frontiers FOR YOUNG MINDS

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EMOTIONS AND THE BRAIN – OR HOW TO MASTER "THE FORCE"

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RIVERSIDE ELEMENTARY SCHOOL
9–10 YEARS OLD

Do you like science fiction? Have you heard of, or are you even a fan of, the famous "*Star Wars*" series? To summarize, there are rebels, emperors, princesses, robots, and many more fabulous creatures. There is also a power source called "The Force." It is used by the Jedi (the good ones) but also by the dark side (the evil ones). Only the dark side uses the destructive power of "The Force," which is based on negative emotions such as fear, anger, jealousy, or hate. A Jedi masters "The Force" and uses it for knowledge and defense by learning to control his emotions. Our research also looks at emotions and how to control them. We know that in our galaxy too, we have more success when we can control our feelings. Therefore, we want to find the brain regions responsible for allowing us to deal with our emotions and to help those children struggling with controlling negative emotions.

Imagine walking down the school hall thinking about your next lesson. Suddenly, your best friend jumps out from a dark corner, right in front of you, wearing a silly mask and scaring you. This trick that was played on you immediately led to a reaction of your body. You can feel your heart beating and maybe you just screamed out loudly. A few seconds later though, you

recognize your friend and notice there is no real threat. You may even start laughing about the joke. This is an example of how a person can react to an emotional situation. It also shows how our mind processes a situation using different clues. **Emotions** are feelings that (1) are caused by situations that are meaningful or important to you, (2) are something you feel or show through your body language, and (3) may compete with other important things [1]. In our example, the scary joke gave you the impression of being attacked, and it is important to you to stay unharmed. Your beating heart and the screaming is the reaction of your body. While you are scared and your first intention might be to run away quickly, you also noticed that this was simply your friend playing a joke on you. Being scared and knowing someone is your friend are two different clues that might compete with each other in your brain. One clue tells you to run away in order to stay unharmed, and the other tells you to stay with someone you like (competing reactions). Within a split second, you make a choice about which emotion you find important and which emotion you choose to control or suppress completely. Overall, people tend to choose to decrease negative emotions (anger, sadness, or fear) and increase positive emotions (happiness, love, and joyfulness). Changing or controlling your feelings is an action we call "**emotion regulation**." The way that you control and change your emotions is called your "emotion regulation strategy." Looking at data from many people, scientists were able to show that the way you regulate your emotions influences how you feel, but it also affects the people around you [1]. For example, if you have difficulties controlling your emotions when being angry you may end up cursing, punching, or even bullying the people around you. This is no fun for them either. Therefore, successful emotion processing and regulation is very important for humans. In fact, emotion regulation difficulties are a part of many mental health issues in children, teenagers, and adults.

EMOTIONS

Feelings, such as happiness, sadness, fear, anger, or joy.

EMOTION REGULATION

The process of adjusting, controlling, and adapting your own feelings depending on the background of a situation.

USING AN MRI CAMERA FOR STUDYING THE BRAIN

The way the brain processes and regulates emotions can be studied using a technique called magnetic resonance imaging (MRI). An MRI scanner looks like a big tunnel (see Figure 1A). Actually, it is just a very fancy camera that is able to take images of all the parts inside your body. For example, an **MRI camera** can take an image of the bones in your leg, of your beating heart, or of the organ we are interested in – the brain. We can use the MRI camera to look at the structure (shape and size) of the brain. When we want to see how the brain works, then we can use an MRI camera to look at brain function. Just as you need more food when you do sports, your brain also needs more energy when it becomes active, but instead of food it needs oxygen. Therefore, when a specific region in the brain is hard at work, it will get more oxygen transported to it by the bloodstream. We call this blood oxygen-rich. Oxygen-rich blood gives different signals to the MRI camera compared with blood that has less oxygen. Using this knowledge, researchers can create an image of both the brain's structure and function. With special computer programs, we can make

MAGNETIC RESONANCE IMAGING (MRI) CAMERA

A machine that allows researchers and doctors to take pictures of the inside of someone's body, such as bones, organs, or the brain.

