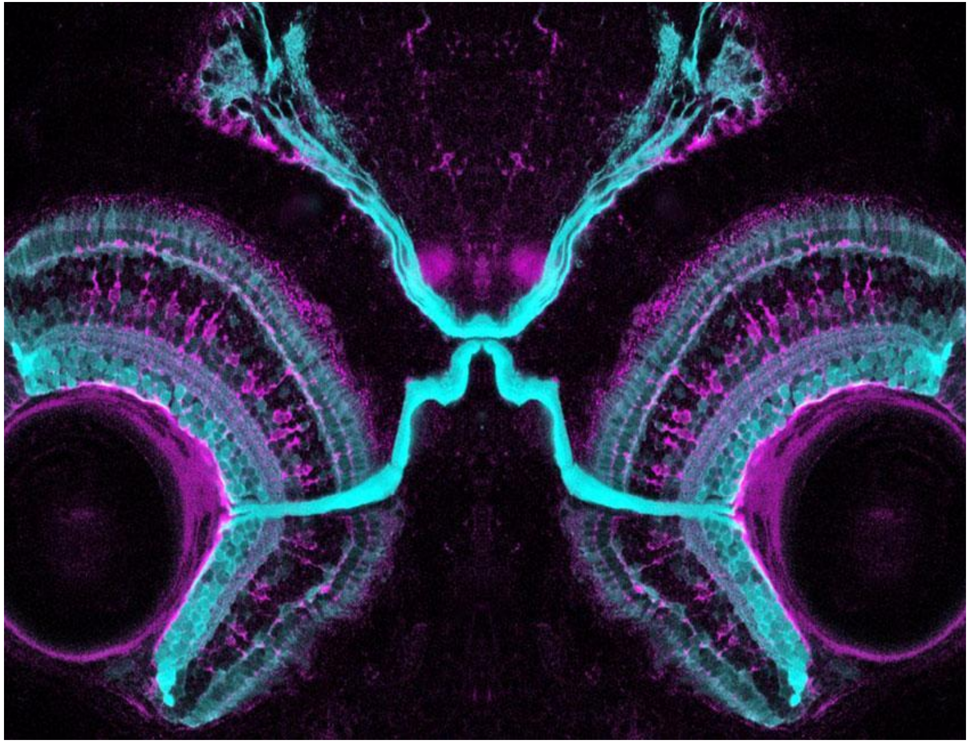


Section:
Dunn et al., 2016

& Live-demo!

Background Recap:

Section W3

Predator avoidance: A highly conserved behavior that is essential for survival

1. Fundamental behavior for survival
2. Highly conserved
3. Predator detection has to be accurate

(Kim et al., 2020)

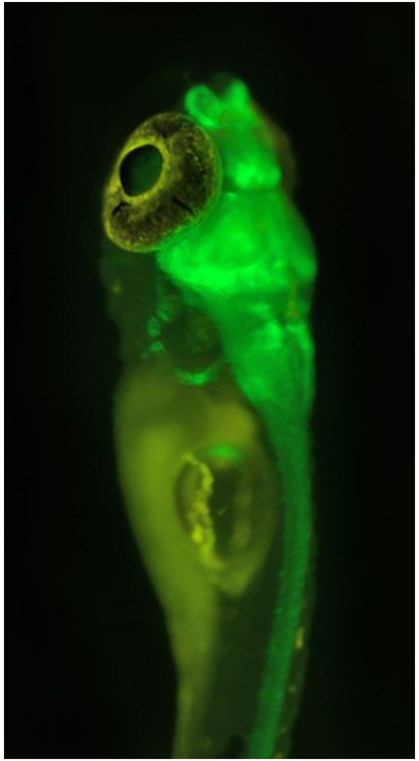
Looming stimulus elicits escape responses

A loom I made earlier

(Purcel et al., 2012)

(Temizer et al., 2015)

Zebrafish are optically transparent – great for imaging!

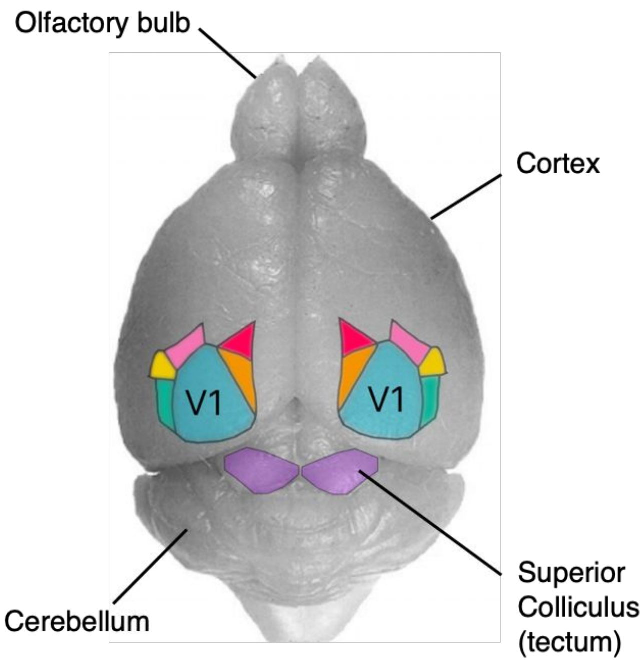


HuC:H2B-GCaMP6s

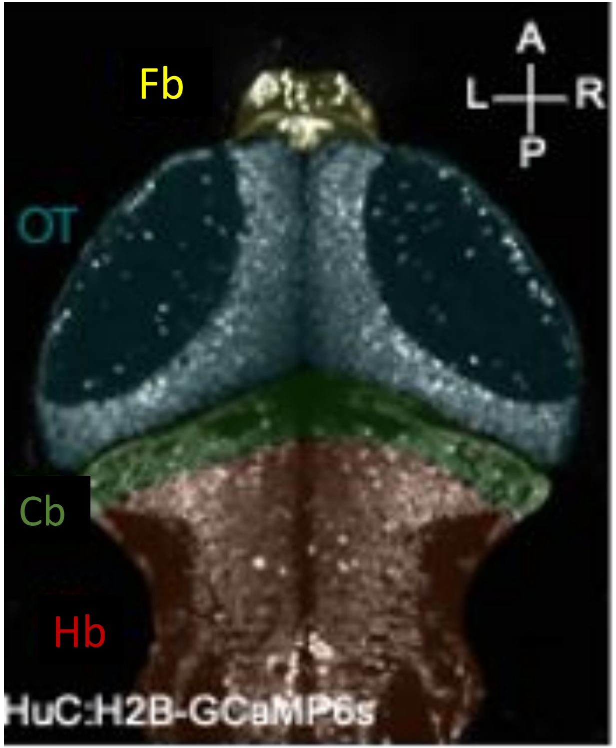
(Ahrens et al., 2012)

