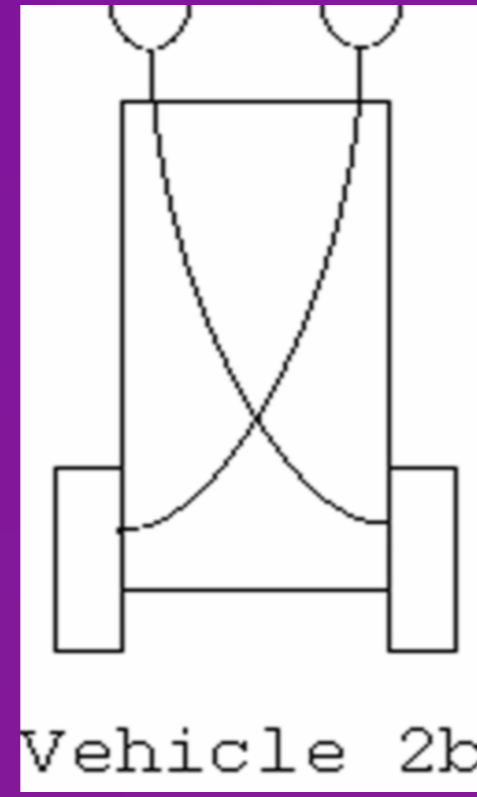




## Description of the task and the system

- Topos is a computational model of Braitenberg-like robots
- Robots have to discriminate between two real sounds like two chirps of a canary in a Skinner-box scheme
- Robots use the sounds as navigation landmarks in order to reach one of the sounds in the arena (the goal is previously set)
- Navigation can be thought as a pattern recognition process in three-dimensional signals like sounds (amplitude, frequency, time)
- The system is developed in a Evolutionary Robotics framework
- The robots obtain a fitness value from five trials of the same task
- Khepera-like robots have two motors connected through a recurrent spiking neural network to bio-inspired sensors that resemble the ears



