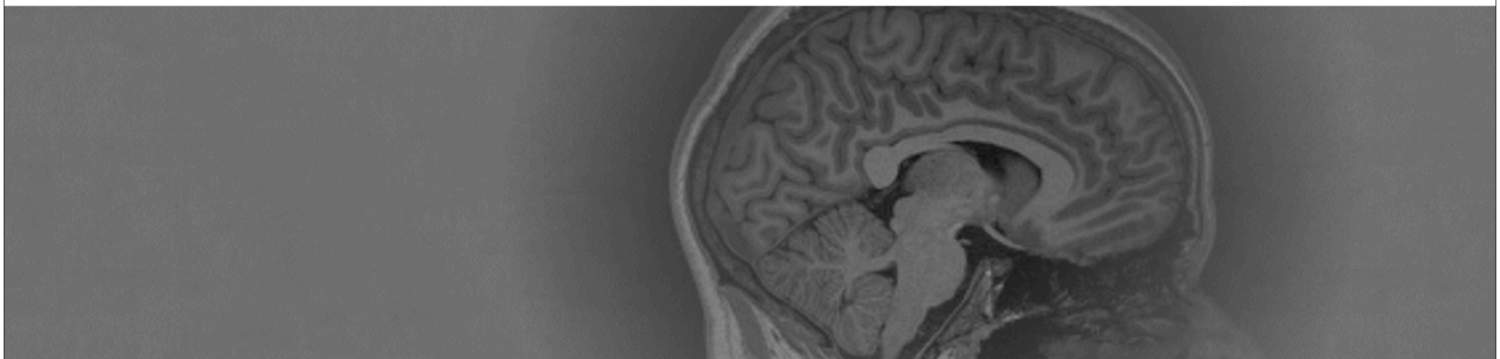
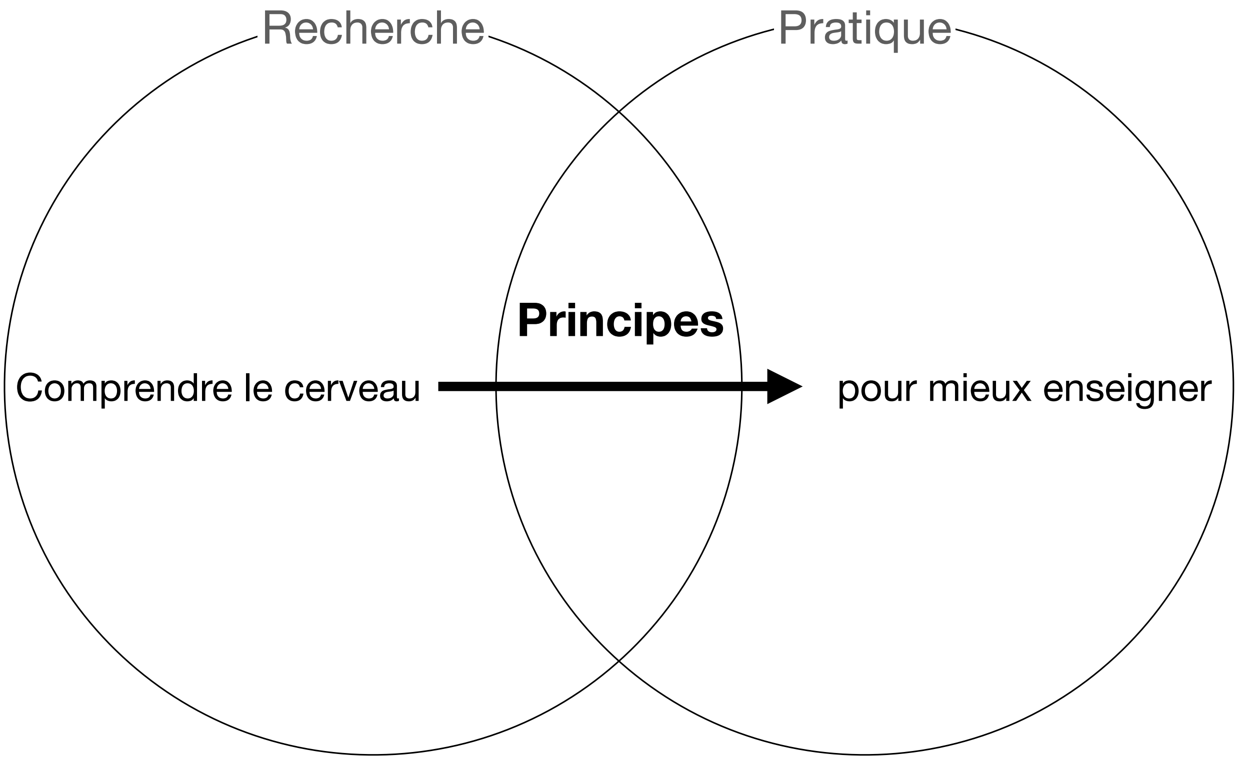
labneuroeducation.org youtube.com/stevemasson facebook.com/profstevemasson twitter.com/stevemasson



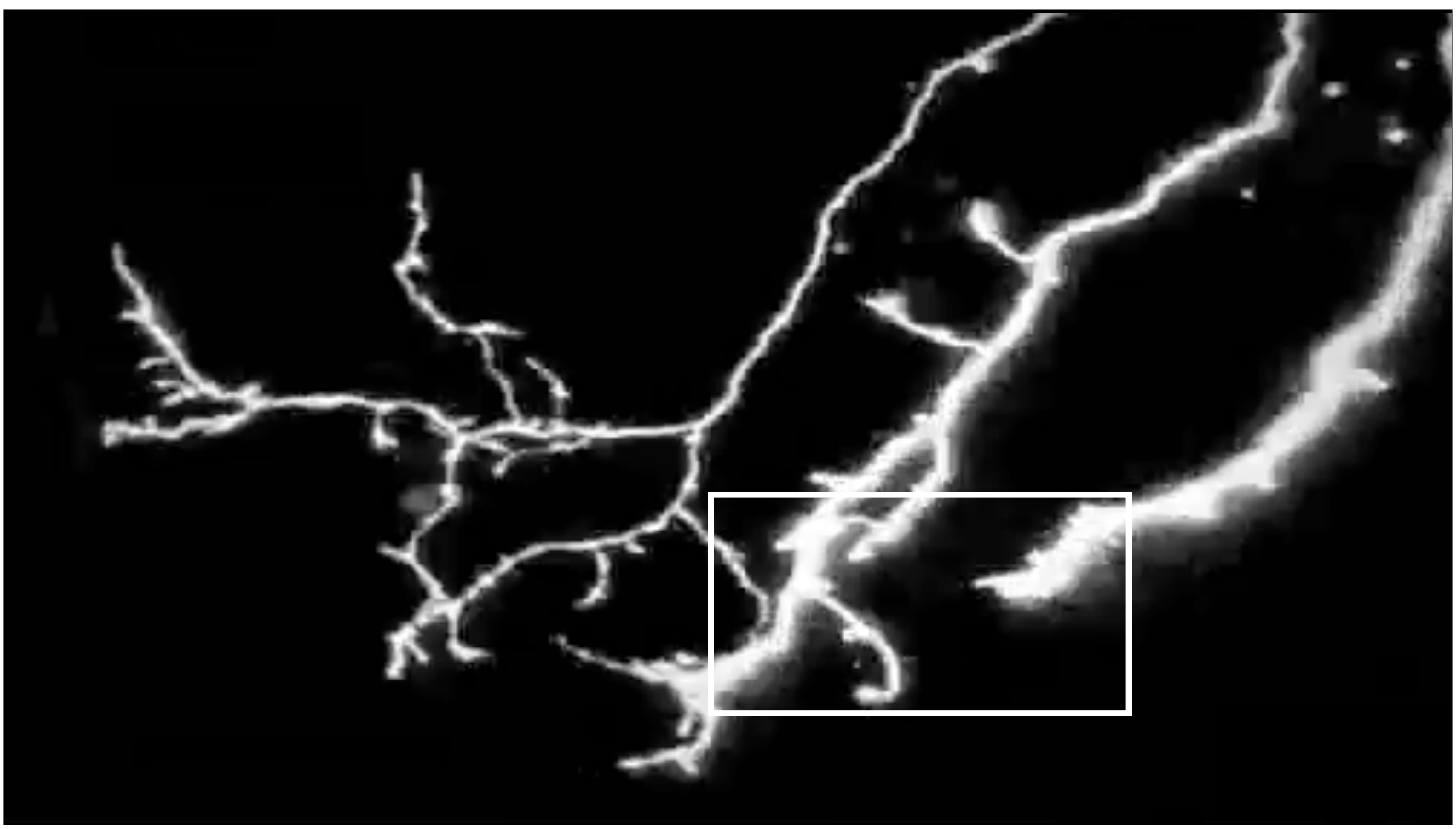
Comprendre le cerveau pour mieux enseigner