Neuroanatomy

The mouse brain

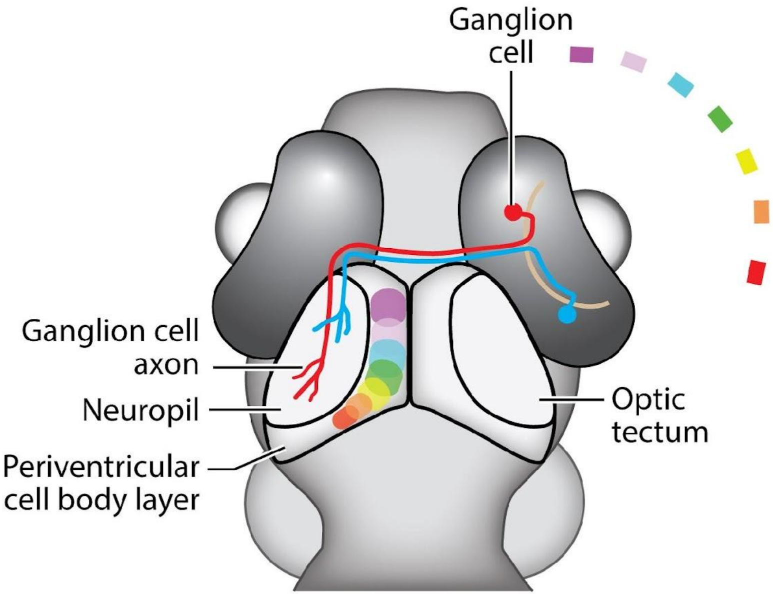


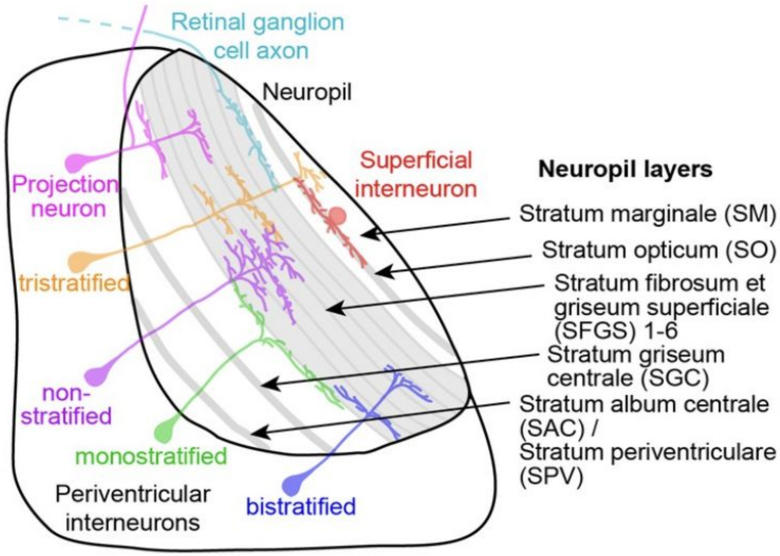
The zebrafish brain



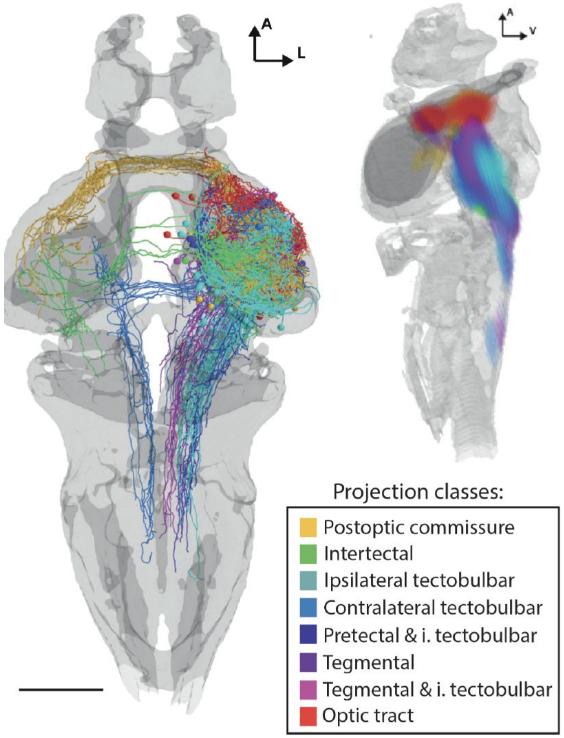
Fb = forebrain
OT = optic tectum
Cb = cerebellum
Hb = hindbrain

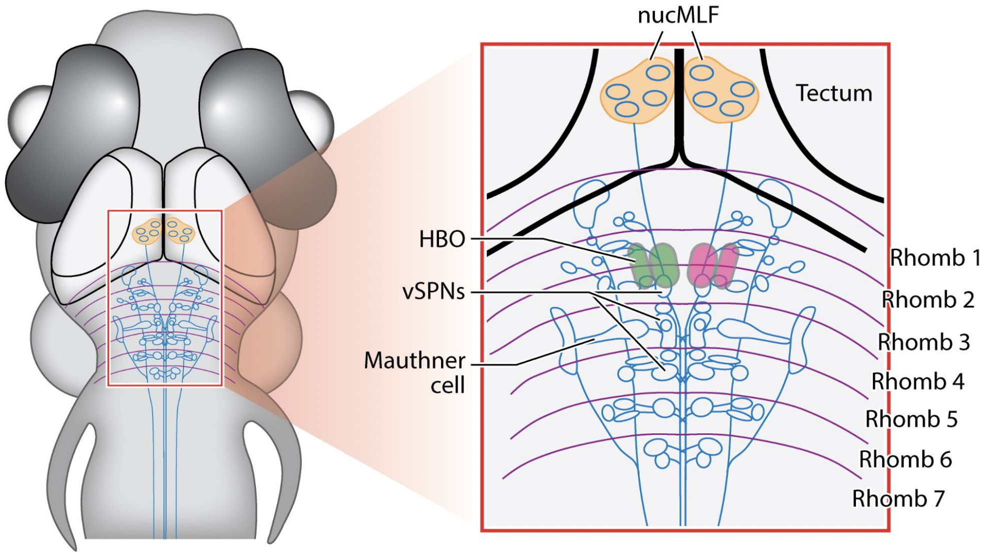
Retinal ganglion cells project to the optic tectum





Tectal neurons project into the hindbrain





A dedicated tectal circuit for detecting predators?