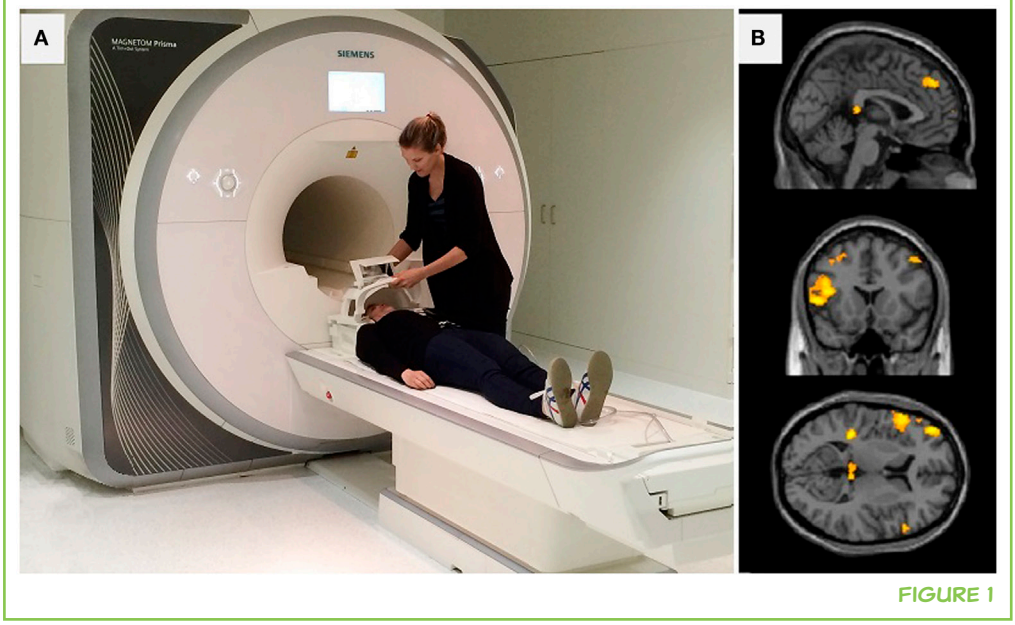

FIGURE 1

A. Two of our research team members showing you an MRI camera and how it is used. **B.** Different views of a child's brain as taken by an MRI camera. The areas that are colored yellow are important for emotion processing and regulation.

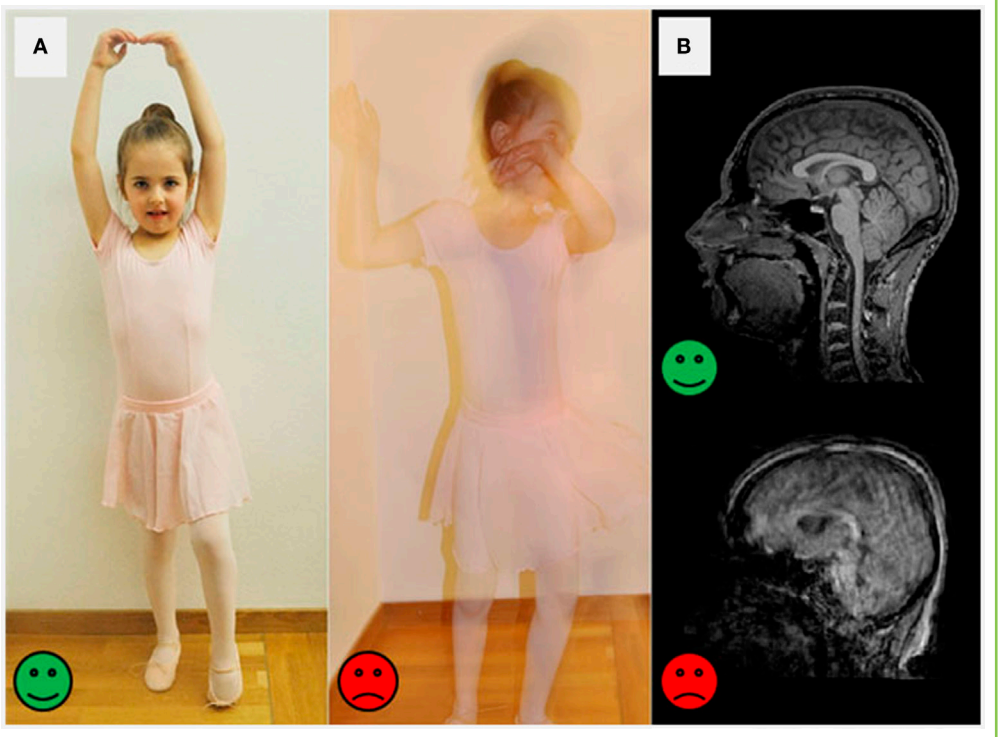

FIGURE 2

Why staying still during an MRI session is important: **A.** A picture taken by a regular camera can be very sharp when the person is standing super still (green happy face). But when the person is moving a lot, the picture becomes blurry (red sad face). **B.** The same is true when taking brain pictures. The pictures can turn out super sharp when the person stays still (green happy face) or blurry and hard for scientists to read for when the person wiggles around (red sad face).

