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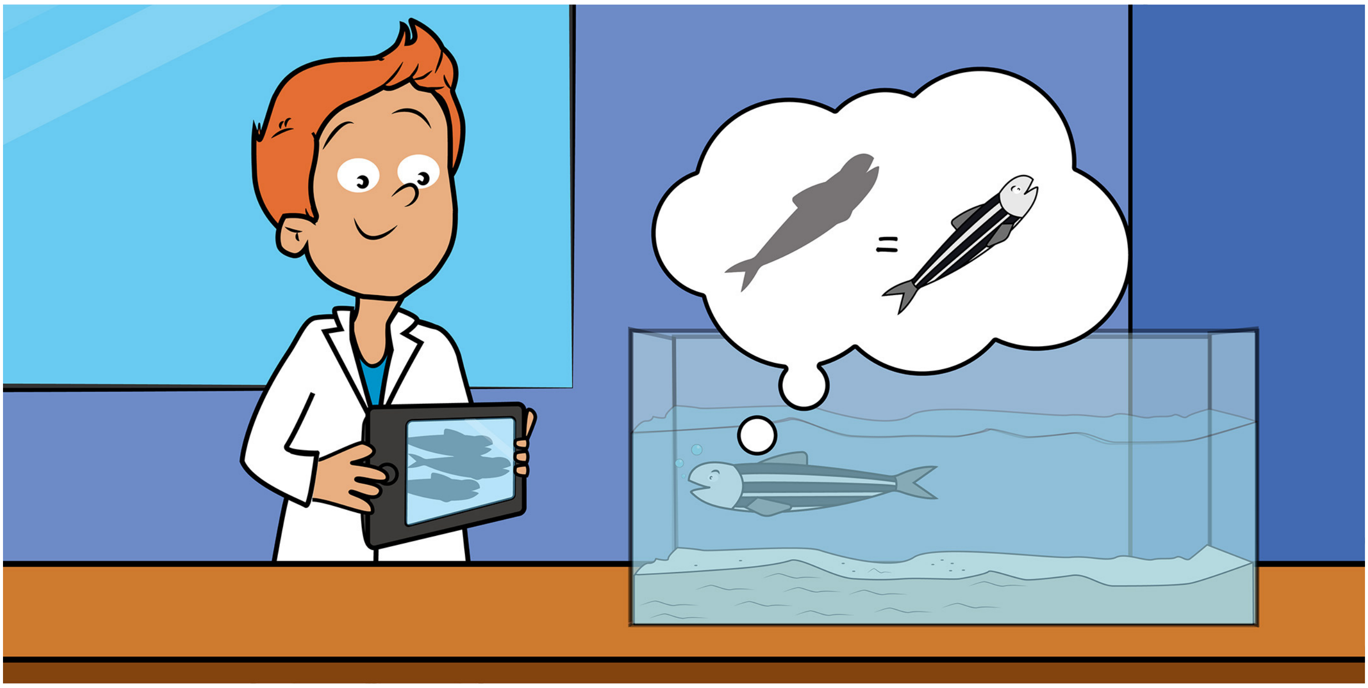

FISHING FOR SOCIALITY: HOW WHAT WE SEE HELPS US WITH SOCIAL INTERACTIONS

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YOUNG REVIEWERS:

ARITRO
AGE: 12

NEEL
AGE: 12

Far in the distance, you see something moving...is it a woman? When you look closely, you recognize the motion pattern and body form: it is definitely your mother. As she approaches, you recognize her face and see that she is moving quickly; you can guess that she is worried because you are late for lunch! Humans can visually distinguish others, their emotions, and their intentions by looking at how they move and the shapes of their bodies. But individuals with social difficulties like autism struggle to get the same information from these visual cues. So, it is important for doctors and scientists to understand how the brain perceives this information. In our work, we studied small fish that rely on visual characteristics, the way we do, to recognize their fellows, and we explored how cues from movement and body shape help these fish to interact with others.

HOW DO WE RECOGNIZE OTHERS?