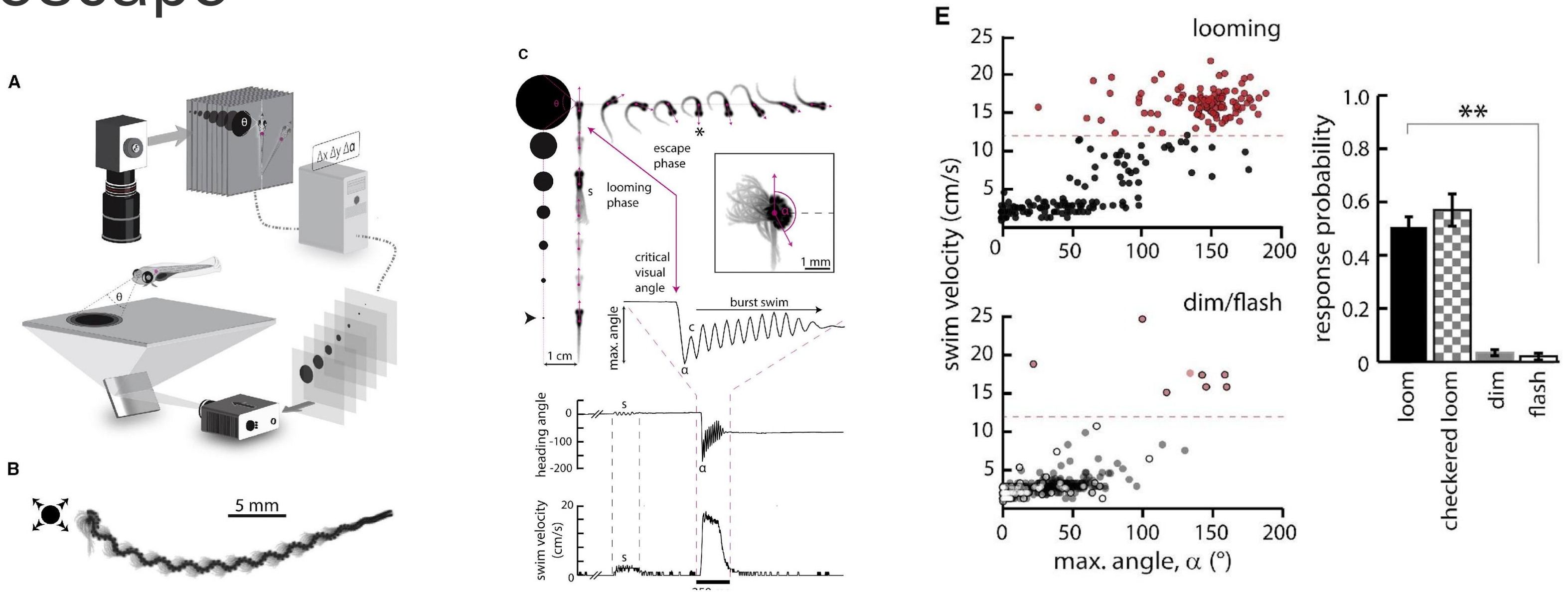
Section paper:

Neural Circuits Underlying Visually Evoked Escapes in Larval Zebrafish

Timothy W. Dunn • Christoph Gebhardt • Eva A. Naumann • ... Misha B. Ahrens • Florian Engert • Filippo Del Bene • Show all authors

Escape behaviors deliver organisms away from imminent catastrophe. Here, we characterize behavioral responses of freely swimming larval zebrafish to looming visual stimuli simulating predators. We report that the visual system alone can recruit lateralized, rapid escape motor programs, similar to those elicited by mechanosensory modalities. Two-photon calcium imaging of retino-recipient midbrain regions isolated the optic tectum as an important center processing looming stimuli, with **ensemble activity encoding the critical image size** determining escape latency. Furthermore, we describe activity in retinal ganglion cell terminals and superficial inhibitory interneurons in the tectum during looming and **propose a model for how temporal dynamics in tectal periventricular neurons might arise from computations between these two fundamental constituents**. Finally, laser ablations of hindbrain circuitry confirmed that visual and mechanosensory modalities share the same premotor output network. Together, we establish a circuit for the processing of aversive stimuli in the context of an innate visual behavior.