pictures like the ones in Figure 1B. One of the most amazing things is that the MRI camera can take pictures of your brain at work without even touching you! But there are some challenges for people who take part in research studies using an MRI. Two of the biggest challenges are that (1) you have to stay super still while the pictures are taken or they become blurry (for an explanation, see Figure 2) and (2) you have to protect your ears against the noise. Big cameras such as an MRI can be quite loud, which is why you need

to wear special headphones. Staying still can be practiced with fun games, such as the freezing game, where you have to stay still like an ice statue. If you want to know more and see what MRI experiments involving young children look like, you can watch the following video (http://www.jove.com/video/1309/making-mr-imaging-child-s-play-pediatric-neuroimaging-protocol [2]).

WHAT DOES THE BRAIN LOOK LIKE WHILE PROCESSING AND REGULATING EMOTIONS?

Now, in the first section, you learned about feelings, which scientists call emotions. You heard that emotions can lead to a reaction in your body. You also know that sometimes we experience several emotions at once and that sometimes it is necessary to control a feeling and not to act on it. This process is called emotion regulation. In the second section, you learned how an MRI camera works and how it can be used to take images of the structure and function of the brain. In the next section, we want to combine these two things and talk about the parts of the brain that are responsible for processing and regulating emotion.

EMOTION PROCESSING NETWORK

All brain regions activated by emotions (feelings).

Using MRI cameras, scientists have shown that emotions are processed by many different areas of the brain. There is not just one place that is responsible for processing an emotion. Several brain regions work together as a team. This is why scientists say that emotions are processed by a network of brain regions. A network of brain regions that process emotions is called an **emotion processing network** (see Figure 3). Let us name some of those brain regions that are activated by emotions. They are the amygdala, the prefrontal cortex, the cingulate cortex, the hippocampus, and the basal ganglia [3]. Fancy names, but it is not these names you need to remember. What is important to understand is that there are many brain regions involved during emotion processing. All the different regions have their own job and they all work together to identify and control an emotion. The amygdala, for example, is a tiny part of the brain (it has the shape and size of an almond), and it is responsible for handling both positive and negative information. The amygdala is especially important when we experience the emotion of fear. Another region of the emotion processing network is the prefrontal cortex, which is named after its location: in the front of the brain. The prefrontal cortex is like a control center, helping to guide our actions, and therefore, this area is also involved during emotion regulation. Both the amygdala and the prefrontal cortex are part of the emotion network. Just like good friends, these different brain regions stay in touch and communicate frequently with each other. For example, the amygdala (the emotion center) can detect an important fearful event and transport that information to the prefrontal cortex (the control center). The prefrontal cortex gets the message that there is something scary happening. If necessary, this control center at the front of your head sends commands to other brain regions telling them to move your body and run away. To sum it

up, many brain regions work together to process and react to an emotional situation (see Figure 3).

WHAT HAPPENS IN THE BRAIN WHEN EMOTION PROCESSING FAILS?

By now, you understand that feelings are complicated and that emotions are represented and processed by many regions in the brain. You also remember that successful emotion regulation is important for a persons' well-being and central for the people around them. As mentioned before, it can be really difficult to be around people that are constantly cursing, hitting, or bullying the people around them because they cannot control their negative emotions. Unfortunately, some children struggle more than others with their emotions. Imagine you have a classmate named Jamie, who has problems with regulating emotions, especially anger and fear. Now picture that you make a silly joke with Jamie, but instead of laughing, Jamie gets very upset and maybe even starts fighting with you. This is an example of someone who has emotion regulation difficulties. Such difficulties in handling emotions can often be observed in very aggressive (frequently fighting and bullying) and antisocial (breaking rules) teenagers. Research studies have shown that these teenagers cannot

