occurs when learners are required to split their attention between and mentally integrate several sources of physically or temporally disparate information, where each source of information is essential for understanding the material. Cognitive load is increased by the need to mentally integrate the multiple sources of information. This increase in extraneous cognitive load (see chapter 2) is likely to have a negative impact on learning compared to conditions where the information has been restructured to eliminate the need to split attention. Restructuring occurs by physically or temporally integrating disparate sources of information to eliminate the need for mental integration. The split-attention effect occurs when learners studying integrated information outperform learners studying the same information

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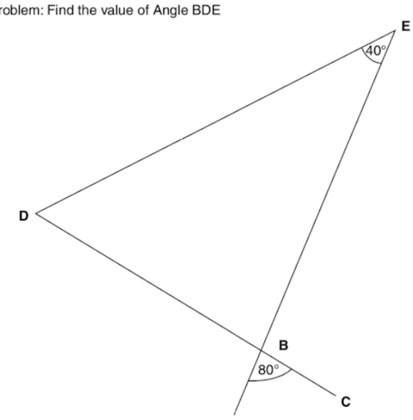
Synthèse sur l'**attention partagée**

Étude de

Ayres et Sweller

Problem: Find the value of Angle BDE

A



Solution
∠DBE=80 (Vertically opposite angles)
∠BDE+40+80=180 (Angle sum of a triangle)
∠BDE+120=180
∠BDE=60

Figure 8.1. *Split-attention format.*

B

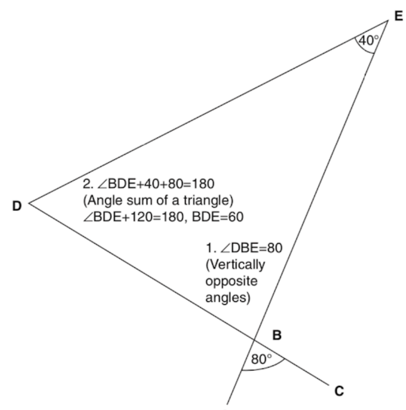


Figure 8.2. *Integrated format.*

Principe 2
Optimiser les modalités de présentation

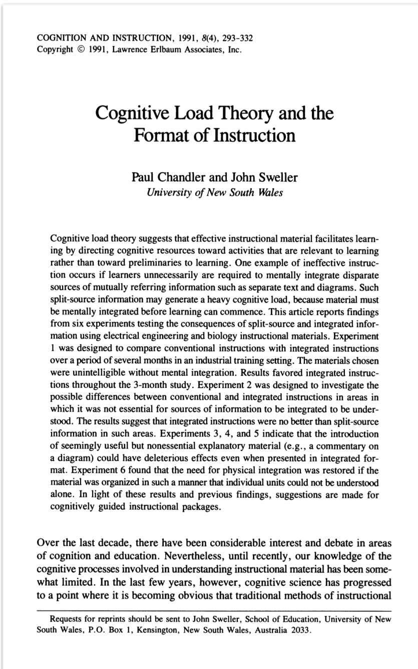
Comment ?

Stratégie 1
Catégoriser l'information

Stratégie 2
Rassembler l'information

Stratégie 3
Éviter la redondance

Étude de Chandler et Sweller



COGNITION AND INSTRUCTION, 1991, *8*(4), 293–332

Cognitive Load Theory and the Format of Instruction

Paul Chandler and John Sweller
University of New South Wales

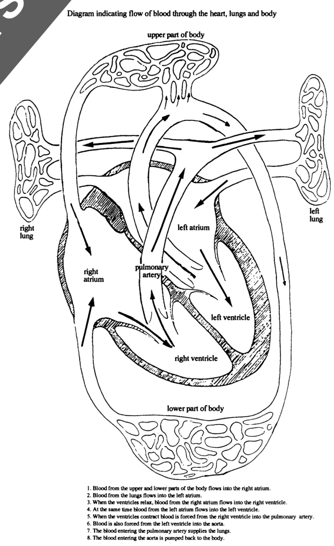
Cognitive load theory suggests that effective instructional material facilitates learning by directing cognitive resources toward activities that are relevant to learning rather than toward preliminaries to learning. One example of ineffective instruction occurs if learners unnecessarily are required 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 restored 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 guided 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

