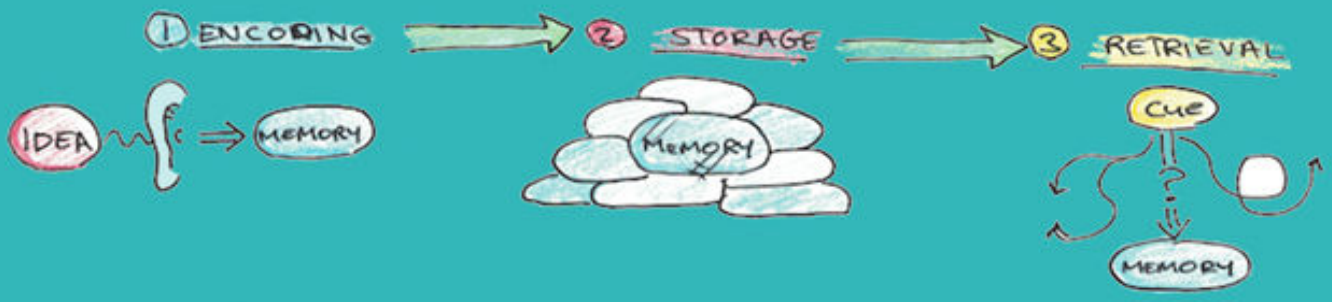
记忆的科学

掌握3个记忆核心过程轻松应对学习工作

【著】 斯科特·扬 SCOTT YOUNG
雅各布·吉莱克 JAKUB JÍLEK

【译】刘广宇



THE COMPLETE GUIDE TO MEMORY

作者简介：

加拿大作家，畅销书《如何高效学习》的作者

1年内学说4国语言，曾登上TEDx讲台向世界分享学习经验

经营着世界上最大的学习博客之一

目录

提高记忆力关键方法总结

注释

Why Memory Matters

The Three Parts Underlying All Your Memories

Encoding: Putting memories into the brain

Intention to learn: Does it matter how much you want to remember?
Depth of Processing: Why how you process information determines how much you'll remember later
Transfer-appropriate processing: The trick to acing your exams
State-dependence: How your physical/mental states drive your memory
Context-dependence: Why your environment matters

Storage: Keeping memories in the brain

Trace decay: Do your memories fade with time?
Consolidation and sleep: Let biology do the work for you
Interference: Does learning new things block your old memories?

你的记忆是怎么工作的？怎样才能记住更多、避免遗忘？

这些问题处于你所学、所做或所经历体验的任何事的核心[1]。你的记忆会影响你所做的每件事，从在学校的成绩，到事业上的表现，再到生活质量，甚至影响你的自我认知和幸福感。

很长时间以来，这个问题一直令我着迷，而且之前我在博客上已经写了大量关于记忆的文章。不过，我想撰写一本指南，包罗整合我们关于记忆已知的一切科学知识，并将那些知识融入可行的建议。

为此，我与雅库布·耶利克合作撰写了这本指南。他拥有伦敦大学认知科学的硕士学位，如今正在攻读博士。在这本完全指南中，我们将涵盖关于记忆你所需要知道的一切，从记忆的工作原理到如何提高记忆力。


斯科特·扬 (Scott Young) 唯一官方公众号
ID: Scott-H-Young

记忆为什么重要

什么是记忆？人们普遍的共识是，记忆是多种认知系统，允许我们把信息存储一段时间，进而可以汲取过去的经验，预测未来的发展。

记忆影响着我们生活的各个方面。更好地记忆事物的第一步，是理解你的记忆系统如何工作。

有两类基本的记忆——回溯记忆和前瞻记忆。回溯记忆是要记起过去发生了什么，而前瞻记忆是提醒你在未来要做某件事情。要是没有前瞻记忆，你会早上想不起去上班，晚上忘记上闹钟。

细分回溯记忆的一种方式，是根据存储事项的类型。区别很大的两类分别是内隐记忆和陈述性记忆。

内隐记忆本质上是一种技能记忆——完成一项任务的能力。如果内隐记忆失效了，你将无法刷牙、洗澡、驾驶或骑车。这种记忆在我们能做的事中表现出来，但我们并不总是能够用词语或概念清楚地表达出我们所知道的是什么。

陈述性记忆则相反，指的是关于事实或含义的（语义）记忆，或关于事件的（情节）记忆。没有了语义记忆，你将无法理解同事或朋友所说的内容。没有了情节记忆，你将很难向其他人讲述自己一天的经历。

另一种研究记忆的方式是根据它持续的时间。工作记忆（WM）负责短期加工并存储信息。如果没有工作记忆，与同事聊天、在会议上讨论一个要点和规划周末的安排，都将变得不可能。与此相反，长期记忆（LTM）负责长期存储信息。我们日常的活动几乎全部依赖长期记忆，例如记得回家的路或如何驾驶一辆汽车。

让我们迅速回顾一下记忆的不同类型：

- **回溯记忆**——记得过去的事情

- **按内容划分**

- **陈述性记忆/外显记忆**

- 语义记忆——关于事实和含义的记忆

- 情节记忆——你的经历

- **按持续时间划分**

- **工作记忆**——你能够同时在脑子里记住什么内容，用来思考、推理和解决问题。

- **长期记忆**——任何你记住超过一会儿的内容：早饭吃了什么，考试题目，或者朋友的生日。

- **前瞻记忆**——提醒你自己未来要做某件事

在这本指南中，我们将主要关注陈述性的语义记忆，这涉及大部分你试图“记住”的东西，例如事实、日期、姓名和思想。

所有记忆背后包含的三个部分

10美元长什么样子？（或者如果你不是美国人，常见的钞票长什么样？）你觉得自己能画出来吗？尽管我们经常看到硬币和钞票，因此的的确确有无数机会了解他们的样子，但很少有人能够准确地勾勒出来。反复看一个东西，并不保证我们日后能记起它。为什么我们没法画出10美元的样子，可是一旦看见立刻就能认出它呢？

要解开这个谜团，我们需要把记住东西这件事分解为更基本的部分，分别是：

编码——把信息输入大脑的过程

存储——在大脑中保存信息的过程

检索——在需要的时候从大脑中取得信息的过程

如果想要拥有更好的记忆力，那么理解这三个功能至关重要。任何尝试提高记忆力的做法，要么更好地编码信息（或者以一种更容易检索的形式编码），更好、更持久地存储信息，要么更好地在需要的情况下检索信息。

让我们来分析一下这三个部分，然后看看可以如何提高我们的记忆力。

编码：将记忆内容输入大脑

编码是让信息在大脑中留下印记的过程。没有正确的编码，就没有可以存储的内容，之后试图检索记忆时也会失败。提高编码能力的一个办法就是简单地把信息重复更多次。研究记忆的科学家将这种重复称作信息“排演”。

然而，正如画钞票的例子所说明的，多次排演并不总意味着你能成功回想起信息。这个例子与我们熟悉的因为频繁使用而记住电话号码之间有什么区别呢？

在试图记住电话号码时，你不是仅仅反复看，而是有意识地试图记住它。可能你已经在心里念了好几遍。也许你试图回想电话号码，然后检查自己记得对不对，并做出相应的纠正。也许你注意到不同数字之间有某种联系（例如某个数字是之前或之后数字的乘积或总和）。概而言之，你运用了特定的认知策略和加工。你依然需要重复，但只有在和这些策略一起使用时，重复才有用。

类似地，如果你想拥有高效的记忆，那么所运用的认知策略将显著影响你在日后记起事情的能力。

什么样的编码策略是最有效的？

学习的意向：你有多想记住对结果有影响吗？

在一个有趣的研究中，科学家要求学生学习一些单词。一组学生被明确告知要记住这些词（同时提醒他们接下来会有测试），而另外两组学生则被要求把这些单词分类，或者仅仅是把它们排成几列（不知道接下来会有测试）。

人们可能预期有意识地学习这些单词的学生会比分类或把单词排成几列的学生表现更好，因为后两组没有付出那么多努力。然而事实并非如此。分类组和记忆组在测试中表现相当，而把单词排成几列的学生表现不如另外两组。

为什么学生的学习意向没起多大作用？

简单来说，研究人员发现，被要求记住单词的学生和那些被明确要求分类的学生一样，也把这些词分类了。通过分类，这两组学生对单词的加工，比仅仅把单词排成几列的学生更深入。结果，他们对单词进行了更有力的编码，并取得了更好的测试成绩。

这个实验显示，仅仅有学习某件事的意向，并不能让你在之后记起它。重要的是你对这些材料做了什么，也就是说，你用了什么具体的记忆策略来加工它，而不是你有多想记住它。

下面我们就来看看这些策略。

加工深度：为什么如何加工信息决定了日后能记起多少

科学家认为，决定编码成功与否的一个重要因素是信息加工的深度。对学习的信息加工得越深入，它就越可能被持久地记住。那么到底什么是“深度”加工？

深度加工本质上关注的是信息的含义。

试试这个例子[2]：把下面这些单词读三遍，然后最小化窗口或在屏幕上挡住它们，试着回想起尽可能多的词：

圆 白菜、桌子、河流、衬衫、枪、广场、铁、牙医、麻雀、山、手、花岗岩

你记住了多少个词？现在和上面一样，试着记下面这一组词：

粉色、绿色、蓝色、紫色、苹果、樱桃、柠檬、李子、狮子、斑马、牛、兔子

你记住了多少个词？再试试下面这一组：

线、别针、眼、缝、尖、点、扎、顶针、草堆、刺、疼、注射

这回你记住了多少个词？很有可能你记住了第二组和第三组中的大部分词汇，而第一组的单词记住的最少。正如你可能已经注意到的，第二组中的词被分成了若干类别（颜色、水果和动物），而第三组的词都和“针”这个含义有关。相反，第一组中的单词则是各种完全无关的事物。

后两组单词之所以更容易记住，是因为其中的事物具有有意义的关联——它们被主观地（无论是有意还是无意）归到一个特殊类别，或者都与一个共同概念相关。为信息赋予意义之所以有助于记忆，是因为它强化了激活扩散的过程（我们会在“激活扩散”一节讨论它）。

这个研究给我们的主要启示是：结构化的信息比无组织的信息更容易编码并记住。[3]

因此，按一种良 好的结构组织笔记就十分有用。结构可以有许多不同的形式——层级结构、流结构、思维导图或其他任何你觉得有用的形式。重要的是，这个方法帮助你用一种轻松、明白、容易理解的方式组织学习材料。（我们会在另外一篇关于学习的文章中详细讨论这些笔记方法。）

为信息赋予意义，并不只有分类和结构化的方法。一个能够明显提高记忆力的有力手段是**自我解释**[4]。自我解释包括在学习时问自己有关学习材料的问题：

- 这个概念与另一个概念有什么关系？
- 这个概念对……有什么意义？

• 为什么……有道理？

• 要解决这个问题我必须采取哪些步骤？

深度加工信息一个非常有效的办法就是用自己的话解释学习材料。如果你要用与书本或老师不同的话来解释一个概念，首先必须消化并理解它的含义，并与其他概念建立逻辑联系，而这通过促进深度加工有效地推动了编码过程。这和只是简单地再读一遍课本非常不同，因为重读课本只涉及信息的浅层加工，而不会引向有效的编码。

在记笔记时，要确保自己不是逐字逐句地照抄课本或老师的话，而是尽可能使用自己的语言。研究者已经证明，与手写笔记不同，在电脑上打字记笔记会鼓励逐字逐句照抄信息（即使学生已经被明确告知要用他们自己的语言）。结果就是，用电脑记笔记的学生在考试中表现不如手写记笔记的学生。[5]

我们一般推荐下面的做法：

• 记结构化的笔记（层级式的、流结构的、思维导图等等，无论哪种最适合你）。

• 不要死记硬背老师或课本上的原话，而是用自己的语言阐释概念。

• 在记笔记时，避免逐字逐句抄写信息，而是改用自己的话。

- 避免用电脑记笔记，而是用纸笔。

迁移适合性加工：考试取得好成绩的技巧

假设要学习如何骑车，你可以买一本花两百页讲述如何骑车的书，滚瓜烂熟地记住所有事项。如果你要参加一场笔试，那可能会取得好成绩。

现在假设真的要骑自行车，你觉得会发生什么？很有可能你一上车就会摔倒。

尽管你知道关于骑车的一切知识，但是少了一个关键要素。你之所以会摔倒，是因为编码时所用到的认知过程与检索记忆时所需要的认知过程不匹配（即无法正确地迁移）。为了有效地记住，练习时所用的信息加工过程需要和使用时的信息加工过程相匹配。

为了说明，考虑下面这个研究的例子：[6]

研究人员要求学生大声读出一组词（浅层加工），或者从它们的反义词想到这些词（深度加工）。之后问学生他们能记起哪些词（自由回忆），或要求他们填上单词中缺失的字母（残词补全）。

人们可能预期，浅层加工的学生在两项测试中都表现较差（因为深度加工的记忆效果通常好于浅层加工——详见上

文）。然而这仅对自由回忆测试成立。令人吃惊的是，在残词补全测试中，浅层加工组的表现要好于深度加工组。

如何解释这个令人惊讶的结果？

朗读组是在视觉感知的层面上加工这些单词，而反义词组则是在语义上进行加工——他们在记忆中检索有特定含义的单词。感知层面的信息加工符合知觉任务所需的加工过程，而语义加工符合自由回想时所需要的加工过程（注意单词是根据它们的含义存储在语义记忆中的）。

这个研究的主要意义在于，尽管深度加工对记忆极有好处，但它还不足以让你在考试中表现最好。要进一步提高考试成绩，重要的是练习与考试类似的信息加工过程。

仔细想想要记住的那些信息会怎么考查？是多项选择题？简答题？还是实际应用题？然后使你的练习与应用的情形相配。不相配的练习是记忆不佳的主要原因——他们只是没有按照有用的方式编码。

如果你的考试包括写作题，一个很棒的策略是带着预读问题来阅读。[7]预读问题迫使你在阅读过程中寻找观点和证据来回答问题，而这正是你在写作类考试中所需要的信息加工过程。

然而，适合迁移的信息加工只是影响记忆的一个考虑，因为有些编码方法普遍强于其他方法，而不论是否与考试形式相

匹配。事实上，有一种编码策略强过几乎所有其他策略，那就是“回想”，我们会在下文讨论它。

总结起来，如果你要参加某种特定形式的考试（例如写文章），最好的方法就是集采各种策略之长。根据最终考试的形式进行练习，能够教你按照考试所需的方式加工材料，而回想能够实现最有效的信息编码。因此，理想情况下你应该：

- 用大约1/4的时间按最终考试的形式（例如多项选择）进行练习

- 余下的3/4时间使用回想和其他深度加工方法。

状态依赖：你的身体/心理状态如何影响记忆

想象下面的情况：你必须要准备明天的考试，但是朋友今晚有个生日派对。你决定去参加派对，最后还喝了点酒。等你回到家的时候，已经醉醺醺了，但还是坚持复习了考试。第二天一早，你到学校参加考试。考试前再喝一两杯酒精饮料，会让你发挥得更好吗？抑或更好的做法是在考试前不再喝酒？

撇开学校可能不会让你在醉醺醺的状态下进入不谈，科学研究给出了一个令人震惊的答案：为了提高考试中的表现，你应该再喝点酒，达到复习时同样的酒精摄入水平（这确实在一个研究中被证明了[8]）。

怎么解释这个惊人的结果呢？

研究表明，我们的记忆是状态依赖的。编码和检索时的心理、生理和化学状态越接近，就越可能成功记起相关信息。记忆依赖一个化学过程实现，在此过程中，神经元之间形成新的联结（通路）并加强已有的联结。如果你在一个特定状态下学习，那么记忆痕迹就和受此状态影响的大脑活动一同被编码，因此也在某种程度上依赖这种状态的恢复。

各种药品都被发现与这种状态依赖的记忆有关，包括尼古丁[9]、咖啡因[10]、大麻[11]、利他林[12]或抗组胺[13]。如果你在

服用利他林之类的药物，那么最好在复习和考试时服用同样的剂量。如果你在考试期间无法喝咖啡或抽烟，那么最好在复习期间也避免这些东西。此外，重要的是要意识到，大多数药物都会损害记忆，尤其是酒精[14]和大麻。如果在复习和考试期间都保持清醒，那么通过考试的概率也最大。

记忆的状态依赖也适用于其他状态。如果你在良 好的心情下复习，那么在同样的好心情下考试有可能表现更好（其他情绪同理）。[15]类似地，如果你是在站立或做有氧运动时学习的，那么当测试也在站立或有氧运动的状态下进行时，更有可能记起材料的内容[16]。

克服状态依赖记忆的一个办法，是在与考试一样的状态下学习。比如，你可以坐在桌边复习，同时模拟压力感（比如计时答题），假设考试时也是一样的条件。

然而，这并不总是可行。另一个办法是在不同的心理和身体状态下学习。其背后的逻辑是，你永远不知道自己在考试时会是什么状态，因此最好使你的记忆不依赖任何特定的状态。例如，你可以同时在精力充沛和筋疲力尽时复习。同样，不管当前处于什么样的情绪状态都坚持学习，也是个不错的主意。

总结：

• 用至少1/4的复习时间模拟你在考试期间可能处于的状态（例如坐在桌边，计时回答问题）。

• 不论处于怎样的心理/身体状态都坚持学习（不同的情绪状态、不同的能量水平等等）。

情境依赖：为什么你的环境很重要

考虑一个日常会遇到的情况：你从桌旁起身想要倒杯茶，等你到了厨房，却忘了自己想要做什么，然而回到桌边时，突然就又想起来了。

科学家发现，记忆是高度依赖情境的。情境基本上就是编码过程中出现的任何事（例如我们所处的环境）。**我们的大脑似乎把情境也编码成了记忆的一部分，就好像在创造记忆的那一刻，对我们周围的一切拍了一张快照。**

因此，成功检索记忆，某种程度上取决于成功激活编码时所处的情境。由于想要一杯茶是和桌边的情境一起被编码的，因此回到桌边会重新激活想要一杯茶的意图。

为了摆脱记忆的情境依赖，我们可以采取与克服记忆的状态依赖时相同的两种办法。第一个办法是模拟考试时的环境情境。例如，根据考试的地点，你可以选择在一个安静或嘈杂的环境下复习。也可以考虑和一两个朋友一起复习，从而适应在考场上受其他人干扰分心的情况。更好的办法是在你将要参加考试的那个教室里复习。

第二个办法是在尽可能多的不同情境下复习。研究已经表明，考前在许多不同房间复习的学生，考试时会比只在一个房间复习的学生表现好（考试成绩提高30%）。[17]

由于环境情境一直在变化，要记的信息就成功变得不依赖情境了。换句话说，你教会了自己如何在任何环境下记起学习材料。鉴于你通常无法预测考试中会遇到怎样的环境，这个办法非常有用。

学习的情境不仅指环境。你所使用的特定问题和练习测验同样构成情境，与你的学习材料一起被编码。因此，对于一个给定的概念，你练习的问题越多，大脑就会在不同的情境与要学的概念之间生成越多的神经联结。大脑建立的通路越多，日后检索相关概念就越容易。这是因为信息的检索变得不那么依赖于特定的起点——提问的类型或特定的表述。

这种情境制约造成的影响在制作记忆卡片时格外重要。如果你的记忆卡片在问题面包含了无关信息，或者在你真正需要记起相关内容时不会出现的信息，那么在需要的时候就可能无法回想起记忆的内容。

考虑下面的记忆卡：

问题：仅指未来会重复的行为时，“again”用中文怎么说？例如让某人重复他们刚刚说过的话……

回答：再

再比较下面的：

问题：Again（future）

回答：再

第一个记忆卡包含太多背景，导致你可能只在这个情境（而在你需要想起这个词时可能并不存在这样的情境）下才能记起二者的对应。

因此，最好问自己包含尽可能少情境信息的问题（由此使难度最大），或者在不同情境下问许多不同问题，从而不需要同样的情境也能成功检索记忆。

总结起来，我们推荐如下做法：

• 在一半的学习时间里，模仿考试的环境条件（嘈杂/安静的环境、类似的干扰、周围的人）。

• 另一半时间，在不同的房间、地点和条件下学习。

• 用不同类型的练习问题考自己

• “什么”类型的问题

• “为什么”类型的问题

• “如何”类型的问题

• 记忆卡片使用最少的情境信息，或者如果可能的话，尝试换不同方式问自己问题，从而充分增大记忆的灵活性。

存储：把记忆保存在大脑中

一旦完成了信息的编码，现在就需要存储了。不幸的是，遗忘是我们大脑运作的一个主要部分。大多数人都记不住三个星期前的星期二晚饭吃了什么，但我们都记得自己的初吻。

遗忘可能由两个不同的过程造成。第一个是**存储失败**——随着时间的流逝，大脑弄丢了相关信息，从而导致遗忘。第二个是**检索失败**——信息可能就“在”那里，但是我们无法访问。在实验中，区分这两个过程非常困难，但鉴于它们是不同的过程，我们将在考察记忆的工作原理时分别考虑它们。（更d书f享搜索雅 书.YabooK）

最早研究遗忘的发展的，是著名实验心理学家赫尔曼·艾宾浩斯（Hermann Ebbinghaus）。艾宾浩斯发现，遗忘符合指数衰减函数。在学习之后的最初几个小时，成功记住的内容迅速减少，从第二天往后，遗忘的就相对很少了。

尽管确切的遗忘曲线可能因人而异，而且取决于与学习材料有关的很多因素（例如材料有多容易/困难/有趣，或者编码得好不好），但它近似是一个指数函数曲线，一开始遗忘速度很快，之后遗忘的速度减慢。

为什么我们一开始会遗忘信息？我们可以做什么来克服这个遗忘过程？

痕迹减退：你的记忆随时间减退吗？

关于遗忘最根本的解释与时间的流逝有关。我们的记忆痕迹存储在活组织中，因此不可避免地随时间而变化。众所周知，神经元之间的联结会随时间而衰退，结果就是存储在这些联结中的记忆痕迹随之变浅。

此外，记忆的减退还有另一个可能的原因。令人惊讶的是，记住新东西或许正是导致我们遗忘的部分原因。随着新的记忆形成，海马体（大脑的记忆中枢）会产生新的神经元，这会改变已有联结的结构和模式。[18]结果，旧的记忆也就更难被检索到了。

因此，如果你需要在记忆中保留旧信息（比如为了期末考试），学了新东西之后再复习一下旧有的内容可能会是个好主意，否则旧信息可能会被新信息取代。

我们建议你设定一个复习旧内容的日程表（即使每天只花几分钟时间就够了），穿插在学习新内容的过程中。如果你一天之内学习好几个不同的科目/主题，这样做就尤其重要了，因为你的记忆还来不及得到睡眠引发的固化过程的保护。学习新东西会损害对旧内容的检索还有另一个原因，我们会在“干扰”一节讨论。

