frontiers FOR YOUNG MINDS

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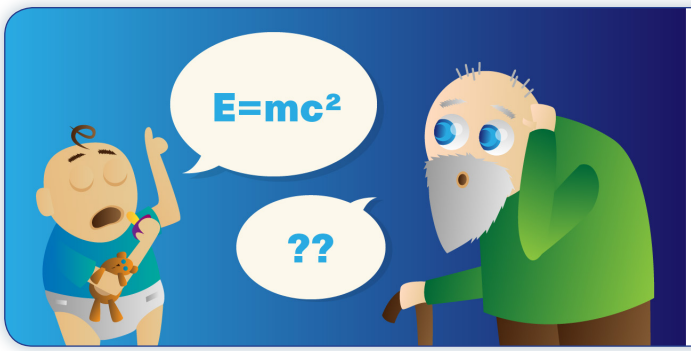


Cognitive development

Manuel C. Voelkle and Ulman Lindenberger

Max Planck Institute for Human Development, Berlin, Germany

Reviewed by:

Autumn
15 years old

Who is the smartest in your family?

INTRODUCTION

That's a no-brainer, you might think: it is clearly mom or dad. But what about your grandma and grandpa, are they smarter than mom and dad? How will things be in a few years from now, when you are done with school: will you be smarter than your parents by then, and have you always been as smart as you are now?

To find out what people think about such questions, we asked a sample of children (aged 9), adolescents (aged 13–15), younger adults (aged 21–26), and older adults (aged 70–76) how they believe things like general knowledge, memory, and thinking speed (also called cognitive speed) change across the lifespan. The sample consisted of an equal number of males and females in each group and the study was carried out at the Max Planck Institute for Human Development in Berlin. Figure 1 shows what we found:

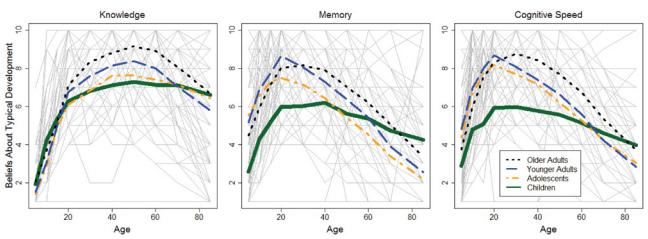


FIGURE 1 - Beliefs about the typical development of selected cognitive abilities between 5 and 85 years of age, rated on a scale from 1 to 10 (adapted from Riediger et al. [1]).

Each thin gray line shows the response of 1 of the 156 people we asked. As you can see, this is a pretty mess: some people thought that really old people have the best memory, while others believed that memory is better at a very young age. This usually happens when you ask different people: everyone has their own opinion. When we look at all the responses together (the main trend, shown by the bold lines), however, we get a clearer picture: all the curves go up, remain flat for a while, and then go down again. So most people, at least among those we asked, believe that the average mom or dad (between 20 and 60 years of

age) has a better memory, knowledge, and cognitive speed than the average child (around 10 years of age) and the average grandma or grandpa (over 60 years of age).

If you look really carefully at Figure 1, you can discover a few interesting details. Firstly, the ups and downs of the curves are not equally strong for knowledge, memory, and cognitive speed. While the curves for memory and cognitive speed show a clear peak, the peak is flatter for knowledge. Secondly, the curves peak at a much earlier age for memory and cognitive speed than for knowledge. Thirdly, in comparison to the other groups, children (the green lines) believed that the age-related decline in cognitive abilities was much weaker.

But are these people right? How do cognitive abilities really change over the course of our lives? Before we get to this question, we first have to answer another one:

WHAT DOES "BEING SMART" ACTUALLY MEAN?

You might already have noticed that we did not ask the participants of our study how *smart* they think people are at certain ages, but we asked them specifically about memory, knowledge, and cognitive speed. The reason for this is simple: people can be smart in different ways.