41e Colloque de l'AQPC, Collège Montmorency - 9 juin 2022
Steve Masson, professeur à l'Université du Québec à Montréal


Recherche
Pratique
Principes
Comprendre le cerveau
pour mieux enseigner

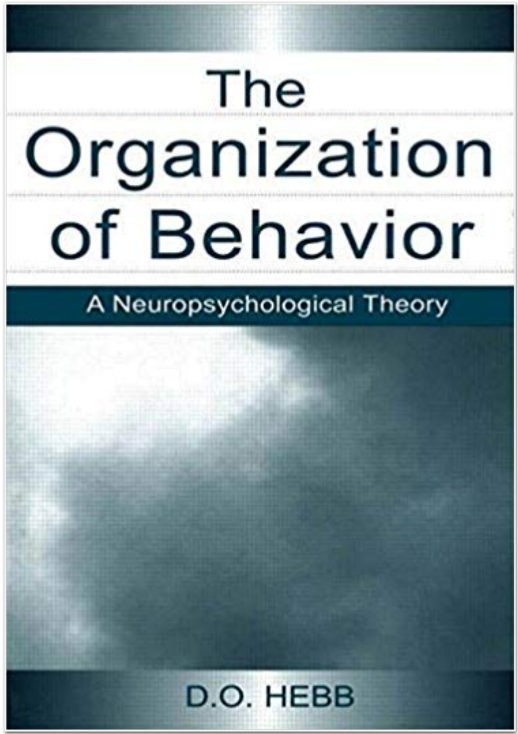
Principe 1

Apprendre, c’est changer son **cerveau**.



Livre de

Hebb



Mécanisme de modification de connexions

Les neurones qui s'**activent** ensemble
se **connectent** ensemble.

Analogie de la forêt

Principe 1
Activer les neurones à plusieurs reprises

Comment ?

Stratégie 1
Planifier plusieurs moments d'activation

Stratégie 2
Entraîner la récupération en mémoire

Étude de Zaromb et al.

Memory & Cognition
2010, 38 (8), 995-1008
doi:10.3758/MC.38.8.995

The testing effect in free recall is associated with enhanced organizational processes

Franklin M. Zaromb and Henry L. Roediger III
Washington University, St. Louis, Missouri

In two experiments with categorized lists, we asked whether the testing effect in free recall is related to enhancements in organizational processing. During a first phase in Experiment 1, subjects studied one list over eight consecutive trials, they studied another list six times while taking two interspersed recall tests, and they learned a third list in four alternating study and test trials. On a test 2 days later, recall was directly related to the number of tests and inversely related to the number of study trials. In addition, increased testing enhanced both the number of categories accessed and the number of items recalled from within those categories. One measure of organization also increased with the number of tests. In a second experiment, different groups of subjects studied a list either once or twice before a final criterial test, or they studied the list once and took an initial recall test before the final test. Prior testing again enhanced recall, relative to studying on the final test a day later, and also improved category clustering. The results suggest that the benefit of testing in free recall learning arises because testing creates retrieval schemas that guide recall.

A robust finding is that testing a person's memory for previously learned material enhances long-term retention, relative to restudying the material for an equivalent amount of time (e.g., Carrier & Pashler, 1992; for a review, see Roediger & Karpicke, 2006a). This finding, known as the *testing effect*, has been demonstrated using a wide range of study materials and types of tests, in both laboratory and classroom settings and in various subject populations (e.g., Butler & Roediger, 2007; Gates, 1917; Kang, McDermott, & Roediger, 2007; McDaniel, Anderson, Derbish, & Morrisette, 2007; Roediger & Karpicke, 2006b; Spitzer, 1939; Tse, Balota, & Roediger, in press). Recent years have seen renewed interest among researchers investigating the potential benefits of testing for learning as a means to improving learning in educational settings (McDaniel, Roediger, & McDermott, 2007; Pashler, Rohrer, Cepeda, & Carpenter, 2007).

One limitation with this work is that testing effects typically report improvements in learners' retention of discrete facts (e.g., foreign vocabulary words) without necessarily demonstrating a better understanding of the subject matter through testing (Daniel & Poole, 2009). However, a growing body of research has shown that testing can serve as a versatile learning tool by enhancing the long-term retention of nontested information that is conceptually related to previously retrieved information (Chan, 2009; Chan, McDermott, & Roediger, 2006), by stimulating the subsequent learning of new information (Izawa, 1970; Karpicke, 2009; Szpunar, McDermott, & Roediger, 2008; Tulving & Watkins, 1974) and by permitting better transfer to new questions (Butler, 2010; Johnson & Mayer, 2009; Rohrer, Taylor, & Sholar, 2010). In the present research, we further examine the potential benefits of testing by asking whether testing can improve individuals' learning and retention of the conceptual organization of study materials, relative to studying the materials alone—a question not yet addressed in the literature.

Psychologists have long grappled with questions of how the processes involved in mentally organizing information influence learning and retention (e.g., Ausubel, 1963; Bartlett, 1932; Katona, 1940). One theoretical assumption that has guided much of the cognitive research examining organization and learning was Miller's (1956) conception of recoding, or *chunking*, in which he argued that the key to learning and retaining large quantities of information was to mentally repackage, or *chunk*, the study materials into smaller units. Evidence for chunking has come primarily from studies using serial recall and free recall paradigms in which subjects often study and attempt to recall verbal materials such as lists of words over multiple alternating study and test trials (e.g., Bower & Springston, 1970; Tulving, 1962), but it has also come from other techniques (e.g., Mandler, 1967).

In support of the chunking hypothesis, researchers have pointed to the finding that when people study lists of words coming from different conceptual categories in a randomized order, they tend to recall them in an organized fashion by clustering conceptually related responses together (W. A. Bousfield, 1953; W. A. Bousfield, Cohen, & Whitmarsh, 1958). Furthermore, response clustering is often associated with greater retention (Mulligan, 2005; Puff, 1979). Similarly, Tulving (1962) found that when students learned

F. M. Zaromb, fzaromb@ets.org

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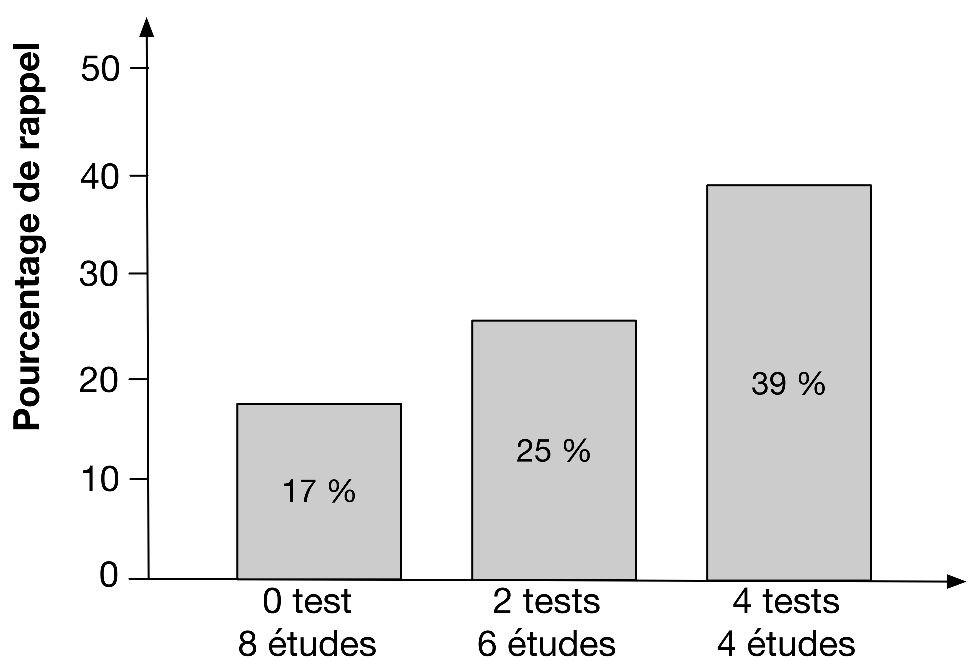
Effets de l'entraînement à la **récupération** en mémoire vs **étude**

11

Étude de Zaromb et al.



