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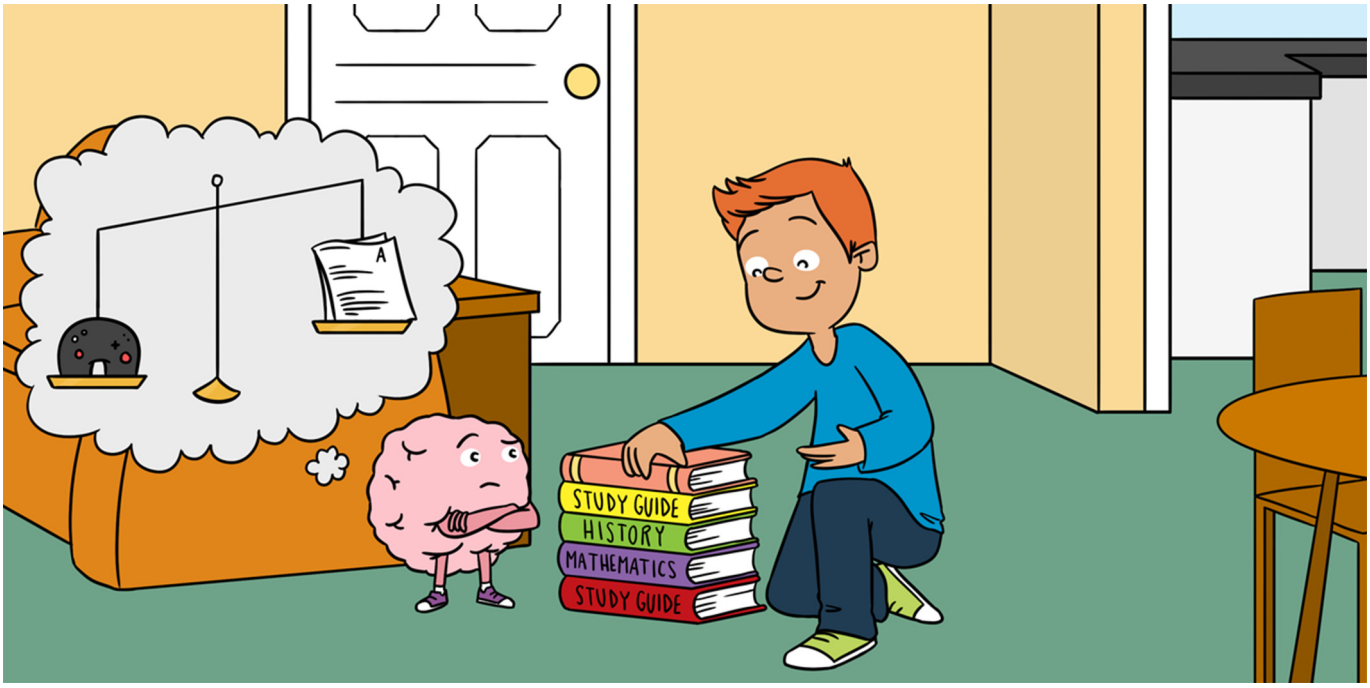
NEUROSCIENCE
Published: 04 June 2020
doi: 10.3389/frym.2020.00073



IS IT WORTH IT? HOW YOUR BRAIN DECIDES TO MAKE AN EFFORT

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SEAWELL ELEMENTARY

AGE: 10

Everything you do requires you to exert effort. For instance, basic things like walking or cycling require physical effort and have to do with using your body. Another type of effort is cognitive effort, which has to do with thinking and using your brain. For instance, think about trying to master a Rubik's cube. Would you want to put in your effort here? The pleasure of finding a solution might outweigh the effort of thinking hard. Or you may decide that finding a solution is not worth your effort. Why and when would you decide to think hard? In this article, we will explain how you decide to exert cognitive effort and what is happening in your brain while you make this decision.