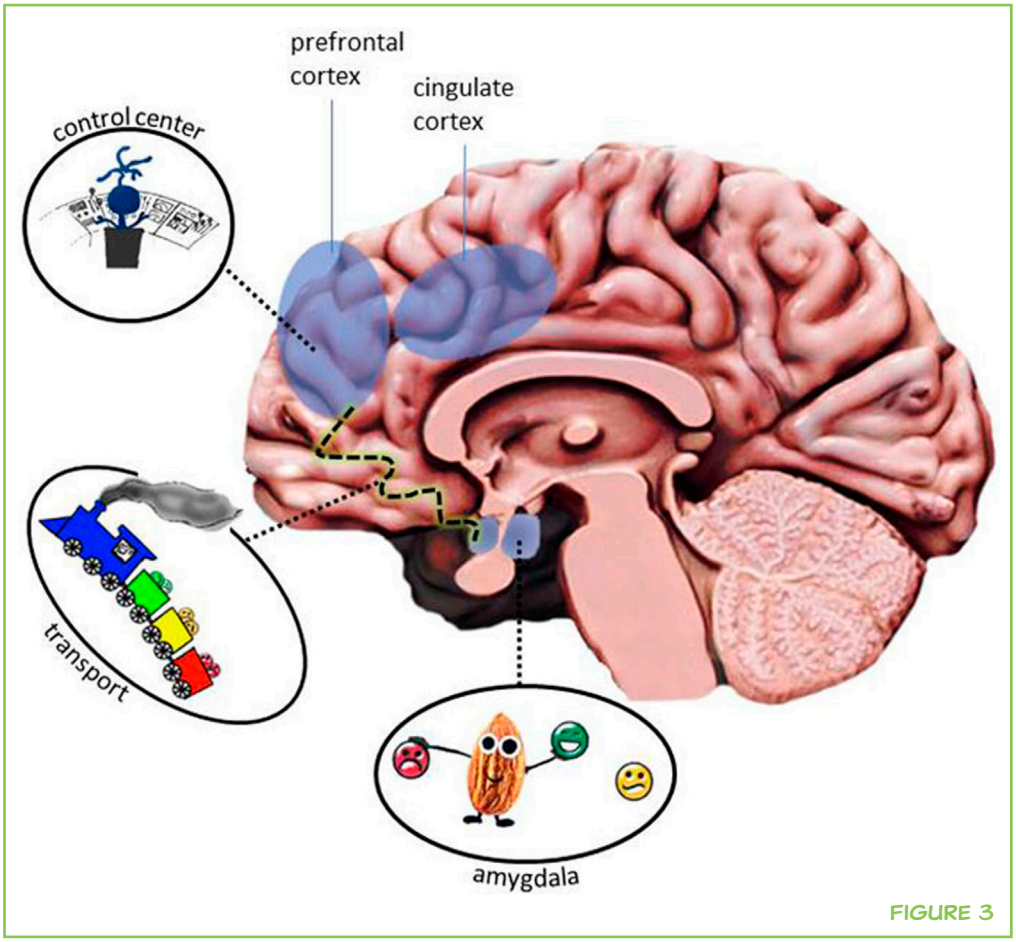

FIGURE 3

FIGURE 3

The emotion processing network includes several areas of the brain. Some of these areas are shown here shaded in blue and you can see their different jobs: the amygdala (almond) recognizes and sorts the emotions before transporting them to other areas. In the picture, this transportation is visualized by a train driving along the dotted track line to the most frontal part of the brain. Once the information arrives there, the prefrontal cortex and the cingulate cortex act as a control center (little man behind desk), deciding what has to be done next with the incoming emotions. Many areas work together to process an emotion! (illustration by Menks).

always successfully identify their emotions. It can also be very hard for these children to control their emotions, like in the case of Jamie. This is not fun for you, if you become a victim of Jamie when he wants to fight you. But it is also not fun for Jamie, who might be expelled from school for his behavior. It is no fun either for his parents or the people around him. You can see that many individuals are affected by Jamie's difficulties controlling his emotions.