总结起来，我们推荐以下做法：

- 花大约十分之一的时间复习旧内容。
- 在学习新内容的过程中，穿插对旧内容的简短回顾。

巩固与睡眠：让生理机能为你工作

学习的结束并不意味着最终学会。为了在长期存储系统中形成永久记忆，大脑的组织中必须发生结构性的生物学变化。神经元之间必须形成并建立稳定的新联结。

这些变化不会立即发生。最新的记忆变成永久记忆的机制，在科学上被称为“巩固”。**尽管有些巩固在清醒的状态下发生，但巩固主要发生在睡眠期间。**

你是否曾为了考试熬夜学习？如果这样做过，你在考试中的表现和享受了一整晚不受打扰的睡眠时一样好吗？大概不是。毫不奇怪，研究人员发现，睡眠不足会损害记忆巩固，从而影响学习。[19]事实上，睡眠不足（不论是学习之前还是学习之后）都会使被试在陈述性记忆测试中的表现降低20%~50%。[20] [21]不仅如此，长期睡眠不足还会对记忆造成永久性伤害。[22]

另一方面，你可以把睡眠用作几个学习时段之间有力的辅助工具。你或许听说过“强效小睡”的说法——用于恢复精力的短时睡眠。**如今有强有力的证据建议人们小睡。**[23]得益于睡眠带来的巩固过程，白天小睡可以避免你的记忆出现痕迹减退（详见“痕记减退”一节）和干扰（详见“干扰”一节）。换句话说，经过同样长时间，睡眠比一直保持清醒状态遗忘的内容更少。

如果你决定试试小睡，那么重要的是要了解睡眠的不同阶段。不超过20分钟的小睡对于恢复精力十分有效，但这还不足以进入深度睡眠，而巩固过程是在深度睡眠期间发生的。

为了增进记忆，你需要至少睡60分钟。然而，小睡60分钟带来的坏处是，接下来的30分钟你都将处于昏昏沉沉的状态（因为你是在深度睡眠的中间醒来的）。因此，最好是睡够一个完整的90分钟周期。结束之后，你将重新恢复活力，而记忆也会得益于巩固过程而变得更加牢固。另一个被发现有效的好办法是在计划日程时把学习环节安排在睡前。

总结起来，我们推荐以下做法：

- 小睡20分钟使你恢复精力

- 在一段学习之后，小睡90分钟来巩固记忆。

- 规划日程时把学习安排在睡前，从而享受巩固带来的全部好处。

干扰：学习新东西会阻断旧有的记忆吗？

你还记得两周之前的晚饭吃的什么吗？现在从之前几年挑选你最喜欢的一次旅行，你还记得多少？很可能你已经不记得晚饭吃了什么，但能清楚地回忆起旅途中发生的事情，尽管它发生的时间比两周前的那顿饭早得多。

这个例子表明，**遗忘并不仅仅是记忆随时间消退**。我们的记忆非常依赖线索。线索本质上可以是与一段记忆痕迹相对应的任何东西（例如一个实体物品、一个情境、一段时间、一个词、一个问题、一个概念等等），只有先启动线索，才能检索到对应的记忆痕迹。

如果我们给同一个线索匹配了多个不同的记忆痕迹，那么将很难检索到特定的某个痕迹，因为当线索被激活时，激活信号会立刻传播到所有对应的记忆痕迹，它们相互竞争，看谁能够进入显意识。

回到上面的例子，如果你经常在同一个地方吃饭，那么许多顿不同的饭都会关联到同样的线索（就餐环境），因此就很难检索到一周之前你享用的特定一顿饭的记忆。相反，你之前不太可能已经把同一段旅程走了很多遍，所以回想起旅途中的细节要容易得多，因为旅程的背景没有关联到任何其他记忆。

由于其他记忆痕迹关联到同一个线索，导致原有的记忆被打乱，这种情况被称作“干扰”。如果你曾学过外语，那么或许已经遇到过这种现象。记忆干扰可能让你无法想起一种语言的单词，而另一种语言中的那个词却不停地蹦到你的脑海中。在这种情况下，干扰并不一定导致记忆丢失，但原来的记忆痕迹被阻断了，因此暂时无法重新想起。

研究发现，克服阻断干扰的唯一办法，就是有意识地努力恢复正确的记忆痕迹（而且要保持耐心，因为这可能会花些时间）。不过，干扰也可能导致永久性的记忆丢失。研究记忆的科学家将此称为检索引起的遗忘（RIF）。

为了说明这种现象，考虑下面的试验：学生们先学习A和B两个岛的各10个地理知识。[24]接下来，在关于岛A的10个知识中，练习想起其中的5个。之后测试他们对这些知识的掌握程度。

你认为学生对岛A相关知识的记忆会是什么情况？

不出意料，检索练习增强了所练习的5个知识的记忆（正确率高于岛B的相关知识），但这也使学生对岛A没有得到练习的5个知识的记忆变差了。这是什么原因呢？

岛A是关于岛A的相关信息的背景线索，岛B也是关于岛B的相关信息的背景线索。在从记忆中检索关于岛A的5个知识时，它们与背景线索之间的联系被加强了，而剩下5个知识与背景线索之间的联系则被削弱了（参见“测试效应”）。

这项研究对于学习的一个主要启示在于，选择性练习测试能够大幅提高所练习项目的记忆表现，但同时也会削弱对于未练习项目的记忆表现。我们怎样才能克服干扰导致的遗忘呢？

克服干扰的一个办法是明确呈现出干扰。如果你经常弄混一些概念，那么就把它们放在一起，然后同时复习它们。

总体思想是，不论学习什么，让不同概念尽可能区分开来都是个好办法[25]，因为这会强迫你的大脑把它们编码成不相似的记忆痕迹。为此，你可以强调学习材料中不同概念之间的差异（例如通过比较和对比）。

另一个有效的办法是把多个概念整合起来。[26]例如，如果你在记忆特定动物/植物家族的成员，则试着找出这些成员之间所有可能的关联。等你日后要检索这些成员的记忆时，它们就不再为进入你的意识相互竞争，而是以一种整体的形式被紧密地编码在一起。如此就不再是一个概念阻断其他概念，而是会被一起检索出来。

科学家发现，学习目的也会影响我们克服干扰的效果。[27]关注相对表现（相比于其他学生，他们做得怎么样）的学生往往只用到浅层加工（不寻找概念之间的关联），而目标是掌握知识的学生常常会用到更多深层加工，例如在不同概念之间建立联系。

总结起来，我们推荐以下做法：

- 重复学习你感到困惑的概念

- 利用比较和对比来发现不同概念之间的区 别
- 把多个概念整合起来（发现概念之间的联系）
- 致力于掌握知识本身，而不要关注其他人的表现

间隔效应：学得更少，记得更多

间隔效应无疑是记忆科学中最重要的发现之一。它的大意是，如果你把学习分散到多个不同时段完成，而不是一口气学完所有内容，那么合起来你只需要少得多的时间就能记住相关内容，从而在特定的考试中取得同样的表现。为了说明这一点，让我们考虑著名心理学家赫尔曼·艾宾浩斯在自己身上进行的一个试验[28]：

艾宾浩斯用两天学习两组单词。第一天，他花了1分钟学习A组单词，7.5分钟学习B组单词。第二天，他不得不再花20分钟才能牢固地记住A组单词，而只需要额外再花7.5分钟就能记住B组单词。

通过更均等地分散安排对单词的学习，艾宾浩斯设法节省了1/4的总学习时间。与此类似，如果不停歇地复习考试需要花上3个小时，那么把复习时间均等地分成2-3份，分布在几天完成，你可能总共只需要不到2小时就能复习完。

一般来说，学习时间越分散，所需的总时间就越短。科学家建议，学习的间隔距离应该是距离考试时间的10%~20%。[29]如果还有10天考试，那么每天学习一次的效果最好。如果考试在6个月之后，你应该每20天复习一遍。

间隔学习不仅能够大幅节省时间，还能够增强长期记忆。每一个紧接着或稍后进入睡眠的学习时段，都额外提供了一次

巩固学习内容的机会（我们在上文已经讲过记忆巩固的过程）。此外，间隔也为你提供了更多机会把学习内容与更多（生理的、心理的、环境的）状态或情境联系起来，从而使记忆在未来更容易检索（参见状态依赖和情境依赖的内容）。

最重要的是，间隔有效地告诉你的大脑，遗忘正在发生——这是在集中学习（即一口气学习好几个小时）时不会出现的一个重要信号。研究已经发现，遗忘信号会自动鼓励学生使用更有效的编码策略。[30]

间隔效应是心理学上一种强有力的现象，对于多种学习材料都极为有效（包括学习外语词汇、数学问题、空间信息等）。[31]

间隔重复背后的核心思想在于，为了最高效地利用时间，并实现更长久的记忆，应该在一个概念快要被遗忘之前就进行复习。由于并不存在一个公式可以准确地计算间隔，因此需要自己尝试。出于实际考虑，最好的办法可能是借助一个运用了间隔算法的专用软件。

尽管目前还没有人比较不同间隔重复算法的效果，但普遍的选择有Anki,Quizlet和Supermemo。我们推荐你试用一种在大多数平台上免费、明确说明所使用的算法，并允许你自行调整的程序（我们最喜欢的是Anki）。

要牢记的是，间隔效应并不会无限制地有效。例如，十个1分钟的学习时段很可能就没有一个10分钟的学习时段效果好，

这是因为每个学习时段开始时都会有一些损耗（必须开始专注，把学习内容“装载”到工作记忆等等）。**因此，复杂科目可能需要更长的时段才能够实现有效学习。**例如，每周花三个一小时学习工程学课程，效果可能就比六个30分钟更好。这完全取决于所学习的科目。

总结起来，我们推荐以下做法：

• 避免集中学习（即一口气学好几个小时）。

• 把学习时段划分成几小块，分散到较长的一段时间中进行。

• 两个学习时段之间的间隔应为距离考试时间的10% 20%（例如，准备十天后的考试，可以每天学习一次）。

• 规划复习安排，在快要遗忘的时候复习每个概念/主题（这需要自己尝试，因为没有公式能够准确地计算）。

• 考虑使用记忆卡片程序（Anki，Quizlet，Supermemo）。

检索：访问大脑中的记忆

检索是访问记忆中存储信息的机制。记忆痕迹的成功检索取决于它与线索的联系。线索指的是与记忆痕迹相联系的任何事物（可以是有形的物体、情境、时间段、单词、问题）。科学家认为，记忆是通过“激活扩散”的过程来检索的。当一个线索在大脑中被激活以后，激活信号就会从线索传递到目标记忆。一个记忆痕迹可以与无数线索相连。如果任何相关的线索都没有被激活，那么即使完好无缺地存储在记忆中，对应的记忆痕迹也无法被检索到。

例如，盖住本页的其余部分，试着回想下列国家的首都：

- 韩国
- 叙利亚
- 丹麦
- 哥伦比亚
- 阿富汗
- 泰国
- 委内瑞拉
- 土耳其

你能想起所有这些首都吗？有没有感到自己知道它们的名字，也许过会儿就能想起来？你或许也遇到过这种就在嘴边却说不出来的现象：你知道自己知道某件事，但依然无法想起来。下面试着在一点小帮助下再做同样的练习：

- 韩国　首
- 叙利亚　大
- 丹麦　哥
- 哥伦比亚　波
- 阿富汗　喀
- 泰国　曼
- 委内瑞拉　加
- 土耳其　安

现在你记起它们了吗？很可能这回记起了更多，因为第一个字就是一个合适的线索，关联到首都的名称。提供了这个线索后，存储首都名称的记忆痕迹自动就被激活了。

检索记忆的过程是如何工作的？对于学习又有什么启示呢？我们能够做些什么来尽可能增加成功检索信息的几率呢？

激活扩散：获得对记忆的快速访问

假设你在准备一场关于世界上所有首都的考试（给出一个国家，你需要说出它的首都）。如果使用最基础的学习策略，可能就只是学习把每个国家与它的首都对应起来。换另一种方法，你也可以欣赏这些首都的照片，观看说这些国家语言的人拍摄的短视频，参观首都的景点，等等。

哪种策略会更有效？

第一种策略被称作“浅层”加工，因为你不会给信息赋予任何额外的意义，在线索（国家）与目标记忆（城市）之间只建立了一个联系。第二种策略被称作“深层”加工，因为你会在首都、国家、当地的人民和景观等等事物之间建立许多联系。

如果采取第二种策略，就会利用到记忆的结构。人们认为记忆的运转遵循激活扩散的原则。[32]如果你遇到一个概念（一个国家），大脑中代表这个概念的神经通路就会被激活，周围编码其他密切相关概念的神经通路也会被激活，然后图像和想法就会进入你的大脑。例如，当有人说法国时，你眼前可能浮现出法国国旗、埃菲尔铁塔、法国红酒、奶酪等等。这个过程会继续，不断延伸到更多想法，直到你开始想起其他事情。

如果你之前把这些形象同时关联到法国和巴黎，那么法国这个线索还会激活其他相关的线索（埃菲尔铁塔、红酒、奶酪

等等），而它们共同作用，会产生比法国单独一个线索更多的激活，然后扩散到相联系的记忆痕迹——巴黎。相反，如果你只是表浅地学习了法国—巴黎这一对关系，仅仅看到法国这个词本身，或许就无法产生足够的激活来触发关于巴黎的记忆痕迹。

激活扩散的主要影响在于，为了最大可能地记住新概念，**你应当尝试在新概念与已知事物之间建立尽可能多的联系。**如果目标概念与其他许多概念都有联系，那么它被激活（并被检索到）的概率一般比只有很少几个联系的情况要大得多。

总结起来，我们推荐以下做法：

- 学习一个新概念时，将它与已知事物建立联系。

- 新旧概念之间建立的联系越多，新概念就越容易被记住。

检索失败：如果考试时卡壳了怎么办

检索失败或者无法回想起一个记忆痕迹，可能有许多原因。一个原因可能是在学习时注意力不够。研究人员发现，在学习的同时做其他事情的学生，在日后测试中的表现比一次只专注一件事的学生差30% 50%。[33]这个结果表明，多任务处理——同时做许多件事——对于学习非常有害。

导致检索失败的另一个原因是激活线索数量不足。线索是与目标记忆痕迹相联系的信息，要检索记忆痕迹，必须先激活它们（关于背景线索的更详细说明，参见检索与干扰部分）。

如果有许多线索被同时激活，从线索到目标记忆痕迹的激活就会传播得更快。为了说明这一点，试试下面这个小实验：

想任何一种超自然生物的名字。

现在想一种发音与“悔”押韵的超自然生物。

你一下子就想到了“鬼”还是在第二个问题之后才想到的？第一个问题只给了你一个线索，可以指向多个可能的目标记忆。例如，你可能想到了仙女、土地神、天使，诸如此类。第二个问题给了你两个线索，它们共同产生了足够的激活让你想起“鬼”这个词，远远超过对其他概念的激活。因此，“鬼”这个词被检索出来。

再考虑一个我们每天生活中都会遇到的例子：你坐在厨房餐桌旁时决定把一本书还到图书馆。后来你在上学路上经过图书馆时忘了还书，可是当你回到家，看到厨房的餐桌，突然就想起这回事了。记忆痕迹是和编码时的背景一起被编码的。尽管图书馆显然是比厨房餐桌更相关的背景线索，但在记忆编码时出现的是厨房餐桌而不是图书馆，因此它和还书被编码在了一起。

当你有一个打算时，尽可能生动地想象自己正在一个理想的环境下做那件事是非常有用的。例如，想象你自己路过图书馆，进入那幢楼，然后还书。关注细节——你在图书馆周边可能注意到哪些物体/建筑？通过这样做，你就将路过图书馆（以及周遭的物体）这个线索与还书这个目的联系了起来。之后当你路过图书馆时，就会自动触发这个目的。

如果在考试期间难以回想起一个重要的概念，那么你需要激活尽可能多的相关线索。例如，试着想想自己正处于复习的环境下，尽可能生动——想象你面对着打开的课本，坐在书桌旁，正在记笔记。仅仅只是想象编码的环境，就有助于产生足够的激活来成功检索到记忆痕迹。

同样，试着回忆你在学习这个一时想不起来的概念时所处环境的细节（例如在课本的哪一页，在这个概念前后你还学习了哪些其他概念）。注意，要成功检索记忆，激活相关联的线索非常重要。

由于你的记忆就像快照一样工作（编码时出现的一切都和记忆痕迹一起被编码），因此这些线索可以是相关的（例如有关联的概念），甚至也可以是完全无关的（例如是什么时候学习的，甚至可以是当时午饭吃了什么等等）。

总结起来，我们推荐以下做法：

• 为了将来更好地记得在某个时间地点做某件事，可以生动地想象你自己正在做那件事（例如，想象你路过图书馆，并归还图书）。

• 想象你需要想起做这件事时的环境细节（物体、建筑、人）。

• 如果你在考试时无法想起学过的某个概念：

• 尽可能多地积极回想与之相关的概念。

• 尽可能多地积极回想在其前后学习的概念。

• 想象自己在学习时所处的情境（坐在房间的书桌前等等）。

• 试着回想你是在什么时间、什么地点学习这个概念的，当时心情如何，那天发生了什么。

练习测试：增进记忆最有力的办法

科学家已经发现，不论所要参加的考试属于什么类型，如果用模拟题来复习，都最有可能取得好成绩。[34]要说明这一点，让我们考虑下面的试验[35]：

学生被要求参加一堂20分钟的统计学讲座，整个讲座被分成等时长的四节。在每一节结束后，第一组学生做一份练习测试（但没有反馈），第二组学生复习讲座材料，第三组学生进行心算。在全部讲座结束后，通过最终的测试对所有学生进行评估。

尽管复习讲座的第二组学生面对学习材料的时间更长，但他们在最终测试中的表现却明显比做练习测试的第一组差（低了30%），甚至也没有好过进行完全无关的心算练习的第三组学生。

大量研究已经表明，即使在没有反馈的情况下，测试也能够比复习更有效地提高记忆持久性和考试成绩，这被称为“测验效应”。然而，并不是所有测验都能达到同等的效果。只有利用一种特定的信息检索模式——回想，通过测验进行复习时，才能从中获益。

回想是在没有看到正确答案，而且没有任何选项可供选择的情况下检索记忆痕迹的方法。例如，回想的问题可以是：“加拿大的人口多少？”或者“星期一在德语中怎么说？”

回想的反面是再认，是在见到正确答案或一些包含正确答案的选项时检索记忆痕迹的方法。例如，再认的问题可以是：“加拿大的首都是渥太华还是蒙特利尔？”或者“星期一在德语中是Dienstag还是Montag？”

不论最终如何考查你掌握的知识，回想测验比其他所有基于再认的学习方法都要好得多。原因之一在于，回想自动鼓励你对学习材料进行深层加工。在上面的研究中，随着每一节讲座的进行，相比于另外两组，做练习测试的第一组学生记下的笔记越来越详细（而他们并没有明确意识到这一点）。

最重要的原因在于，再认对于大脑来说很容易，因为它确切地知道要从记忆中检索哪个概念。如果你再读一遍自己的笔记，事实上是在问你的大脑：我知道这个吗？这听起来熟悉吗？如果此前你已经至少复习过一遍这些笔记，那么其实就是在告诉你的大脑：“我之前已经见过这个了，没必要再做进一步的努力。”

相反，回想是需要付出努力的，因为大脑必须搞明白需要检索的目标记忆是哪个。如果你通过回想来自测（提出问题，但不给提示或答案选项），你的大脑就不得不重新建立从问题到目标概念的通路。由此，已有的通路被巩固（或新的通路得到建立），进而使日后检索概念变得更容易。

注意，回想必须是成功的——不成功的回想不会强化记忆痕迹。因此复习概念的最佳时机就是在快要忘记他们的时候（参见关于间隔效应一节）。

事实上，所有学习中常用的方法主要都涉及再认过程，例如复习（重新阅读）、划重点或开卷归纳概括，因此这些学习方法被证明对于成功检索记忆和提高考试成绩收效甚微，也就不足为奇了。另一些方法使用自我解释等深层加工方法，虽然比重新学习有用得多，但也不如练习测验高效。[36]

然而，这并不是说重读课本没有任何价值。当与练习测试一起进行时，重读依然是有用的。有选择性地重读那些你无法回想起来的概念无疑是个好主意。

同样，在测验练习期间复习所学内容作为一种反馈也很重要。尽管没有反馈的测验练习本身对于提高记忆已经非常有效，但如果错误得不到纠正，它们日积月累，就会越来越顽固地停留在记忆中。因此，反馈是练习测验的一种重要补充，能够大大提高它的有效性。反馈是立即的（直接跟在每个问题之后）还是延迟的（在整个学习单元结束之后）则无关紧要。[37]

最后，别忘了实际运用你的知识（例如完成一个真实世界中的项目）也是一种练习测验（和间隔重复）的形式，你需要定期从记忆中检索对应的知识和技能。与其纸上谈兵，不如躬行实践。

总结起来，我们推荐以下做法：

• 避免基于再认的学习策略（复习/重读课本章节/笔记、划重点、总结概述）。

• 通过练习测验/问题来复习，从而在考试中获得最好的结果。

§ 运用自由回想（不带提示或答案选项的问题/任务）

§ 只有当你的考试也有多选题时才练习再认问题（例如多选题）（参见迁移适合性加工），而且不超过1/4的学习时间。

§ 只有当你记不起来时，才选择性地重读相关内容。

§ 获得对答案的立即或延迟反馈。通过练习测验/问题复习，从而在考试和测验中取得最好成绩

提高记忆力关键方法总结

让我们简要回顾一下已学内容!

记忆包括三个部分：编码、存储和检索。记住想记的内容，需要这三部分都成功运转。

为了更好地编码信息：

• 深入地加工信息。关注深层含义，与已知事物建立联系，用自己的话表述而不是逐字逐句地记笔记。

• 意向并不重要。如果使用的认知策略不变，只是试着多记住一些，这个意向并不会有什么影响。

• 如果可以，使你在编码信息时所处的状态和环境与需要记起它时的状态和环境一致。如果无法做到这一点，就在更多的环境/情境下学习，使你的记忆更扎实。

为了更好地存储信息，你需要了解自己是怎么遗忘的。以下是可能造成遗忘的主要原因：

• 痕迹减退。当你的记忆变老，或者新的知识覆盖了原有的数据，就会出现这种情况。定期重新想起重要的信息，这样就不会遗忘了。

• **干扰。**当新的记忆阻碍了旧记忆，就会出现这种情况（例如，你想不起来西班牙语的“水”怎么说了，因为你学了法语里的这个词）。同样，当旧记忆给学习新事物带来困难时，也会出现这种情况。

怎样才能更好地存储记忆？

• **拥有充足的睡眠！**小睡可以恢复精力。长睡（超过1小时）可以进入记忆巩固的睡眠阶段。在一个完整的睡眠周期之后醒来，可以避免昏昏沉沉。当然，晚上拥有足够的睡眠是至关重要的!