INTRODUCTION

At school, your teachers may say that if you had put in a little more effort, you would have passed a test, or that, with a bit more effort, you would have gotten a higher grade. While you may feel that putting in more effort could lead to better outcomes, it is not always clear what that effort is, exactly.

Effortful actions can be seen as the opposite of automatic actions [1]. For example, you do not have to do anything special to make your brain see colors: it is an automatic process. In contrast, other actions involve non-automatic processes and take effort. Effortful actions are everywhere. Think about the effort it takes to walk or cycle to school. Such bodily actions require physical effort. On the other hand, actions that require **cognitive effort** have to do with your thinking. Cognitive effort is the thinking effort you put in to achieve a complicated task. For instance, you exert cognitive effort when studying for school, solving a complicated puzzle, or trying to solve a riddle.

COGNITIVE EFFORT

The thinking effort you put in to achieve a complicated task.

Many people report that effortful behaviors that are helpful in the long-run, such as studying for a test, feel unpleasant in the moment [2]. Why would exerting cognitive effort feel unpleasant? And maybe more interestingly, why does it sometimes feel like fun? In this article, we will explain why and when you may decide to put in cognitive effort, and what happens in your brain when you make this decision.

COSTS AND BENEFITS

Imagine that you have a test tomorrow that you need to study for. How much cognitive effort will you put in? Researchers have found that your behavior can be predicted by the calculation of the costs and benefits of studying [1]. What might these costs and benefits be?

To keep it simple, we can say that the benefit of studying is to obtain a good grade. Obtaining a good grade is better for your final report, and you may just like getting good grades. An important cost has to do with the level of cognitive effort you must exert—to obtain a good grade, you will sometimes have to think harder.

Researchers describe your decision to use cognitive effort as a function of the potential benefits and costs. You could think of this as a math equation: the sum of costs and benefits results in a certain value. The more you value something, the more likely you are to put cognitive effort into it.

EFFORT DISCOUNTING

The phenomenon that something loses its value if more effort is needed to obtain it.

In Figure 1, you can see that if you have to study very hard for a good grade, the value of getting that grade decreases. That means cognitive effort probably also decreases or discounts the value a good grade. This is what scientists call **effort discounting**.

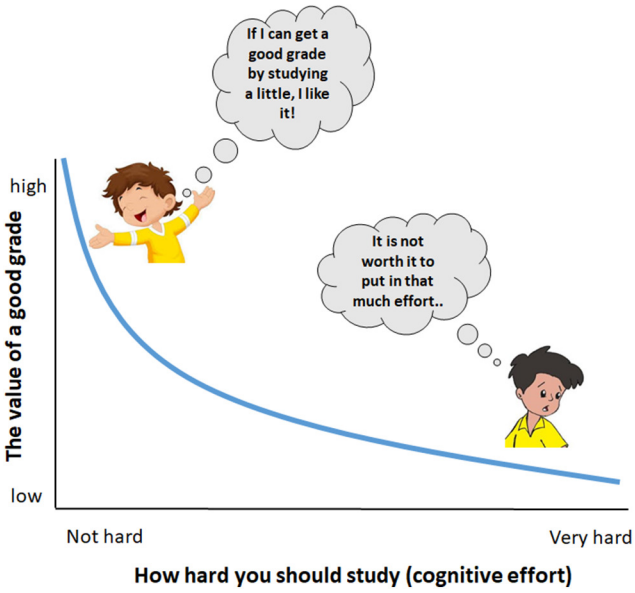

Figure 1

Figure 1

The blue line represents the value a good grade as a function of how hard you have to study for it. As you can see, the value of a good grade will decrease if you need to exert more cognitive effort (study harder). This is what scientists call effort discounting: you like something less because of the effort it requires. The blue line is therefore called an effort-discounting curve.

Box 1 | How do neuroscientists measure brain activity?