12

Principe 1
Activer les neurones à plusieurs reprises

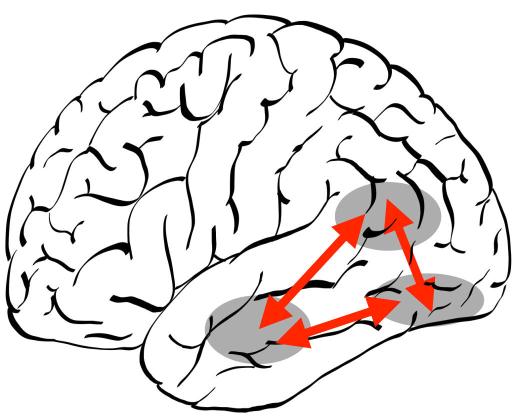
Comment ?

Stratégie 1
Planifier plusieurs moments d'activation

Stratégie 2
Utiliser fréquemment des approches actives

Stratégie 3
Entraîner la récupération en mémoire

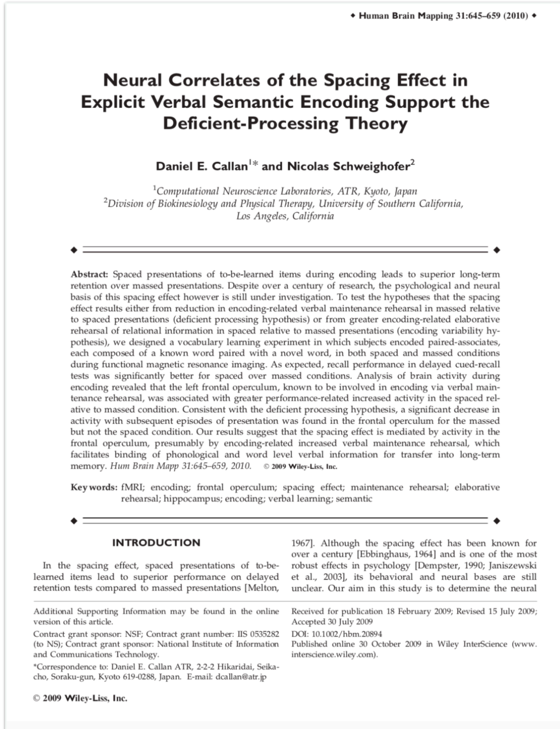
Stratégie 4
Élaborer des explications



Principe 2

Activation 1	Activation 2	Activation 3

Étude de Callan et al.



• Human Brain Mapping 31:645–659 (2010) •

Neural Correlates of the Spacing Effect in Explicit Verbal Semantic Encoding Support the Deficient-Processing Theory

Daniel E. Callan[1]* and Nicolas Schweighofer[2]

[1]*Computational Neuroscience Laboratories, ATR, Kyoto, Japan*
[2]*Division of Biokinesiology and Physical Therapy, University of Southern California, Los Angeles, California*

Abstract: Spaced presentations of to-be-learned items during encoding leads to superior long-term retention over massed presentations. Despite over a century of research, the psychological and neural basis of this spacing effect however is still under investigation. To test the hypotheses that the spacing effect results either from reduction in encoding-related verbal maintenance rehearsal in massed relative to spaced presentations (deficient processing hypothesis) or from greater encoding-related elaborative rehearsal of relational information in spaced relative to massed presentations (encoding variability hypothesis), we designed a vocabulary learning experiment in which subjects encoded paired-associates, each composed of a known word paired with a novel word, in both spaced and massed conditions during functional magnetic resonance imaging. As expected, recall performance in delayed cued-recall tests was significantly better for spaced over massed conditions. Analysis of brain activity during encoding revealed that the left frontal operculum, known to be involved in encoding via verbal maintenance rehearsal, was associated with greater performance-related increased activity in the spaced relative to massed condition. Consistent with the deficient processing hypothesis, a significant decrease in activity with subsequent episodes of presentation was found in the frontal operculum for the massed but not the spaced condition. Our results suggest that the spacing effect is mediated by activity in the frontal operculum, presumably by encoding-related increased verbal maintenance rehearsal, which facilitates binding of phonological and word level verbal information for transfer into long-term memory. *Hum Brain Mapp 31:645–659, 2010.* © 2009 Wiley-Liss, Inc.

Key words: fMRI; encoding; frontal operculum; spacing effect; maintenance rehearsal; elaborative rehearsal; hippocampus; encoding; verbal learning; semantic

INTRODUCTION

In the spacing effect, spaced presentations of to-be-learned items lead to superior performance on delayed retention tests compared to massed presentations [Melton, 1967]. Although the spacing effect has been known for over a century [Ebbinghaus, 1964] and is one of the most robust effects in psychology [Dempster, 1990; Janiszewski et al., 2003], its behavioral and neural bases are still unclear. Our aim in this study is to determine the neural

Additional Supporting Information may be found in the online version of this article.

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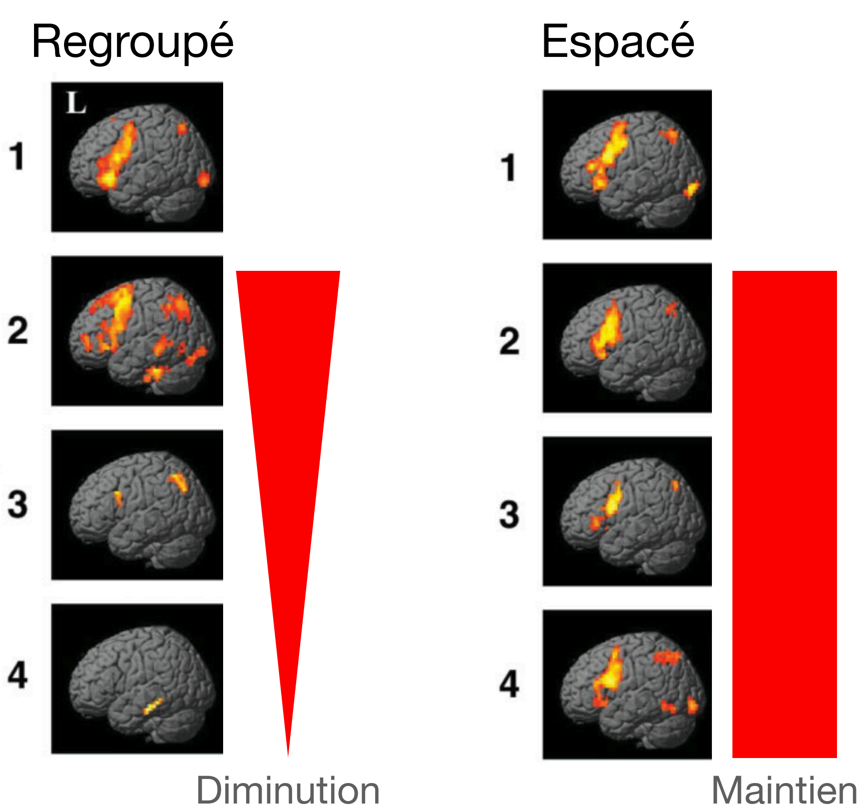
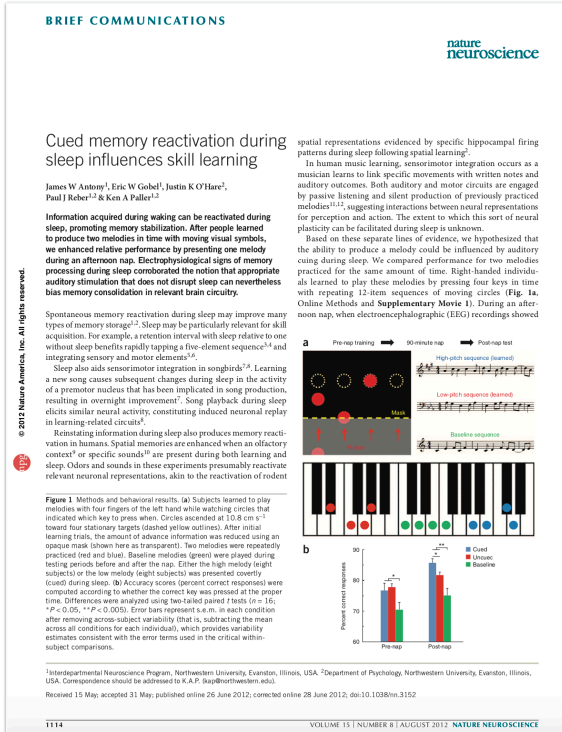
Published online 30 October 2009 in Wiley InterScience (www.interscience.wiley.com).