• **间隔练习。**通过正确地间隔，你可以节省20 30%的时间，就达到同样的记忆效果。

最后，我们需要在必要的时候检索记忆。这是怎么做到的？

• **更多的联系有助于记忆检索。**记忆很可能是通过激活扩散访问的。因此，如果想到相关的事项，它们有助于你检索到某些很难想起来的记忆。

• **提前规划，**并在复习时想象你需要检索相关记忆时所处的环境。

• **练习测验是你能运用的最有效的技术！**练习回想，而不只是再认。越困难的回想会产生越坚实的记忆。

注释

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How does your memory work? How can you remember more? Prevent forgetting?

These questions lie at the heart of anything you'll ever learn, do or experience. Your memory impacts everything you do, from how well you'll do in school, your career, life and even your sense of self and happiness.

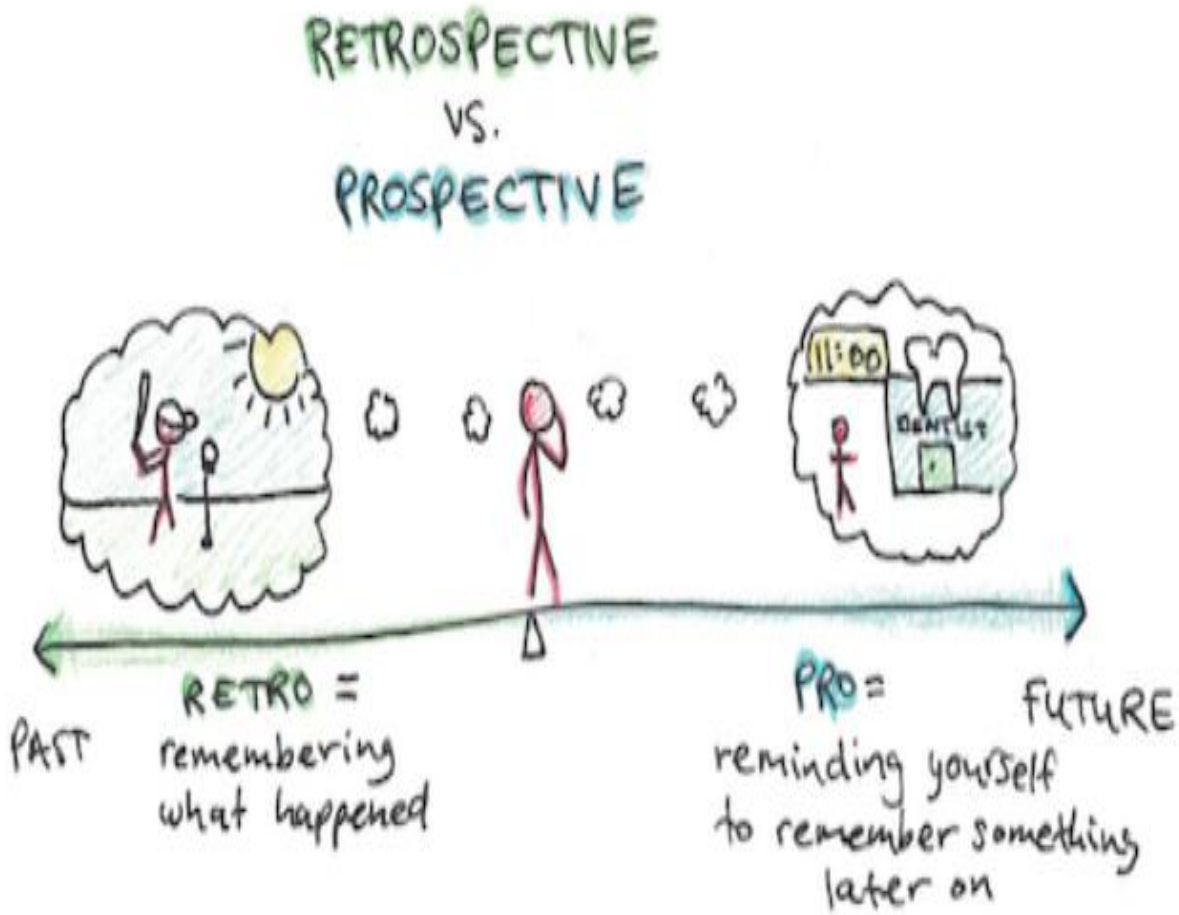
This is a topic that has long fascinated me, and I've written a lot about memory previously on this blog. However, I wanted to create a guide that would combine and integrate everything we know scientifically about memory, and distill that knowledge into practical advice.

To do that I collaborated with Jakub Jilek, who has his masters in cognitive science at University College London, and is currently studying for his PhD. In this complete guide, we will cover everything you need to know about memory, how it works and how you can improve it.

Why Memory Matters

What is memory? The general consensus is that memory is a multitude of cognitive systems which allow us to store information for certain periods of time so that we can learn from our past experiences and predict the future.

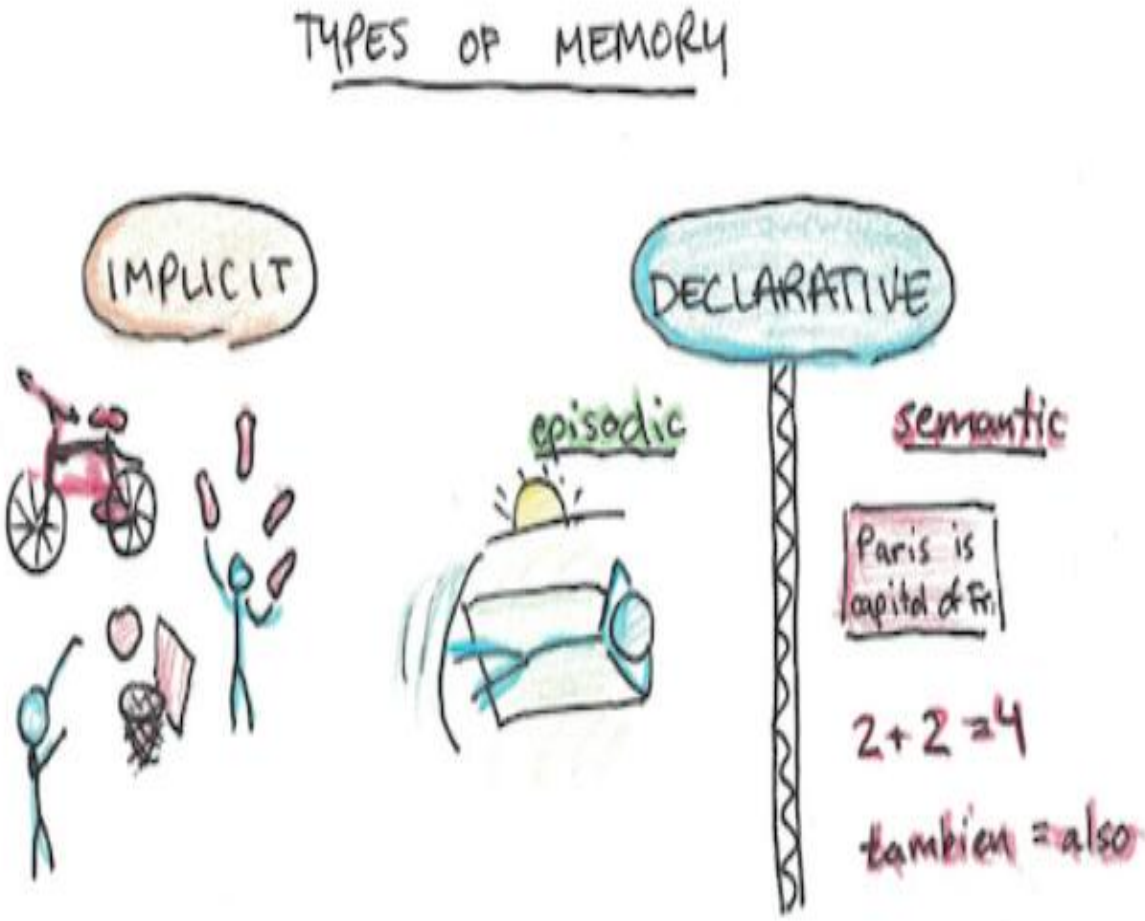
Memory impacts every facet of our lives. The first step to remembering things better is to understand how your memory works.



There are two basic kinds of memory - **retrospective and prospective.** Whereas retrospective memory is about remembering what happened in the past, prospective memory is about reminding yourself to do something in the future. Without prospective memory, you would not remember to go to work in the morning and you would forget to set your alarm clock in the evening.

One way to divide up retrospective memory is in the kinds of things it stores. A big difference here is

between implicit and declarative memory.



Implicit memory is essentially skill memory - the ability to do a task. If your implicit memory failed, you would not be able to brush your teeth, take a shower, drive your car or ride a bike. This kind of memory shows up in our abilities, but we can't always articulate what it is we know in words and concepts.

Declarative memory, in contrast, is either memory for facts and meaning (semantic) or memory for events (episodic). Without semantic memory, you would not understand the content of what your colleagues or friends were saying. Without episodic memory, you would struggle to recount your day later to someone else.

Another way to examine memory is based on its duration. Working memory (WM) manipulates and stores information for short periods of time. Talking with your colleagues, discussing a point at a meeting and planning your weekend would be entirely impossible without WM. In contrast, long-term memory (LTM) serves as a long-term storage of information. Almost all of our everyday activities depend on LTM, such as remembering our way home or how to drive a car.

Here's a quick recap of the different types of memory:

- Retrospective Memory

— Remembering the past

- …by Content

- Declarative / Explicit

- Semantic — Memory of facts and meaning

- Episodic — Experiences you've had

- …by Duration

• **Working Memory** - What you can "keep in mind" at the same time, to think, reason and solve problems.

• **Long-term Memory** - Anything you remember longer than a moment- what you ate for breakfast, exam questions or your friend's birthday.

• **Prospective Memory** — Reminding yourself to do something in the future

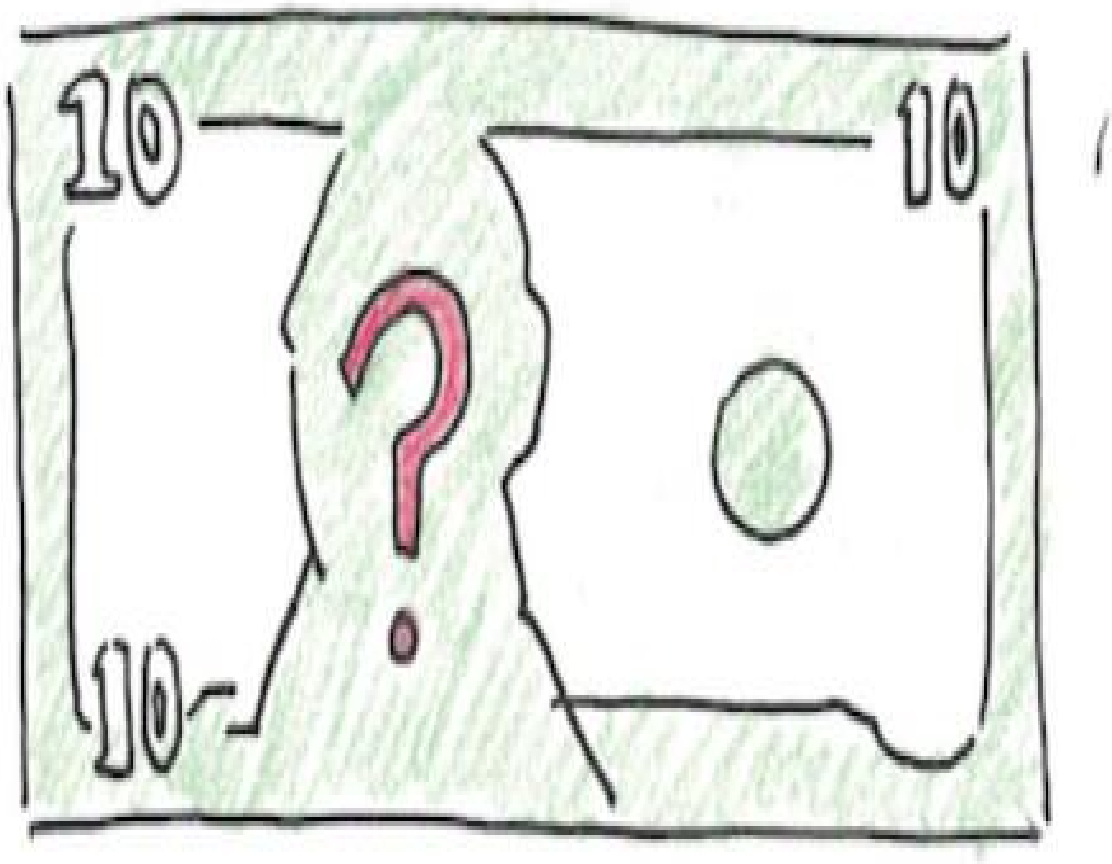
In this guide, we're going to focus mostly on declarative, semantic memories. This is covers most of the things you're trying to "remember", like facts, dates, names and ideas.

One quick thing before we get started. If you're interested in this stuff, you'll probably enjoy my weekly newsletter, devoted to the art of learning, productivity and getting more from life. If you sign-up below, I'll send you a free rapid-learning ebook:

Enter your email and hit "Submit" to get my best articles on learning and productivity!

The Three Parts Underlying All Your Memories

What does a ten-dollar bill look like (or a common banknote, if you're not American)? Do you think you'd be able to draw one? Although we see coins and banknotes on a regular basis and therefore have virtually limitless opportunities to learn their shape, few people could sketch one accurately. Looking at something repetitively does not guarantee that we will remember it later. Why can't we draw a ten-dollar bill, yet we could recognize it instantly if we saw one?

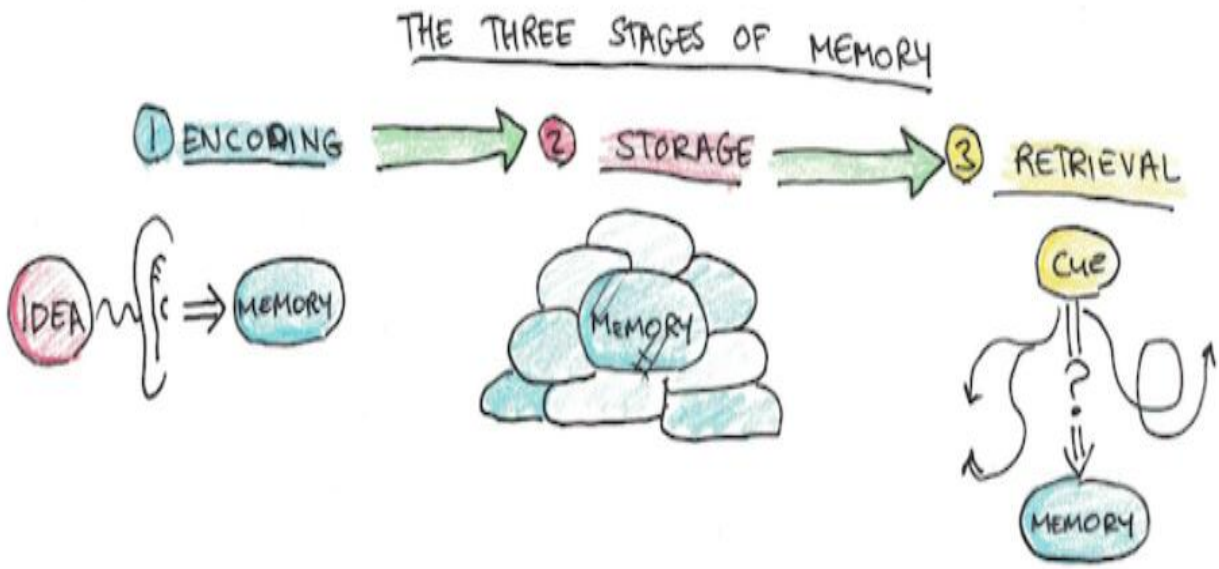


To unravel this mystery, we need to break the act of remembering things into its atomic parts. Those parts are:

1. **Encoding**—the process of putting the information into your brain.

2. **Storage**—the process of keeping the information in your brain.

3. **Retrieval**—the process of getting the information out of your brain when you need it.



Understanding these three functions is essential if you want to have a better memory. Any attempt to improve your memory must either encode the information better (or in a format you're more likely to retrieve), store the information better and longer, or retrieve it in the situation you need.

Let's look at all three and see how we might be able to improve our memories.

Encoding: Putting memories into the brain

Encoding is a process of imprinting information into the brain. Without proper encoding, there is nothing to store and attempting to retrieve the memory later will fail. One way to improve encoding is simply to repeat the information more times. Scientists who study memory call these repetitions “rehearsals” of the information.

However, as the case with the bank note illustrates, many rehearsals do not always mean you’ll successfully recall the information. What makes the difference between this case and the more familiar case of remembering your phone number because you’ve had to use it a lot?

When you were trying to memorize the phone number, you did not merely look at it repetitively. Instead, you deliberately tried to memorize it. You may have read it to yourself several times. Maybe you attempted to recall it from your memory, checked whether you were right and corrected yourself accordingly. Perhaps you

noticed that there were some relationships between different numbers (e.g. some numbers were the multiples or sums of preceding or following numbers). In summary, you employed certain cognitive strategies and processes. You still needed repetition, but repetition was effective only when used together with these strategies.

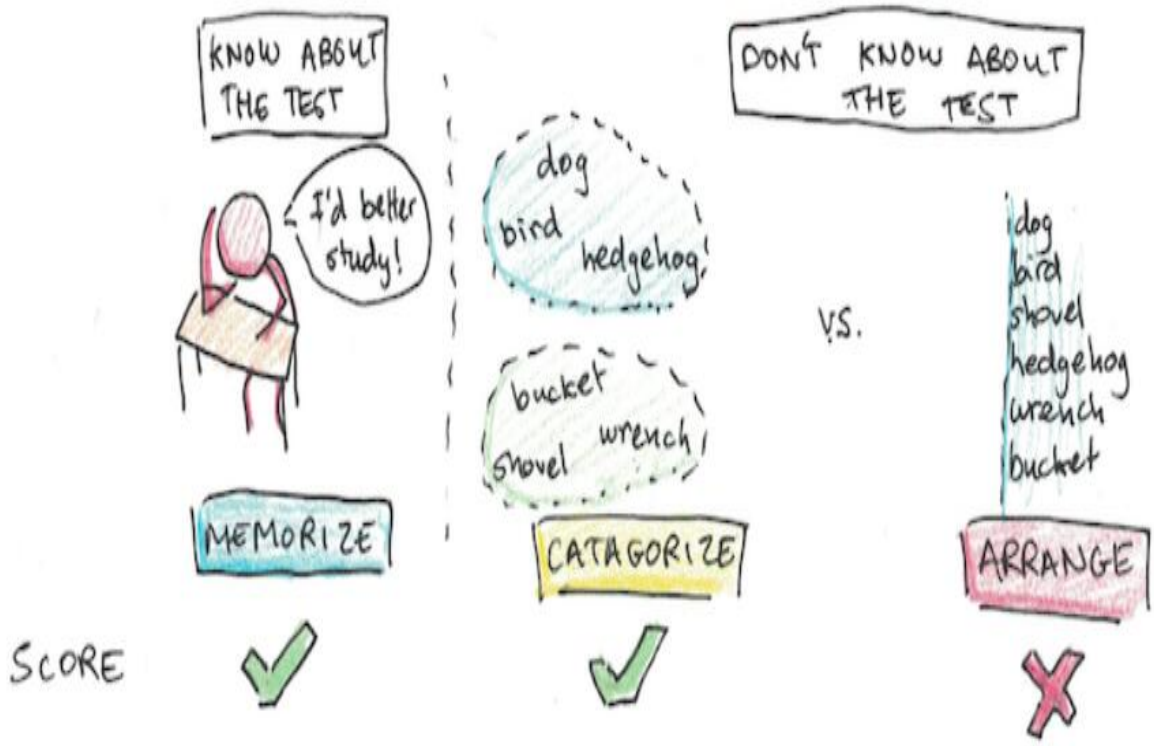
Similarly, if you want to have an effective memory, the cognitive strategies you use will make a big difference on your ability to remember things later.

What kind of encoding strategies are most effective?

Intention to learn: Does it matter how much you want to remember?

In an intriguing study, scientists asked students to study lists of words.[1] One group was explicitly told to memorize the words (with a warning that there would be a test later), whereas the other two groups were asked to either sort the words into categories or to simply arrange them into columns (unaware that there would be a test later).

One would expect that the students who deliberately studied the words would perform better than the categorizing and arranging groups, who did not make such effort. However, this was not the case. The categorizing and memorizing groups performed equally well in the test, whereas the arranging group performed worse than the other two groups.



Why didn't the students intention to learn make much difference?

In brief, the researchers found that the students who were told to memorize categorized the words in the same way as the students who were explicitly told to do so. By categorizing, the two groups effectively processed the words more deeply than the students who simply arranged them. As a result, they encoded the words more strongly than the arranging group and achieved better test results.