Functional magnetic resonance imaging (fMRI) is a brain imaging technique used by scientists to visualize what the brain is doing in different circumstances. The brain consists of around 100 billion cells, called neurons. These neurons communicate with each other through chemical and electric signals. If neurons send more signals to each other, they need more oxygen. This oxygen is delivered via the blood, and if the blood contains more oxygen, it is more magnetic. Thus, with fMRI techniques, we measure how much oxygen different brain regions use by measuring its magnetic signal. This tells us indirectly how active a certain brain region is. For more information about how MRI scanners work, see another Frontiers for Young Minds article [3].

BUT ... WHAT HAPPENS IN THE BRAIN WHEN DECIDING TO EXERT COGNITIVE EFFORT?

To measure what happens in your brain when deciding to exert cognitive effort, researchers can use a technique called **functional magnetic resonance imaging** (fMRI) (for an explanation of fMRI, see Box 1). With fMRI, we can find out which brain areas are active, meaning which ones you are using at that very moment. From fMRI studies, we learned that your brain constantly computes the values of your future actions, by considering the costs and benefits of these actions. A specific brain region that is important for signaling potential benefits is called the **ventral striatum**. This region lies deep in the brain and is involved in signaling all kinds of benefits [4], for instance, money, yummy food, or getting a good grade. But what about costs? Scientists observed that the cost of cognitive effort is signaled mainly by a different brain region, which is called the **anterior cingulate cortex** [5].

FUNCTIONAL MAGNETIC RESONANCE IMAGING (FMRI)

A brain imaging technique used to visualize which brain areas are active at a given moment.

VENTRAL STRIATUM

A brain area involved in signaling benefits of expending cognitive effort.

ANTERIOR CINGULATE CORTEX

A brain area involved in signaling costs of expending cognitive effort.

Figure 2

The brain from the front (left) and from the side (right) of your head. On the left, you can see the ventral striatum ("benefit region"). On the right, you can see the anterior cingulate cortex ("cost region") and the ventral medial prefrontal cortex ("sum-of-costs-and-benefits region").

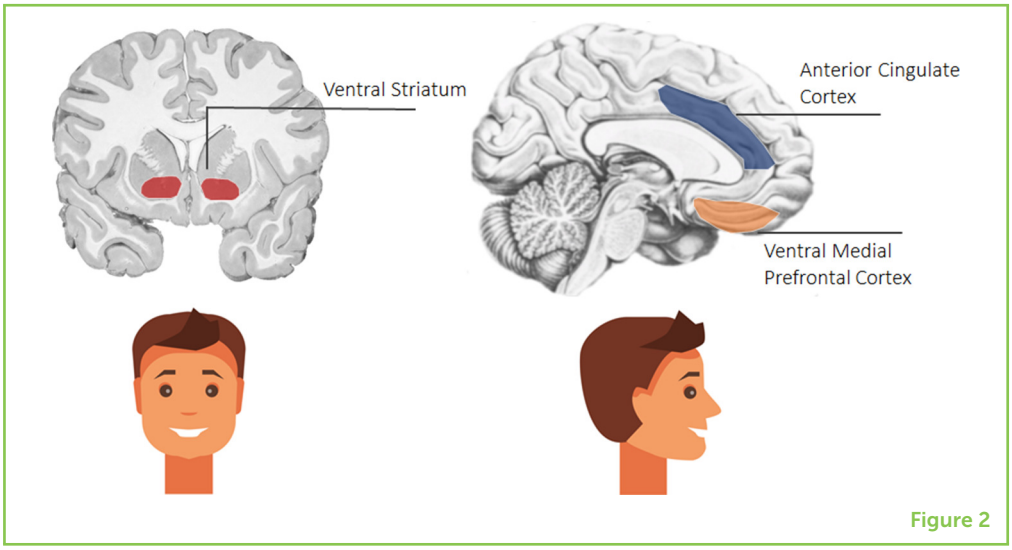

Figure 2

After your brain has considered the costs and benefits, the ventral striatum and the anterior cingulate cortex will work together to exchange information. Thus, in our example, your brain weighs in the costs (cognitive effort) and benefits (good grade) of studying, and then calculates how much you value obtaining a good grade and, as a consequence, whether it is worthwhile to study. Researchers think this exchange of information happens in a brain region toward the front of your brain, called the **ventral medial prefrontal cortex** (Figure 2).