After a long and tiring day, you go to bed. It is quiet and cozy. Suddenly something moves and immediately captures your attention! A scary shadow appears in the dark…it is moving slowly…PHEW! It has a long tail! It is your cat! Interestingly, you did not need to see your cat clearly to recognize it. Have you ever wondered why? When I was a child, I enjoyed doing dot-to-dot activities, in which dots must be connected by number to create pictures. I usually tried to guess the drawing before connecting the dots. There is a Japanese proverb that states, "by seeing one spot, you know the entire leopard." In fact, your brain can link visual cues to knowledge that it has already stored, and in doing so, it can make educated guesses about things that you see, even if you are not seeing the "whole picture," but only specific features.

This brain ability has been known for a while. In 1973, a scientist filmed a person dressed entirely in black, with several small lights attached to the person's main joints. By watching the video, observers could only see the lights moving in the dark—not the body itself. Still, it was possible for observers to identify whether the person was walking, running, or even dancing [1]. Follow-up experiments showed that observers could even tell the person's gender and emotions from the motion of the lights! This is called **biological motion perception**, which means the ability to identify actions and/or emotions by looking at the movement of living beings.

BIOLOGICAL MOTION PERCEPTION

The ability to understand actions and/or emotions from the movement of living beings.

Other species, including fish, can also do this. Imagine that you are a little fish in the vast sea. You must be able to tell your fellow fish apart from rocks, or even from wide-mouthed sharks that move differently. This is a matter of life or death! Most fish use their vision to get information from the environment. The brain processes these **visual cues** and if other animals are present, it decides how to interact with them: swim closer or swim away? How does this happen?

VISUAL CUES

Observations that allow us to understand actions, to learn information, to communicate with others.

ZEBRAFISH USE THEIR VISION TO RECOGNIZE THEIR FELLOWS

To answer this question, we studied a tiny and sociable striped fish called the zebrafish. Originally from South Asia, these fish are used in research laboratories around the world because they are easy to handle and breed. Their behaviors in the lab are very similar to those found in their natural environment. Zebrafish do not like to be alone, ever! When they see other zebrafish they quickly approach them, forming groups called **shoals**, in which they feel protected from predators and can easily find food or partners. To shoal, zebrafish must first recognize their fellows. How do they do this? Several researchers have demonstrated that zebrafish rely on visual characteristics, such as shape (body form) and **biological motion**,

SHOAL

A group of fish swimming together.

BIOLOGICAL MOTION

The movement of living beings.

CONSPECIFICS

Individuals belonging to the same species.

OXYTOCIN

A molecule that is involved in how animals behave/interact with others.

to identify **conspecifics**—individuals from the same species. Yet, the exact details of how these two cues promote social interactions between fishes are still not fully understood.

Like the human brain, the fish brain produces molecules that allow communication between various parts of the brain and the body. These molecules control many functions, including hunger and memory. One interesting molecule produced in the brain is called **oxytocin**, which is also known as the "love hormone" because it plays a role in parental and romantic relationships. For instance, oxytocin is released when we hug others. Recent studies have shown that oxytocin is involved in the social behaviors of several species, including fish [2]. If you are interested in learning more about oxytocin, check out this Frontiers for Young Minds article [3].

EXPERIMENTS WITH ZEBRAFISH

In our work, we asked two main questions. First, we asked how biological motion and shape promote interactions between fish. Second, we asked whether oxytocin is involved in this process. We already knew that zebrafish are highly social and form shoals with their conspecifics. We placed zebrafish in a tank with two sealed transparent compartments on opposite sides, one empty and the other containing a shoal. We saw that zebrafish spent most of their time close to the shoal, meaning that they prefer the shoal to the empty compartment. Since the zebrafish were not in the same water as the shoal, they must be able to recognize conspecifics based on visual cues (Figure 1A). We also tried placing zebrafish in a tank that looks like a movie theater for fish, where the zebrafish could choose from two movies: one showing a fish swimming and the other showing an empty tank (Figure 1B). Not surprisingly, the zebrafish spent most of their time closer to their favorite movie—the swimming fish. What are zebrafish actually seeing when they look at either the movie or real shoal?