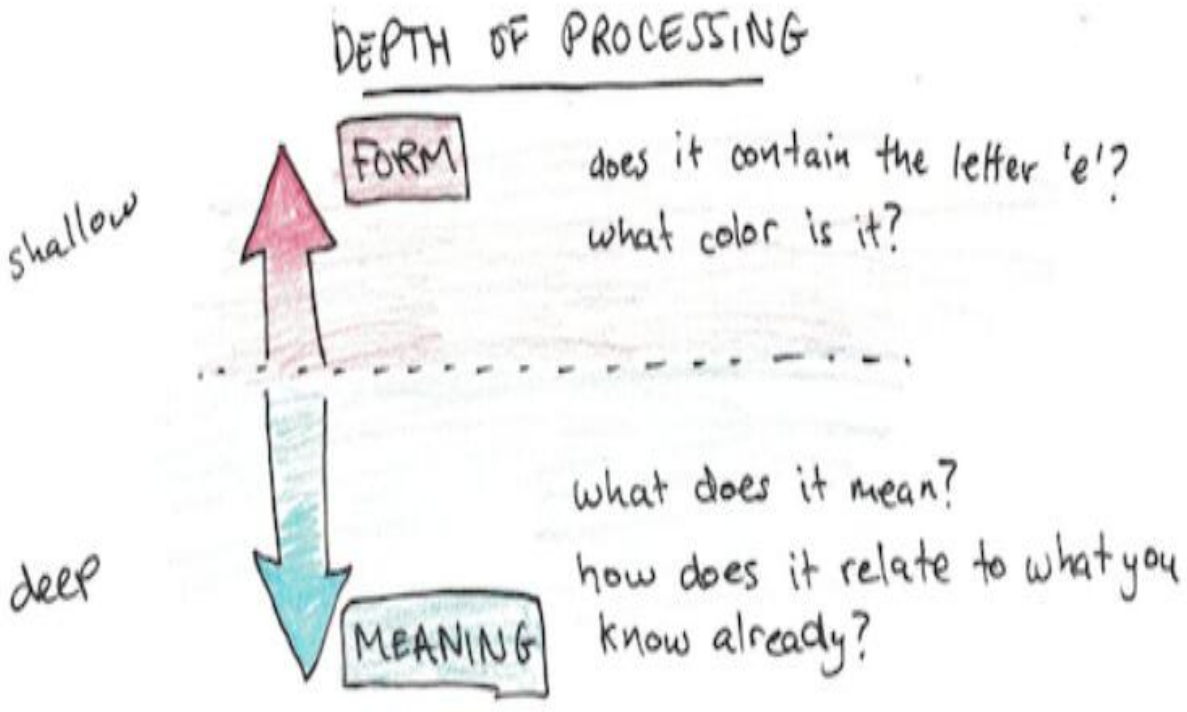
This experiment shows that the mere intention to learn something is not what makes you remember it later.

What matters is what you do with the material, i.e. what specific strategies you use to process it, rather than how much you want to memorize it.

Let us take a look at these strategies.

Depth of Processing: Why how you process information determines how much you'll remember later

Scientists believe that one of the critical factors determining the success of encoding is the depth of processing. The deeper you process the to-be-learnt information, the more likely it is to stick. What exactly is ' deep' processing?



In essence, deep processing focuses on the meaning of the information.

Try this demonstration:[2] Read the following list of words 3 times. After you have read the list, try to recall as many words as possible, minimizing your window or otherwise covering up the words on the screen:

cabbage, table, river, shirt, gun, square, iron, dentist, sparrow, mountain, hand, granite

How many words did you remember? Now try the same thing with another list:

pink, green, blue, purple, apple, cherry, lemon, plum, lion, zebra, cow, rabbit

How many words did you remember? Try it once more with the following list:

thread, pin, eye, sewing, sharp, point, prick, thimble, haystack, thorn, hurt, injection

How many words did you remember now? It is quite likely that you remembered most items from the second and third lists and the fewest items from the first list. As you may have noticed, the second list consists of items grouped into categories (color, fruit and

animal), whereas the third list contains items which are related to the word ‘ needle’. In contrast, the first list consists of completely unrelated items.

The reason why it was easier to memorize items from the latter two lists is that the items were meaningfully connected - they were subjectively (consciously or unconsciously) organized into a specific category or related to a common concept. Giving meaning to information is beneficial as it harnesses the process of spreading activation (which we’ll cover in the section on “Spreading activation”).

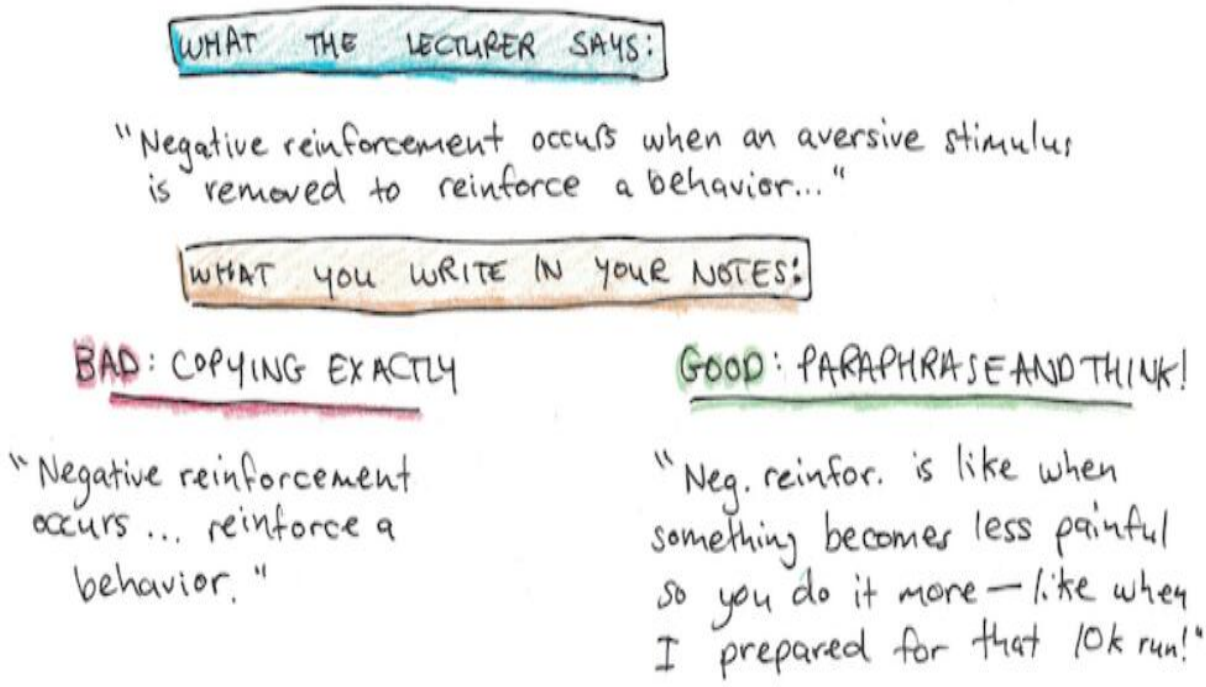
The main implication of this study is that structured information is much easier to encode to memory than disorganized information.[3]

Therefore, it is extremely useful to impose a good structure on your notes. The structure can take many different shapes - hierarchical, flow-based, mind-mapping or anything else that you find useful. What matters is that the particular technique helps you organize the study material in an easy, clear and understandable way. (we will cover these note-taking techniques in detail in a separate article on learning)

Categorization and structuring are not the only ways that you can give meaning to information. A powerful technique that substantially improves memorization is **self-explanation.**[4] Self-explanation simply consists of asking yourself questions about the study material as you study:

- **How does this concept related to the other?**
- **What are the implications of this concept for…?**
- **Why does it make sense that…?**
- **What are the steps that I must take to solve this problem?**

A very effective way to make yourself process information deeply is to explain the study material in your own words. If you are to explain a concept using different words than those used by the textbook or the lecturer, you firstly have to process and understand its meaning and logical connections with other concepts, which effectively boosts encoding by stimulating deep processing. This stands in stark contrast with the situation where you simply re-read the textbook or lecture notes, which constitutes only superficial processing and does not lead to effective encoding.



When taking notes, make sure that you do not copy the words of your textbook and lecturer verbatim. Instead, try to use your own words as much as possible. Researchers have shown that typing notes on a computer encourages copying information verbatim (even if students are explicitly instructed to use their own words), unlike writing notes by hand. As a consequence, students who take notes on a computer underperform in tests compared to students using handwriting.[5]

Our general recommendations are the following

• Take structured notes (whatever suits you best: hierarchical, flow-based, mind-maps, etc.)

- Do not memorize lecturer's or textbook phrases, explain concepts to yourself in your own words

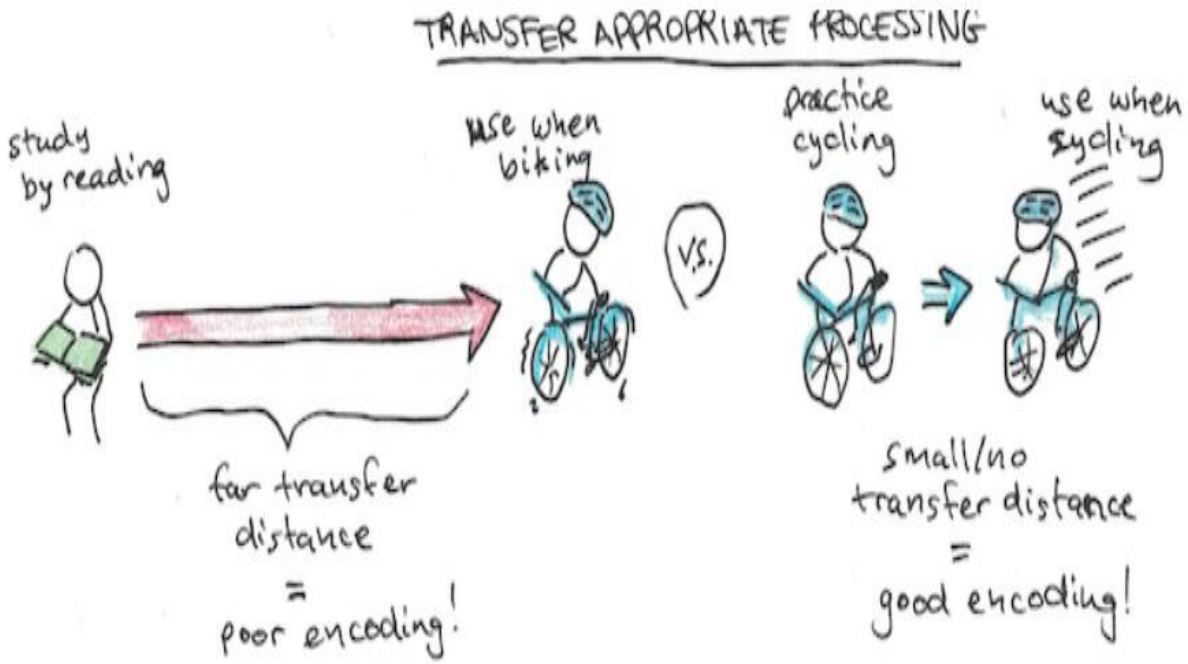
- When taking notes, avoid copying information word-for-word. Use your own phrasing instead.

- Avoid taking notes on a computer. Take handwritten notes instead.

Transfer-appropriate processing: The trick to acing your exams

Imagine yourself learning how to ride a bike. You could buy a 200-page long book on cycling and memorize everything perfectly. If you were to sit a written test, you would ace it.

Now imagine that you were to actually ride your bike. What do you think would happen? The chances are that you would crash as soon as you got on your bike.

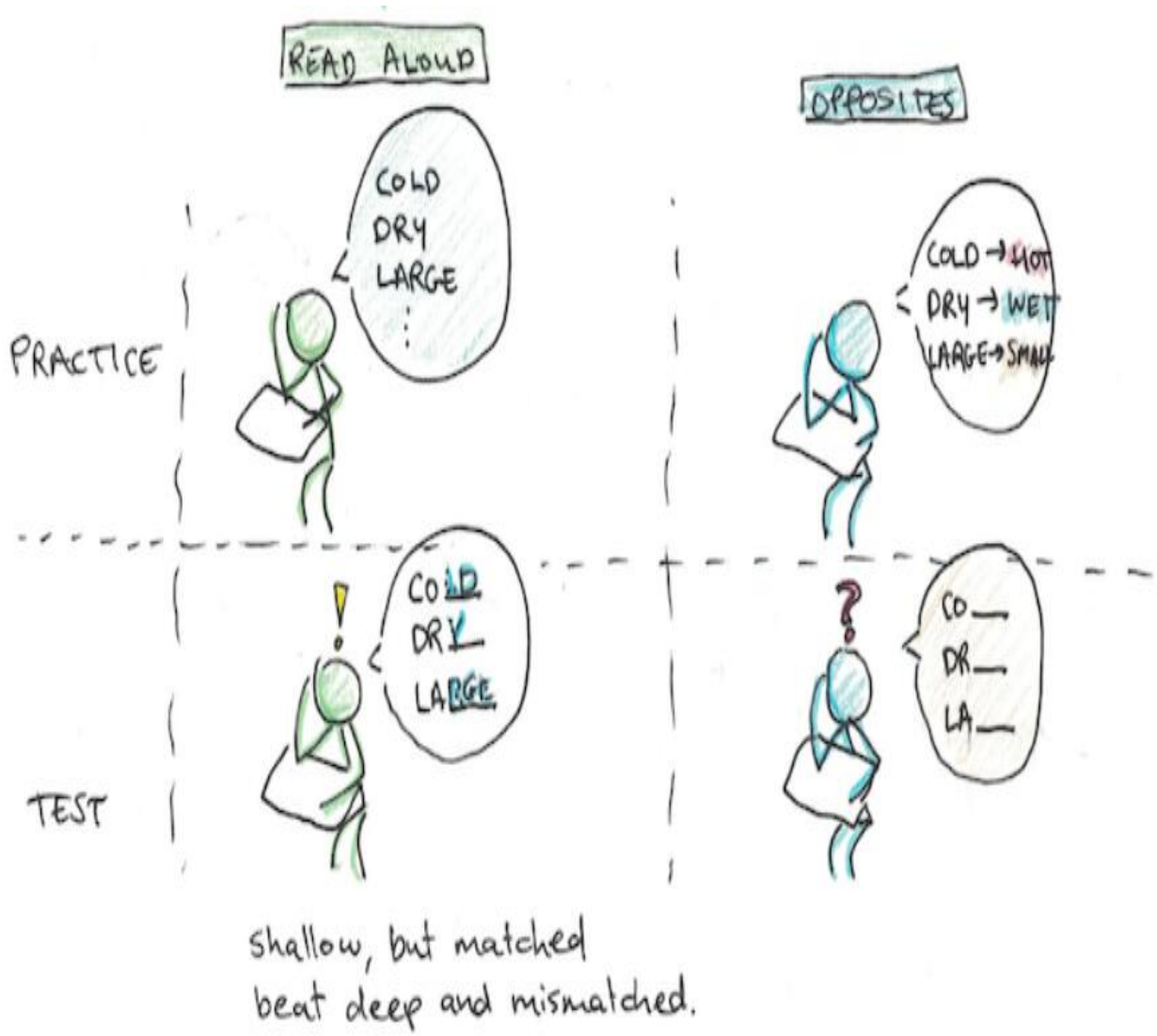


Although you knew everything you could about cycling, a key element was missing. The reason for the crash is that the cognitive processes used during during encoding did not match (=transfer appropriately to) the processes needed during retrieval. **To remember effectively, the processes used during practice need to correspond with the processes during use.**

As an illustration, consider the following study:[6]

Researchers asked students to either read aloud a list of words (superficial processing), or to generate these words from their antonyms (deep processing). The students were later asked which words they could remember (free-recall) or to fill in missing letters in words (fragment completion).

One would expect that the superficially-processing students would underperform in both tests (because deep processing is generally better than superficial processing - see previous section). However, this was the case only for the free-recall test. Surprisingly, in fragment completion, the superficial-processing group was better than the deep-processing group.



What could explain this surprising result?

The reading group processed the words perceptually, while the generating group processed them semantically – they had to retrieve from memory words with a particular meaning. Whereas perceptual processing matched the processing needed by the perceptual task, semantic processing matched the processing needed during

recall (note that words are stored in semantic memory based on their meaning).

The main implication of this study is that although deep processing is extremely beneficial for memory, it may not be enough to fully optimize your test performance. To further improve your results, it is important that you practice with similar processing that will be required during the test.

Think hard about how you will be tested on the information you need to remember. Will it be multiple choice tests? Essay questions? Applied in real life problems? Then make your practice match the situation where you use it. Mismatched practice is a major cause of poor memories- they simply aren't encoded in a way that is useful.

If your exam will consist of writing an essay, an excellent strategy is to do your reading with pre-reading questions.[7] Pre-reading questions force you look for arguments and evidence in order to answer the questions, which are precisely the processes that you will need during your essay-type exam.

However, it turns out that transfer-appropriate processing is only one consideration that matters for

memory. This is because some encoding strategies are generally better than others, regardless of whether they match the test format or not. In fact, one specific encoding strategy dominates almost all other strategies. This strategy is called “recall” and is discussed later.

In summary, if you are going to take a test of a particular format (such as an essay format), the best approach is to reap the benefits of multiple strategies. Whereas practicing with the final test format will teach you to processes the material in the way required by the test, recall will lead to most effective encoding. Therefore, ideally you should:

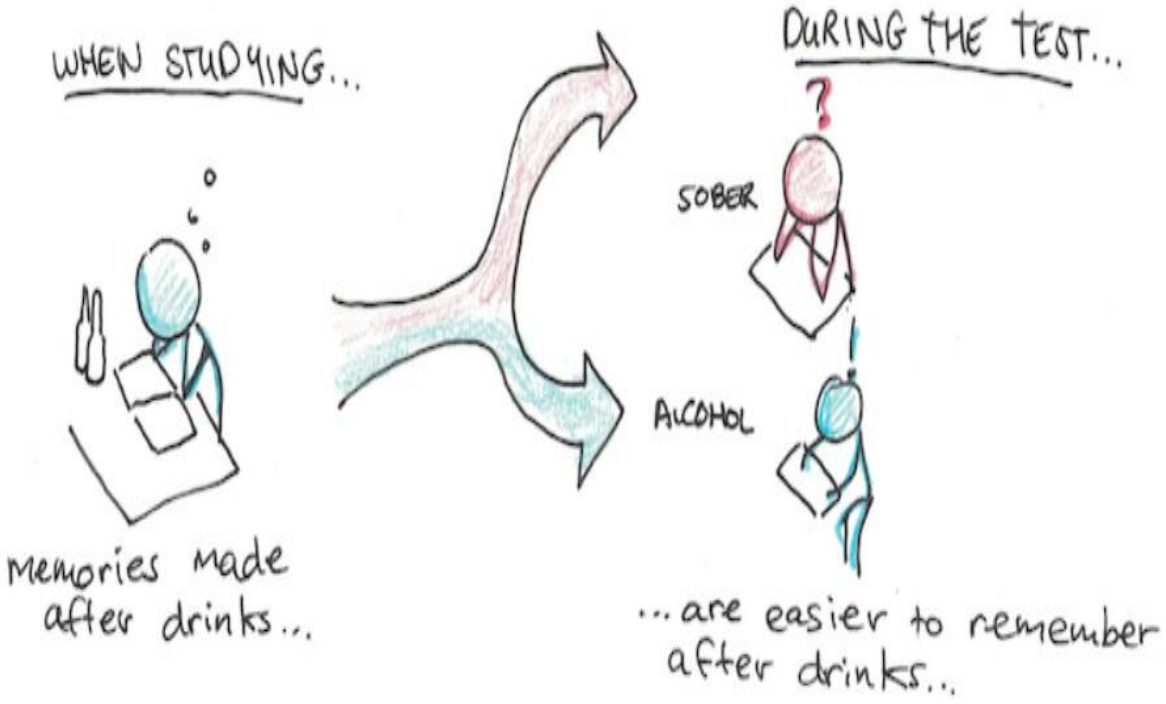
- Spend about 1/4 of your time practicing with the final test format (e.g. multiple choice)

- Spend the remaining 3/4 practicing with recall combined with deep-processing techniques

State-dependence: How your physical/mental states drive your memory

Imagine the following scenario: You have to prepare for tomorrow's test but your friend has a birthday party tonight. You decide to go to the party and end up having a few alcoholic drinks. When you come back home, you are quite drunk but you study for the test anyway. The next morning you go to school to sit the test. Would you be better off taking a shot or two of an alcoholic beverage before the test or is it a better idea to refrain from drinking any more alcohol?

Setting aside the fact that you would likely not be admitted to school in a drunk state, science has an astonishing answer: **In order to improve your performance, you should top up alcohol to approximately the same level you had during revision** (this was actually shown in a study[8]).



What could explain this surprising result?

Research has show that our memories are state-dependent. The more similar are our mental, physical and chemical states between encoding and retrieval, the more likely we are to successfully remember. Memory relies on a chemical process through which new connections (pathways) are formed and strengthened between neurons. If you study in a particular state, the memory trace is encoded with brain activity influenced by this state and becomes to some degree dependent on its reinstatement.

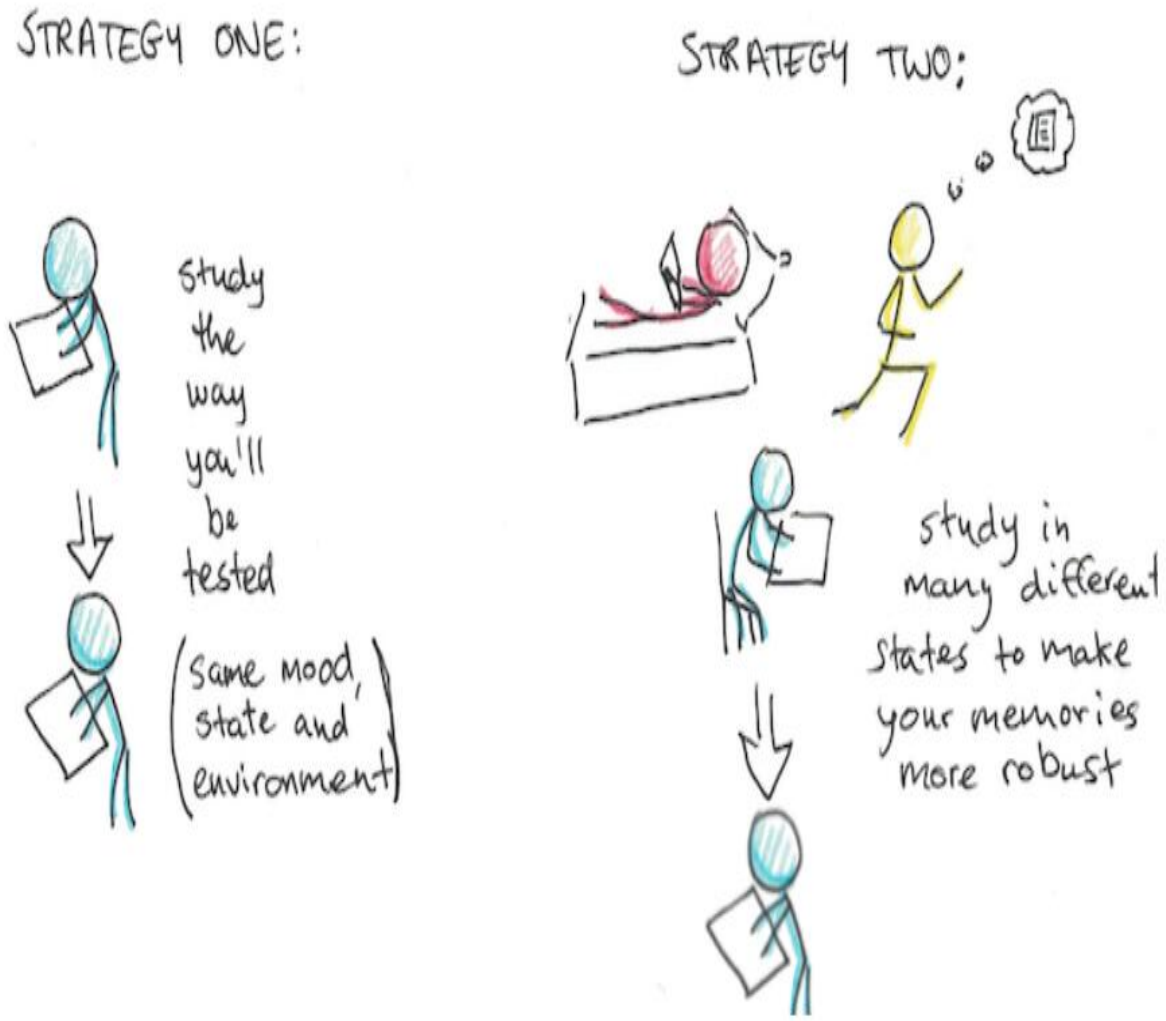
State-dependence of memory has been found for all kinds of drugs and medications, including nicotine[9], caffeine[10], cannabis[11], Ritalin[12] or anti-histamines[13]. If you are on medications such as Ritalin, it is therefore a good idea to keep the same dose during both revision and testing. If you cannot drink coffee or smoke cigarettes while you are taking a test, you had better avoid these drugs during revision as well. Moreover, it is important to realize that, the majority of drugs have well-known detrimental effects on memory, especially alcohol[14] and cannabis. You stand the best chance of passing your test if you both revise and take the test while you are sober.