Figure 1: Kinematic analysis of looming-specific escape



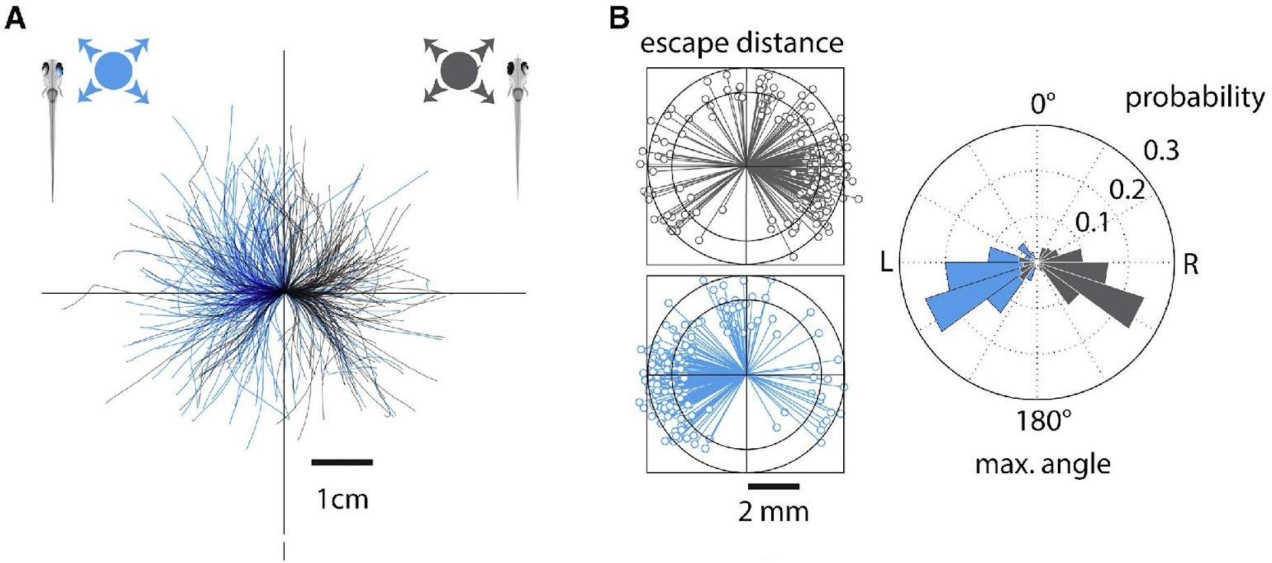
How do the authors define an escape behavior?

A swim velocity > 12.5 cm/s

Why did they present the checkered loom?

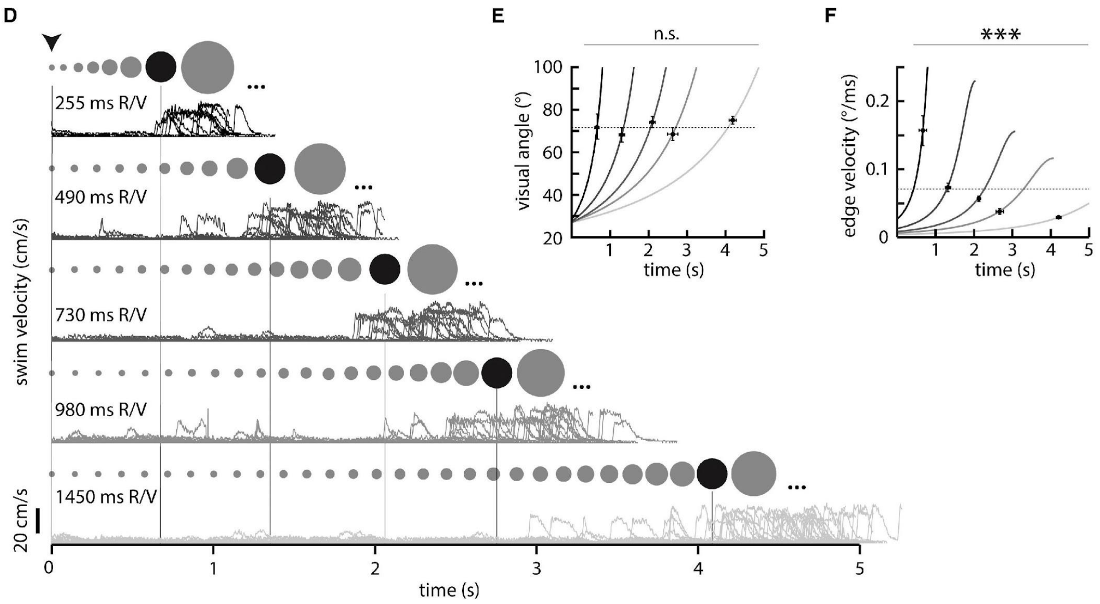
The looming stimulus contains many visual features (moving edges, dimming of the visual scene). The checkered loom still has moving edges but is luminance matched → control that luminance-independent visual computation to detect expanding borders.

Escapes are related to the side that the loom is presented.



Why do you think the escape is directional?

Figure 2: Stimulus and dynamics dictate escape latency



What is the hypotheses behind presenting the loop at different velocities?

Zebrafish may detect a critical angle of the loom, alternatively they may be detecting the velocity of looms angular expansion.

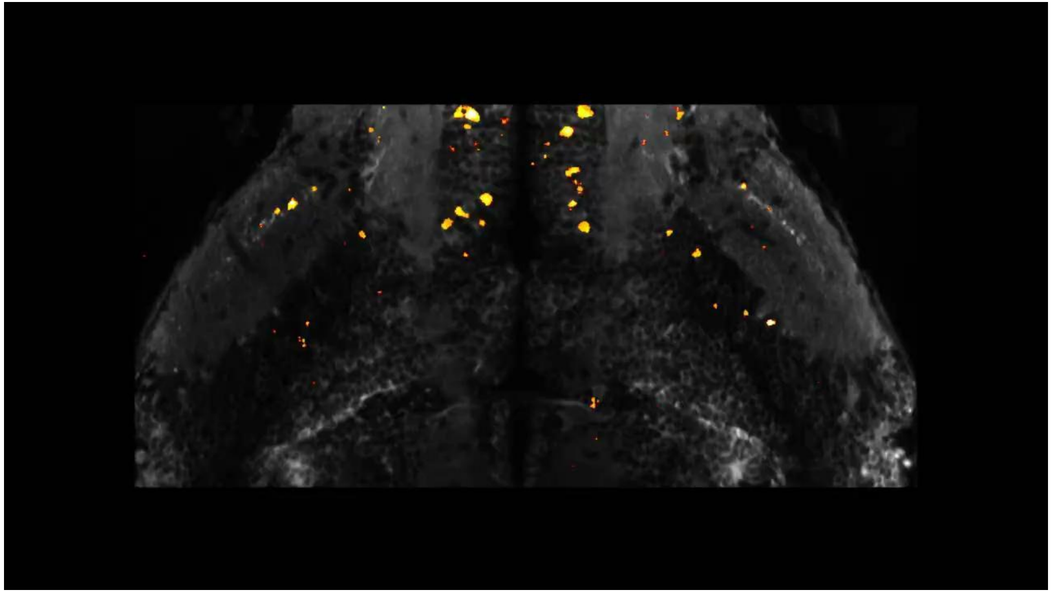
What feature of the looming stimulus is the fish brain likely to be encoding?