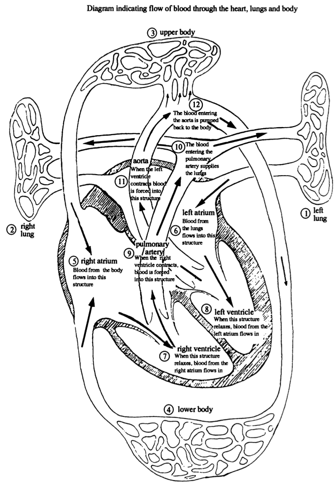
Requests for reprints should be sent to John Sweller, School of Education, University of New South Wales, P.O. Box 1, Kensington, New South Wales, Australia 2033.

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

Étude de Chandler et Sweller



A



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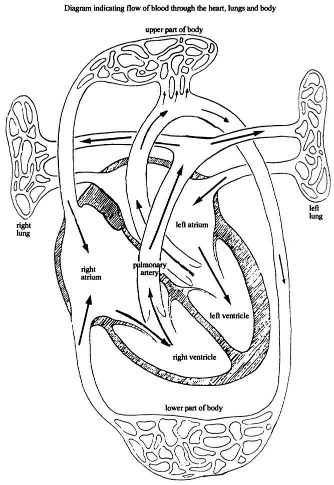


C

Étude de Chandler et Sweller

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

	Group	*Instruction Time*	*Problem* 1	2	3	4	5	6
Diagramme seulement (C)	Diagram only							
	M	69.1	5.3	4.9	3.7	3.5	14.9	1.8
	SD	12.0	1.2	1.5	2.1	2.8	1.4	1.5
Redondant (B)	Modified							
	M	105.7	4.5	2.8	1.7	1.4	7.8	0.9
	SD	9.6	1.2	2.4	1.6	2.1	4.5	1.1
Redondante + attention partagée (A)	Conventional							
	M	158.8	3.5	1.7	0.8	1.1	7.6	0.9
	SD	38.5	1.2	1.3	0.8	1.5	4.1	0.9

Diagramme seulement = plus **efficace** et plus **rapide**

Principe 3

Réduire les distractions

(diminue la charge environnementale)

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

youtube.com/stevemasson

Principe 4

Complexifier progressivement

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

Il faut :

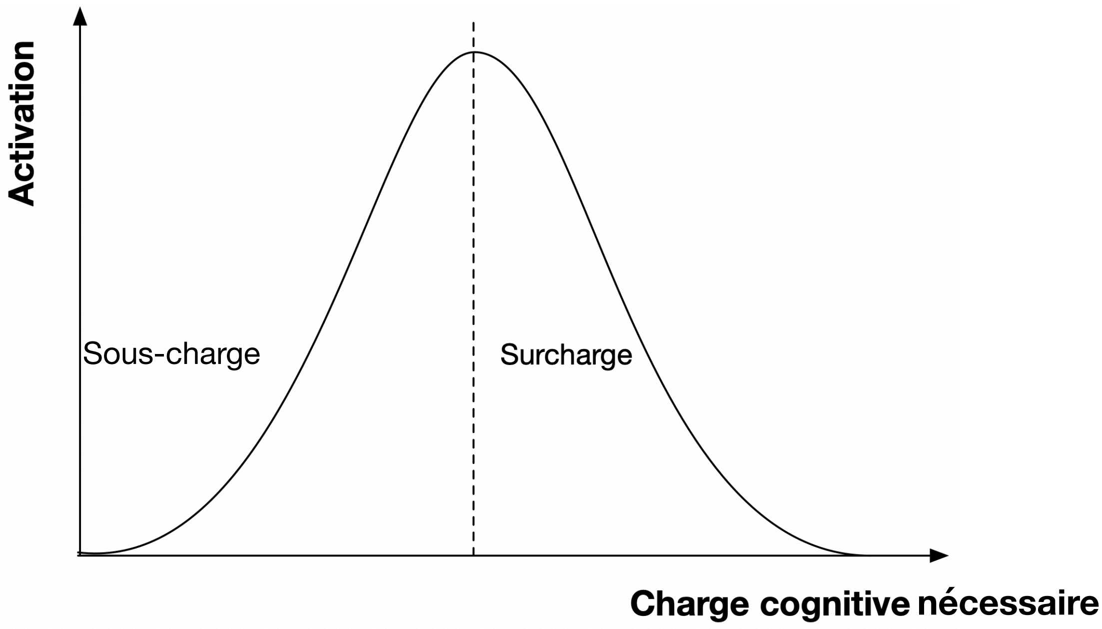
charge **interne** ↓ + charge **de décodage** ↓ + charge **environnementale** ↓