State-dependence of memory applies to other states as well. If you study in a good mood, you are likely to perform better in a test if you are also in a good mood (and the same applies to other moods)[15]. Similarly, if you study while standing up/doing aerobic exercise, you are more likely to remember the material if you are also tested while standing up/doing aerobic exercise[16].

One approach to overcome state-dependence of memory is to try to study in the same state that you will be in during the exam. You could, for instance, revise sitting at a desk, while simulating stressful feelings (e.g. by

timing your answers), assuming that these conditions will be the same during the exam.

However, this is not always possible. An alternative approach is to study in various mental and physical states. The logic behind this is that you never know what kind state you will be in during your exam therefore it is best to make your memory independent of any particular states. For example, you could revise both when you have a lot of energy and when you are low on energy. Also, it is a good idea to study regardless of the mood you are currently in.



In summary:

• Spend at least 1/4 of your study time simulating the state you will likely be in during your exam (e.g. sit at a desk, time your answers)

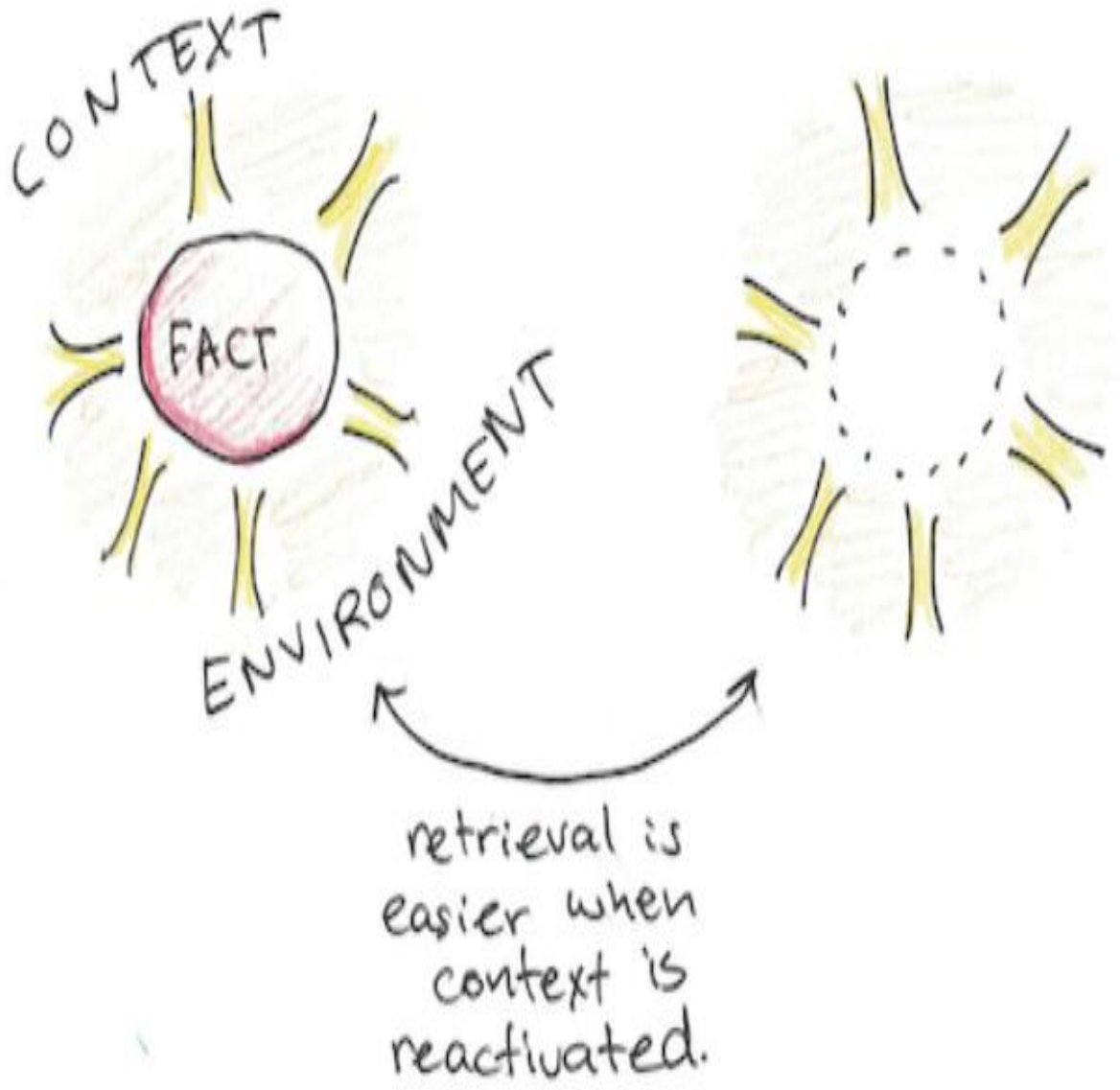
• Study regardless of your mental/physical state (in different moods, with different energy levels, etc.)

Context-dependence: Why your environment matters

Consider an everyday situation: You get up from your desk to have a cup of tea. Once you arrive in the kitchen, you forget what you wanted. However, when you get back to your desk, you suddenly remember.

Scientists have discovered that memories are heavily context-dependent. Context is essentially anything that is present during encoding (for instance the environment we are in). **Our brains seem to encode the context as a part of the memory trace as if taking a snapshot of everything that is around us at the moment of creating the memory.**

Successful retrieval of the memory trace then depends to some degree on the re-activation of the context in which it was encoded. Since the intention to have a cup of tea was encoded with the context of standing up from your desk, coming back to the kitchen re-activated the intention to have a cup of tea.



To combat context-dependence, you can adopt the same two approaches used for overcoming state-dependence. The first approach would be to emulate the environmental context of the test. For instance, you could revise in a quiet/noisy environment depending on where your exam will be situated. You may also consider revising

together with a friend or two to get used to being distracted by other people in the examination room. An even better idea would be to revise in the classroom where you will be taking the test.

The second approach would be to revise in as many different contexts as possible. Studies have shown that students who revise in many different rooms prior to their test perform better than those who study in one room only (with a 30% improvement in test performance) [17].

Since the environmental context keeps changing, the information effectively becomes context-independent. In other words, you teach yourself how to retrieve the studied material in any kind of circumstance, which is extremely useful given that fact that you often cannot predict the exact circumstances you will face during the exam.

The context of study need not be only environmental. The particular questions and practice tests you use also become the context that is encoded with your study material. Therefore, the more questions you practice on for a given concept, the more neural connections the brain has to generate between different contexts and the target concept. The more routes the brain has built, the

easier it is to retrieve the concept later. This is because retrieval becomes less dependent on the particular starting point - the type of question asked or its particular wording.

The impact of this kind of context-sensitivity is particularly important when creating flashcards. If the question side of your flashcard contains irrelevant information, or information that won't be present when you really need to remember, you may not be able to recall it when you need it.

Consider the following flashcards:

Q: How do you say "again" in Chinese, but only for actions that you will repeat in the future? Like asking someone to do repeat something they just said… A: 再

Compare that to:

Q: Again (future) A: 再

The former has so much more context, that you may memorize the pairing only with this context (which may be missing when you need to think about the term).

For this reason, it is better to either ask yourself questions with as little context as possible (and thus

maximum difficulty) or to ask many different questions, with different contexts, so the same context isn't required for successful retrieval.

In summary, we recommend the following:

- For 1/2 of your study time, simulate the environmental conditions of your test (a noisy/quiet environment, similar distractions, people around)

- For the other 1/2, alternate rooms, places and conditions as you study

- Test yourself with different kinds of practice questions

  - what-questions

  - why-questions

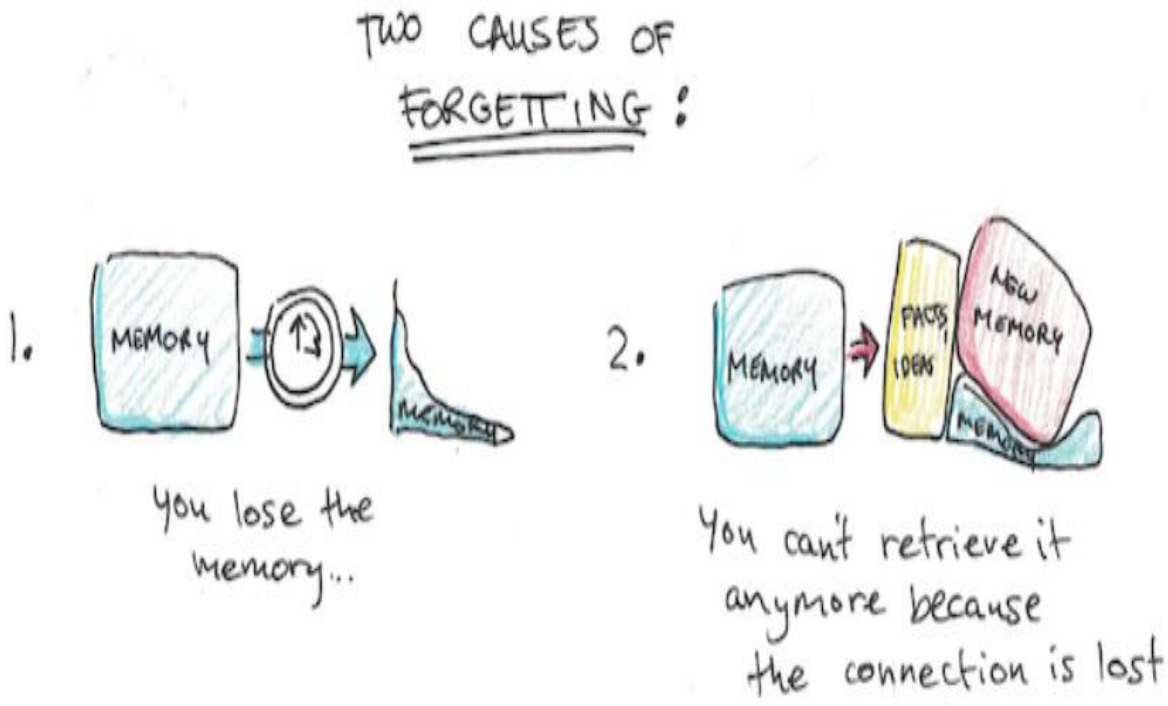
  - how-questions

- Make use of minimal context for flashcards, or if possible, try different ways of asking yourself questions to maximize your flexibility.

Storage: Keeping memories in the brain

Once you've encoded information, you now need to store it. Unfortunately, forgetting is a major part of how our brains work. Most of us can't remember what we had for dinner Tuesday, three weeks ago. However, we can all remember our first kiss.

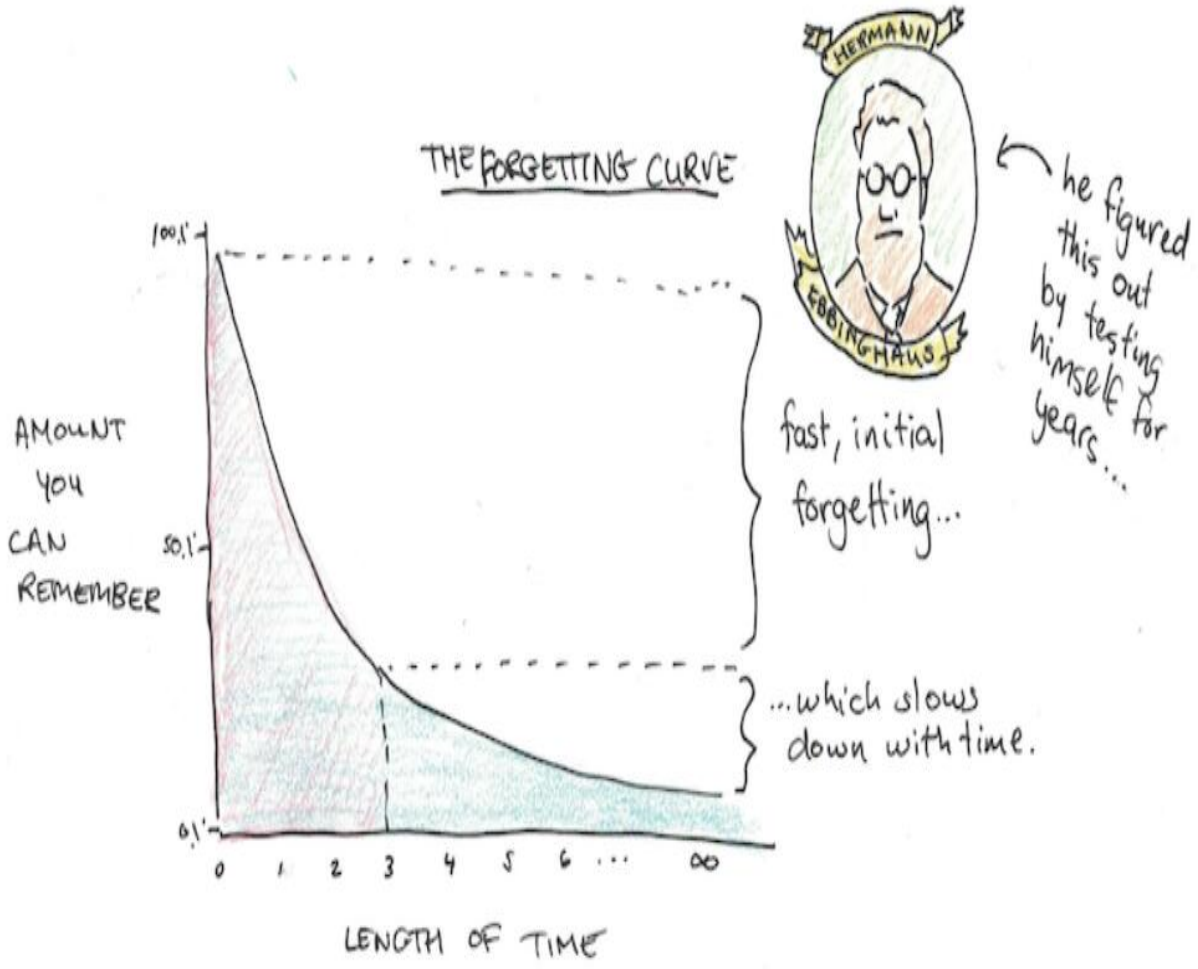
Forgetting can be caused by two different processes. The first is a **failure of storage**—the information might be forgotten because our brain loses it over time. The second is a **failure of retrieval**—the information might be "in" there, but we can't access it. Experimentally, it's very difficult to tell these two apart, but since they are separate processes, we'll consider each separately as we look at how memory works.



The progression of forgetting was originally studied by the famous experimental psychologist Hermann Ebbinghaus. Ebbinghaus discovered that forgetting follows an exponential decay function. Whereas in the first hours after study there is a rapid drop in the number of items successfully remembered, there is relatively little forgetting from the 2nd day onwards.

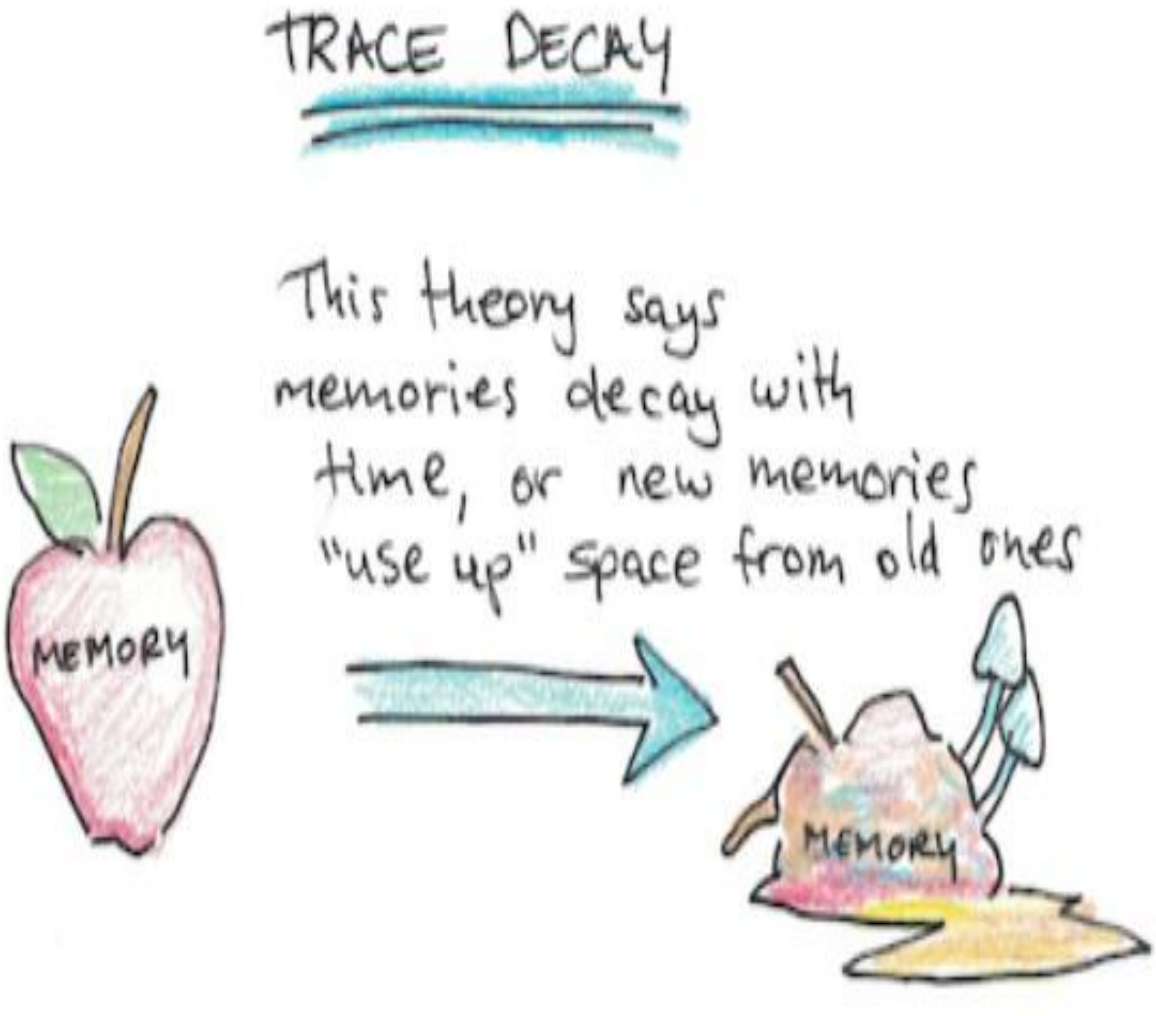
Although the exact shape of the forgetting curve is likely individual and depends on many factors related to the study material (e.g. how easy/difficult/interesting the material is or how well it was encoded), it approximates an exponential curve, with rapid forgetting

in the beginning and less forgetting in later periods of time.



Why do we forget information in the first place? What can we do counteract the process of forgetting?

Trace decay: Do your memories fade with time?



The most basic explanation of forgetting has to do with the passage of time. Our memory traces are stored in living tissue, which inevitably changes over time. It

is a well-known fact that connections between neurons deteriorate over time and as a consequence, the memory traces stored within these connections decay.

In addition, there is another possible cause for the decay of our memories. Surprisingly, making new memories may be part of the reason we forget. As new memories are formed, new neurons are produced in the hippocampus (the memory hub), which changes its structure and patterns of connections.[18] As a consequence, older memories are more difficult to retrieve.

Therefore, if you need to retain old information in memory (for a final exam for instance), it would be a good idea to revise it again while you are studying something new, otherwise the old information might be superseded by the new information.