VENTRAL MEDIAL PREFRONTAL CORTEX

A brain area where the costs and benefits are weighted.

WHEN DO YOU WANT TO EXERT COGNITIVE EFFORT?

Now that we know what cognitive effort is and what happens in the brain when deciding how much cognitive effort to put in, we can return to the question we started with: when do you want to invest cognitive effort?

By now, you may realize that the brain considers cognitive effort to be costly. Therefore, too much effort typically feels unpleasant. You may think that your brain makes you lazy, but that is not necessarily the case. Your brain is trying to balance whether it is worth putting in cognitive effort.

However, your willingness to exert cognitive effort is not always the same. You may recognize that sometimes you feel like putting in cognitive effort and sometimes you really dislike thinking hard. The willingness to exert cognitive effort is not always the same—it is changeable! How hard you feel like thinking can depend on the time of day (morning or evening), how you feel (tired or rested), and whether or not you enjoy the activity that needs your effort [6].

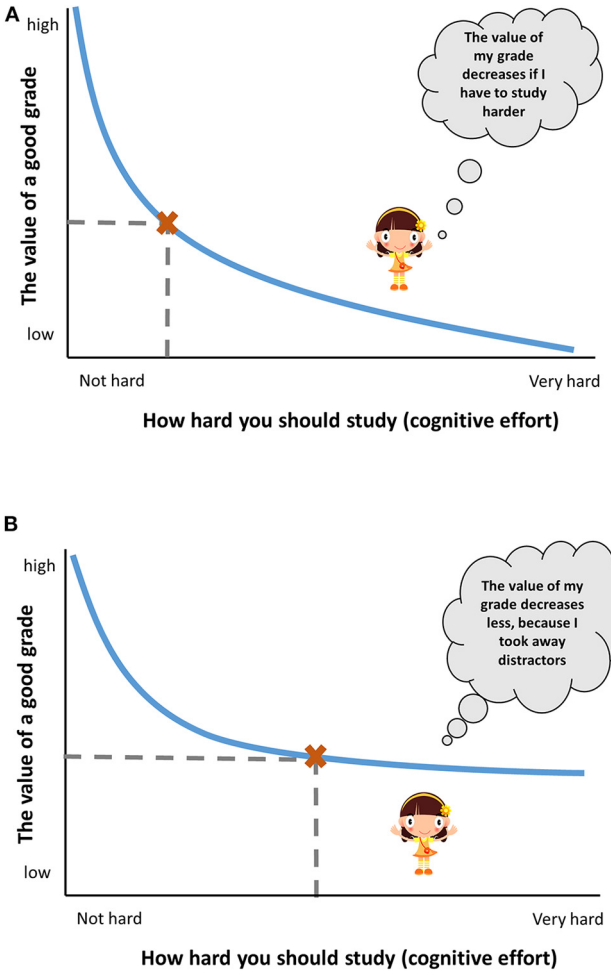

Figure 3

(A) A standard effort-discounting curve: the value of a good grade decreases with increasing cognitive effort. The red cross in both pictures indicates a point where the value of a good grade is average, and the gray dotted line shows the amount of studying needed to get to that average-value grade. **(B)** If you take away distractors, like your phone or the TV, adding more effort now decreases the value of a good grade less quickly. This will lead you to study more, because the cognitive effort feels less costly.