Effets de l'**espacement** sur l'activité cérébrale

Étude de Callan et al.



Étude de Antony et al.



BRIEF COMMUNICATIONS

nature neuroscience

Cued memory reactivation during sleep influences skill learning

James W Antony[1], Eric W Gobel[1], Justin K O'Hare[2], Paul J Reber[1,2] & Ken A Paller[1,2]

Information acquired during waking can be reactivated during sleep, promoting memory stabilization. After people learned to produce two melodies in time with moving visual symbols, we enhanced relative performance by presenting one melody during an afternoon nap. Electrophysiological signs of memory processing during sleep corroborated the notion that appropriate auditory stimulation that does not disrupt sleep can nevertheless bias memory consolidation in relevant brain circuitry.

Spontaneous memory reactivation during sleep may improve many types of memory storage[1,2]. Sleep may be particularly relevant for skill acquisition. For example, a retention interval with sleep relative to one without sleep benefits rapidly tapping a five-element sequence[3,4] and integrating sensory and motor elements[5,6].

Sleep also aids sensorimotor integration in songbirds[7,8]. Learning a new song causes subsequent changes during sleep in the activity of a premotor nucleus that has been implicated in song production, resulting in overnight improvement[7]. Song playback during sleep elicits similar neural activity, constituting induced neuronal replay in learning-related circuits[8].

Reinstating information during sleep also produces memory reactivation in humans. Spatial memories are enhanced when an olfactory context[9] or specific sounds[10] are present during both learning and sleep. Odors and sounds in these experiments presumably reactivate relevant neuronal representations, akin to the reactivation of rodent spatial representations evidenced by specific hippocampal firing patterns during sleep following spatial learning[2].

In human music learning, sensorimotor integration occurs as a musician learns to link specific movements with written notes and auditory outcomes. Both auditory and motor circuits are engaged by passive listening and silent production of previously practiced melodies[11,12], suggesting interactions between neural representations for perception and action. The extent to which this sort of neural plasticity can be facilitated during sleep is unknown.

Based on these separate lines of evidence, we hypothesized that the ability to produce a melody could be influenced by auditory cuing during sleep. We compared performance for two melodies practiced for the same amount of time. Right-handed individuals learned to play these melodies by pressing four keys in time with repeating 12-item sequences of moving circles (**Fig. 1a**, Online Methods and **Supplementary Movie 1**). During an afternoon nap, when electroencephalographic (EEG) recordings showed

Figure 1 Methods and behavioral results. (**a**) Subjects learned to play melodies with four fingers of the left hand while watching circles that indicated which key to press when. Circles ascended at 10.8 cm s^{-1} toward four stationary targets (dashed yellow outlines). After initial learning trials, the amount of advance information was reduced using an opaque mask (shown here as transparent). Two melodies were repeatedly practiced (red and blue). Baseline melodies (green) were played during testing periods before and after the nap. Either the high melody (eight subjects) or the low melody (eight subjects) was presented covertly (cued) during sleep. (**b**) Accuracy scores (percent correct responses) were computed according to whether the correct key was pressed at the proper time. Differences were analyzed using two-tailed paired t tests ($n = 16$; $*P < 0.05$, $**P < 0.005$). Error bars represent s.e.m. in each condition after removing across-subject variability (that is, subtracting the mean across all conditions for each individual), which provides variability estimates consistent with the error terms used in the critical within-subject comparisons.

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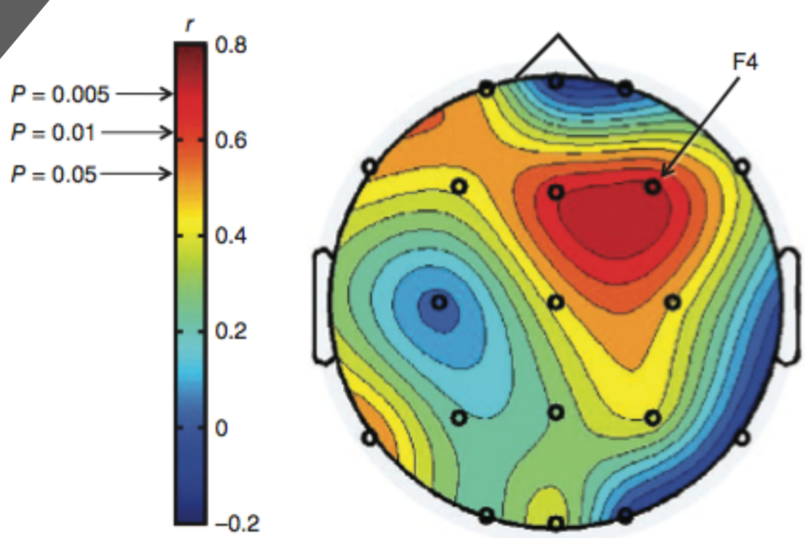
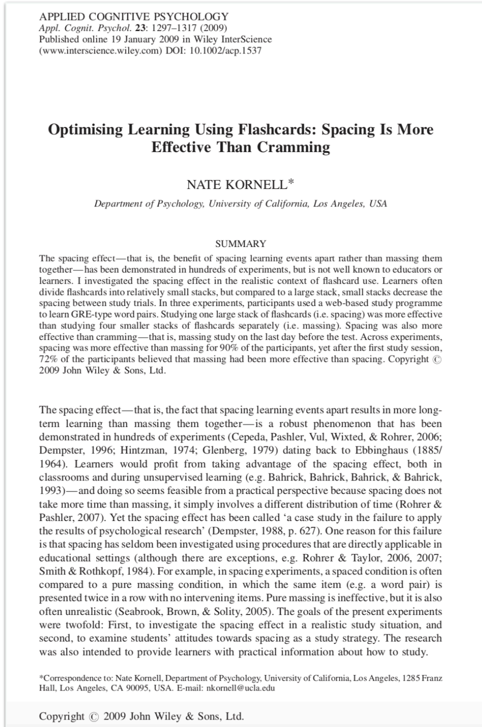
Effets du **sommeil** sur l'apprentissage et l'activité cérébrale

Étude de Antony et al.



Cortex prémoteur lié à la main utilisée

Étude de
Kornell et al.