We recommend that you establish a schedule of revision of the old material (even a couple of minutes every day should suffice) that is interspersed with the study of the new material. This is especially important if you study several different subjects/topics within one day because you memory cannot yet benefit from protective sleep-induced consolidation processes. There is another reason why studying new things can impair the

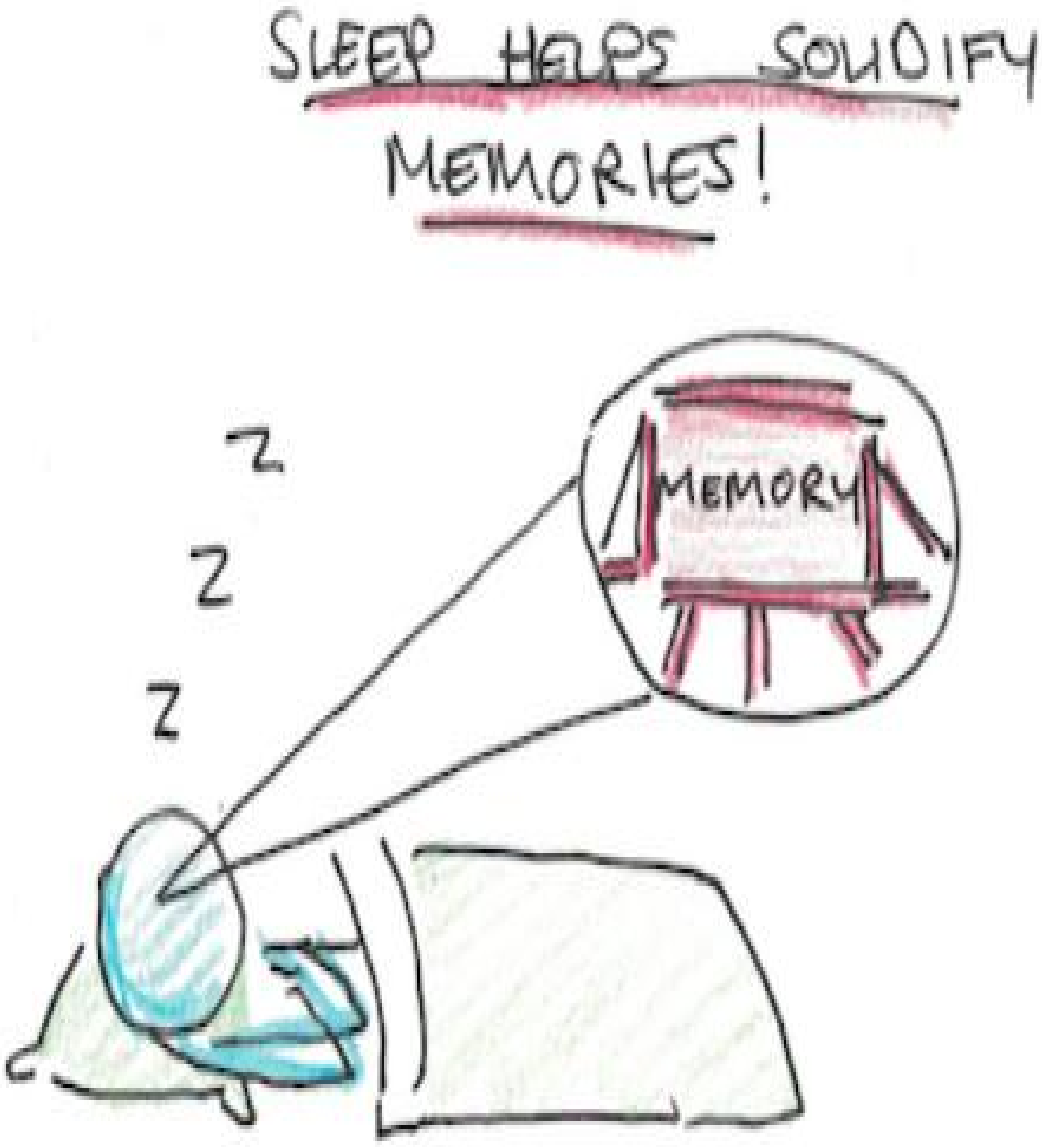
retrieval of old things and we discuss it in the section “interference”.

In summary, we recommend the following

- Spend about 1/10 of your study time revising old material

- Insert brief periods of revision of old material into the study of new material

Consolidation and sleep: Let biology do the work for you



Learning does not finish with the end of studying. For a memory trace to become permanently established in our long-term storage systems, structural biological changes must take place in brain tissue. New connections between neurons must be formed and firmly established.

These changes are not immediate and take time. In scientific terms, the mechanism through which recent memories become permanent memories is called ‘consolidation’. **Although some consolidation occurs during wakefulness, the primary time for consolidation is sleep.**

Have you ever studied for an exam through the night? If so, did you perform as well as in other exams for which you enjoyed a full night of undisturbed sleep? Probably not. Unsurprisingly, researchers have found that sleep deprivation impairs memory consolidation and undermines learning.[19] In fact, sleep deprivation (before or after learning) can worsen performance in a declarative memory test by as much as 20-50%[20], [21]. Moreover, prolonged sleep deprivation has permanent damaging effects on memory.[22]

On the other hand, you can use sleep as a powerful aid in-between your study sessions. You may have heard of ‘power naps’ - short periods of sleep used to

refresh energy. **There is now robust evidence to recommend naps.**[23] Napping during the day will protect your memory from trace decay (see section ‘ Trace decay’) and interference (see section “Interference”) due to sleep-induced consolidation processes. In other words, you will forget less of the subject studied than if you stayed awake for the same amount of time.

If you decide to give napping a try, it is important to be aware of the different stages of sleep. Napping for the maximum of 20 minutes is effective for restoring your energy, however, it is not enough to reach deeper stages of sleep during which consolidation occurs.

In order to boost your memory, you need to sleep for at least 60 minutes. However, napping for 60 minutes has the downside of leaving you in a groggy state for about 30 minutes afterward (because you wake up in the middle of deep sleep). Therefore, it is best to sleep for a full 90 minute cycle. After that, you will both feel refreshed and your memory will benefit from consolidation. Another good option that has been found to be effective is to schedule your study session to the evening right before sleep.

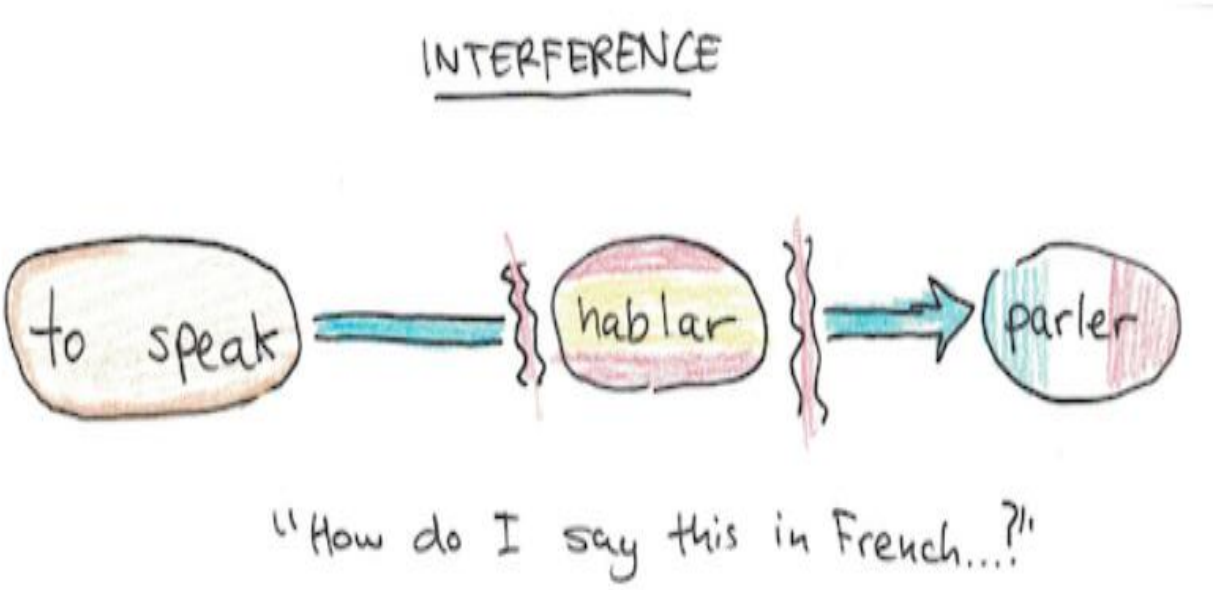
In summary, we recommend the following:

- Take a 20-minute nap to restore your energy.

- Take a 90-minute nap after a study session to consolidate your memory.

- Schedule your study sessions before sleep to reap the full benefits of consolidation.

Interference: Does learning new things block your old memories?



Do you remember what you had for dinner two weeks ago? Now choose your favorite trip from a couple of years ago. How much do you remember from that trip? The chances are that you do not remember what you had for dinner but you do remember something about your trip, although it took place much earlier than the meal.

This example shows that **forgetting is not simply memories decaying with time.** Our memories crucially depend on cues. A cue is essentially anything (such as a physical object, situation, time period, word, question, concept, etc.) which is paired with a memory trace and

which must be activated for the memory trace to be retrieved.

If we pair the same cues with multiple memory traces then it will be difficult to retrieve one particular trace because once the cue is activated, the activation will spread to all paired memory traces at once and these will compete for entry to consciousness.

Coming back to the example above, if you usually dine in the same place, many different meals will become associated with the same cues (the dining environment). Therefore, it will be hard to retrieve the specific meal that you enjoyed a week ago. In contrast, you probably have not been on the same trip many times before, therefore it is easier to remember its details because they context of the trip is not paired with any other memories.

The disruption of memories by other memories which are paired to the same cues is called “interference”. You may have experienced interference yourself if you ever studied a second language. Interference may have caused you to be unable to retrieve vocabulary from one language. Instead, vocabulary from the other language popped to your mind. In this case, interference did not

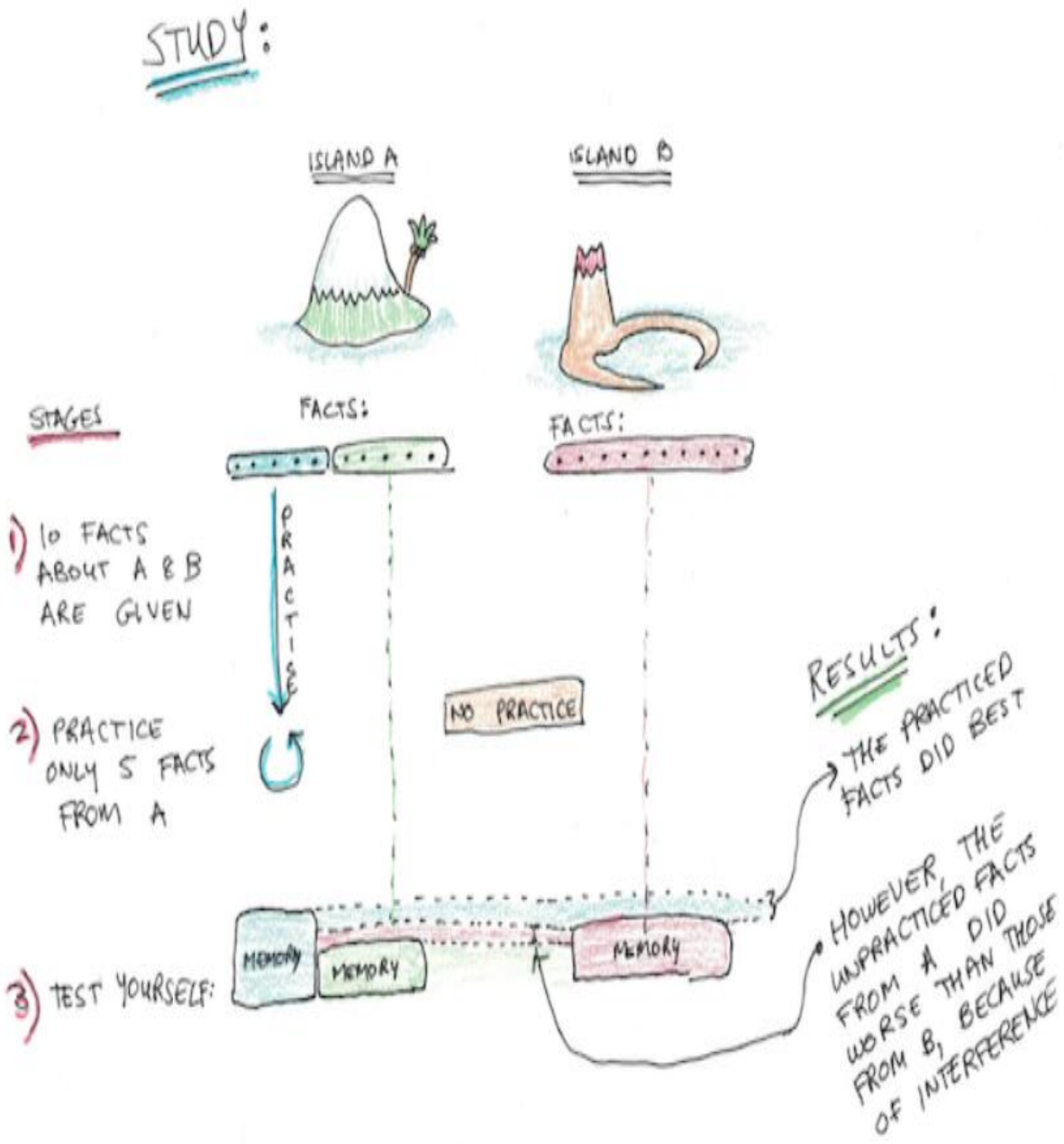
necessarily cause a loss of memory, but the memory trace became blocked thus temporarily inaccessible.

Research has found that the only way to overcome blocking interference is by making conscious effort to recover the correct memory trace (and have patience as this may take some time). Interference may, however, also cause a permanent loss of memory. Scientists who study memory call this the retrieval-induced forgetting effect (RIF).

As a demonstration, consider the following experiment: Students studied 10 geographical facts about each of 2 islands (A and B).[24] They subsequently practiced retrieving 5 out of 10 facts for island A. Afterwards, their knowledge of these facts was tested.

What do you think happened to students' memory about island A?

Unsurprisingly, retrieval practice boosted retention for the 5 facts that were practiced (the percentage of correct answers was greater than for island B). However, it also worsened the memory for the 5 facts about island A that were not practiced (again compared to island B). What caused this effect?



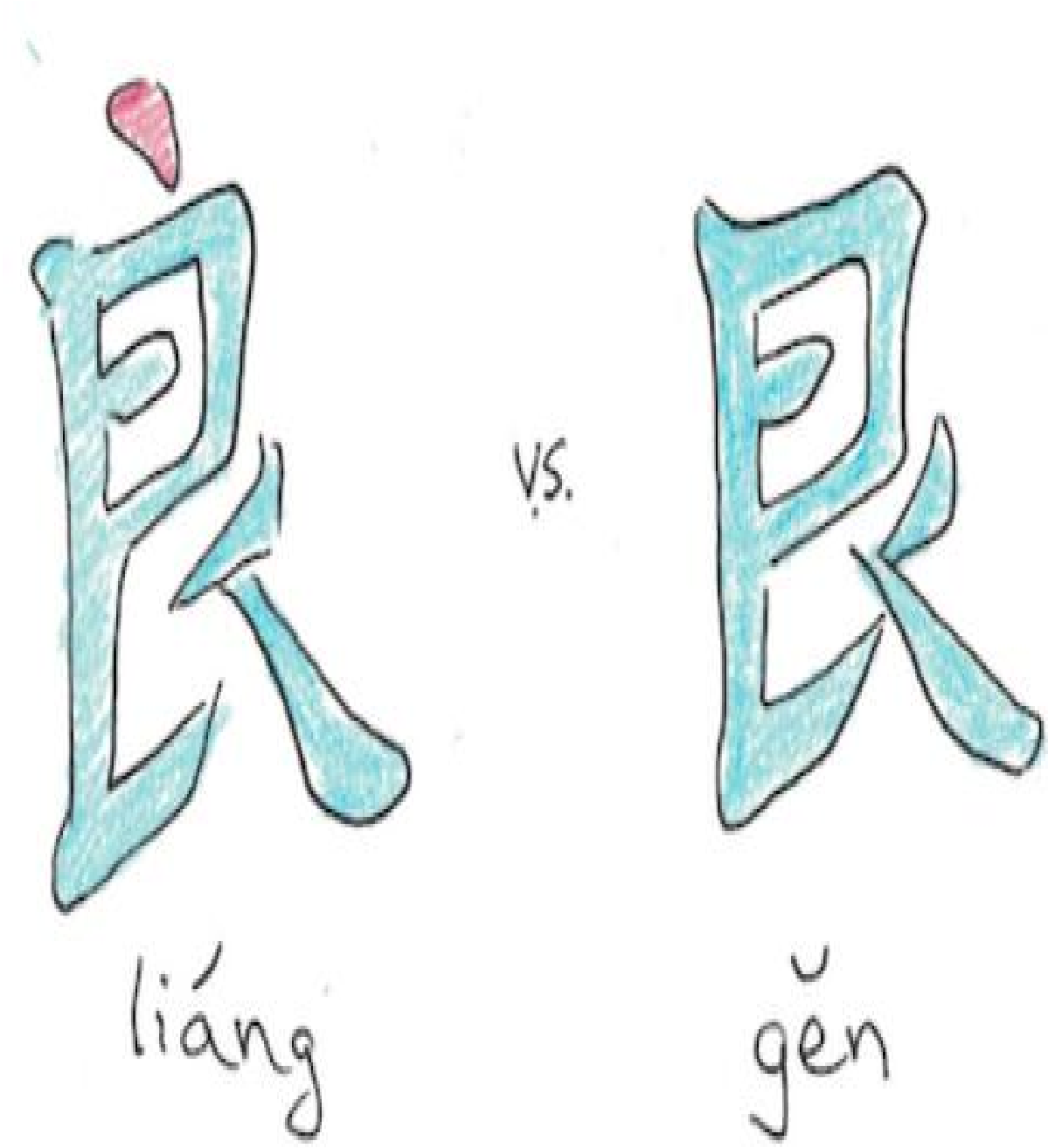
The island A serves as the context cue for information about island A, whereas island B serves as the context cue for information about island B. When the 5 facts about island A were retrieved from memory, their connection with the context cue was strengthened and the

connection of the remaining 5 facts with the context cue was weakened (see "Testing effect").

The main implication of this study for learning is that selective practice testing substantially boosts performance for the practiced items but can also worsen the performance for the unpracticed items. How can we combat forgetting caused by interference?

One way we can overcome interference is by making it explicit. If there are concepts that you get mixed up frequently then put them side by side and re-study them at the same time.

The general idea is that whatever you are studying, it is good practice to make different concepts as distinctive as possible.[25] This forces your brain to encode them as dissimilar memory traces. You can achieve this by stressing the differences between different concepts from your study material (by comparing and contrasting, for instance).



Another effective strategy is to integrate the concepts.[26] For instance, if you are memorizing the members of a particular animal/plant family, then try to find all possible relations between the members. When you're later retrieving these members, they will no

longer compete for access to consciousness as they will be encoded closely together in an integrative manner. Instead of one concept blocking the other, they will be retrieved simultaneously.

Scientists have found that our study goals also impact on how well we overcome interference.[27] Students who focus on comparative performance (how well they do compared to other students) tend to use superficial processing (do not look for relations among concepts), whereas students who aim for mastery tend to use more deeper processing, such as establishing connections between different concepts.

In summary, we recommend the following:

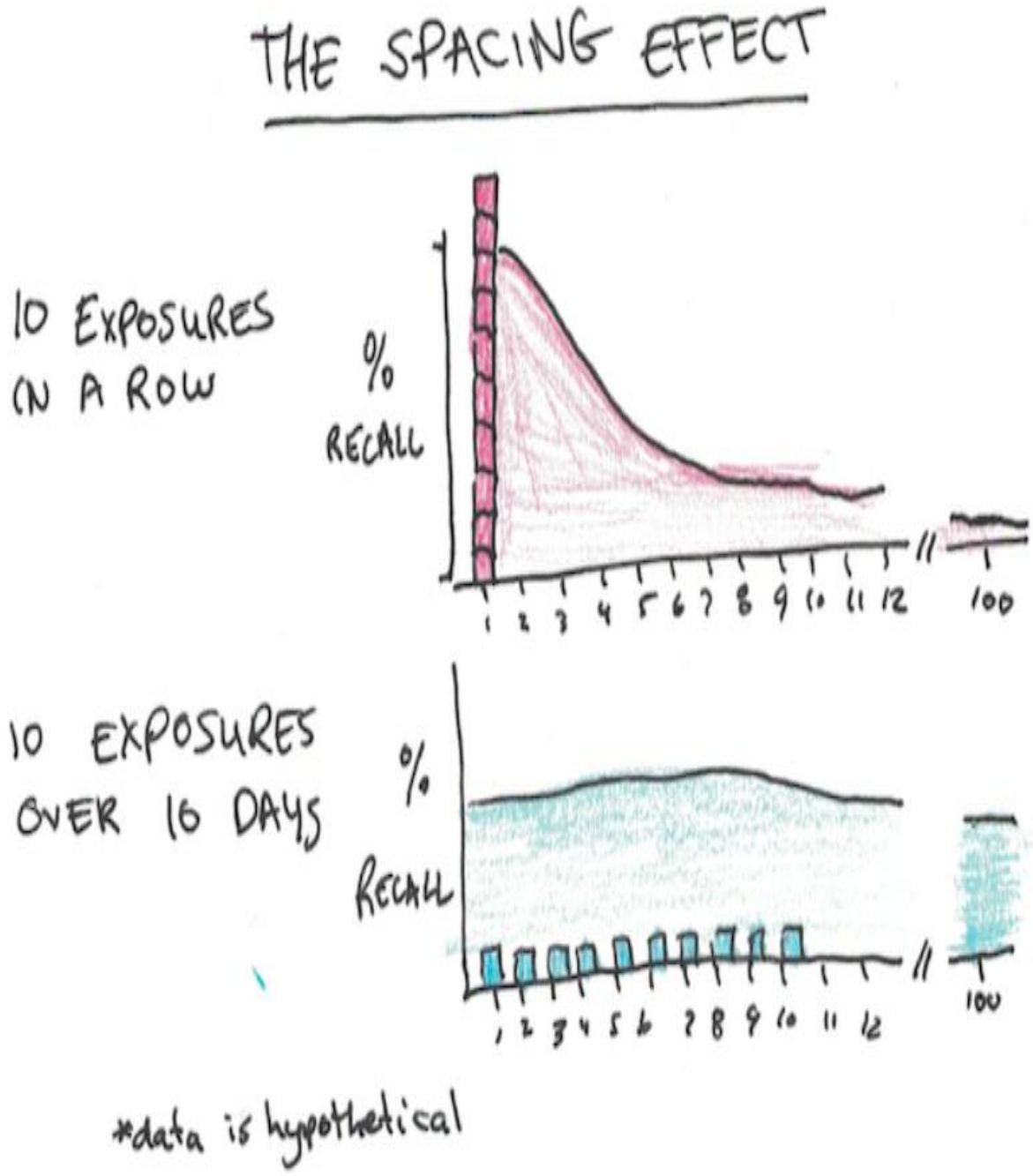
• Re-study concepts that you confuse

- Use comparing and contrasting to find differences between the concepts

- Integrate the concepts (find the relations between them)