A critical angle of the loom because despite the speed of the loom all escapes happen at ~70°.

What would you expect to see if edge velocity was being encoded?

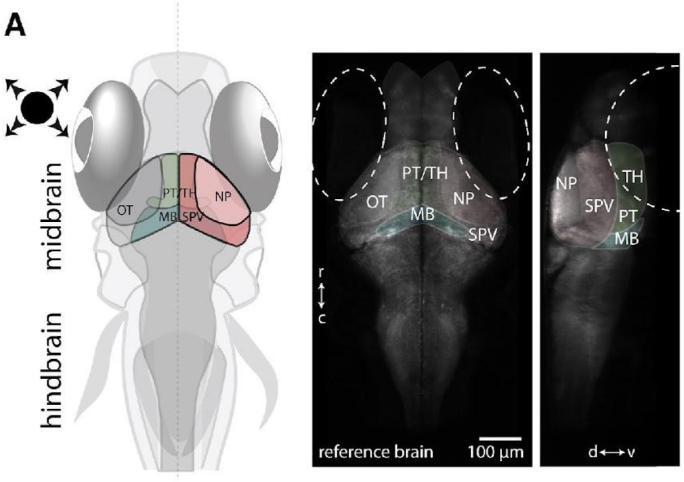
If the visual system was encoding edge velocity you would expect escapes for some loom speeds but not for others.

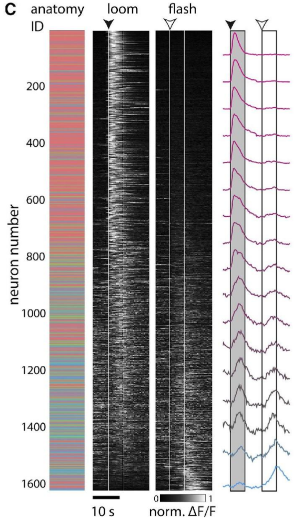
Functional imaging of the midbrain and tectum

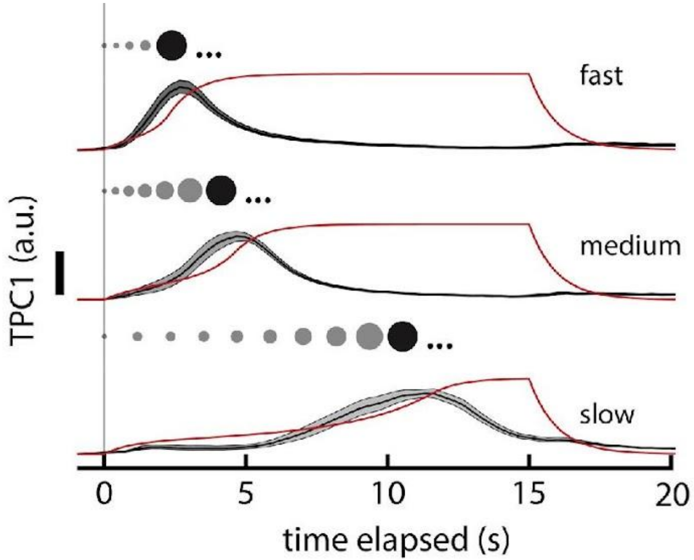


Why did they image ventral tectum and not more dorsal?

Figure 3 Looming-Specific Neurons in the Optic Tectum Encode Critical Size







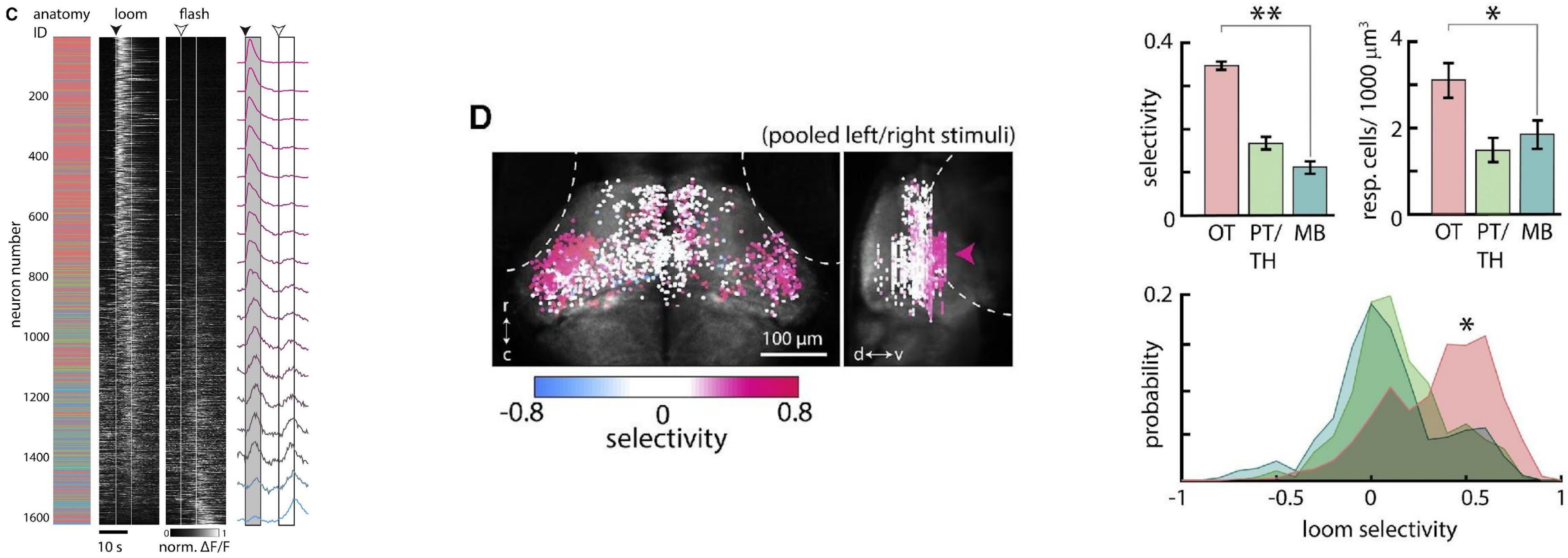
How was the tectal population activity obtained?

