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WHAT THE BARN OWL CAN TEACH US ABOUT HUMAN VISUAL ATTENTION

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YOUNG REVIEWERS

"ORT DAFNA" MIDDLE SCHOOL, KIRYAT BIALIK

AGE: 13

Visual attention is the brain's process of extracting information we receive through the eyes. It guides our gaze to the most important things around us. How do scientists research such a complicated subject? And can birds, which are separated from humans by 300 million years of evolution, help us understand attention in the human brain? The barn owl is a member of the owl family, and its extremely sharp vision and hearing allow it to hunt in total darkness. Researchers can use the barn owl to learn about attention, both in animals and humans. This article will explain the visual attention experiments we performed using barn owls and what we learned from them. An understanding of visual attention may help doctors and scientists to treat important brain disorders and may also help with the development of technologies that need to "pay attention," like self-driving cars.

ATTENTION, ATTENTION!

When I was young, I wondered why my brother had to go to a special school for children with attention deficit disorders. Why did he seem to have more difficulty following what the teacher was saying? When I grew up and became a scientist, I was excited to study the brain and learn more about the process that probably caused my brother troubles: attention. But I soon realized how complicated attention really is!

The process of attention starts with receiving information from the environment through the sense organs (such as eyes, ears, and nose). This information is then processed by the brain, which then turns the eyes or shifts the body toward objects of interest. This all happens in a split second! How can scientists study such a complex subject? Keep reading to find out!

OPTIC TECTUM

A brain structure that receives information from various sensory organs and separates out salient information from unimportant information. The optic tectum is also named superior colliculus.

SALIENCE

The quality of standing out among others.

SALIENCY MAPPING

An early stage in the attentional process, in which the optic tectum receives information about an object and creates a "map" representing its location in the space around the animal.

THE ROLE OF THE EYES

We live in a world where we are constantly bombarded with information. Yet, thanks to our sophisticated brains, most of us are not bothered or distracted by all of the extra, unimportant information. To do even the simplest tasks, our brains must be able to filter out all the information that is not relevant. For animals, the ability to concentrate on important details is a matter of life or death! Attention mechanisms evolved in animals over hundreds of millions of years, as they hunted for food, searched for suitable mates, and avoided dangers.

The information that comes through the senses is processed in an area of the brain called the **optic tectum**. There, the important—or **salient**—information is separated from the unimportant information. Salient information is information that is different, surprising, or somehow more powerful than all the other information entering the brain. As the optic tectum separates out the salient information, it creates a map that stores locations in the image it gets from the world of salient information. This step is called **saliency mapping** (Figure 1).

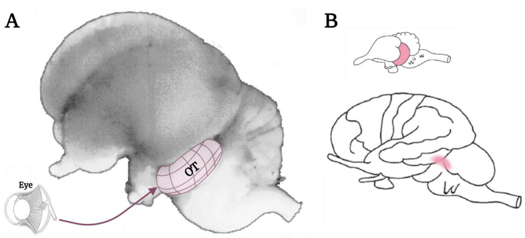


Figure 1

Figure 1

The structure of the optic tectum (OT). **(A)** Brain of a barn owl, viewed from the left side. Information perceived by the eye is sent directly to the OT (pink), where initial processing called saliency mapping is performed to select the details around the animal that are most meaningful for its survival. **(B)** Illustration of a bird (top) and a monkey (bottom) brains. The OT and its homologous in monkies, superior colliculus, are marked in pink. Size differences in the image implies on natural differences but is not precise.

The information then passes into other areas of the brain for more complex processing. In addition to the saliency and location of a stimulus, other characteristics of the stimulus are registered by the brain, such as color and sound frequency. The brain also considers the urgency of the response to a stimulus—for example, if you are hungry, you will grab a piece of pizza much faster than if you are full!

After a winding journey that lasts less than the blink of an eye, all of the information collected by the brain reaches the brain area responsible for eye and head movements. There, a command is given to the muscles: turn toward the place where the most significant stimulus is located. Hence, **visual attention** is the process of paying attention to objects perceived by the light receptors in the eyes.