—> charge **nécessaire** pour apprendre

Principe 4

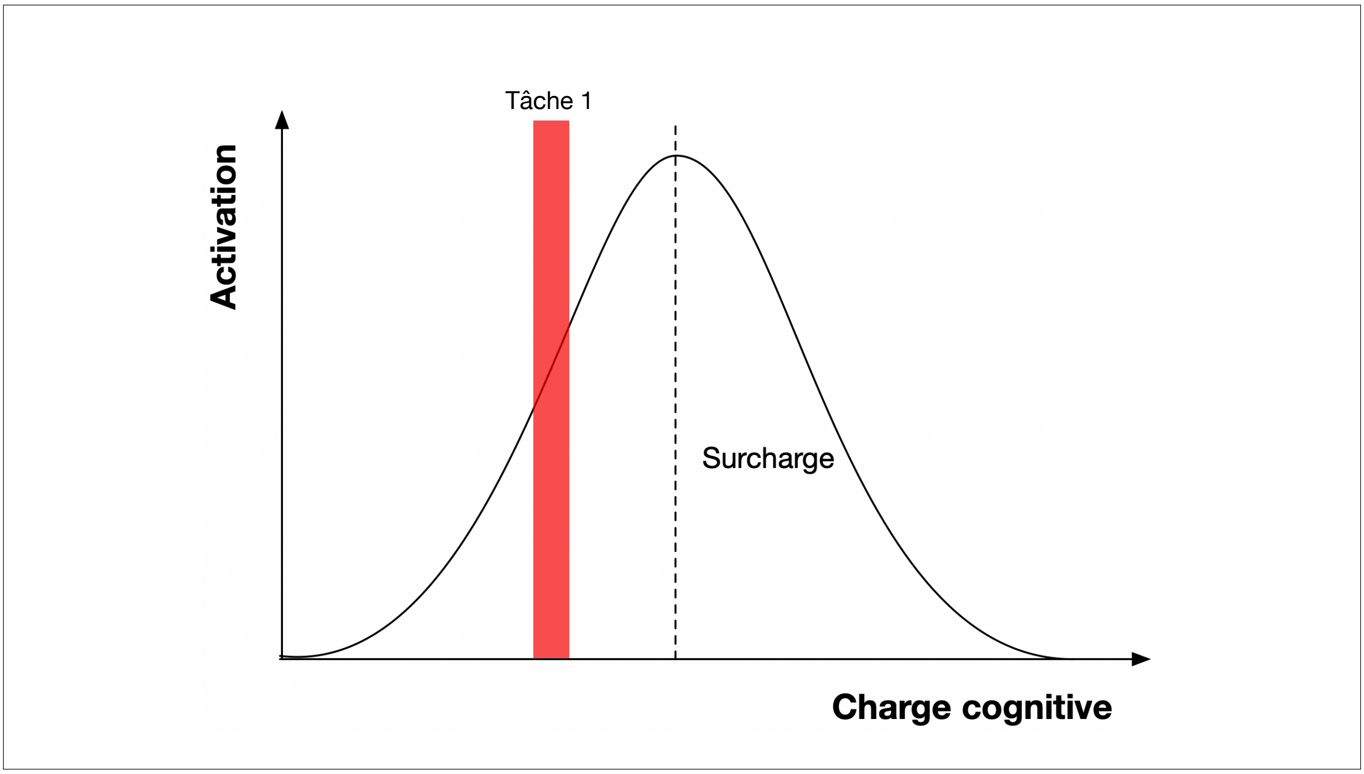
Complexifier progressivement

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

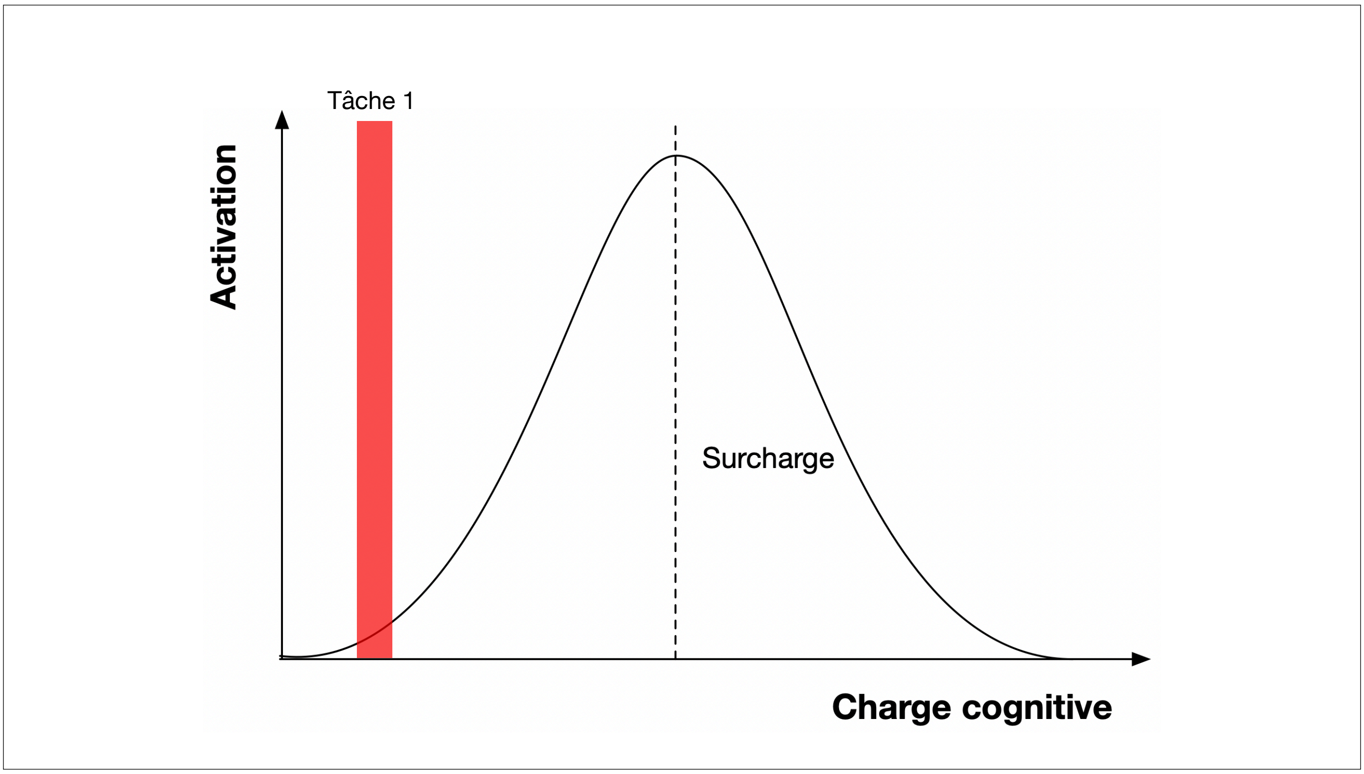


La charge d’une tâche dépend du **niveau d’expertise.**

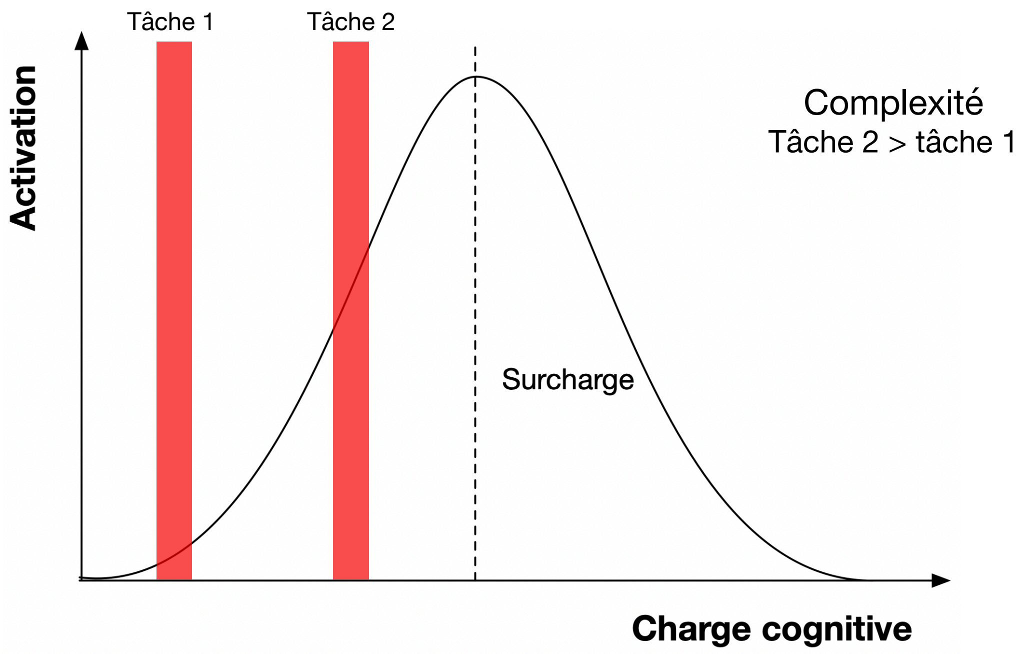
La charge d’une tâche **se déplace** donc au cours de l’apprentissage.


Tâche 1
Activation
Surcharge
Charge cognitive

49


Tâche 1
Activation
Surcharge
Charge cognitive

50



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

Complexité ni trop grande ni trop faible

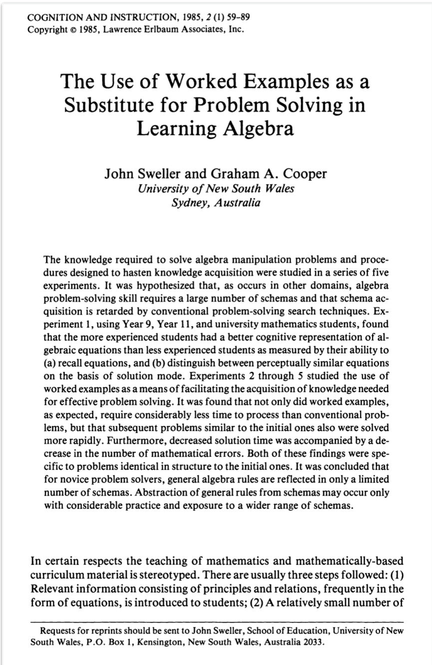
Principe 4
Complexifier progressivement
(assure que la charge nécessaire n'est ni trop grande ni trop faible)

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

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

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 fournir un **exemple de solution**

Étude de Sweller et Cooper

Meilleure séquence ?