Vehicle 2b

## Sensors and Spiking Neural Networks

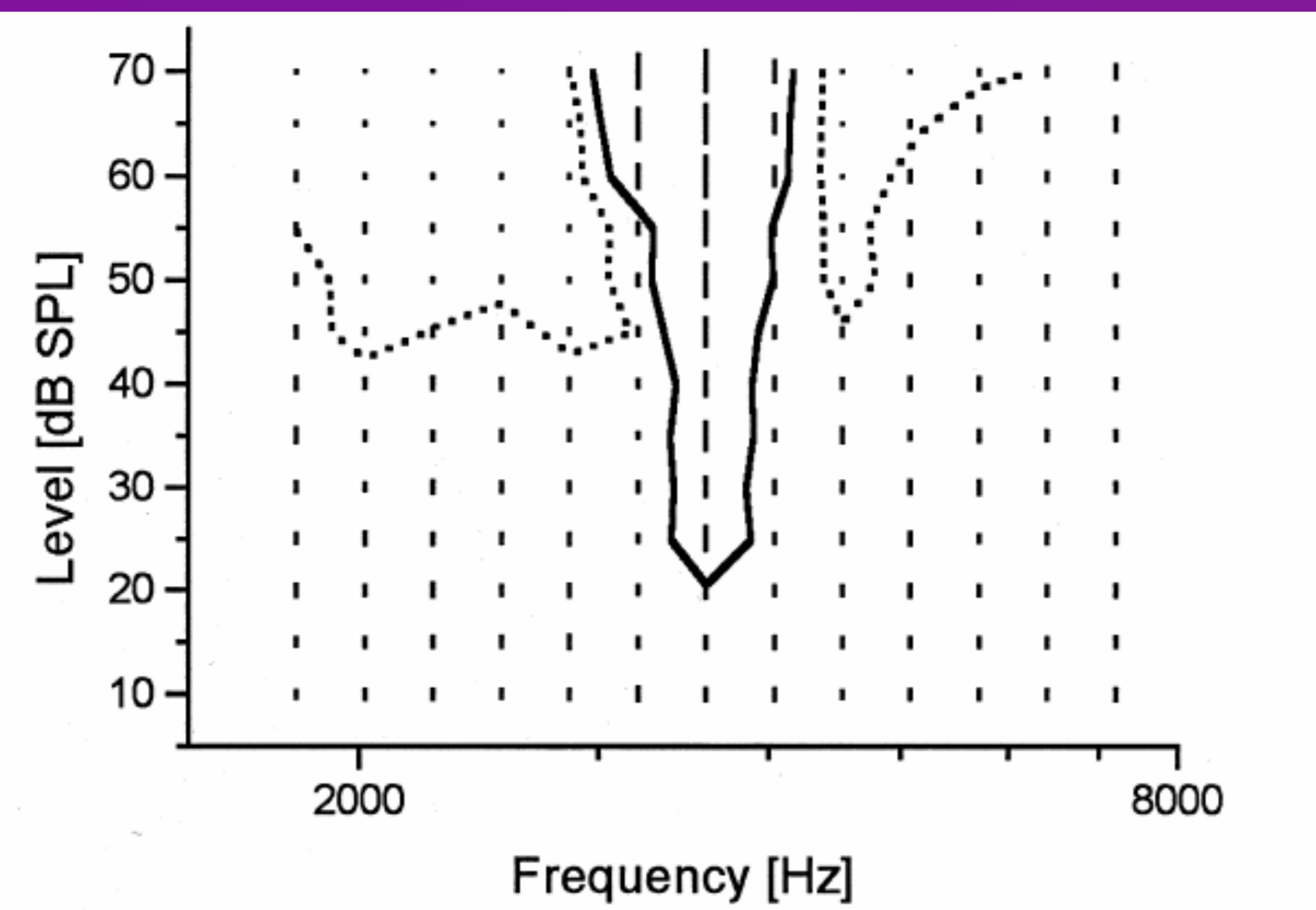


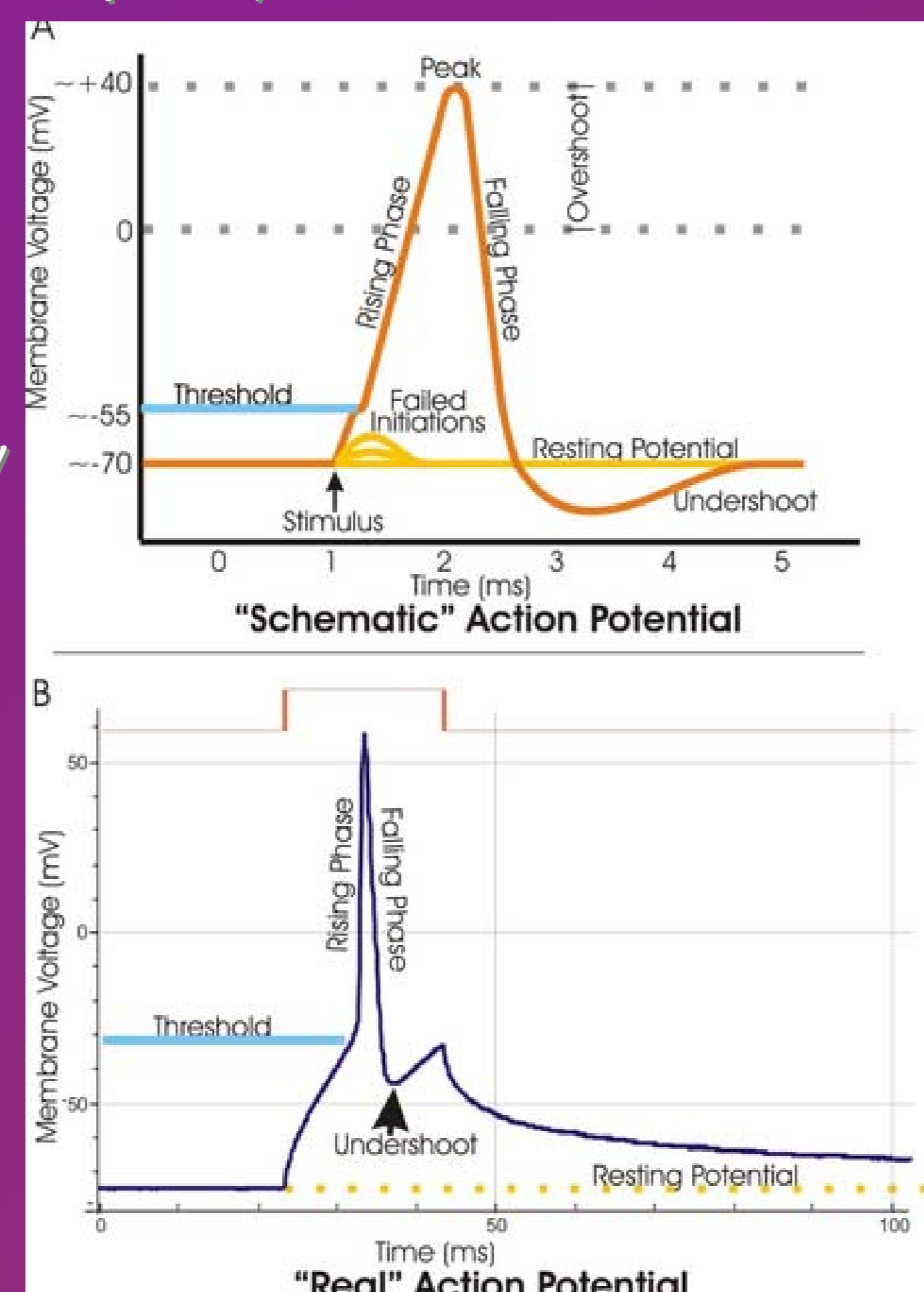
Fig. 1. Example of a response matrix defining the tuning characteristics. The height of the bars indicates the number of impulses per frequency-level combination. A FTC (solid line) and inhibitory sidebands (dotted lines) are added according to the threshold criteria described in the text.