VISUAL ATTENTION

A process that takes place in many areas of the brain and tells the eyes to focus on necessary information while ignoring unnecessary information.

There has been lots of research on visual attention because experiments based on the sense of sight are fairly easy to perform in both animals and humans. Many kinds of scientists—from biologists to psychologists to philosophers—study this fascinating process.

THE SHARP-EYED BARN OWL

The barn owl is a nocturnal raptor from the owl family. Male and female owls usually raise their young as a couple and grow old together. Barn owls eat mainly rodents (like mice), small birds, and reptiles. They hunt at night using their sharp vision and remarkable **sound-localization** ability, which allows the owls to pinpoint exactly where a sound is coming from.

SOUND LOCALIZATION

The ability to determine the direction and distance of a sound source.

In the early 1960's, when the main **animal model** used in scientific research was the barn owl's favorite dinner—the mouse—a scientist from the California Institute of Technology named Masakazu "Mark" Konishi started to study birds, including the barn owl. Konishi discovered the owl's astonishing hunting skills (Figure 2), which made him realize that barn owls would be a great animal model for researching the senses and attention [1]. Not long afterward, other brain researchers began studying barn owls too.

ANIMAL MODEL

A laboratory animal with features that make it useful for shedding light on the biology of other animals.

In scientific research, choosing the right animal model is very important. In the case of barn owls, many studies about attention have shown that some parts of their brains resemble those of humans. Other attention experiments have shown that people and barn owls often respond similarly to stimuli of attention [2]. For example, the speed of finding a target object among many others is equivalent in humans. Thus, barn owls can make a great model to study attention in humans.

Figure 2

Figure 2

A barn owl catches a mouse in the dark. This picture was taken in complete darkness using infrared photography. The barn owl was photographed flying and precisely descending toward a mouse (photo credit: Prof. Mark Konishi).

STUDYING ATTENTION IN OWLS

Over the course of evolution, birds and mammals began to separate about 300 million years ago. That is, body parts that they both shared changed according to each group's changing environmental preferences—hands vs. wings, for example. We hypothesized that, although mammal brains changed a lot during this evolutionary process, some areas associated with visual attention remained almost as they were 300 million years ago! To prove this, we had to compare the attention process of mammals with that of other animals. Since barn owls are a good animal model for attentional research, we chose to use them for experiments comparing attention in mammals and birds.

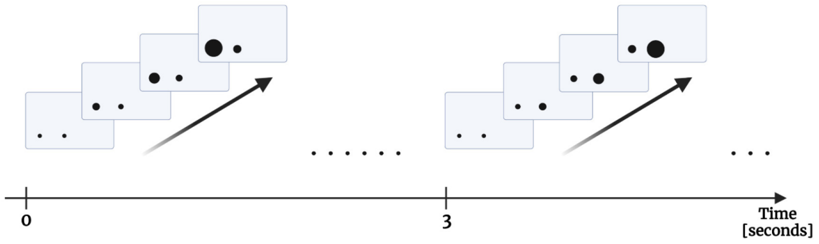
We started with a question: "How does the attention process happen in the brain of a barn owl?" To answer this, we focused on sub-questions like: "How does saliency mapping happen in the optic tectum of barn owls?" and "Can we understand brain processes by watching an owl perform a visual attention task?"

In our experiment, barn owls viewed a screen on which two black dots of the same size appeared every few seconds, expanded, and disappeared; however, one dot expanded faster than the other, at different rates each time we ran the experiment (Figure 3A). We got the barn owls to watch the screen in two ways. In one method, the barn owls were free to fly around, but they chose to stand in front of the screen because we gave them food (Video 1). We used a computer program that tracked the owls' head movements. In the second method, barn owls were given laughing gas, which made them relaxed as we kept them still in front of the screen. In this case, we looked at their brain activity. Using a microscope, we inserted an electrode (a very thin needle) into the barn owl's brain—a method called **electrophysiology**. Since there are no pain sensors inside the brain, the electrodes do not hurt the owls at all.