Exemple → Problème → Test

Problème → Problème → Test

Exemple = charge ↓

Étude de Sweller et Cooper

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

	Acquisition		
Group	*Initial Presentation*	*Repeat Presentation*	*Test*
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 guidage

Étude de

Van Merr. et al.

EDUCATIONAL PSYCHOLOGIST, *38*(1), 5–13

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

Jeroen J. G. van Merriënboer, Paul A. Kirschner, and Liesbeth Kester
Educational Technology Expertise Center
Open University of The Netherlands, Heerlen

Complex learning aims at the integration of knowledge, skills, and attitudes; the coordination of qualitatively different constituent skills; and the transfer of what is learned to daily life or work settings. Recent instructional theories stress authentic learning tasks as the driving force for learning; but due to the complexity of those tasks, learning may be hampered by the limited processing capacity of the human mind. In this article we present a framework for scaffolding practice and just-in-time information presentation, aiming to control cognitive load effectively. We briefly describe a design model for complex learning consistent with cognitive load theory. Theoretical and practical implications of the presented framework are discussed.

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; Reigeluth, 1999a; van Merriënboer & Kirschner, 2001). The general assumption is that such tasks help learners to integrate 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 educational approaches, such as project-based education, the case method, problem-based learning, and competency-based learning; and in theoretical models, such as Collins, Brown, and Newman’s (1989) theory of cognitive apprenticeship learning, Jonassen’s (1999) theory of constructive learning environments, Nelson’s (1999) theory of collaborative problem solving, and Schank, Berman, and MacPerson’s (1999) theory of goal-based scenario.