- The "outer ear" of a sensor is a cardioid-shape filter that attenuates the signal depending on the angle of incidence of the signal
- An artificial cochlea allows the perception of recorded sounds, translating them from the time domain to the frequency domain (using the Fourier Transform)
- Each sensor neuron is activated if the signal in its characteristic frequency is above the threshold

- The model uses Spiking Neural Networks
- The delays in axons process time information from the signal to discover temporal patterns.
- Synapses are weighted and can be inhibitory

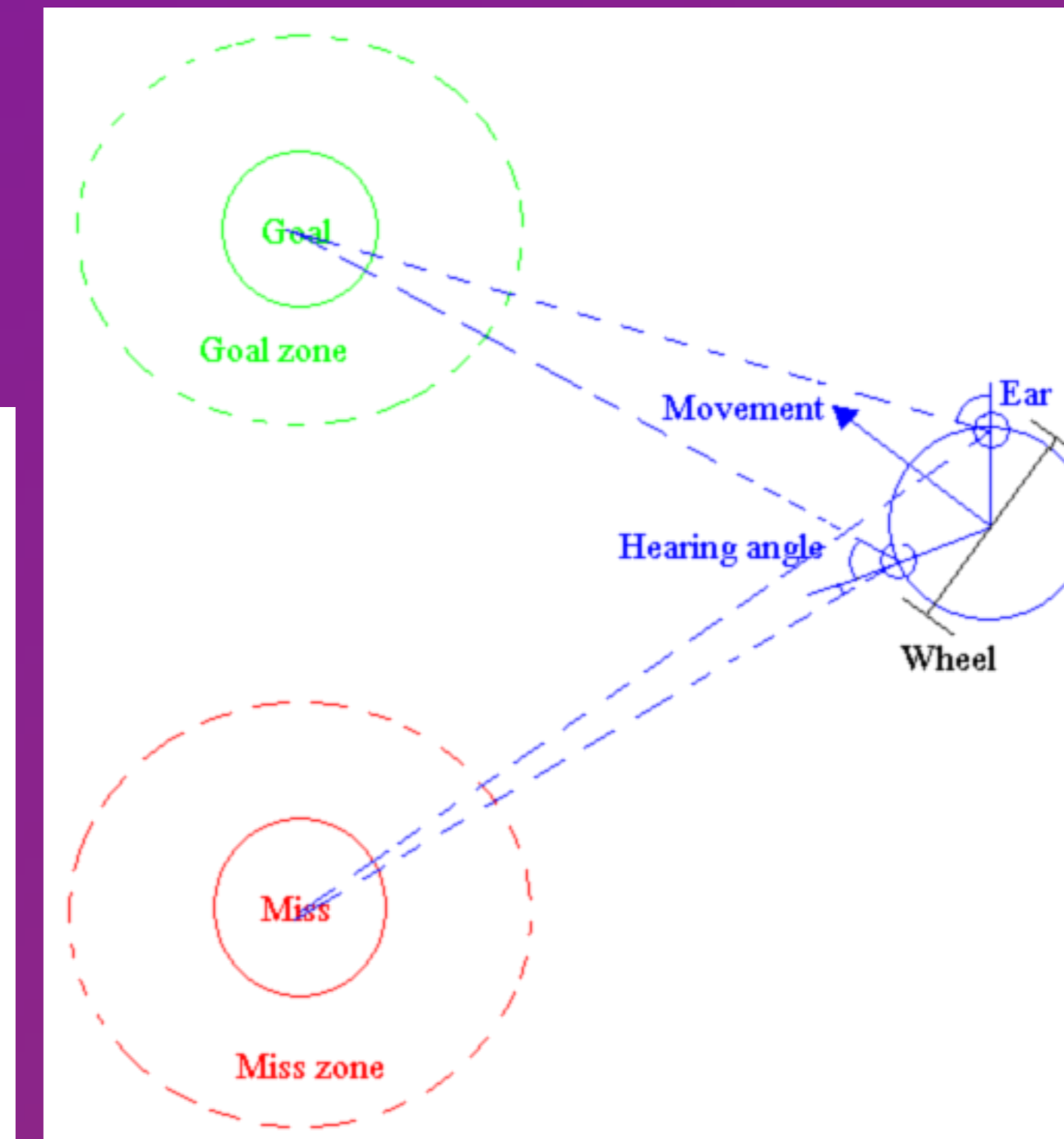
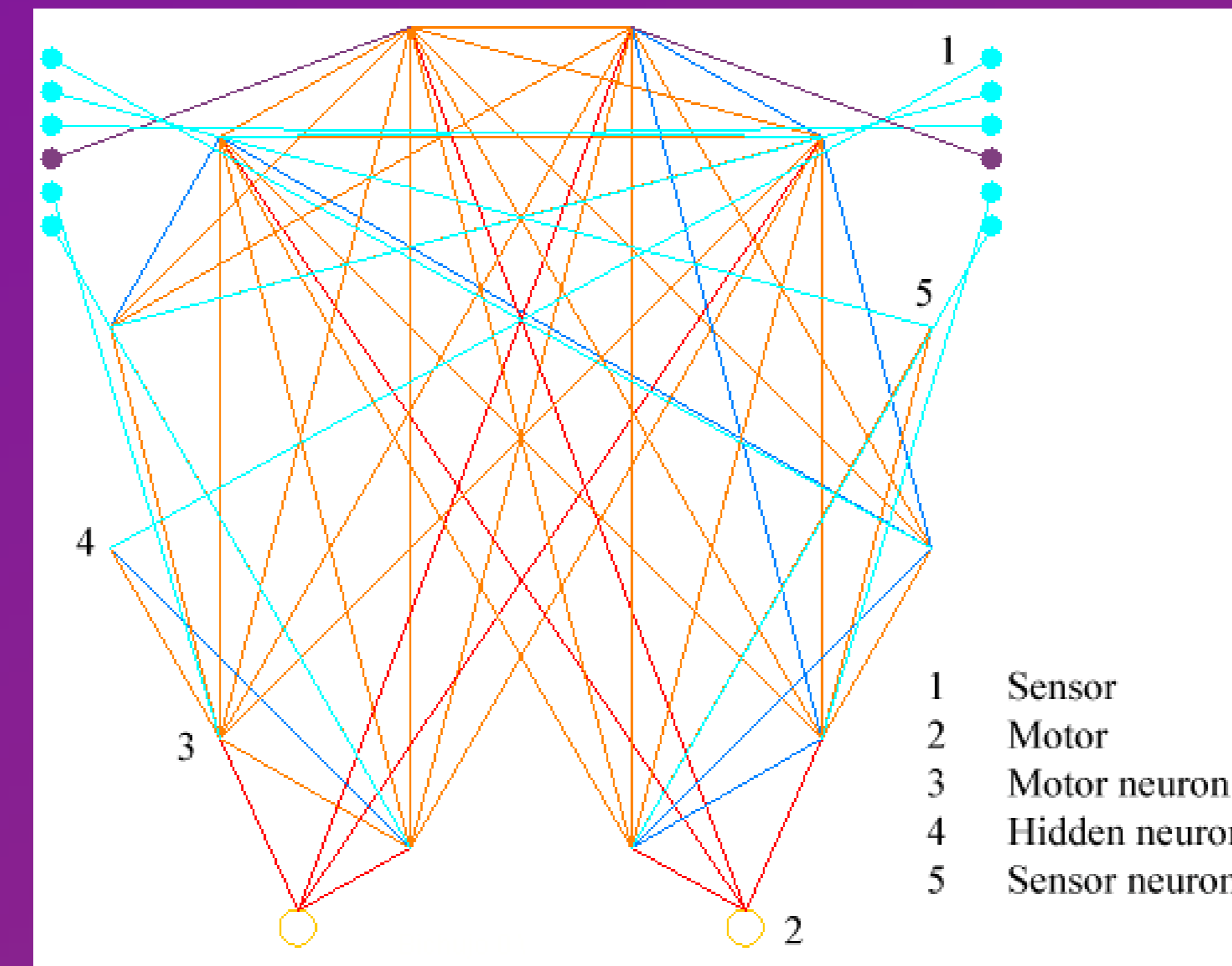
The main advantages of a Spiking Neural Network are:

- they are biologically plausible
- they can integrate perceptions in time
- they can process temporal information
- they can endure the noise
- they are mathematically equivalent to sigmoid neurons
- in some problems they do the same task with less neurons



## Neural Network Topology

The structure is twice expressed to develop the symmetry in a generalized Braitenberg vehicle

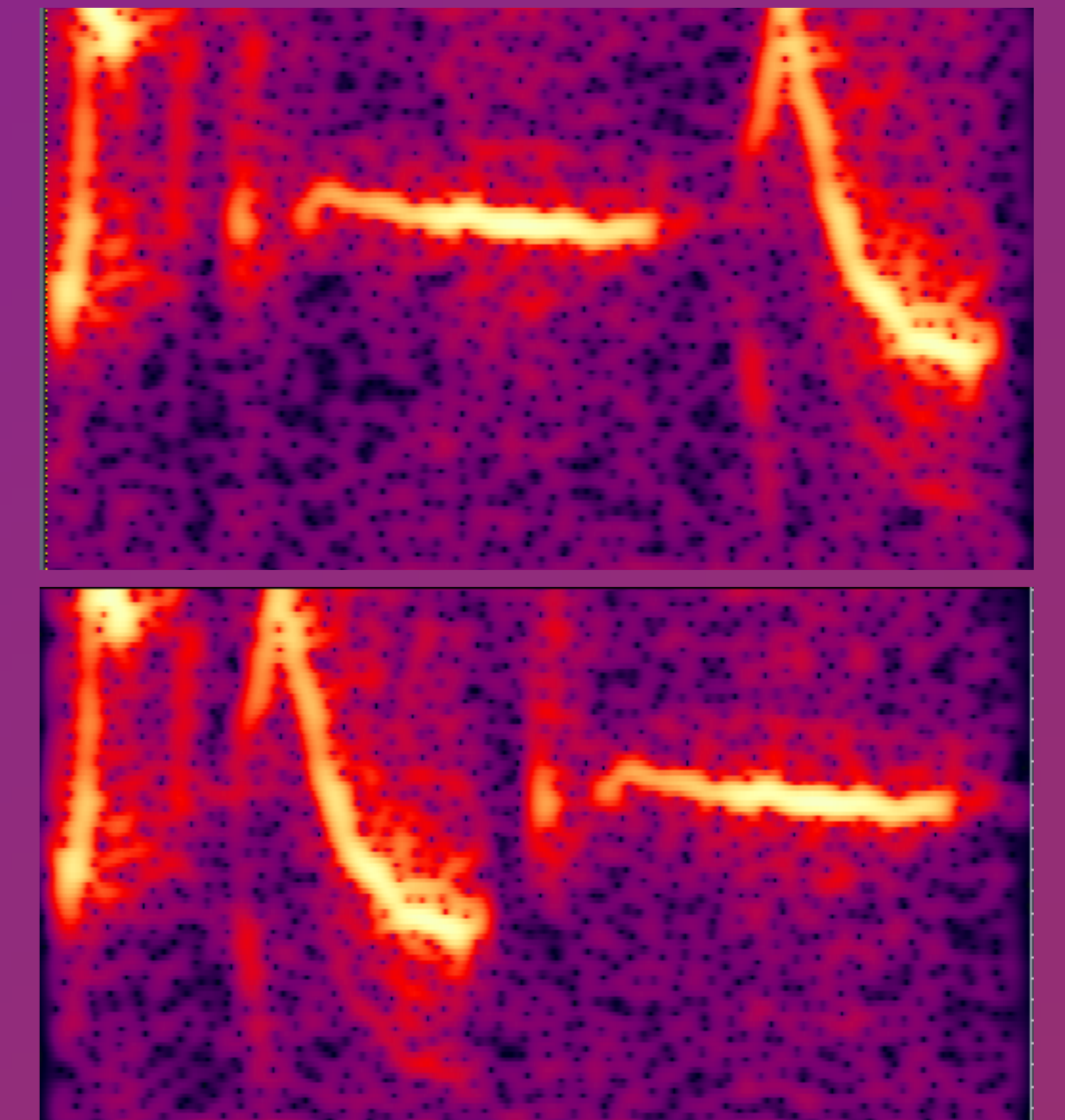


## Process of Hearing

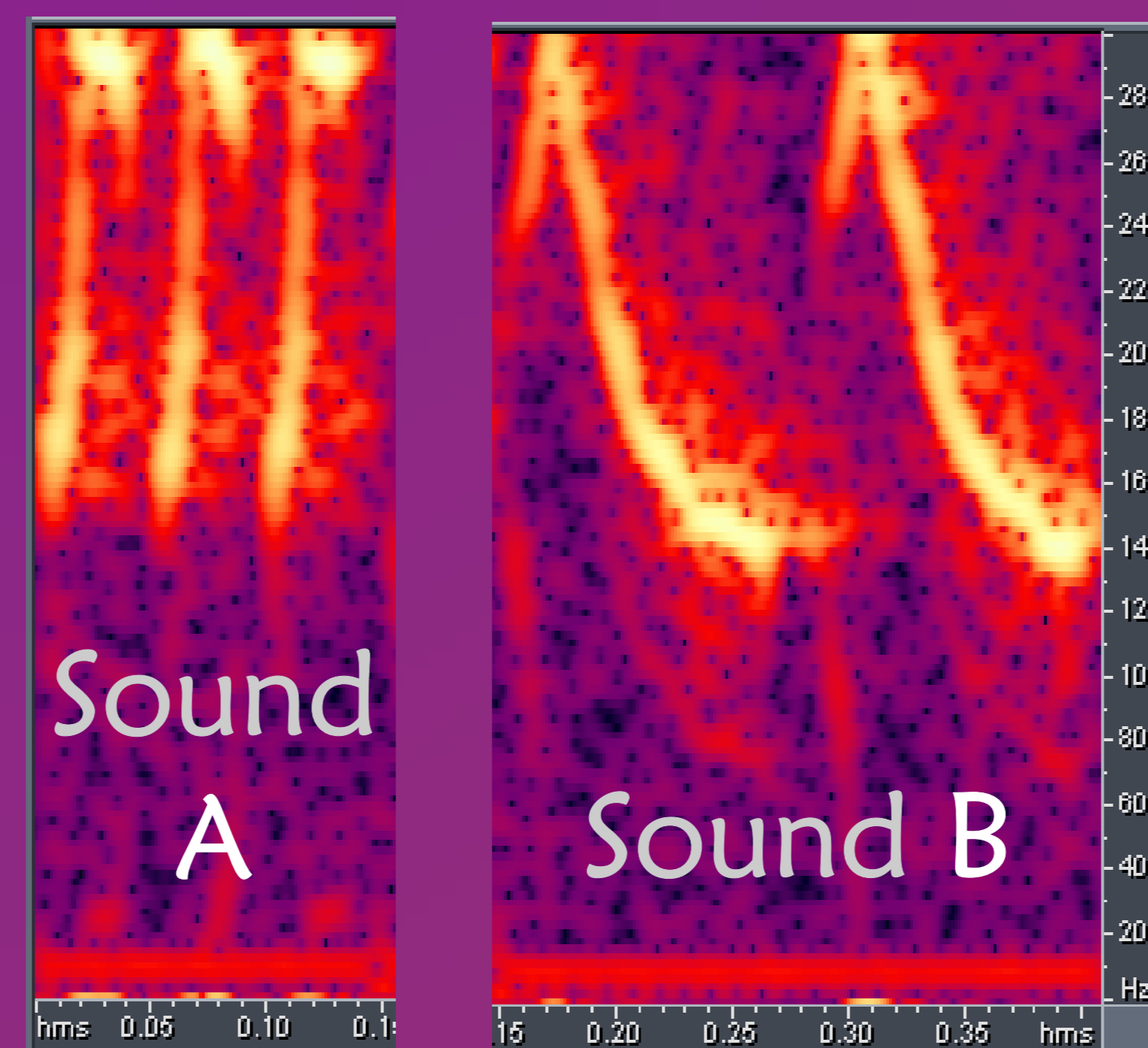
The angle and the distance modify the sound level to help the isolation of one of the signals

## Another experiment

The robots differentiate and reach one determined source from these two ones, the same chirps in a different order



## The Sounds we use



The sounds emitted from the sources are parts of a real sound, a song recorded to the same canary bird

- Each experiment follows a *Skinner-box* design:
  - Each experiment has two sources of sound and a genetically determined robot
  - one sound is set as the *goal* and the other is the *miss*
  - the robot has to recognize and reach the correct sound
  - the closer it gets to the goal, the better the fitness score is
- The robot is embodied and situated related to the sounds in the arena
- Both sounds are placed randomly equidistant from the start position of the robot

## Results of the Experiment

Mean and Std. Deviation of Relative and Absolute Effectiveness. The measured individuals are the *élite* from the last generation of the Genetic Algorithm

A A is a test experiment, that has the same sound in both sources

Goal	Miss	Relative Mean	Relative $\delta$	Absolute Mean	Absolute $\delta$
Sound A	Sound B	99.1	1.76	90.5	4.21
Sound B	Sound A	100	0	97.8	2.33
Sound A	Sound A	34.8	37.6	2.6	2.86

## Conclusions

- The experiment shows that this scheme can evolve virtual robots that are able to perform a complex recognition task for a navigation behavior.
- Though, an exhaustive analysis is needed to find the relationship among the network dynamics, the showed behavior, the embodiment and the situatedness
- It is also necessary to test the robustness with other types of real sounds

## Acknowledgements

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