Because we are interested in how the brain processes and regulates emotions, we do a lot of work with children who can successfully handle their emotions. We also invite children who struggle with emotion processing and regulation to see whether their brain structure and function looks any different from the children who do not have trouble with emotion processing. So far, there have been several small studies, suggesting that there are differences in brain function and structure in children with aggressive behavior [4]. But, as our MRI section describes, there are challenges when doing research studies with younger participants. For example, it is very hard for children to stay very still while the MRI takes pictures (Figure 2A). Because of this, most studies have a very small number of participants, and the results are not as clear. A method called "**meta-analysis**" helps to summarize the information from all of these very important small studies. Meta-analysis takes the results of many studies and combines them into one big finding. For example, we have combined all small studies done so far in children and teenagers with aggressive behavior [5]. While each study had a maximum size of about 40 participants, combining all of them into one meta-analysis allowed us to look at over 500 children at once. By doing so, we were able to show changes in both brain structure and brain activity (function) in the emotion processing network in aggressive teenagers (Figure 3).

META-ANALYSIS

This is a study that takes the results of several studies about a certain subject and calculates the results based on all these studies combined together.

MAY "THE FORCE" BE WITH YOU!

To summarize, emotions are feelings that are processed by a team of brain regions. Emotion processing is a complicated process, which sometimes does not work so well. Difficulties with emotion processing and regulation are found in children and teenagers with very aggressive and antisocial behavior. Using structural and functional neuroimaging techniques, we showed that areas of the emotion processing network of the brain are different in the youths with aggressive behavior. Luckily, the brain has the ability to change and adapt, especially when people are still young. The more we know about how our brain develops and how it processes and regulates emotions, the more we can help children with emotion processing problems. This knowledge also helps doctors to choose the most helpful treatment for these children. For example, if we know that a child struggles with recognizing an emotion, then that is what we teach them to practice. Or if we see that a child cannot control his emotions, we teach him ways to do so. In the end, we want to understand and teach others how to deal with feelings of anger, fear, and aggression in a good

way. We hope that we can help those children struggling with their emotions and bring all of us a little closer to the "Jedi in us."

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RIVERSIDE ELEMENTARY SCHOOL, 9–10 YEARS OLD

Riverside Elementary School serves children from prekindergarten through fifth grade in Princeton, NJ, USA. Our diverse student body includes children from more than 23 different countries, and we all love to learn about brains! We also have a science lab, a courtyard with frogs and box turtles, a team of dedicated teachers and support staff, and a great principal who always supports new opportunities for learning. Fourth grade students are either in Ms. Levy's or Mr. McGovern's classroom, and Mr. Eastburn is their teacher in the science lab.

AUTHORS

NORA MARIA RASCHLE

I am a developmental neuroscientist, and I have always been fascinated by how the brain makes us tick. I am particularly interested in understanding how the brain develops, how it learns, and what might be going on if it does things a bit differently in one child compared to other children. You kids are the ones with all the answers for me, and I enjoy very much working and learning from you. I also like star wars, shooting stars, rock climbing, rock music, and Roquefort. *nora.raschle@upkbs.ch

EBONGO TSHOMBA

I am a master's student of psychology and work as an intern at the Department of Child and Adolescent Psychiatry in Basel. Two things are especially exciting about our research field: working with kids and looking at brains. I also enjoy dancing to Caribbean music, planning adventurous trips, and I just recently did a "Star Wars" puzzle with 2000 pieces.

WILLEKE MARTINE MENKS

I am a biologist from the Netherlands, and I am intrigued by the brain and human behavior. I currently work in Switzerland where I study the brains of children with behavioral problems. With the help of my favorite machine (the MRI scanner), I try to answer difficult questions as: "How does our brain recognize emotions?" and "What happens in the brain when you have behavioral problems?" And besides all this science fun, I bake silly cakes, travel around the world, love to dance, and play basketball.

LYNN VALÉRIE FEHLBAUM

I am a PhD candidate at the Department of Child and Adolescent Psychiatry at the Psychiatric University Clinics in Basel, Switzerland. I like brains and enjoy working with children. In particular, I am interested in how the child's brain develops and how it responds to different environmental settings and individual characteristics, such as aggressive behavior. I believe that an increased knowledge about the mechanisms of your brain can help us understand kids even better!

CHRISTINA STADLER

I am a professor working at the University Hospital for Child and Adolescent Psychiatry in Basel. I would like to better understand why some children sometimes become rapidly stressed and often react very aggressively. From my clinical work, I learnt that the reasons often lead back to negative living conditions in which the children grew up. It seems that because of these negative experiences, kids with aggressive behavior have developed a super sensor to detect signs of danger. Thus, one of my research interests is to investigate the biological mechanism of this super sensor in order to better understand those children who have problems inhibiting aggressive behavior.