APPLIED COGNITIVE PSYCHOLOGY
Appl. Cognit. Psychol. **23**: 1297–1317 (2009)
Published online 19 January 2009 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/acp.1537

Optimising Learning Using Flashcards: Spacing Is More Effective Than Cramming

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Department of Psychology, University of California, Los Angeles, USA

SUMMARY
The spacing effect—that is, the benefit of spacing learning events apart rather than massing them together—has been demonstrated in hundreds of experiments, but is not well known to educators or learners. I investigated the spacing effect in the realistic context of flashcard use. Learners often divide flashcards into relatively small stacks, but compared to a large stack, small stacks decrease the spacing between study trials. In three experiments, participants used a web-based study programme to learn GRE-type word pairs. Studying one large stack of flashcards (i.e. spacing) was more effective than studying four smaller stacks of flashcards separately (i.e. massing). Spacing was also more effective than cramming—that is, massing study on the last day before the test. Across experiments, spacing was more effective than massing for 90% of the participants, yet after the first study session, 72% of the participants believed that massing had been more effective than spacing. Copyright © 2009 John Wiley & Sons, Ltd.

The spacing effect—that is, the fact that spacing learning events apart results in more long-term learning than massing them together—is a robust phenomenon that has been demonstrated in hundreds of experiments (Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006; Dempster, 1996; Hintzman, 1974; Glenberg, 1979) dating back to Ebbinghaus (1885/1964). Learners would profit from taking advantage of the spacing effect, both in classrooms and during unsupervised learning (e.g. Bahrick, Bahrick, Bahrick, & Bahrick, 1993)—and doing so seems feasible from a practical perspective because spacing does not take more time than massing, it simply involves a different distribution of time (Rohrer & Pashler, 2007). Yet the spacing effect has been called 'a case study in the failure to apply the results of psychological research' (Dempster, 1988, p. 627). One reason for this failure is that spacing has seldom been investigated using procedures that are directly applicable in educational settings (although there are exceptions, e.g. Rohrer & Taylor, 2006, 2007; Smith & Rothkopf, 1984). For example, in spacing experiments, a spaced condition is often compared to a pure massing condition, in which the same item (e.g. a word pair) is presented twice in a row with no intervening items. Pure massing is ineffective, but it is also often unrealistic (Seabrook, Brown, & Solity, 2005). The goals of the present experiments were twofold: First, to investigate the spacing effect in a realistic study situation, and second, to examine students' attitudes towards spacing as a study strategy. The research was also intended to provide learners with practical information about how to study.

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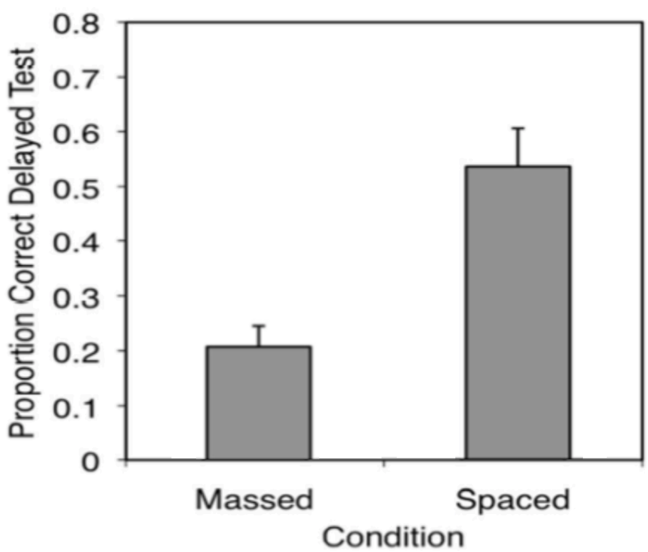
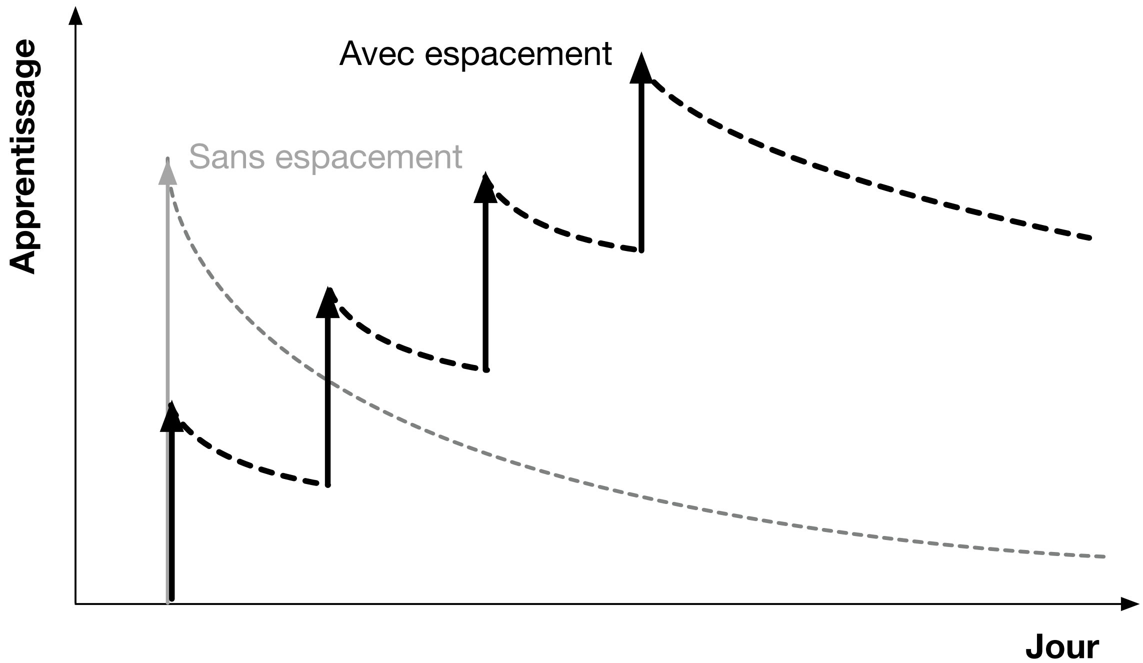
Effets de l'**espacement** sur l'apprentissage

Étude de
Kornell et al.





Plus d'apprentissage + moins d'oubli

Principe 2
Espacer les activités d'apprentissage

Comment ?

Stratégie 1
Distribuer l'apprentissage

Regroupé

Activité 1	Activité 2	Activité 3

Distribué

Activité 1	Activité 2	Activité 3

Plus souvent moins longtemps

Principe 2
Espacer les activités d’apprentissage

Comment ?

Stratégie 1
Distribuer l’apprentissage

Stratégie 2
Entrelacer les apprentissages

27

Regroupé

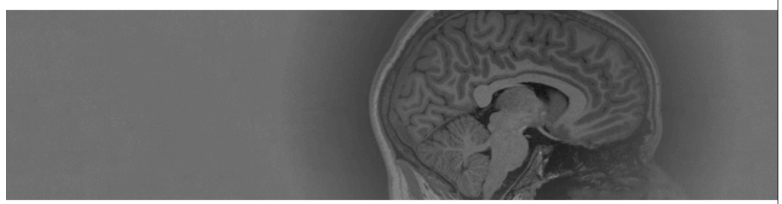
Entrelacé

Lundi	Mardi	Mercredi	Jeudi
Étude du chapitre 3 en physique *(20 minutes)*	Étude du chapitre 3 en chimie *(20 minutes)*	Étude du chapitre 4 en maths *(20 minutes)*	Étude du chapitre 3 en physique *(20 minutes)*
Étude du chapitre 4 en maths *(20 minutes)*	Étude du chapitre 3 en physique *(20 minutes)*	Devoir en philosophie Partie 1 *(30 minutes)*	Étude du chapitre 3 en chimie *(20 minutes)*
Devoir en philosophie Partie 1 *(30 minutes)*	Étude du chapitre 4 en maths *(20 minutes)*	Étude du chapitre 3 en chimie *(20 minutes)*	Imprévus

Regroupé	$\frac{3}{7} \times \frac{2}{3} = ?$	$\frac{2}{4} \times \frac{1}{2} = ?$	$\frac{5}{9} \times \frac{3}{6} = ?$	$\frac{1}{5} \times \frac{3}{8} = ?$
Entrelacé	$\frac{3}{7} \times \frac{2}{3} = ?$	$\frac{1}{2} + \frac{3}{5} = ?$	$\frac{5}{9} \times \frac{3}{6} = ?$	$\frac{5}{6} + \frac{2}{3} = ?$