When you look at the tanks in the nearest city aquarium and see fish swimming, you not only see their shapes, but you also see how they move—their biological motion. Zebrafish can also perceive these features: they recognize the shape of other zebrafish and the way their fellows move. To explore this, we filmed a fish swimming in a tank and edited the video by changing the shape and/or the motion of the fish. We ended up with several different videos: the original, of a fish swimming with normal biological motion, one in which we replaced the shape of the fish with a dot but left the biological motion, and two others in which we included either the dot or the fish but changed the movement to a non-biological motion. An example of non-biological motion is the movement of a swinging pendulum on a clock. The fish being tested could choose between two different videos, and we measured the time the fish spent close to each one, to determine its preference for that video.

Figure 1

Zebrafish prefer to interact with other zebrafish. **(A)** Zebrafish were placed in a tank with a compartment on each side: one empty and the other with a shoal. The zebrafish being tested spent most of their time closer to their fellow fish. **(B)** In a similar experiment, we put zebrafish in a tank with a monitor displaying a movie on each side. If we showed a movie of a swimming shoal on one side and one of an empty tank on the other, zebrafish spent most of their time close to their fellows (Figure adapted from source article).

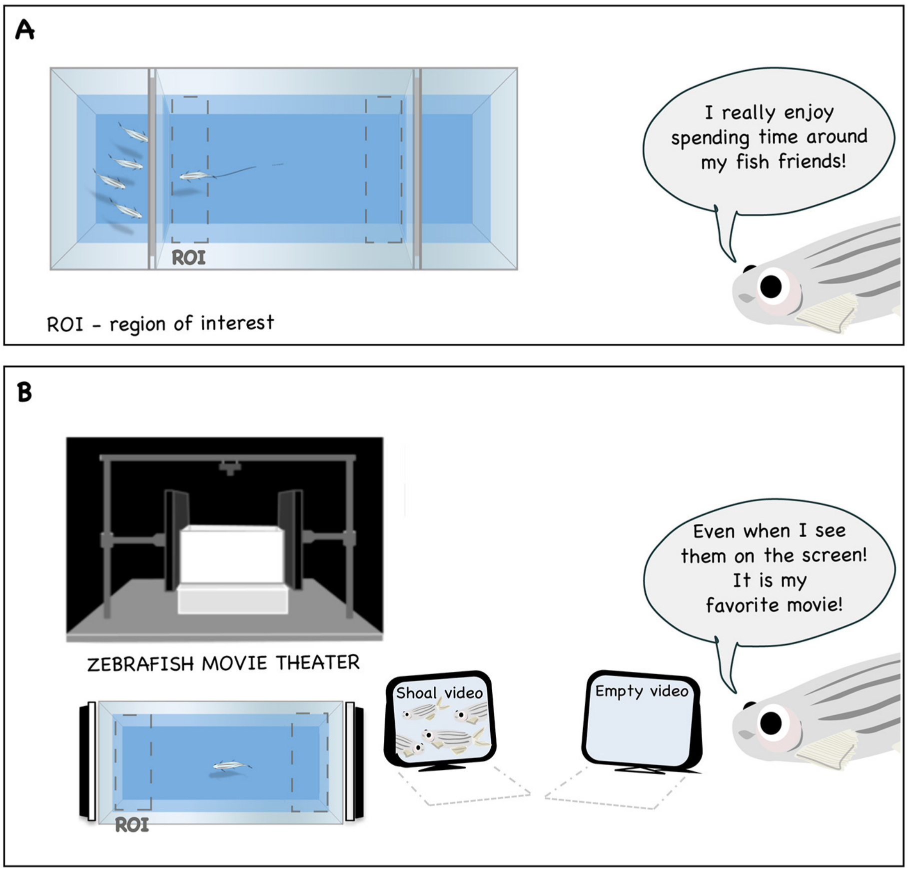

Figure 1

What did we find? When we tested the preference of zebrafish for fish vs. dot, we found that zebrafish showed a greater preference for the fish form. This preference was stronger in the presence of motion (Figures 2A–C). Can zebrafish identify biological motion? We presented zebrafish with two videos showing the same shape, either a dot or a fish, but with biological vs. non-biological motion. In the case of both the dot and the fish images, zebrafish spent more time closer to the videos with biological motion, showing a clear preference for this cue (Figures 2D,E). When zebrafish had a choice between fish with biological motion vs. a dot with non-biological motion, they spent more time closer to the swimming fish (Figure 2F).