Calcium imaging two-photon laser scanning microscope during stimulus presentation.

Panel C-E: What is the tectal activity encoding?

The results suggest that the OT neurons encode for a critical threshold angular image size in looming detection.

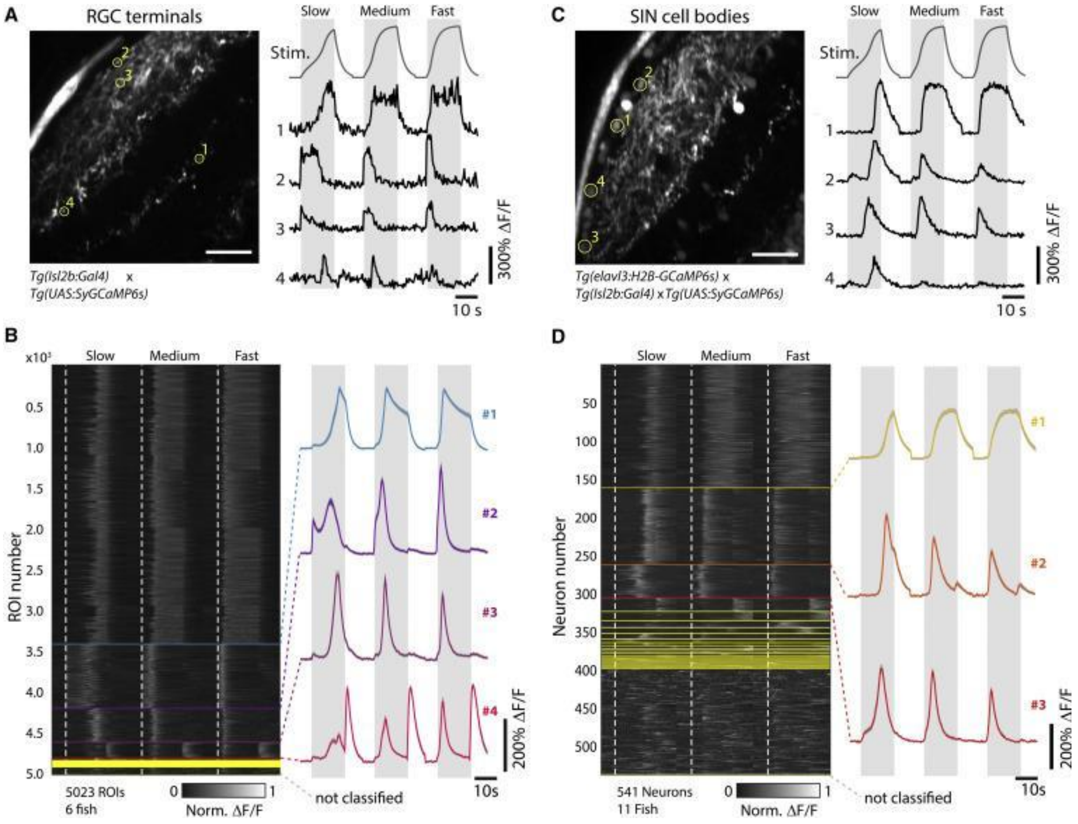
Figure 3 Looming-Specific Neurons in the Optic Tectum Encode Critical Size



How do the authors show that the tectal neurons are selective for the loom?

By using a selectivity index which compare selectivity to the flash in different regions: SI; [zloom − zflash]/[zloom + zflash] >0 → higher selectivity to the loom.

Figure 4: Retinotectal Processing of Looming Stimuli



Why do they image the RGC terminals and not their cell bodies?

RGC terminals are in the OT. Cell bodies are located in the retina, which contains pigment, making it difficult to image while the animal is alive.

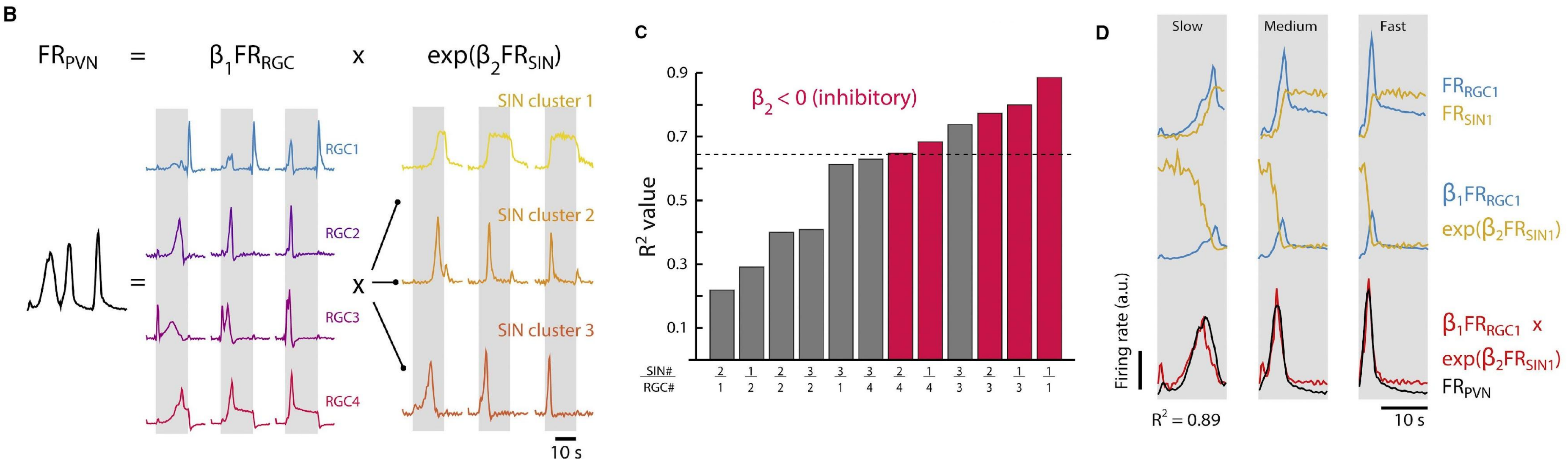
What are the Superficial interneurons (SINs)?

Known to play a role in filtering out large and small moving visual stimuli. Inhibitory interneuron operating on excitatory RCG inputs.