One way of being smart is being able to give a correct answer to a question because you have learned that answer before. For example, take the question: "What is the capital city of the USA?" If you know the answer, then this is so because you have learned it in school, from your parents, or in some other way, and the answer has been stored in your brain.[1]

A second way of being smart is being able to answer a question without having learned the correct answer before. For example: "What is the next number in the following sequence: 2 – 4 – 6 – 8 – ?" Or, a more difficult one: "What is the next number in the following sequence: 2 – 3 – 5 – 8 – ?" Do you know the answers? If so, it is not because someone else taught you what the next numbers are, but because your brain figured it out.

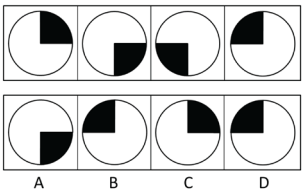
Cognitive psychologists call these two different ways of being smart **fluid intelligence** and **crystallized intelligence** or, more generally, fluid cognitive mechanics and crystallized cognitive pragmatics (for more details, see Ref. [2]). Fluid intelligence comprises basic information processes, which are known under such technical terms as reasoning, inhibition, executive functions, and many others. Crystallized intelligence comprises things like professional expertise or general knowledge, which often depend on the cultural context people live in. For example, not all children in Germany know what the capital of the USA is, but they all know the capital of Germany. Do you? Table 1 shows a couple of sample tasks to assess different aspects of fluid and crystallized intelligence. Can you solve them?

WHAT CHANGES IN OUR COGNITIVE FUNCTIONING AS WE GET OLDER?

The distinction between fluid and crystallized intelligence is important because the two are influenced by different factors. While the former is more biologically determined and genetically predisposed, the latter is shaped more by experience. This is a little bit similar to what we know of sports: some people are more likely to develop stronger muscles than others, but this does not turn them automatically into world-class athletes. Instead, they need many years of training and experience to make it to the top. Likewise, people need to apply their fluid intelligence to a particular domain of knowledge, such as physics or history or neuroscience, to become really good at what they are doing.

When it comes to cognition, psychologists speak of a **two-component model of cognitive development**. By that, they mean that cognition is always a combination of some aspects of fluid intelligence

TABLE 1 - Sample tasks to assess selected aspects of fluid and crystallized intelligence.

Fluid intelligence	Crystallized intelligence
Reasoning: Reorganizing, transforming, and extrapolating novel information Example: Which of the shapes in the lower row best completes the sequence in the upper row (from left to right). Can you tell?  Inhibition: Suppressing irrelevant information and responses Example: Name the color in which the following words are written as fast as possible. Do not read the words, just name the color of the letters Green Blue Orange Red Purple Red Yellow Purple Orange Blue Red Yellow Green Red	Vocabulary knowledge In each row, mark the one word that exists in English Sistern – cistern – nestris – nisters – cistres Flask – klafs – falks – lafks – slafk Vilan – navil – anvil – lanviv – vlian General knowledge When did the first manned mission land on the moon? 1949 – 1959 – 1969 – 1979 – 1989 Which animal is the fastest? Horse – antelope – cheetah – crocodile – cat Which nation has the largest population? USA – Russia – Brazil – India – Japan

The correct solutions are provided at the end of the text.

and some aspects of crystallized intelligence, but the two components develop differently across the lifespan. After you are born, your body and brain develop and you become smarter without much effort. Pretty cool. At one point, however, not only does your body stop growing, but so does your fluid intelligence. Fortunately, that does not mean that you then become stupid. As you get older, you also learn more things. You learn how to read and write, how to drive a car, and maybe even how to fly an airplane or a space shuttle (at least if you become an astronaut).

Although fluid intelligence does not get much better after maturity, and even starts to decline, crystallized intelligence steadily continues to get better and better for a long time. You can even do a little experiment to test this yourself: the next time you watch a game show like *Who Wants to be a Millionaire* together with your parents, write down who of you can correctly answer most of the questions. Likely, this will be your mom or dad, because of their higher levels of crystallized intelligence (if this is the case, tell them they only won because of their "crystallized intelligence" and they will be very impressed!). Then, ask your parents to play a tile matching video game like *Tetris* with you. With just a little bit of practice, you will probably become as good as, or even better than, your parents, because this game depends less on crystallized than on fluid intelligence.