These experiments demonstrated that shape and biological motion are *both* important to promote social interactions between zebrafish. Also, motion alone had a stronger effect than shape by itself.

THE ROLE OF OXYTOCIN IN THE PERCEPTION OF SOCIAL VISUAL CUES

How does the brain process these cues? Is oxytocin involved? To answer this second question, we tested mutant zebrafish that lacked

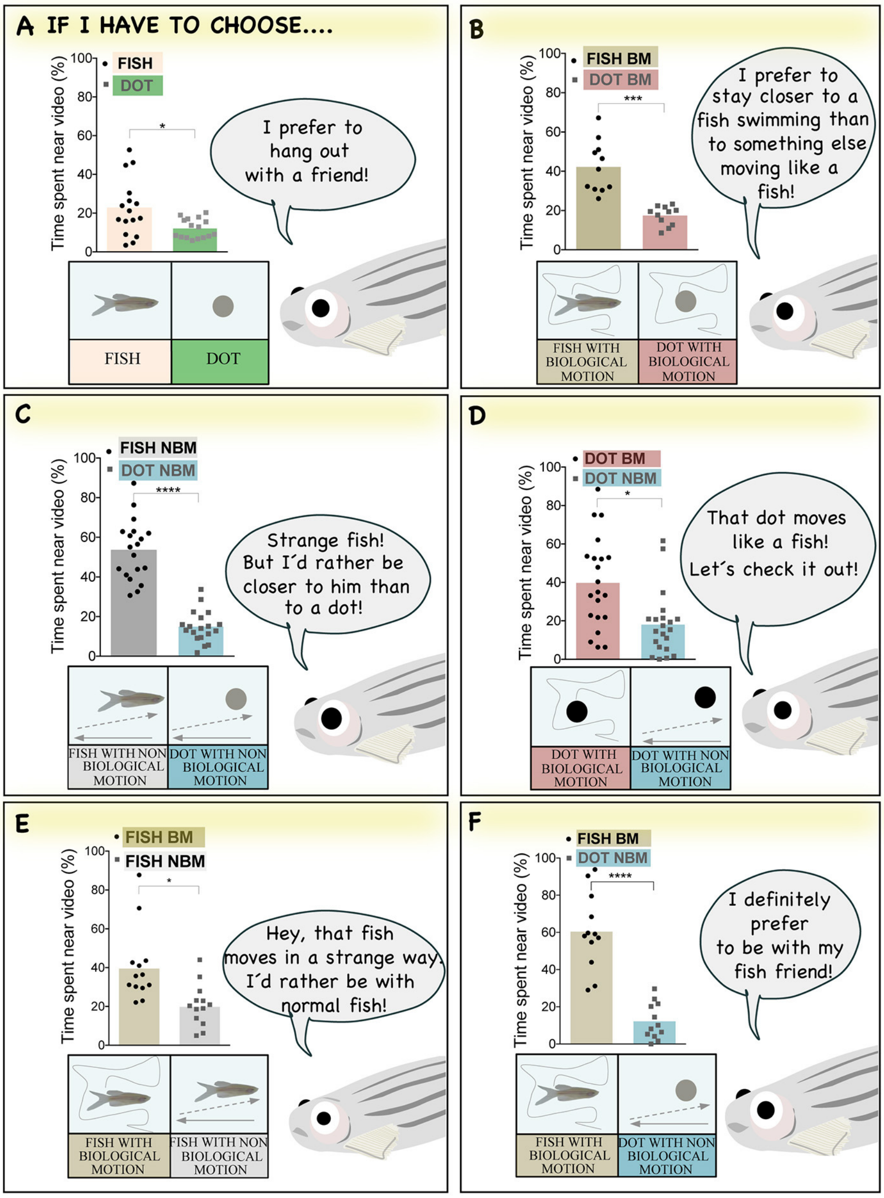

Figure 2

Figure 2

Zebrafish prefer fish shape and biological motion. We presented two videos and measured the time zebrafish spent close to each one. Each dot represents one fish. The y axis shows the time spent near the video. Videos were: **(A)** non-moving fish vs. non-moving dot; **(B)** fish swimming (biological motion) vs. dot with the same motion; **(C)** fish vs. dot, both with non-biological motion; **(D)** dot with biological motion vs. dot with non-biological motion; **(E)** fish swimming vs. fish with non-biological motion; and **(F)** fish swimming vs. dot with non-biological motion. Asterisks indicate statistically significant differences (Figure adapted from source article).