Entrelacer en revenant sur les contenus déjà abordés

- Capsule de révision
- Ajout aux exercices et examens de questions portant sur du contenu antérieur
- Étude avec retour sur le contenu antérieur

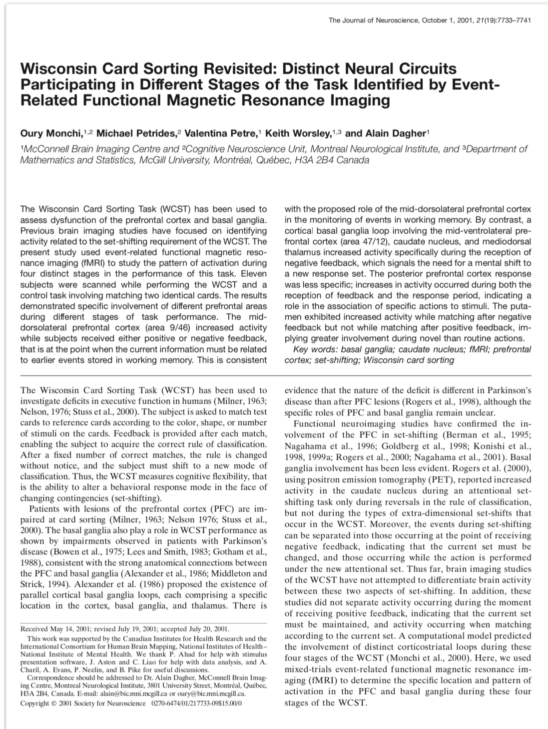


Principe 3

Rétroaction =
retour d'information survenant à la suite d'une **action**

Rétroaction négative =
retour d'**information** indiquant qu'une **erreur** a été commise

Étude de Monchi et al.


The Journal of Neuroscience, October 1, 2001, *21*(19):7733–7741

Wisconsin Card Sorting Revisited: Distinct Neural Circuits Participating in Different Stages of the Task Identified by Event-Related Functional Magnetic Resonance Imaging

Oury Monchi,[1,2] Michael Petrides,[2] Valentina Petre,[1] Keith Worsley,[1,3] and Alain Dagher[1]

[1]McConnell Brain Imaging Centre and [2]Cognitive Neuroscience Unit, Montreal Neurological Institute, and [3]Department of Mathematics and Statistics, McGill University, Montréal, Québec, H3A 2B4 Canada

The Wisconsin Card Sorting Task (WCST) has been used to assess dysfunction of the prefrontal cortex and basal ganglia. Previous brain imaging studies have focused on identifying activity related to the set-shifting requirement of the WCST. The present study used event-related functional magnetic resonance imaging (fMRI) to study the pattern of activation during four distinct stages in the performance of this task. Eleven subjects were scanned while performing the WCST and a control task involving matching two identical cards. The results demonstrated specific involvement of different prefrontal areas during different stages of task performance. The mid-dorsolateral prefrontal cortex (area 9/46) increased activity while subjects received either positive or negative feedback, that is at the point when the current information must be related to earlier events stored in working memory. This is consistent with the proposed role of the mid-dorsolateral prefrontal cortex in the monitoring of events in working memory. By contrast, a cortical basal ganglia loop involving the mid-ventrolateral prefrontal cortex (area 47/12), caudate nucleus, and mediodorsal thalamus increased activity specifically during the reception of negative feedback, which signals the need for a mental shift to a new response set. The posterior prefrontal cortex response was less specific; increases in activity occurred during both the reception of feedback and the response period, indicating a role in the association of specific actions to stimuli. The putamen exhibited increased activity while matching after negative feedback but not while matching after positive feedback, implying greater involvement during novel than routine actions.

Key words: basal ganglia; caudate nucleus; fMRI; prefrontal cortex; set-shifting; Wisconsin card sorting

The Wisconsin Card Sorting Task (WCST) has been used to investigate deficits in executive function in humans (Milner, 1963; Nelson, 1976; Stuss et al., 2000). The subject is asked to match test cards to reference cards according to the color, shape, or number of stimuli on the cards. Feedback is provided after each match, enabling the subject to acquire the correct rule of classification. After a fixed number of correct matches, the rule is changed without notice, and the subject must shift to a new mode of classification. Thus, the WCST measures cognitive flexibility, that is the ability to alter a behavioral response mode in the face of changing contingencies (set-shifting).

Patients with lesions of the prefrontal cortex (PFC) are impaired at card sorting (Milner, 1963; Nelson 1976; Stuss et al., 2000). The basal ganglia also play a role in WCST performance as shown by impairments observed in patients with Parkinson's disease (Bowen et al., 1975; Lees and Smith, 1983; Gotham et al., 1988), consistent with the strong anatomical connections between the PFC and basal ganglia (Alexander et al., 1986; Middleton and Strick, 1994). Alexander et al. (1986) proposed the existence of parallel cortical basal ganglia loops, each comprising a specific location in the cortex, basal ganglia, and thalamus. There is evidence that the nature of the deficit is different in Parkinson's disease than after PFC lesions (Rogers et al., 1998), although the specific roles of PFC and basal ganglia remain unclear.

Functional neuroimaging studies have confirmed the involvement of the PFC in set-shifting (Berman et al., 1995; Nagahama et al., 1996; Goldberg et al., 1998; Konishi et al., 1998, 1999a; Rogers et al., 2000; Nagahama et al., 2001). Basal ganglia involvement has been less evident. Rogers et al. (2000), using positron emission tomography (PET), reported increased activity in the caudate nucleus during an attentional set-shifting task only during reversals in the rule of classification, but not during the types of extra-dimensional set-shifts that occur in the WCST. Moreover, the events during set-shifting can be separated into those occurring at the point of receiving negative feedback, indicating that the current set must be changed, and those occurring while the action is performed under the new attentional set. Thus far, brain imaging studies of the WCST have not attempted to differentiate brain activity between these two aspects of set-shifting. In addition, these studies did not separate activity occurring during the moment of receiving positive feedback, indicating that the current set must be maintained, and activity occurring when matching according to the current set. A computational model predicted the involvement of distinct corticostriatal loops during these four stages of the WCST (Monchi et al., 2000). Here, we used mixed-trials event-related functional magnetic resonance imaging (fMRI) to determine the specific location and pattern of activation in the PFC and basal ganglia during these four stages of the WCST.

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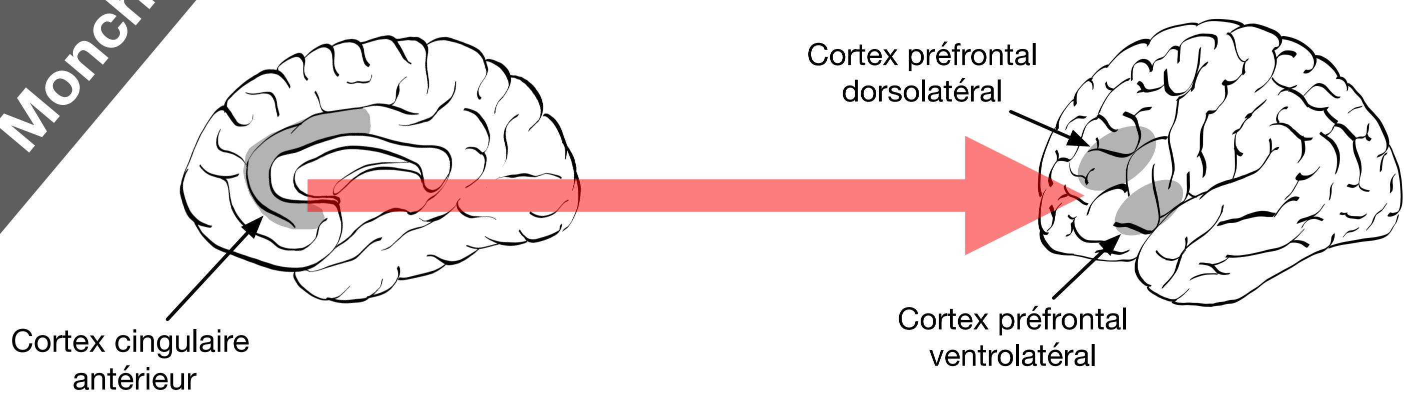
Effets de la **rétroaction négative** sur le cerveau

Étude de Monchi et al.