What do the heterogeneous responses indicate?

4 main RGC terminals responses types indicate that they capture distinct features of the stimulus. 3 main SIN responses types for the 3 different speeds of the looming stimuli.

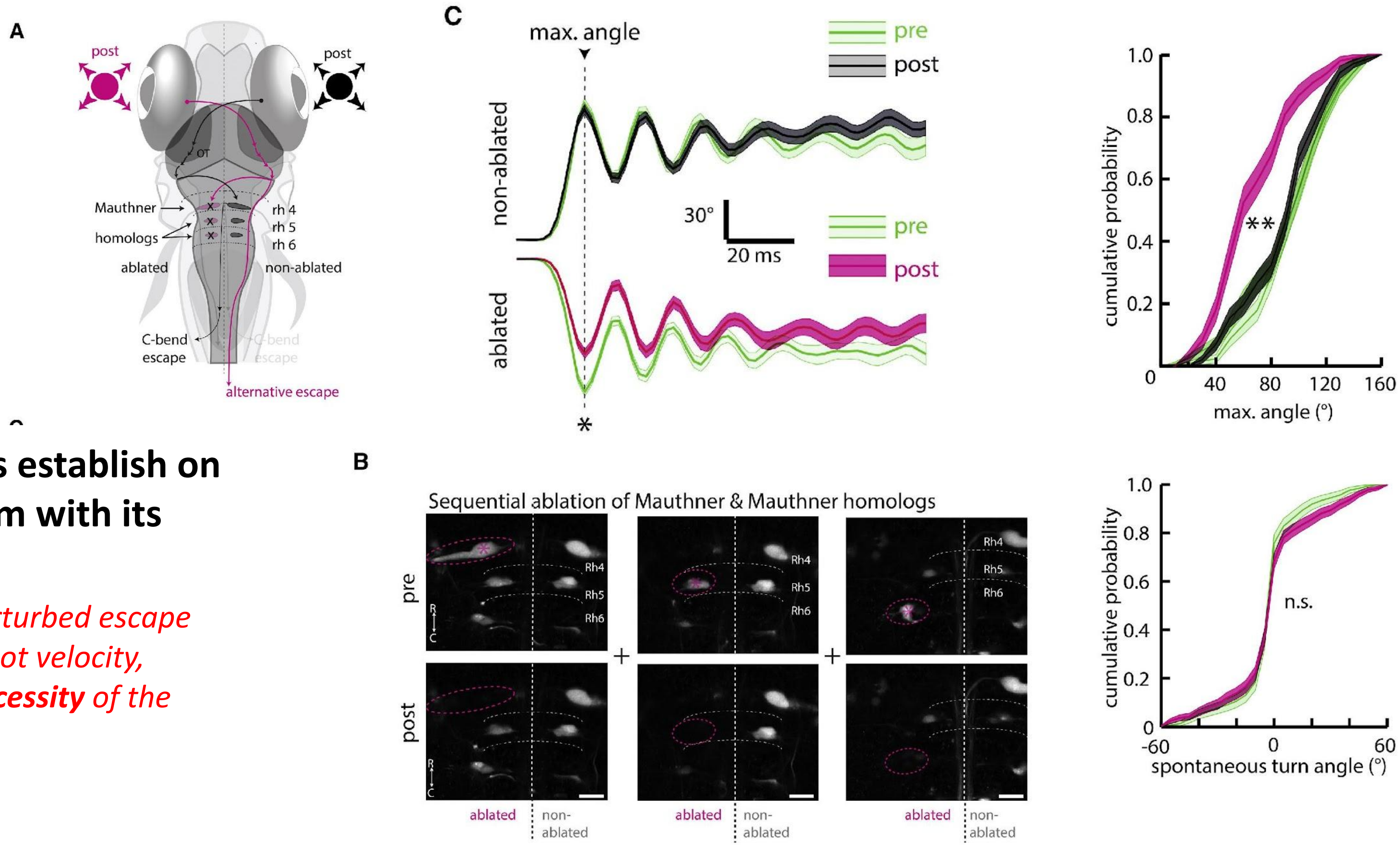
Figure 5: Regression Models Predict PVN Responses to Looming Stimuli



What is the authors' hypothesis about interaction between the different neurons in the OT?

No matching between RGNs and PVNs → further processing + SINs inhibit excitatory RGNs axons → PVNs might receive a nonlinear combination of excitatory and inhibitory inputs to create receptive fields that encode critical angle.

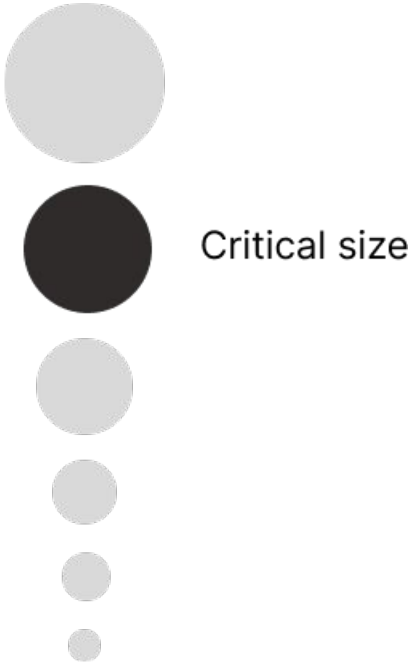
Figure 6: Laser Ablation of the Mauthner System Alters Escape Trajectory and Reduces Initial Bend Angle