OXYTOCIN RECEPTOR

A molecule where oxytocin binds to, like in a puzzle, to produce its effects. Without this molecule, oxytocin cannot act in the brain.

the molecule that oxytocin must stick to, called the **oxytocin receptor**, to promote its effects. We used a mutant fish in which a specific part of the DNA that codes for the oxytocin receptor had been modified, in such a way that this type of receptor is not functional anymore. If oxytocin is important for regulating the perception of these visual cues, mutant fish without the oxytocin receptor will have less preference for shape and/or biological motion. Indeed, mutant fish showed a decreased preference for biological motion when exposed to a dot with biological motion vs. a dot with non-biological motion (Figures 3A,C). However, when mutant fish were shown a still dot vs. a still fish, they still preferred the fish (Figures 3A,B). These results suggest that oxytocin is important for perceiving biological motion, but not body shape.

Figure 3

Oxytocin helps zebrafish to perceive biological motion. **(A)** Preference score formula: time fish spent closer to a video with social cues divided by time spent closer to the two videos. **(B)** Normal zebrafish and mutant zebrafish lacking the oxytocin receptor were shown videos of a still fish vs. a still dot. Both normal and mutant zebrafish spent more time near the fish shape. **(C)** Normal and mutant zebrafish were shown videos of a swimming dot vs. a dot with non-biological motion. Mutant fish were less attracted to the swimming dot. Asterisks indicate statistically significant differences (Figure adapted from source article).