Later in life, however, crystallized intelligence will also decrease: people learn less and less things and even start to forget some of their previous knowledge. This reduction in crystallized intelligence, however, sets in fairly late. Researchers believe that this happens when the decreasing fluid intelligence reaches a certain point, so that people can no longer efficiently use their remaining fluid intelligence to learn new things and acquire new skills, or to retrieve some of the things they learned in the past.

The idea of distinguishing between two different components in cognitive development is not new. In 1777 already, philosopher and psychologist Johann Nicolaus Tetens noted that, in young age, basic abilities will develop faster than well-trained skills but that, in older age, the former are also more likely to decrease than the latter.

Here is what Tetens claimed in 1777:

> *"… During the first years, the child's soul develops its capacities [fluid intelligence] more than its knowledge [crystallized intelligence]. However, in the course of the years, the growth of the capacities comes to an end, whereas knowledge continues to grow. The insights continue to multiply during manhood, but the capacities of the mind, as they reveal themselves when used on completely new objects, no longer noticeably gain in inner absolute strength. Like bodily forces, mental forces have their natural periods, and reach their maximum, after which, in turn, they decline." ([3], p. 432; translated from German by the authors)*

In his time, Tetens could not check whether he was right because he lacked the methods to do so. As a matter of fact, it took more than 200 years until modern science could show that Tetens was indeed right. As an example, Figure 2 shows the results of a study in which 291 people between the ages of 6 and 89 years were tested using a large collection of tasks that were similar to the ones shown in Table 1.

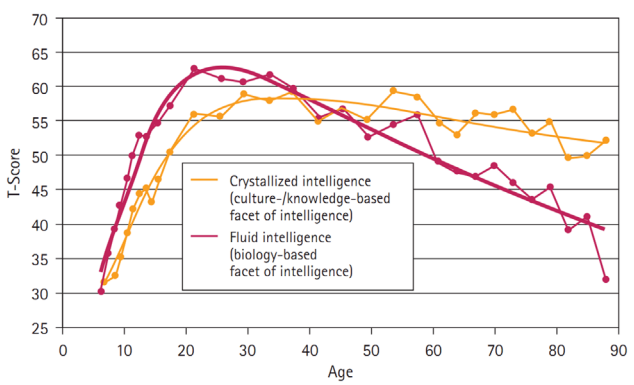


FIGURE 2 - Crystallized and fluid intelligences evolve differently across the lifespan. *T*-scores are standardized scores that facilitate the interpretation and allow for comparison between different measures (adapted from Li et al. [4]).

As you can see, cognitive abilities develop quickly in early ages but then slowly start to decline. In contrast, crystallized intelligence develops much more slowly but also suffers from a lesser decline later on.

SO … HOW SMART ARE THE SCIENTISTS?

Modern science knows a lot about the structure of cognitive abilities and about how to measure them. Psychologists distinguish between different types of cognitive abilities that predict important things such as school grades, performance at university, or success on a job. Of course, these predictions are not always correct, but they are definitely better than chance. As you have learned in this article, we also know quite a bit about how our cognitive functioning changes across the lifespan. Most importantly, we have seen that we need to distinguish between fluid and crystallized intelligence. The two are determined to different degrees by different factors (biological versus cultural), and they differ with regards to the way in which they change over time. We also know that the associations among different cognitive abilities are stronger in childhood and old age, whereas they are less closely related to each other during adulthood. This is called the **differentiation–dedifferentiation** of cognitive abilities.

What is less well-known – and what a lot of scientists are currently looking into – is how cognitive abilities identified at the behavioral level (that is, how we behave, for example how good people are at solving tasks like the ones in Table 1) link up with the brain.