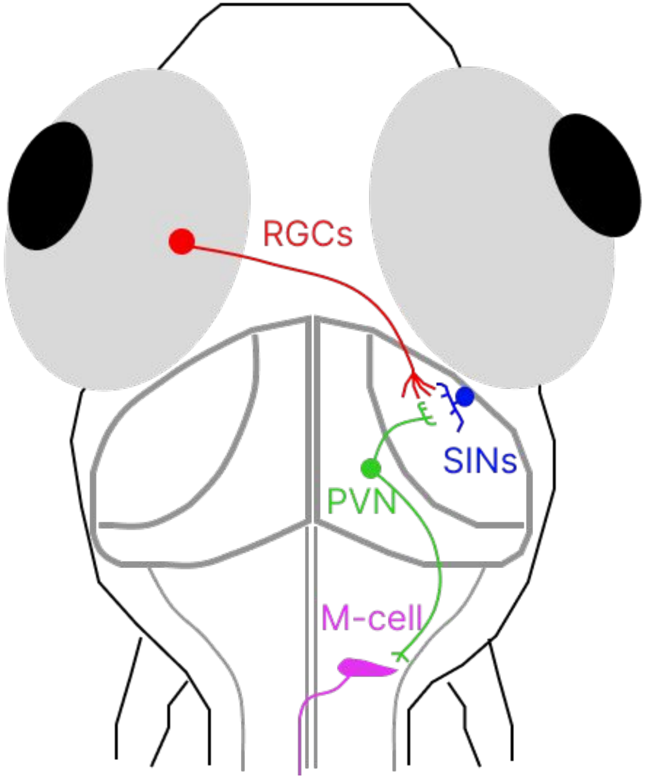


What can the authors establish on utility of the M-system with its ablation?

*M-system ablation → perturbed escape response (in turn angle, not velocity, distance, duration) → **necessity** of the M-cell.*

Summary: Dedicated visual circuit for predator avoidance





Paper round-up

- They provide the first detailed description of a rapid escape behavior elicited by a visual stimulus in freely swimming larval zebrafish.
- They suggest that the circuits processing looming stimuli may primarily use stimulus size information when determining when and if an escape should be initiated.
- They show that the optic tectum (OT) might serve as a primary nucleus involved in looming detection within the larval zebrafish brain, by encoding a critical looming visual angle as an ensemble.
- They establish a necessary role of the M-system in the sensorimotor transformation from looming stimuli to escape behavior, providing a functional scaffold for the zebrafish to quickly evade threats identified with their eyes alone.

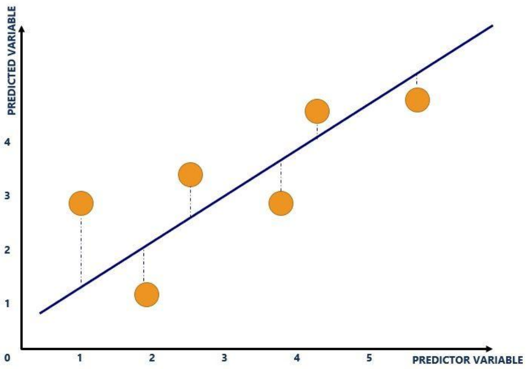
What did we learn? What questions do we have?

- **Is anything unclear?**

- **What would you do next if you had to design an experiment?**

- *What is the actual connectivity between the neurons in OT and M-system? How are the primary RGC and SIN types specifically combined to affect population activity in the OT?*
- *Causal manipulations: what happens if you optogenetically disrupt SIN activity.*
- *Similar circuit in mice? predator detectors in retina and SC (Bohl et al., 2023; Kim et al., 2020; Gale and Murphy 2016)*

R-squared



PREDICTED VARIABLE
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2
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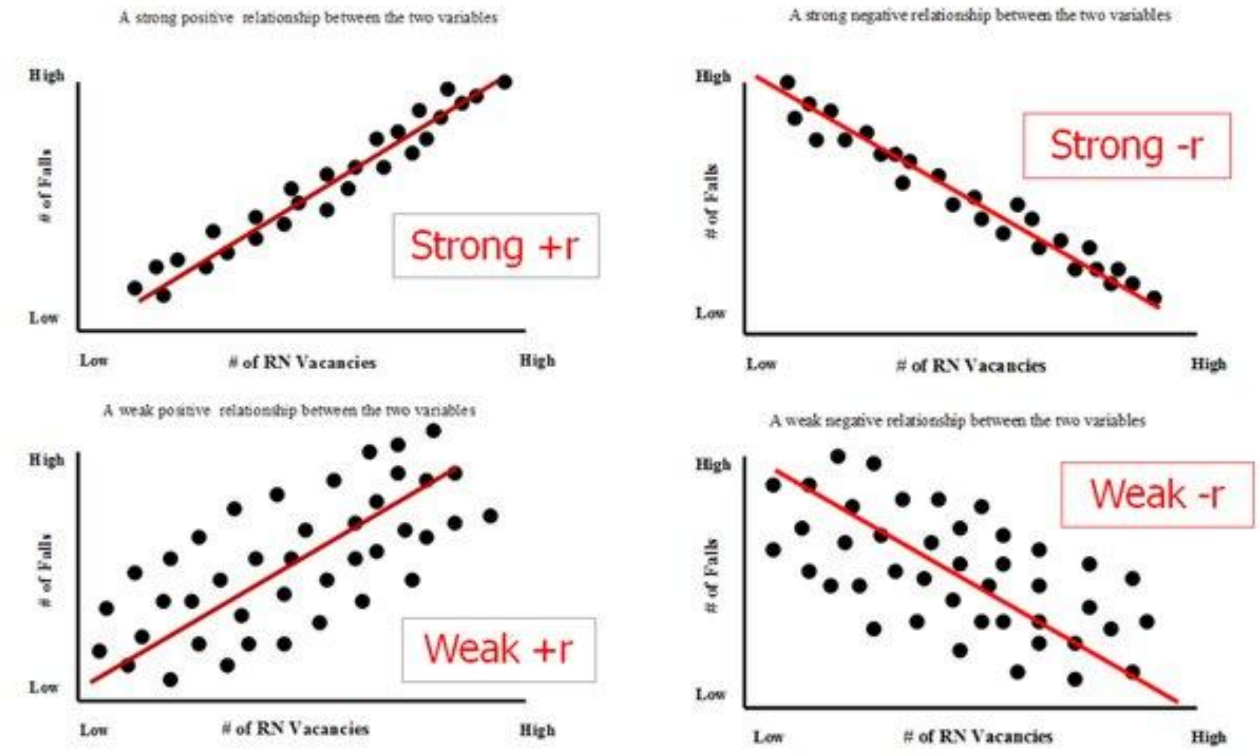
4
5
PREDICTOR VARIABLE



A strong positive relationship between the two variables
High
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Strong +r
A strong negative relationship between the two variables
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A weak negative relationship between the two variables
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