• Aim for mastery in a subject, do not pay attention to other people's performance

Spacing effect: Study less, remember more



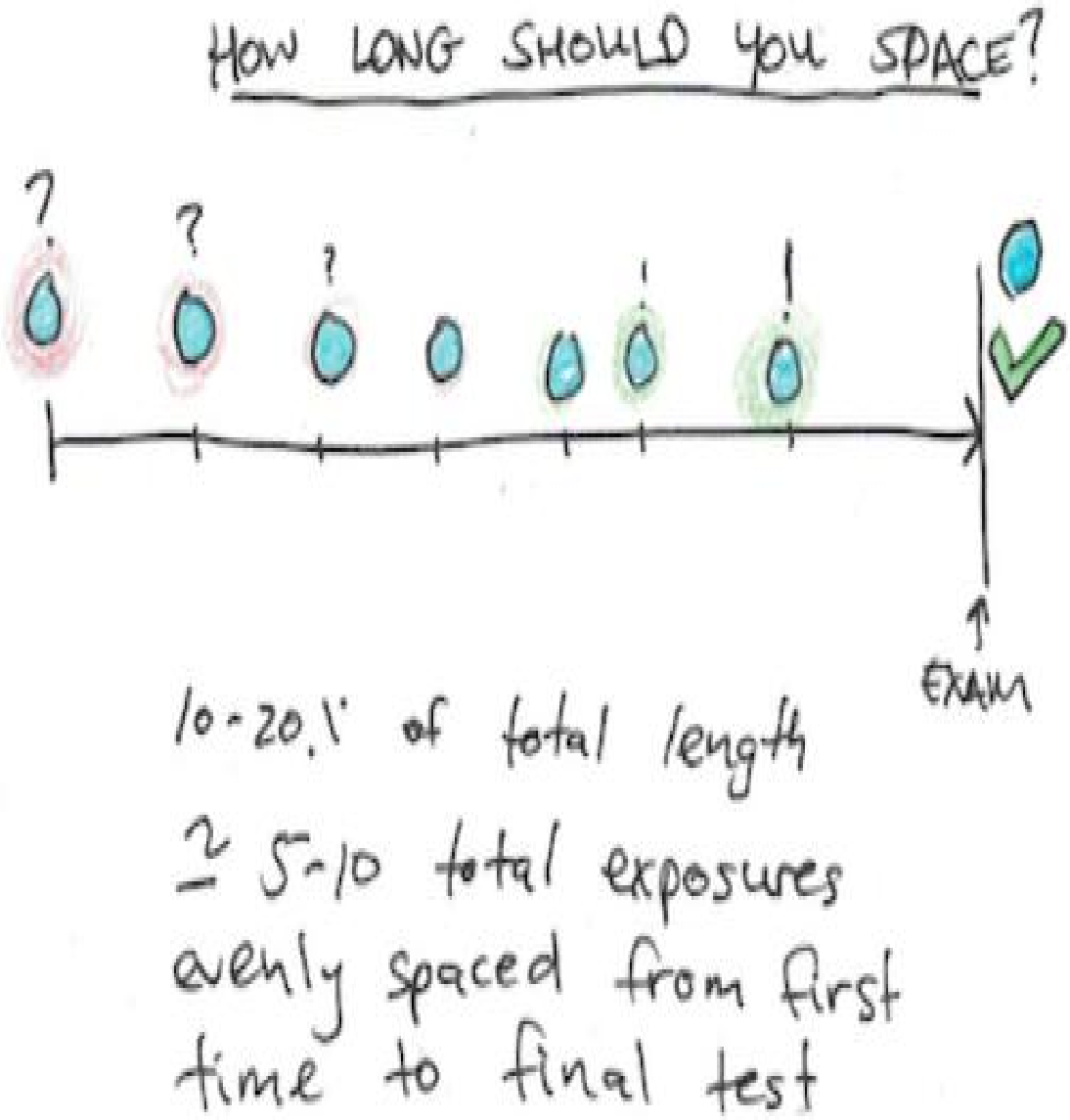
The spacing effect is undoubtedly one the most important discoveries in the science of memory. The general idea of spacing is that to achieve the same performance at a given test, you need substantially less time overall to memorize something if you spread your study into multiple sessions as opposed to if you study everything in a single session. As a demonstration, consider an experiment that the famous psychologist Hermann Ebbinghaus performed on himself: [28]

Ebbinghaus studied 2 lists of words on two following days. On the first day, he spent 1 minute studying list A and 7.5 minutes studying list B. On the second day, he had to spend another 20 minutes on list A to memorize it perfectly. However, he needed only 7.5 extra minutes to memorize list B.

By spacing the sessions more equally for list B, Ebbinghaus managed to save himself about ¼ of total time spent on studying. In a similar way, if it takes you 3 hours in a row to prepare for a test, you may need less than 2 hours in total if you divide the time into 2 or 3 equally-sized sessions spread across several days.

In general, the more you spread your sessions, the less overall time you will need. Scientists recommend that the spacing distance should be about 10-20% of the

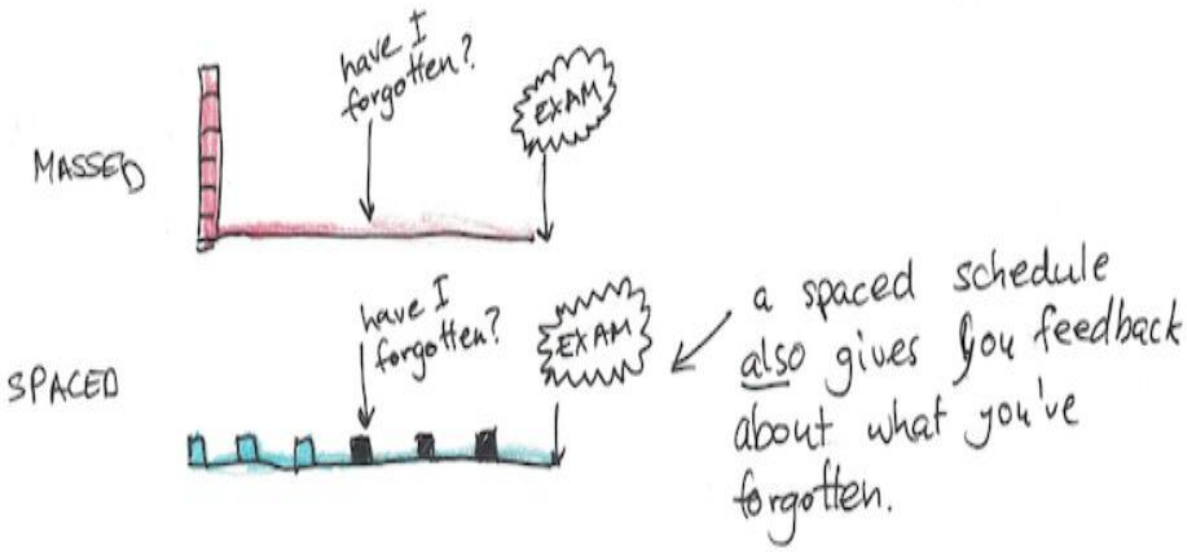
test delay.[29] If your test is in 10 days, you will benefit most from studying once a day. If your test is in 6 months, you should study every 20 days.



Spacing not only substantially saves time, it also boosts long-term retention. Each study session that is

followed by immediate or delayed sleep provides another opportunity to consolidate the studied material (we cover consolidation processes above). Furthermore, spacing can give you more opportunities to associate the study material with more states and contexts (physical, mental, environmental), which makes it easier to retrieve it in the future (see state-dependence and context-dependence).

Most importantly, spacing effectively reveals to your brain that forgetting is taking place - a crucial signal that is not available in massed practice (= if you study for many hours within a single session). The signal of forgetting has been found to automatically encourage more effective encoding strategies in students. [30]



The spacing effect is a robust phenomenon in psychology and is extremely effective for a wide range of study materials (including foreign language vocabulary, math problems, spatial information).[31]

The key idea behind spaced repetition is that revision of a particular concept should be done right before the concept is about to be forgotten in order to achieve maximum time-efficiency and length of retention. As there is no formula that could calculate this exactly, you need to experiment with yourself. For practical reasons, it is probably best to use a specialized software that uses a spacing algorithm.

Although there is currently no comparison of the effectiveness of different spaced-repetition algorithms, popular choices include Anki, Quizlet or Supermemo. We recommend that you experiment with a program that is free on most platforms, explicitly states the algorithm used and allows you to tweak it (our favorite pick is Anki).

Bear in mind that the spacing effect does not continue indefinitely. For example, ten 1-minute sessions will likely not be better than one 10-minute session. This is because starting each learning sessions carries some costs with it (you have to start to focus,

‘load’ the material into working memory, etc.). For this reason, complex subjects may require longer study sessions for learning to be effective. For instance, it may be better to have three 1-hour sessions per week for your engineering class than six 30-minute sessions. It all depends on the subject studied.

In summary, we recommend the following:

- Avoid massed studying (i.e. many hours in one session)

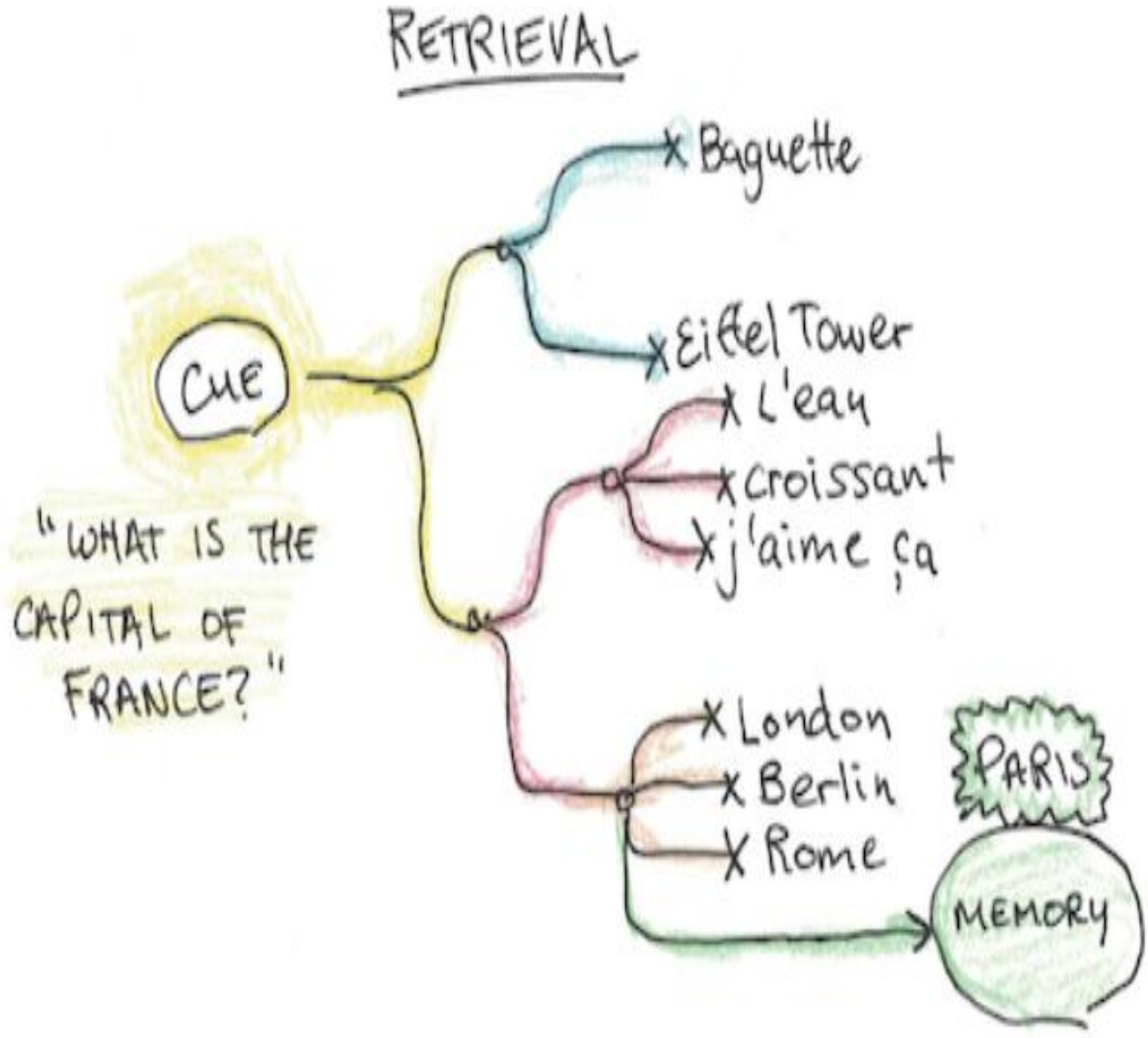
- Divide your study sessions into smaller blocks spread out over longer periods of time

- The distance between study sessions should be about 10-20% of the test delay (e.g. for a test in 10 days, study once a day)

- Schedule your revision of each concept/topic to about the time that you would forget it (this needs self-experimentation as there is no formula to calculate this precisely)

- Consider using a flashcards program (Anki, Quizlet, Supermemo)

Retrieval: Accessing Memories in Your Brain



Retrieval is the mechanism of accessing information stored in memory. Successful retrieval of a memory trace

hinges on its associations with cues. A cue is anything that is connected to the memory trace (physical object, situation, time period, word, question). Scientists believe that memories are retrieved through the process of ‘ spreading activation’. Once a cue is activated in the brain, the activation spreads from the cue to the target memory. A single memory trace can be connected to an infinite number of cues. If none of the relevant cues is activated, the memory trace cannot be retrieved, even though it may be well stored in memory.

As an example, try to remember the capitals of the following countries while covering the rest of the page:

- South Korea
- Syria
- Denmark
- Colombia
- Afghanistan
- Thailand
- Venezuela
- Turkey

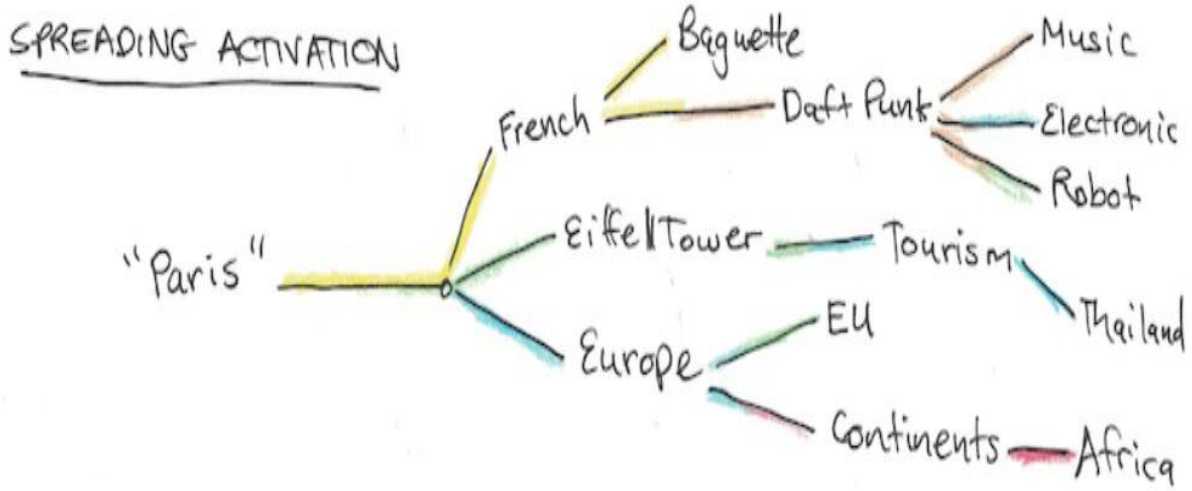
Could you remember all of the capitals? Do you feel that you know their names and may be able to remember them later? You may be experiencing the tip-of-the-tongue phenomenon: you know that you know something but still can't remember it. Now try the same exercise with a little help:

- South Korea S
- Syria D
- Denmark C
- Colombia B
- Afghanistan K
- Thailand B
- Venezuela C
- Turkey A

Did you remember all of them now? You most likely remembered more of them. This is because the starting letter functions as a suitable cue that is connected to the capital's name. When the cue is provided, the memory trace storing the capital's name becomes automatically activated.

How does the process of retrieval function and what are its implications for learning? What can we do to maximize our chances of successfully retrieving information?

Spreading activation: Gain quick access to your memory

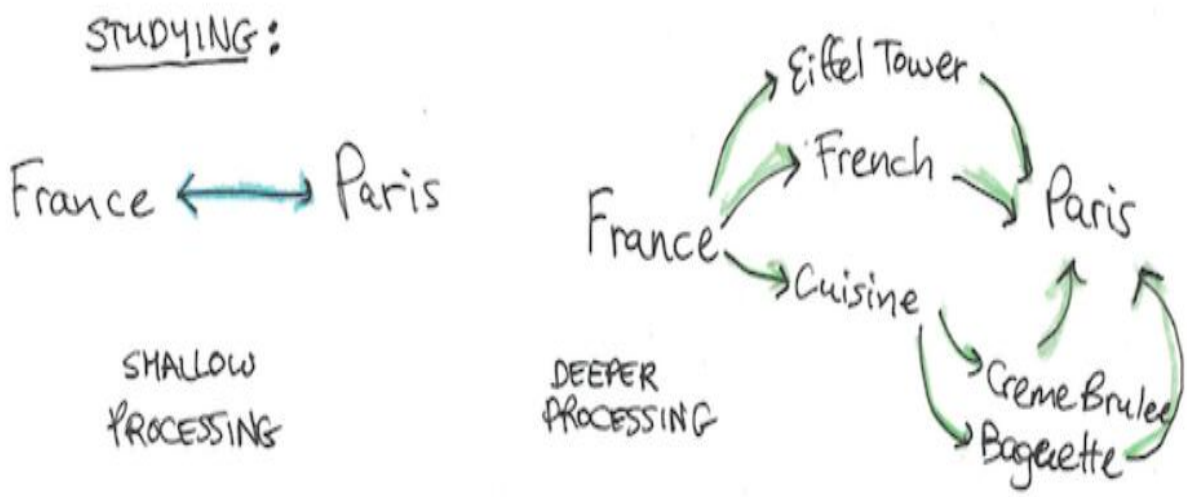


Imagine that you are preparing for a test on all capital cities in the world (given a country, you have to state the capital). If you used the most basic learning strategy, you would simply learn to match each country with its corresponding capital. Alternatively, you could look at pictures taken from these capitals, maybe watch short videos of people speaking the country's language, visiting the capital sights and so on.

Which strategy would be more effective?

The first strategy would be called ‘ shallow’ processing because you would not be giving the information any additional meaning. You would be making only one connection between the cues (countries) and the target memories (cities). The second strategy would be called ‘ deep’ processing as you would be drawing many connections - between the capital, the country, its people and its sights, and so on.

If you adopted the second strategy, you would be making use of the structure of your memory. Memory is believed to operate on the principle of spreading activation.[32] If you encounter one concept (a country), the neural pathways representing this concept are activated in your brain. As a consequence, nearby neural pathways encoding closely related concepts are also activated. Images and ideas come to your mind. For instance, when someone says France, you may visualize the French flag, the Eiffel tower, French wine, cheese, etc. This process continues to further and further concepts until you start thinking about something else.



If you previously connected these images with both France and Paris, the cue France will activate additional related cues (Eiffel tower, wine, cheese, etc.) and together they will generate more activation than France alone, which spreads to the connected memory trace – Paris. Conversely, if you studied the France-Paris pairing superficially, seeing the word France might not generate sufficient activation on its own to trigger the memory trace of Paris.

The main implication of spreading-activation is that in order to maximize the chances of remembering new concepts, **you should try to make as many connections as possible between the new concepts and what you already know.** If the target concept is connected to many other concepts, the chances of it getting activated

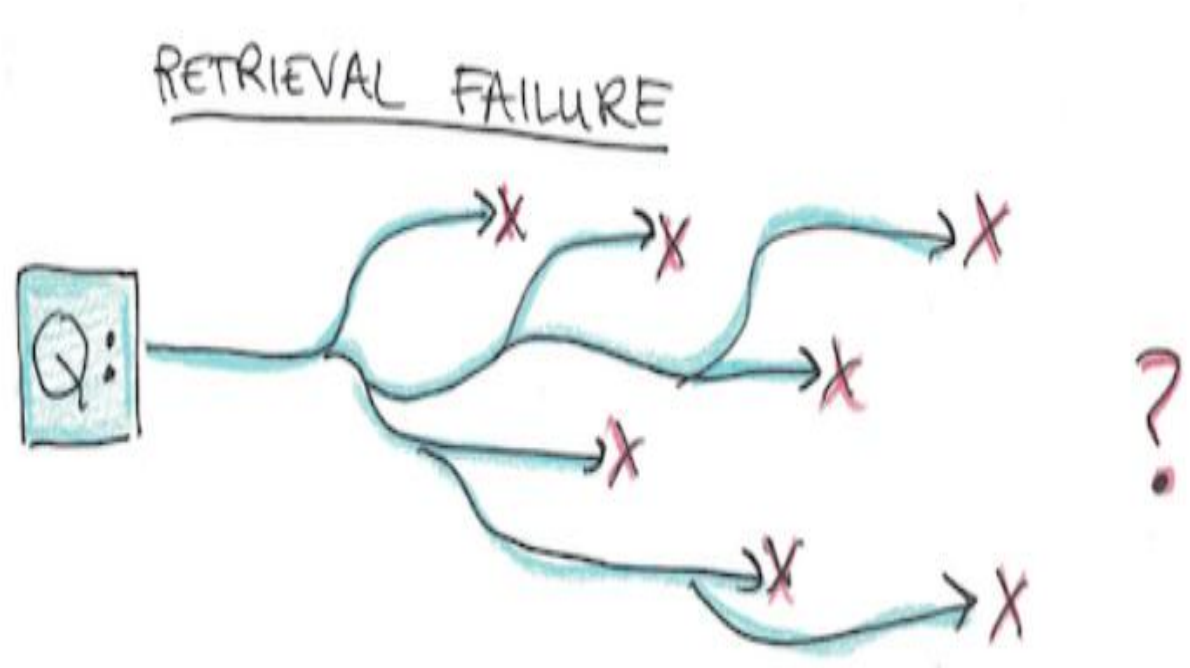
(and retrieved) are generally much higher than if it only has few connections.

In summary, we recommend the following:

- When learning a new concept, connect it to the things that you already know

- The more connections you make between the new concept and old concepts, the more easily it will be to remember the new concept

Retrieval failure: What to do if you get stuck in an exam



Retrieval failure or the failure to remember a memory trace can have multiple reasons. One reason can be a lack of attention during study. Researchers have found that students who do a secondary task while studying underperform in a later test by as much as 30-50% compared to students who focus on one thing at a time.[33] These results suggest that multi-tasking - doing of many activities at once - is particularly harmful to learning.