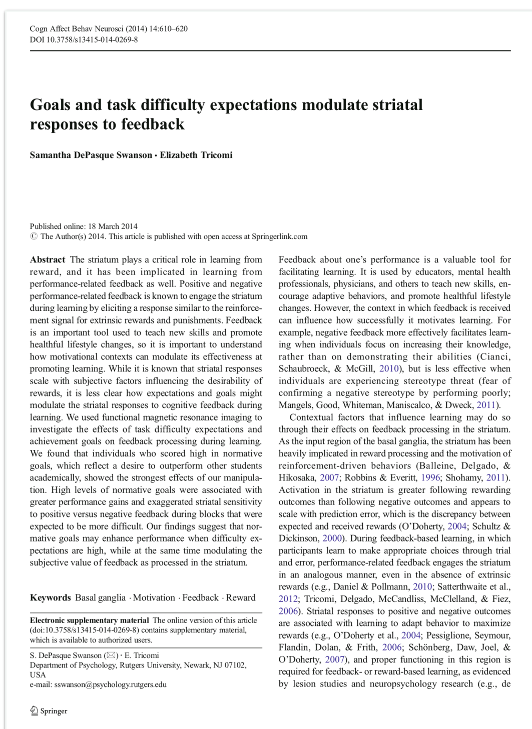
Étape 1
Détection de **conflit** d'information

Étape 2
Analyse de la situation

Activation du système de **correction d'erreur**

Rétroaction positive =
retour d’**information** confirmant la **réussite**
ou les bienfaits d’une action

Étude de **DePasque et al.**



Cogn Affect Behav Neurosci (2014) 14:610–620
DOI 10.3758/s13415-014-0269-8

Goals and task difficulty expectations modulate striatal responses to feedback

Samantha DePasque Swanson · Elizabeth Tricomi

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Abstract The striatum plays a critical role in learning from reward, and it has been implicated in learning from performance-related feedback as well. Positive and negative performance-related feedback is known to engage the striatum during learning by eliciting a response similar to the reinforcement signal for extrinsic rewards and punishments. Feedback is an important tool used to teach new skills and promote healthful lifestyle changes, so it is important to understand how motivational contexts can modulate its effectiveness at promoting learning. While it is known that striatal responses scale with subjective factors influencing the desirability of rewards, it is less clear how expectations and goals might modulate the striatal responses to cognitive feedback during learning. We used functional magnetic resonance imaging to investigate the effects of task difficulty expectations and achievement goals on feedback processing during learning. We found that individuals who scored high in normative goals, which reflect a desire to outperform other students academically, showed the strongest effects of our manipulation. High levels of normative goals were associated with greater performance gains and exaggerated striatal sensitivity to positive versus negative feedback during blocks that were expected to be more difficult. Our findings suggest that normative goals may enhance performance when difficulty expectations are high, while at the same time modulating the subjective value of feedback as processed in the striatum.

Keywords Basal ganglia · Motivation · Feedback · Reward

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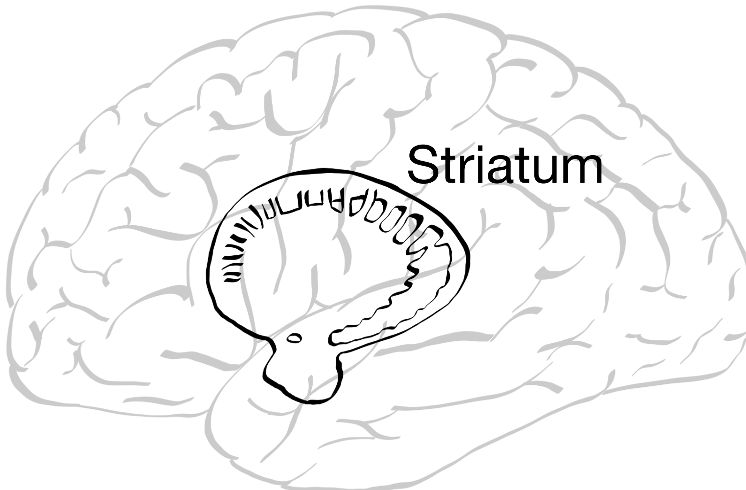
Feedback about one’s performance is a valuable tool for facilitating learning. It is used by educators, mental health professionals, physicians, and others to teach new skills, encourage adaptive behaviors, and promote healthful lifestyle changes. However, the context in which feedback is received can influence how successfully it motivates learning. For example, negative feedback more effectively facilitates learning when individuals focus on increasing their knowledge, rather than on demonstrating their abilities (Cianci, Schaubroeck, & McGill, 2010), but is less effective when individuals are experiencing stereotype threat (fear of confirming a negative stereotype by performing poorly; Mangels, Good, Whiteman, Maniscalco, & Dweck, 2011).

Contextual factors that influence learning may do so through their effects on feedback processing in the striatum. As the input region of the basal ganglia, the striatum has been heavily implicated in reward processing and the motivation of reinforcement-driven behaviors (Balleine, Delgado, & Hikosaka, 2007; Robbins & Everitt, 1996; Shohamy, 2011). Activation in the striatum is greater following rewarding outcomes than following negative outcomes and appears to scale with prediction error, which is the discrepancy between expected and received rewards (O’Doherty, 2004; Schultz & Dickinson, 2000). During feedback-based learning, in which participants learn to make appropriate choices through trial and error, performance-related feedback engages the striatum in an analogous manner, even in the absence of extrinsic rewards (e.g., Daniel & Pollmann, 2010; Satterthwaite et al., 2012; Tricomi, Delgado, McCandliss, McClelland, & Fiez, 2006). Striatal responses to positive and negative outcomes are associated with learning to adapt behavior to maximize rewards (e.g., O’Doherty et al., 2004; Pessiglione, Seymour, Flandin, Dolan, & Frith, 2006; Schönberg, Daw, Joel, & O’Doherty, 2007), and proper functioning in this region is required for feedback- or reward-based learning, as evidenced by lesion studies and neuropsychology research (e.g., de

Effet de la **rétroaction positive** sur le cerveau

Étude de DePasque et al.



Activation du système de **récompense** et augmentation de la **dopamine**

Réussite ⇒ rétroaction positive ↑ ⇒ striatum ↑ ⇒ dopamine ↑

⇒ sentiment de plaisir/satisfaction ↑ ⇒ **motivation**

Principe 3
Maximiser la rétroaction

Comment ?

Stratégie 1
Offrir un maximum de rétroaction

Stratégie 2
Viser un équilibre entre rétroactions positive et nég.

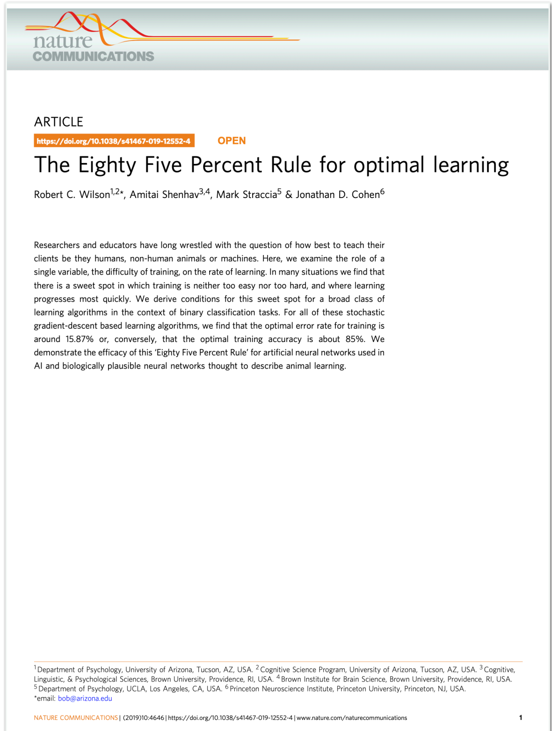
Effets de la rétroaction

Rétroaction **positive** ↑ ⇒ satisfaction ↑ + correction d'erreur ↓

Rétroaction **négative** ↑ ⇒ correction d'erreur ↑ + satisfaction ↓

Donc équilibre

Étude de Wilson et al.