A severe risk of all of 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 simple-to-complex 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 briefly sketch an instructional design model for complex learning fully consistent with cognitive load theory (CLT). We conclude that CLT offers useful guidelines for decreasing intrinsic and extraneous cognitive load, so that sufficient processing capacity is left for genuine learning.

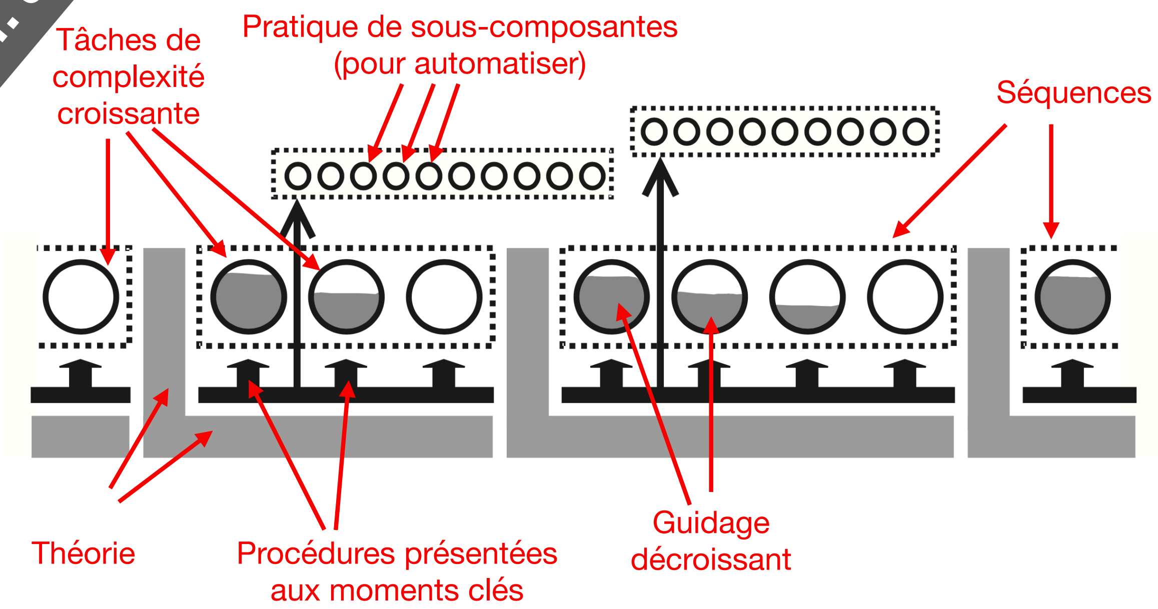
SCAFFOLDING WHOLE-TASK PRACTICE

Scaffolds, according to their original meaning within educational psychology, include all devices or strategies that support students’ learning (Rosenshine & Meister, 1992). In both cognitive apprenticeship learning and our framework, *scaffolding* explicitly pertains to a combination of performance support and fading. Initially, the support enables a learner to achieve a goal or action not achievable without that support. When the learner achieves the desired goal, support gradually diminishes until it is no longer needed. Because excessive or insufficient support can hamper the learning process, it is critical to determine the right type and amount of support and to fade at the appropriate time and rate. Many types of support share the common characteristic that they do not direct the learner, as one can do when teaching an algorithm (i.e., procedure support), but rather guide the learner during his or her work on complex learning tasks (i.e., problem-solving sup-

Requests for reprints should be sent to Jeroen J. G. van Merriënboer, Open University of The Netherlands, Educational Technology Expertise Center, P.O. Box 2960, NL–6401 DL Heerlen, The Netherlands. E-mail: jeroen.vanmerrienboer@ou.nl

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

Étude de Van Merr. et al.



Synthèse

Principe 1 Automatiser les préalables	→ **Charge interne ↓** Identifier, vérifier et automatiser les préalables
Principe 2 Optimiser les modalités de présentation	→ **Charge de décodage ↓** Catégoriser Rassembler l'information Éviter la redondance
Principe 3 Réduire les distractions	→ **Charge environnementale ↓** Réduire les distractions sonores, visuelles, technologiques, etc.
Principe 4 Complexifier progressivement	→ **Charge nécessaire optimisée**