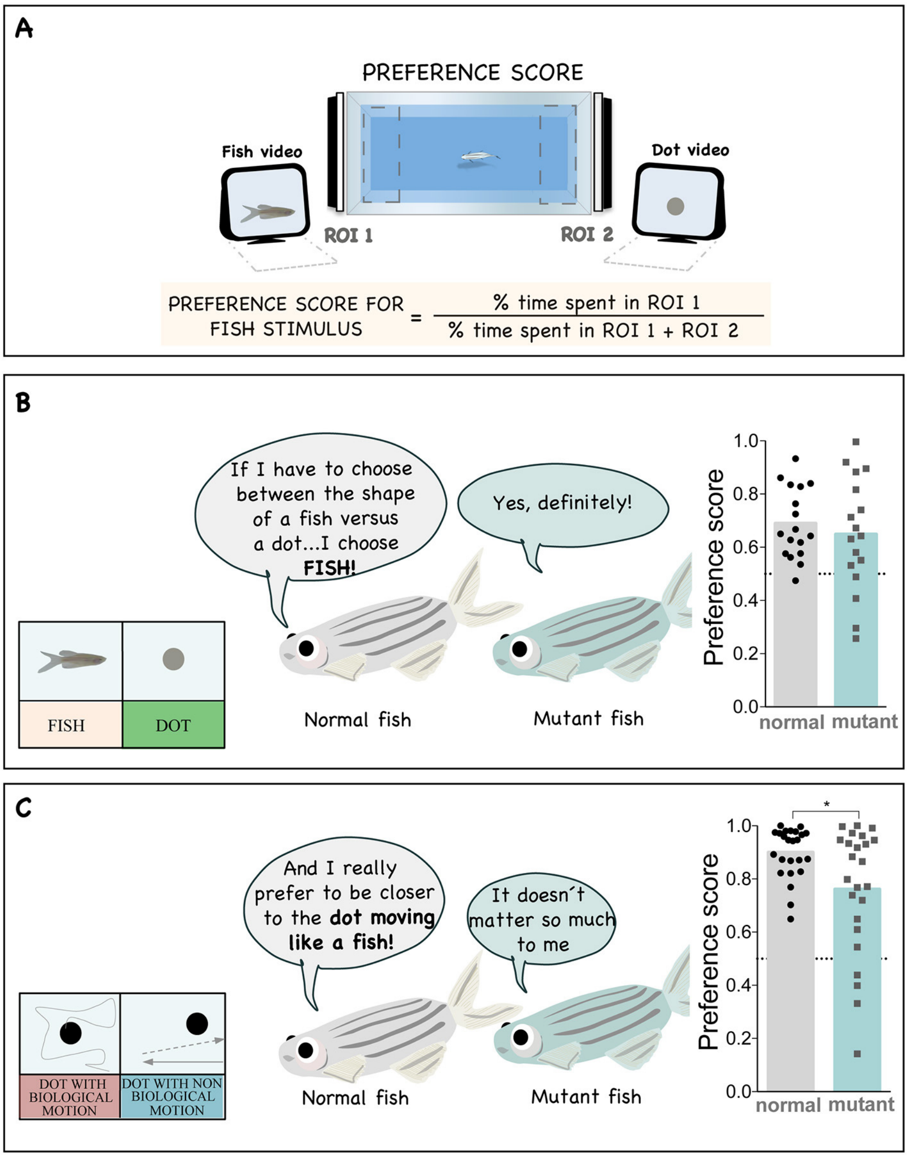

Figure 3

AUTISM SPECTRUM DISORDERS

Complex conditions that begin during children's brain development which affect the behavior, communication and social interactions of a person.

People with social difficulties, like **autism spectrum disorders**, are not as good at using social visual cues [4]. Autism is a complex condition with many different causes, and it is not yet fully understood. We still do not know which molecules are failing to do their jobs properly in autism, but oxytocin is a great candidate. Oxytocin is known to regulate social behaviors and now we know it is involved in the perception of biological motion [5]. Studies with autistic children have tried to improve their social abilities with oxytocin nasal spray. Some studies have reported improvements, but others have not [6, 7], so more studies are still needed.

CONCLUSION

Imagine our zebrafish in its natural environment, swimming freely and happily. Now you know that zebrafish use visual cues to interact with other fishes. Humans do the same! Perhaps zebrafish and humans obtain and process social information in a similar way—maybe there is an evolutionary mechanism shared across species! Like fish, we can easily distinguish biological from non-biological motion, and we can even identify a man running from only light animation, as we described earlier. More research is needed to understand exactly how humans process social visual cues and which molecules are involved. This research is important because it could eventually be used to help people with social disorders, like autism, to have an easier time with social interactions.

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ORIGINAL SOURCE ARTICLE

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YOUNG REVIEWERS

ARITRO, AGE: 12

I am a music nerd who likes to also solve different permutations of the rubix cube. In my free time I enjoy kayaking, developing model n-gauge trains, and I am a fan of the Star Wars franchise. In school, I am looking forward to learning science and math in a classroom again!

NEEL, AGE: 12

I am Neel, I am 12 years old and in the 6th grade. I am interested in neuroscience because much of what we do not understand about being humans is linked to the brain. My favorite periods in school are math and science, I enjoy all the hands-on experiences in science and I love the logical nature of maths. In my free time, I like to play soccer, tease my sister and play around with my dog Noki.

AUTHORS

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I have a Ph.D. in life sciences and pharmacology and I am a postdoctoral researcher at Instituto Gulbenkian de Ciência, Portugal. For several years, I have been studying mechanisms related to social interactions in zebrafish. Being a scientist is fun and exciting, and it has allowed me to travel and work around the world, collaborating with many interesting people. I also love hiking and diving.

ANA S. FÉLIX

I have been involved in research for several years. I started as a technician in the lab and discovered that I love science. As a Ph.D. student, I enjoyed studying how several molecules, like hormones, influence social behavior. This fascination has not left me, but instead has deepened over the years. Currently, I teach others about how the brain works and I really love doing that. In my free time, I enjoy spending time with my family and playing around with my kids.

RUI F. OLIVEIRA

I have a Ph.D. in biology and I lead a research group at Instituto Gulbenkian de Ciência, Portugal, that studies the biology of social behavior. In our lab, we aim to understand why social behavior evolved the way it did in each species, and what the mechanisms are—genes, molecules, and their interactions with the environment—that produce it. I also teach neuroscience and behavior at a university college in Lisbon (ISPA). Besides science, I also love arts and spending time in the sea, surfing. *ruiol@ispa.pt