Another reason for retrieval failure is an insufficient number of activated cues. Cues are pieces of information which are connected to the target memory trace and which must be activated for the memory trace to be retrieved (for more more detailed explanation of context cues, see sections on Retrieval and Interference).

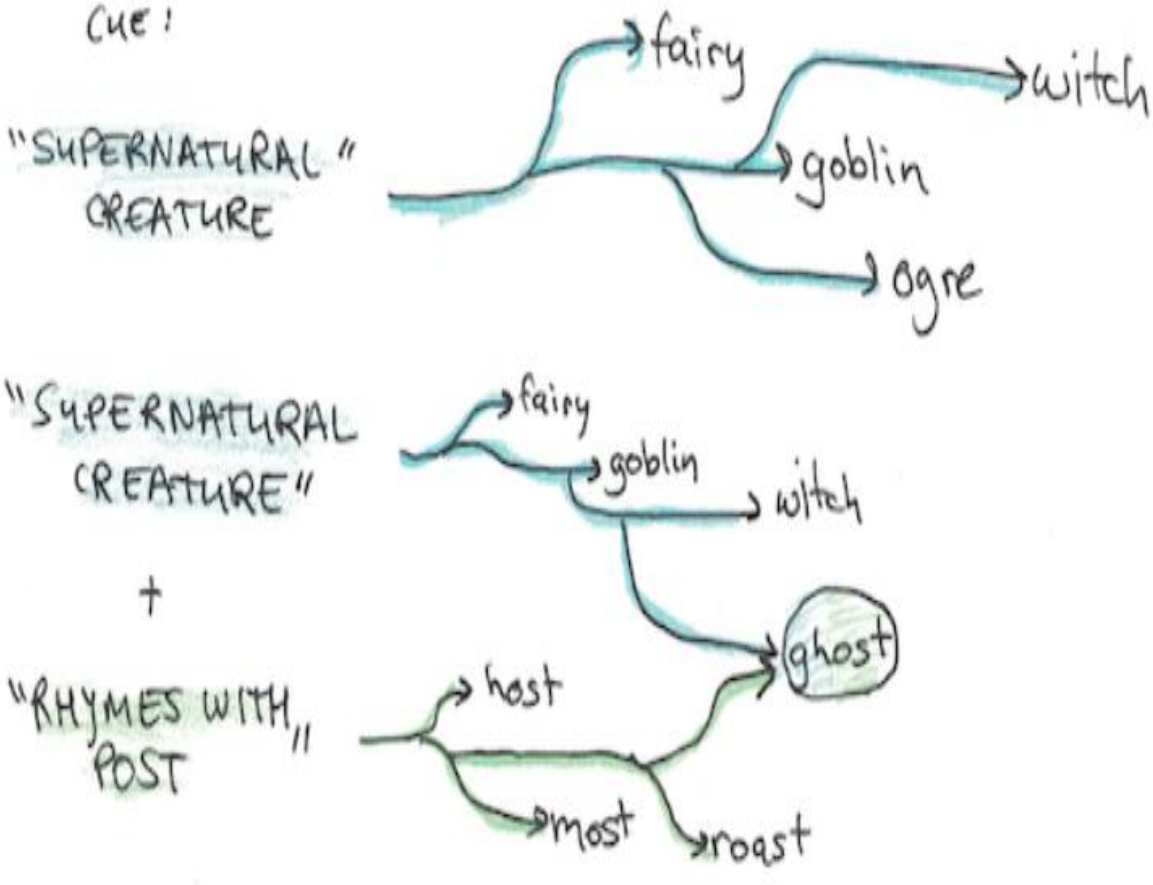
Activation from the cue to the target memory trace spreads faster if more cues are activated simultaneously. As a demonstration, try the following little experiment:

Think of the name of any kind of supernatural creature.

Now think of a supernatural creature that rhymes with‘ post’.

Did you think of‘ ghost’ on the first time or only after the second question? The first question gave you only one cue, which led to multiple possible target memories. For instance, you may have thought of fairies, gnomes, angels and the like. The second question gave you 2 cues. These two cues jointly generated enough activation of the word‘ ghost’ that far surpassed the

activation of other concepts. Therefore, the word ‘ ghost’ was retrieved.

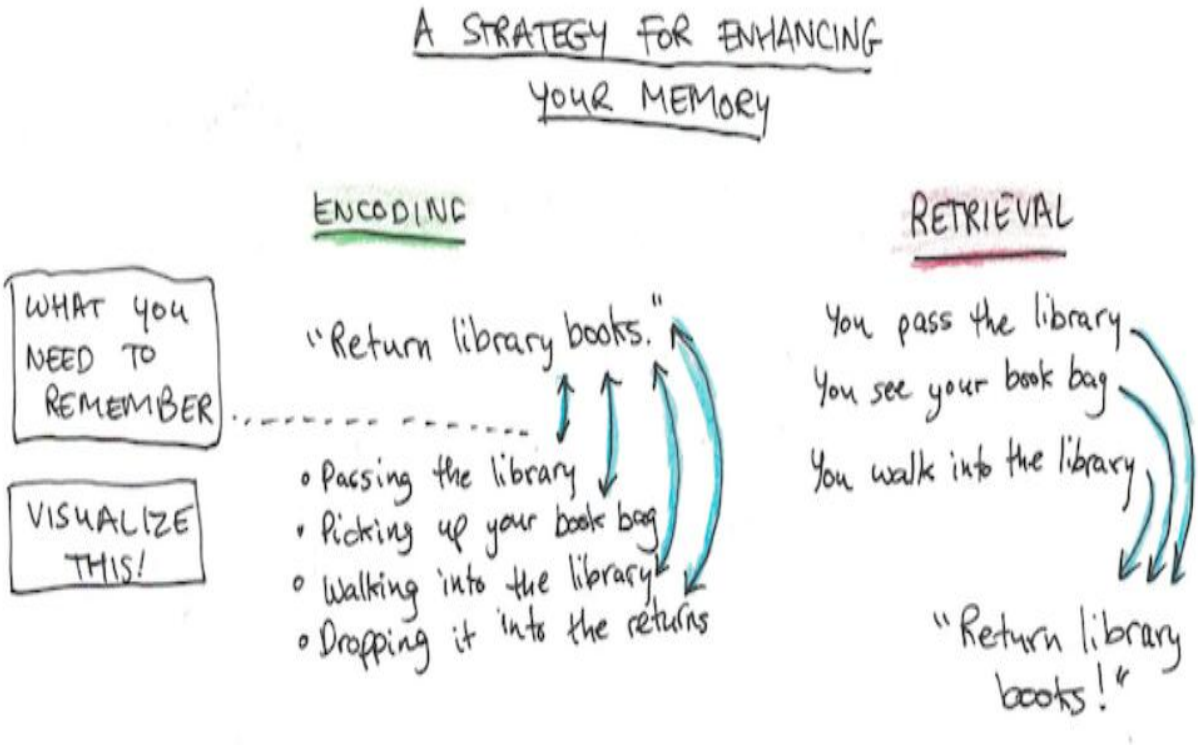


Consider another example from everyday life: You decide to return a book to the library while sitting at the kitchen table. Later, as you pass the library on your way from school, you forget to return the book. However, when you come back home and see the kitchen table, you suddenly remember. Memory traces are encoded together with the context present at encoding. Although the library would surely be a far more relevant context

cue than a kitchen table, it was the kitchen table - not the library - that was present during encoding and thus encoded with the intention.

When you are forming an intention, it is very useful to imagine yourself doing the desired action in the desired context as vividly as possible. For instance, visualize yourself passing the library, entering the building and returning the book. Focus on the details - which objects/buildings are you likely to notice on your way round the library? By doing this, you connect the cue of passing the library (and the surrounding objects) to the intention. When you later pass the library, it will automatically trigger the intention.

If you are struggling to remember an important concept during your exam, you need to activate as many connected cues as possible. For instance, try visualizing yourself in the context of studying. Be as vivid as possible - imagine yourself with an open textbook, taking notes, sitting at your desk. Simply imagining the context of encoding can be helpful to generate enough activation to successfully retrieve the memory trace.



Also, try to remember the details of the context in which you studied the particular concept you are struggling with (such as what page it was in the book, what other concepts you studied before and after this concept). Note that for successful retrieval it is important to activate the connected cues. Since our memories work like snapshots (everything that is present during encoding is encoded together with the memory trace), these cues can either be relevant (such as related concepts) or even completely irrelevant (such as the time of day or even what you had for lunch around the time of study, etc.).

In summary, we recommend the following:

• To better remember to do something in a particular place and time in the future, visualize yourself vividly doing it (e.g. imagine yourself passing the library and returning the book)

- visualize the details of the context where you need to remember the intention (objects, buildings, people)

• If you cannot remember a particular concept that you studied during your exam:

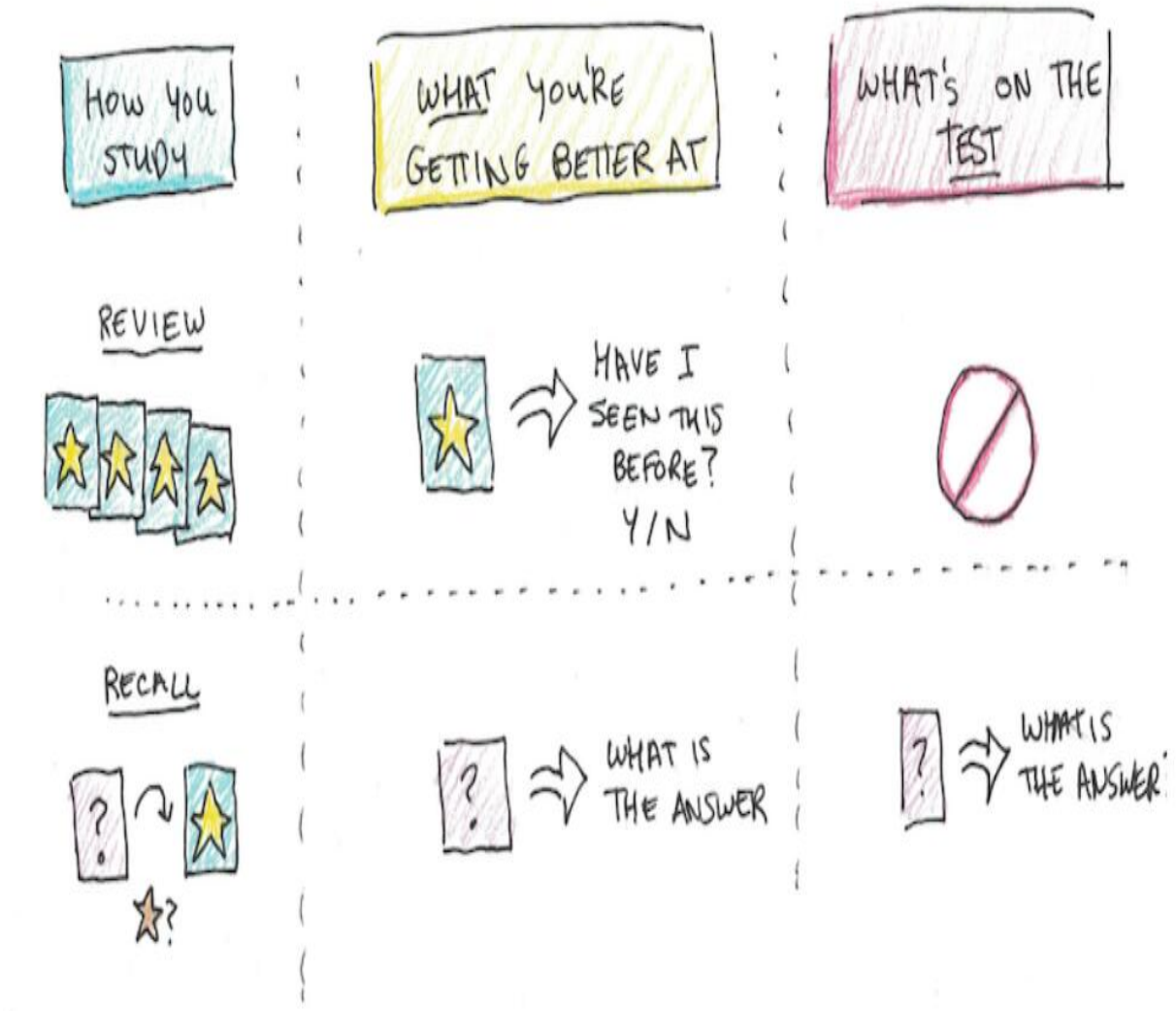
- Actively remember as many concepts as possible which are related to this concept

- Actively remember as many concepts as possible which you studied before and after this concept

- Visualize yourself in the context of studying (sitting at the desk in your room, etc.)

- Try to remember what time and where you studied the concept, what kind of mood you were in and what had happened on that day

Practice tests: The most powerful technique for boosting memory



Scientists have found that regardless of type of test/exam you are going to take, you stand the best

chance of succeeding if you revise with practice tests.[34] As a demonstration, consider the following experiment:[35]

Students attended a 20-minute Statistics lecture, which was divided into 4 equally long sessions. After each session, the first group took a practice test (without feedback), the second group had to re-study the lecture material and the third group performed mental arithmetic. All students were assessed with a final test after the lecture.

Although the re-reading group had more exposure to the material, their final test performance was substantially worse than that of the testing group (by 30%). Moreover, **students who re-studied the lecture material did not perform any better than students who did a completely unrelated arithmetic task.**

A wealth of research has shown that testing is more effective at improving retention and test performance than re-studying, even if no feedback is provided. This is called the ‘ testing effect’. However, not all tests are created equal. You will greatly benefit from practice testing only if you revise with tests using a particular retrieval mode - recall.

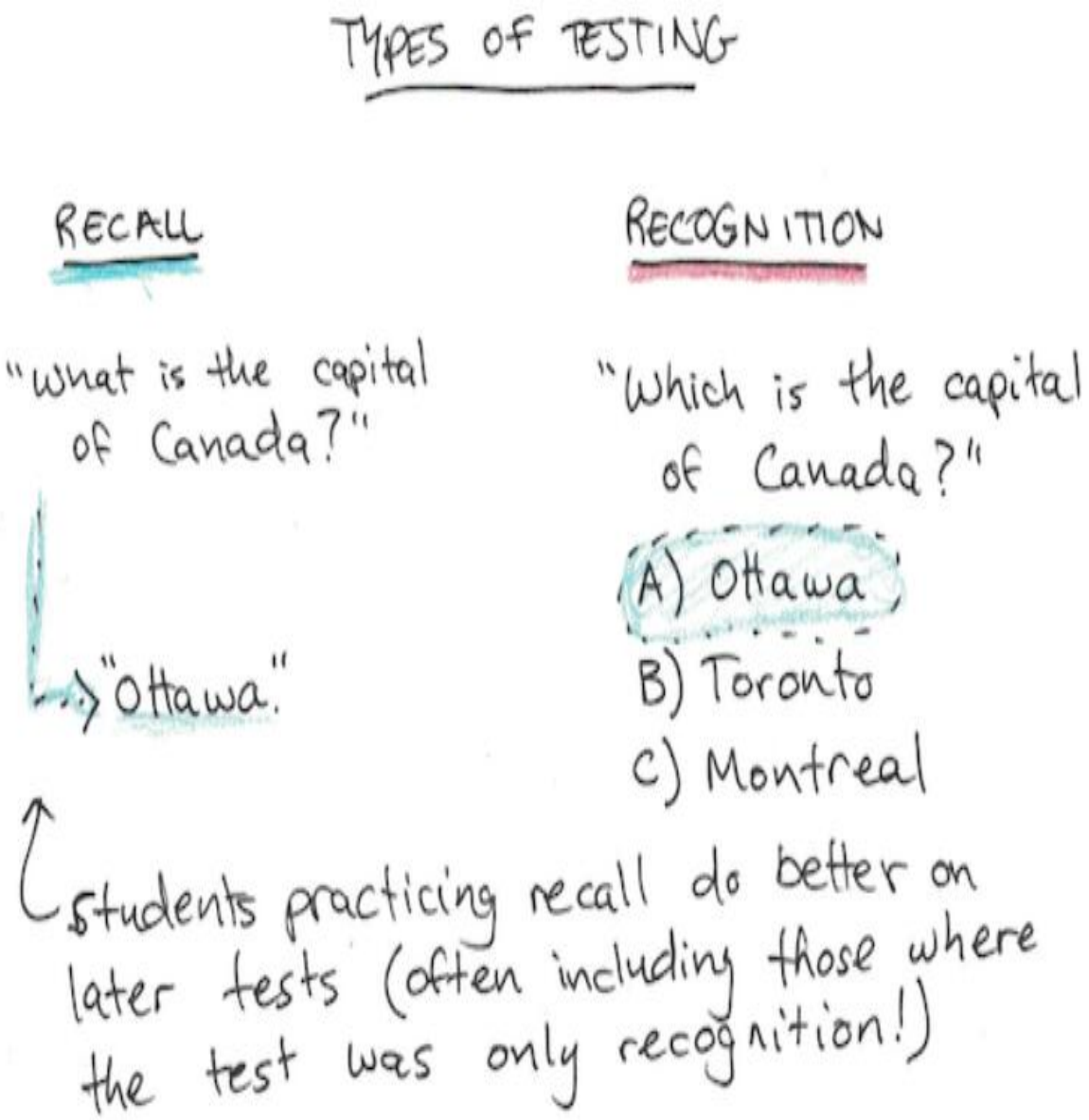
Recall is a way of retrieving a memory trace when you do not see the correct answer and do not have any options to choose from. Example recall questions could be: “What is the population of Canada?”, or “What is the German word for Monday?”

The opposite of recall is recognition, which is a way of retrieving a memory trace when you see the correct answer or a set of options that includes the correct answer. Example recognition questions could be: “Is the capital of Canada Ottawa or Montréal?”, or “Is the German word for Monday Dienstag or Montag?”.

Regardless of how your knowledge is tested in the end, recall testing is vastly superior to all other learning methods based on recognition. One of the reasons for this is that it automatically encourages deeper processing of the study material. In the study above, the testing group took increasingly elaborate notes as the sessions progressed compared to the other groups (without being consciously aware of it).

The most important reason is that recognition is easy for the brain because it knows exactly which concept it must retrieve from memory. If you re-read your notes, you are in fact asking your brain: do I know this? Does it sound familiar? If you have already

studied the notes at least once before, you are in effect telling your brain: "I've seen this before, there is no need to make any further effort".



In contrast, recall is effortful because the brain has to figure out which target memory is to be

retrieved. If you test yourself with recall (questions with no hints or answers to choose from), your brain has to reconstruct the pathway from the question to the target concept. In this manner, the pathway is strengthened (or new pathways are built) and as a result, the concept becomes more easily retrievable later.

Note that the recall has to be successful - unsuccessful recall does not strengthen the memory trace. The best time to revise concepts is therefore just before they are about to be forgotten (see our section on spacing effect).

Virtually all methods commonly used in studying engage primarily recognition processes, such as reviewing (re-reading), highlighting or open-book summarizing. It comes as no surprise then that these learning methods have been shown to have little to no utility in improving retrieval success and test performance. Other methods using deeper processing such as self-explanation are far more useful than re-studying but still not as effective as practice testing.[36]

However, it is not the case that re-reading has no value whatsoever. Re-reading is useful inasmuch as it is used together with practice testing. It is definitely a

good idea to selectively re-study the concepts which you cannot recall.

Also, it is important to re-study material during practice testing as a form of feedback. Although practice testing without feedback is very effective on its own at improving memory, if errors go uncorrected, they build up over time and become more and more firmly lodged in memory. For this reason, feedback is an essential complement to practice testing that substantially enhances its effectiveness. It does not matter whether feedback is immediate (straight after each question/problem) or delayed (after the study session).[37]

Finally, do not forget that practical usage your knowledge (such as doing a real-world project) also amounts to a form of practice testing (and spaced repetition) where you have to regularly retrieve your knowledge and skills from memory. A fair amount of real-world practice can be superior to extensive theoretical study.

In summary, we recommend the following:

- Avoid learning strategies based on recognition (reviewing/re-reading of textbook chapters/notes,

highlighting, summarizing)

• Revise with practice tests / questions to achieve the best results in your tests and exams

- Use free recall (questions/tasks with no hints or options to choose from)

- Practice with recognition questions (such as multiple-choice) only if your test will also be multiple-choice (see transfer-appropriate processing) and for 1/4 of your study time only

- Selectively re-read only the material that you cannot remember

- Get immediate or delayed feedback on your answers Revise with practice tests / questions to achieve the best results in your tests and exams

Summary of Key Methods for Enhancing Memory

Let's recap what we've learned!

Memory has three parts: encoding, storage and retrieval. All three need to function successfully to remember what you need to.

To encode information better:

- **Process information deeply.** Pay attention to the deeper meaning, make connections to what you already know and paraphrase rather than take notes verbatim.

- **Intention doesn't matter so much.** Trying to remember more doesn't make a difference if you use the same cognitive strategies!

- **Match your practice and studying time to how you'll eventually use the information.** Greater overlap means you'll remember more later.

- **If possible, align your state and context when you're encoding the information to when you need to remember it.** If this isn't possible, study in more

environments/situations to make your memories more robust!

To store information better, you need to be aware of how you forget. Here are the main possible causes of forgetting:

- **Trace decay.** This occurs when memories get old, or new knowledge overwrites the old data. Refresh important information on a schedule so it doesn't get lost!

- **Interference.** This happens when a new memory blocks an old one (e.g. you can't remember the Spanish word for water anymore because you learned the French one.) Alternatively, it can happen when old memories make learning something new harder.

How can you store your memories better?

- **Get enough sleep!** Short naps can recover energy. Longer naps (60+ minutes) can enter the phase of sleep where memory consolidation happens. Ending your naps on a full sleep cycle can prevent grogginess. Of course, getting enough sleep at night is essential!

- **Space out your practice.** Done properly, you can get the same memory strength with 20-30% less time by

spacing properly.

Finally, you need to retrieve the memories in the situations that need them. How can you do this?

- **More connections help.** Memories are likely accessed by spreading activation, so if you think of related items, that can help you retrieve something difficult.

- **Plan ahead and visualize the context** you'll need to retrieve something in when you study.

- **Practice testing is the single most-effective technique you can use!** Practice recall, not just recognition. Harder recall creates stronger memories.

注释

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Table of Contents