TIPS FOR EXERTING MORE EFFORT

If your willingness to exert cognitive effort is changeable, then a very important question is: can you increase your willingness to exert cognitive effort for your test tomorrow? Well, the answer is … yes! Based on the knowledge you now have, you can try three simple tips.

First, lower all other costs for your thinking brain [1]. So, take away distractors, such as your phone, to help you focus. To see what might happen, take a look at Figure 3. Removing distractors makes cognitive effort feel less costly.

Second, increase the benefits. For example, you could reward yourself with a treat after studying hard for 1 h. Or you could tell yourself that if you get a good grade, you will buy yourself something nice.

Third, try to increase your enjoyment of the effortful task itself. For example, if you do not like maths, use a math game to make it more

fun. In this way, you might even come to enjoy the efforts you spend on learning maths.

With these tricks, you will surely get your homework done with more ease. Good luck!

AUTHOR CONTRIBUTIONS

A-WK and AD wrote the manuscript together. HH and LK provided the critical revisions.

ACKNOWLEDGMENTS

We would like to thank those who assisted in the translation of the articles in this Collection to make them more accessible to kids outside English-speaking countries, and for the Jacobs Foundation for providing the funds necessary to translate the articles. For this article, the authors themselves translated it into Dutch as well. This work was supported by the Start Impulse grant to NeuroLabNL from the Dutch National Science Agenda (NWA).

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SUBMITTED: 22 October 2019; **ACCEPTED:** 01 May 2020;
PUBLISHED ONLINE: 04 June 2020.

EDITED BY: Jessica Massonnie, University College London, United Kingdom

CITATION: Kramer A-W, Huizenga HM, Krabbendam L and van Duijvenvoorde ACK (2020) Is It Worth It? How Your Brain Decides to Make an Effort. Front. Young Minds 8:73. doi: 10.3389/frym.2020.00073

CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

SEAWELL ELEMENTARY, AGE: 10

Our amazing classroom in NC is full of sparking, learning minds. We love helping each other. We think, solve, and learn! We do projects that stretch our brain, and sometimes when we work together, our ideas can get messy but the results are always fun. One of the ways we love to be awesome? Embrace your inner editor! We love to read and peer edit, and were so excited to have the opportunity to work with Frontiers for Young Minds!

AUTHORS

ANNE-WIL KRAMER

I am a Ph.D. candidate at the University of Amsterdam. I fill my time with a variety of efforts. I like to expend physical effort by cycling through Amsterdam and swimming (not in the canals). I also enjoy expending cognitive effort, for example by playing games or thinking about how things work. Sometimes I look at my cat, wondering why he can be fine not expending any effort all day! But honestly, I also sometimes feel like that. Because of this, I wondered how this all works? To study effort, we conduct research in which we let people make decisions about how much effort they want to spend. *a.kramer@uva.nl

HILDE M. HUIZENGA

I am a professor in Developmental Psychology at the University of Amsterdam. I use a lot of math to study how children grow into adults and how adults grow into older people. Sometimes I think hard when I am standing at my desk, sometimes I also do so when I am running, or talking with our teenage daughters, or cycling through Amsterdam. While cycling, I came up with the figures in this paper. I hope you like them.

LYDIA KRABBENDAM

I am a professor in Developmental Neuropsychology at the Free University of Amsterdam. I know all about cognitive effort in education, as I have three school-going children myself! I further investigate social interactions in classrooms and how this relates to the interplay between social interactions and brain and cognitive development. I find this an interesting topic, because if you work or study together with people you like, this may also make effort feel much more fun.

ANNA C. K. VAN DUIJVENVOORDE

I am an associate professor in Developmental Psychology and brain development at Leiden University. I want to know everything about motivation, learning, and how the brain works. Is not it interesting that your motivation changes as you age? Does that relate to the development of your brain? I was not always motivated in school, but when I got to choose my own studies of neuropsychology, I found it fascinating. Working hard was not difficult anymore! With my work, I hope to be able to build motivational experiences and help children learn.