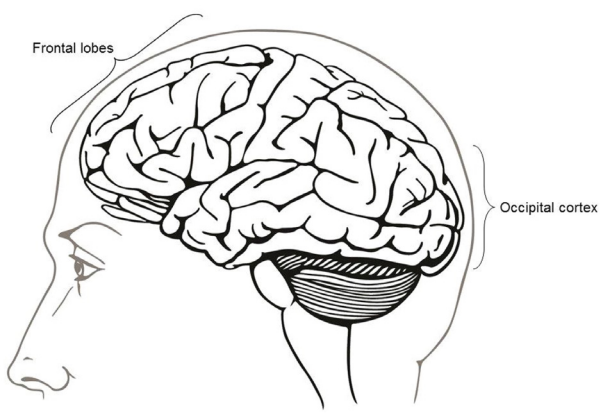


FIGURE 3 - The location of the frontal lobes and the occipital cortex.

We know, for example, that normal aging hurts the frontal lobes (this is the part of your brain right behind your forehead; see Figure 3 for an illustration) to a larger degree than other parts of the brain, such as the occipital cortex, which is located at the back of your head. We also know that the frontal lobes play a crucial role in cognitive abilities like reasoning (see Table 1 for an example) and that these areas mature relatively late in childhood, and age relatively early. Thus, researchers believe that the decline in fluid intelligence in adulthood and old age is, to some extent, due to age-related changes in the frontal lobes. If you want to know more about this idea, take a look at Lindenberger et al. [5]. Many researchers think that the frontal lobes help the various areas of the brain to communicate with each other. This may be one of the reasons why fluid intelligence suffers when the frontal lobes and their connections to other brain areas deteriorate. But other brain areas also play an important role, and many of the links between changes in behavior and changes in the brain still need to be discovered. There is much more to find out and kids like you may be the scientists of the future who will answer these open questions.

There are also large differences between people. Remember the many gray lines in Figure 1? The same holds for actual cognitive development: people differ a lot in the way they change! For instance, for some adults, some aspects of fluid intelligence actually do not show much of a decrease up to old age, and no one really knows why this is so. At present, scientists are pretty good at explaining how cognition develops in the average human, but they cannot tell you exactly how smart you personally, or any other specific person, will be in 60 years from now. Present-day scientists know that certain behaviors help people keep their brains young, and that the brain (in particular the older one) is much more plastic (i.e., modifiable) than what was assumed in the past. For example, physical exercise, cognitive challenges, and a happy social life are all linked to greater cognitive fitness in old age. Even simple everyday activities such as reading can help to ward off cognitive decline. So, the way we age depends on the choices we make. But then, how do we come to make our choices? It is this complex interplay between person and environment that makes studying cognitive development such an exciting endeavor.

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FOOTNOTES AND SOLUTIONS

[1] If you do not know the answer to this or any of the following questions, here are the solutions:

(a) The capital of the USA is **Washington, DC.**

(b) The next number in the sequence is

2 – 4 – 6 – 8 – **10**

2 – 3 – 5 – 8 – **12**

(c) The capital of Germany is **Berlin**

(d) Table 1 left side: The correct answer is **C**

(e) Table 1 right side: The correct answers are

Cistern

Flask

Anvil

1969

Cheetah

India

REVIEWED BY:

Autumn, 15 years old

I am a high school student in Washington State in the USA. I have loved science and math my whole life. I also like to ski, swim, and play volleyball with my friends. I enjoy writing and I am the editor-in-chief for my school newspaper and yearbook. When I graduate from high school, I want to study to become either an anesthesiologist or forensic anthropologist.

AUTHORS

Manuel C. Voelkle

I am a quantitative psychologist. A quantitative psychologist develops statistical methods and techniques for the study of human attributes and processes. I am particularly interested in the study of human development and how affect and cognition change as we age. I love to be outside with my friends and like all kinds of sports (and all kinds of candy).

Ulman Lindenberger

I am a lifespan psychologist. I study how the way we think and act changes with age, and why people differ in the way they change. I am interested in finding out how changes in behavior relate to changes in the brain, and how changes in childhood differ from changes in adulthood and old age. I listen to music while working, and like to go on long runs.