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ARTICLE

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The Eighty Five Percent Rule for optimal learning

Robert C. Wilson[1,2*], Amitai Shenhav[3,4], Mark Straccia[5] & Jonathan D. Cohen[6]

Researchers and educators have long wrestled with the question of how best to teach their clients be they humans, non-human animals or machines. Here, we examine the role of a single variable, the difficulty of training, on the rate of learning. In many situations we find that there is a sweet spot in which training is neither too easy nor too hard, and where learning progresses most quickly. We derive conditions for this sweet spot for a broad class of learning algorithms in the context of binary classification tasks. For all of these stochastic gradient-descent based learning algorithms, we find that the optimal error rate for training is around 15.87% or, conversely, that the optimal training accuracy is about 85%. We demonstrate the efficacy of this 'Eighty Five Percent Rule' for artificial neural networks used in AI and biologically plausible neural networks thought to describe animal learning.

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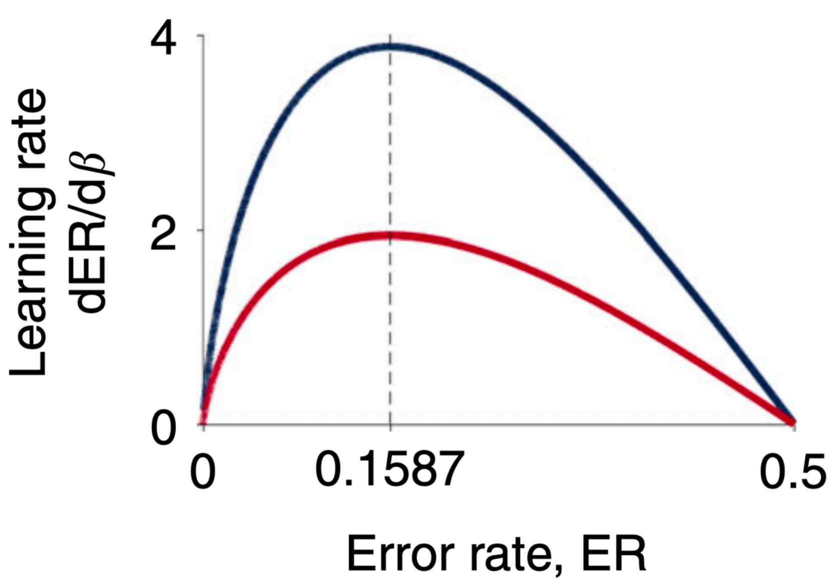
Effet du **taux de réussite** sur l'apprentissage

Étude de Wilson et al.

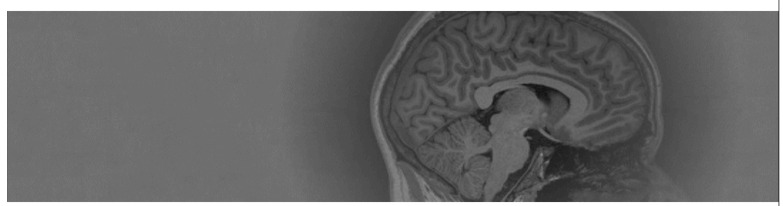


Taux d'erreur optimal : 15,9%

Taux de réussite optimal : 84,1%

Viser un équilibre entre rétroactions positive et négative

- Fixer des **attentes** élevées, mais réalistes
- Ni trop **facile** ni trop **difficile** (pour avoir rétroaction positive + négative)



Principe 3
Maximiser la rétroaction

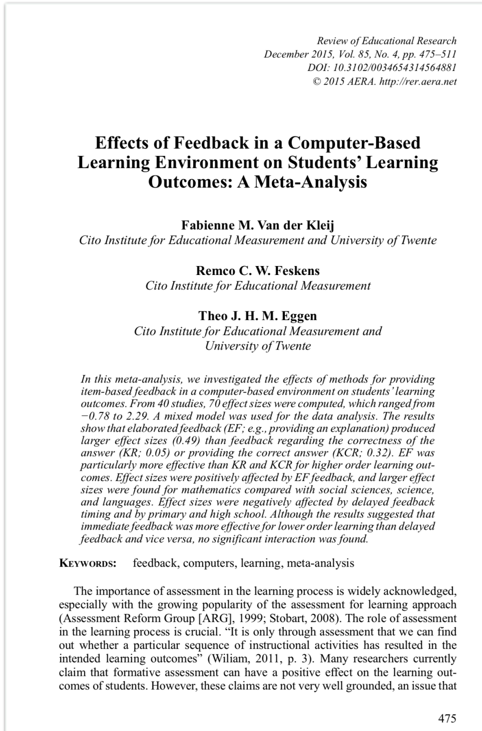
Comment ?

Stratégie 1
Offrir un maximum de rétroaction

Stratégie 2
Viser un équilibre entre rétroactions positive et nég.

Stratégie 3
Privilégier la rétroaction immédiate

Méta-analyse de Kleij et al.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Effects of Feedback in a Computer-Based Learning Environment on Students' Learning Outcomes: A Meta-Analysis

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In this meta-analysis, we investigated the effects of methods for providing item-based feedback in a computer-based environment on students' learning outcomes. From 40 studies, 70 effect sizes were computed, which ranged from −0.78 to 2.29. A mixed model was used for the data analysis. The results show that elaborated feedback (EF; e.g., providing an explanation) produced larger effect sizes (0.49) than feedback regarding the correctness of the answer (KR; 0.05) or providing the correct answer (KCR; 0.32). EF was particularly more effective than KR and KCR for higher order learning outcomes. Effect sizes were positively affected by EF feedback, and larger effect sizes were found for mathematics compared with social sciences, science, and languages. Effect sizes were negatively affected by delayed feedback timing and by primary and high school. Although the results suggested that immediate feedback was more effective for lower order learning than delayed feedback and vice versa, no significant interaction was found.

Keywords: feedback, computers, learning, meta-analysis

The importance of assessment in the learning process is widely acknowledged, especially with the growing popularity of the assessment for learning approach (Assessment Reform Group [ARG], 1999; Stobart, 2008). The role of assessment in the learning process is crucial. "It is only through assessment that we can find out whether a particular sequence of instructional activities has resulted in the intended learning outcomes" (Wiliam, 2011, p. 3). Many researchers currently claim that formative assessment can have a positive effect on the learning outcomes of students. However, these claims are not very well grounded, an issue that

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Méta-analyse sur l'effet de la **rétroaction**

Méta-analyse de Kleij et al.

Facteur	**Ampleur de l'effet**
Moment de la rétroaction	
Rétroaction immédiate	0,46
Rétroaction différée	0,22

Principe 3
Maximiser la rétroaction

Comment ?

Stratégie 1
Offrir un maximum de rétroaction

Stratégie 2
Viser un équilibre entre rétroactions positive et nég.

Stratégie 3
Privilégier la rétroaction immédiate

Stratégie 4
Privilégier la rétroaction élaborée et axée sur la tâche

Méta-analyse de Kleij et al.

Facteur	Ampleur de l'effet
Type de rétroaction	
Rétroaction élaborée *(Fournir une explication)*	0,49
Rétroaction sur l'exactitude *(Dire si la réponse est correcte ou incorrecte)*	0,32
Rétroaction présentant la réponse correcte (Fournir la réponse correcte)	0,05

Synthèse

Principe 1
Activer les neurones à plusieurs reprises

- Planifier plusieurs moments d'activation
- Entraîner la récupération en mémoire
- Élaborer des explications

Principe 2
Espacer les activités d'apprentissage

- Distribuer l'apprentissage
- Entrelacer les apprentissages

Principe 3
Maximiser la rétroaction

- Offrir un maximum de rétroaction
- Viser un équilibre entre rétroactions positive et nég.
- Privilégier la rétroaction immédiate
- Privilégier la rétroaction élaborée et axée sur la tâche