ELECTROPHYSIOLOGY

A field of scientific research that examines the electrical activity of the brain, from individual nerve cells to the entire brain.

A



B

Dora	Dana
mean gaze duration at right stimulus [seconds]	
1.28	1.35
1.60	1.25
1.91	1.64
1.73	1.68
1.81	1.95
2.81	2.45

C

Dora	Dana
mean reaction time to right stimulus [seconds]	
2.24	2.72
1.59	2.91
1.25	2.36
1.58	2.50
1.33	2.16
1.15	1.85

Figure 3

Figure 3

Barn owl visual attention experiment. **(A)** The gray rectangles represent the screen, upon which two black dots appeared and grew at different speeds (bottom to top). New dots appeared every 3 s, with a little time between each test. **(B)** The average amount of time the owls looked at the dots and **(C)** their average reaction times in response to the pairs of dots. Two female barn owls were tested: Dana and Dora. You can see that as the left stimulus expand faster, it takes the owl longer to turn to the right stimulus and it spends less time looking at it.

SALIENT OBJECTS ATTRACT OWLS' ATTENTION

We found that, when one of the dots was much bigger than the other, the barn owl turned its head faster (Figure 3B) and looked for a longer time at the dot that was expanding more quickly (Figure 3C). That is, the more salient one dot was compared to the other, the more it attracted the owl's attention. This may sound like an obvious result, but in science, we need to collect evidence to back up our hypotheses!

The results of the electrophysiology experiments showed that there was more brain activity in the optic tectum as one of the dots grew larger. Together, these results told us that, when there was a salient stimulus on the screen (a larger/faster dot), the increased activity in the optic tectum caused the barn owl to turn to look at the screen faster and to gaze at it for longer.

REAL-LIFE IMPLICATIONS

What we learn from studying visual attention in barn owls will hopefully help us to understand human brain disorders. Our research could help scientists to understand brain injuries, attention deficit disorders, and even the developing brains of babies and toddlers! Further, attention research is also important for the development of certain technologies. For example, self-driving cars need to process, filter, and respond to visual information while they are moving—tasks that are similar to the process of human visual attention.

Overall, understanding how owl brains separate salient stimuli from background "noise," can improve the comprehension of how humans avoid distractions.

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"ORT DAFNA" MIDDLE SCHOOL, KIRYAT BIALIK, AGE: 13
We are a 7th grade class for scientific and technological leadership in the ORT Dafna Middle School in Kiryat Bialik. The class is made up of outstanding students with high scientific and mathematical affinity. We are a curious class who loves to discover new things.

AUTHORS

HADAR BEERI
Both my parents are involved in the arts—my mother in theater and my father in graphic design and painting. For most of my life, I was also involved in art—I danced,

sang, and worked in the theater for a few years after completing my military service. I also chose the topic of my undergraduate degree through art—after reading *Moby Dick*, I decided to be a marine biologist. As the romance of the book waned, I realized I was drawn to the realm of the mind and behavior. I started a master's degree in Prof. Gutfreund's laboratory, studying attention in barn owls. Today, after about seven fascinating years, I am nearing the end of my doctoral studies. *hadar9331@gmail.com

YORAM GUTFREUND

I wrote my doctoral dissertation 22 years ago, on the subject of octopus behavior and their brains. I then moved to the United States, with the goal of researching the hearing and vision systems of barn owls. I am currently an associate professor, serving as the head of the Laboratory for Animal Behavior Research at the Technion. We study barn owls and other birds to understand what happens in their brains when they make decisions, respond, and navigate to their nests. Sometimes people ask me: why is it important to learn about bird brains? The answer is that the brains of all animals evolved from a common source; therefore, research on bird behavior and brains may also teach us interesting and important things about human behavior and how the human brain works.