

Neuronal model of human time perception

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Details of this research
are available in [KK15].

Why develop working models of timing?

Motivations

Simulation environment

The clock-counter model as an ANN

Human timing phenomenon: TOE

Fitting the model to experimental data

Future work

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- There are many quantitative experimental results on human timing, including timing disorders,

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Goal:

- To develop of a working model (ANN) that encompasses many experimental findings and is able to predict new results.

Simulation environment: Framsticks

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- Models bodies and brains of agents
- Body: connected “sticks” (or can be just a “point”)
- Brain: a network of units
 - Signal processing
 - Receptors (sensors)
 - Effectors (actuators, “muscles”)
 - ... can be defined in a script file
- Environment: land, water, hills, gravity, communication
- Flexible definition of experiments, including various analyses and optimization (evolution)
- A number of genetic encodings: explicit, implicit, direct, developmental, generative, ...

The clock-counter model – architecture

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Simulation environment

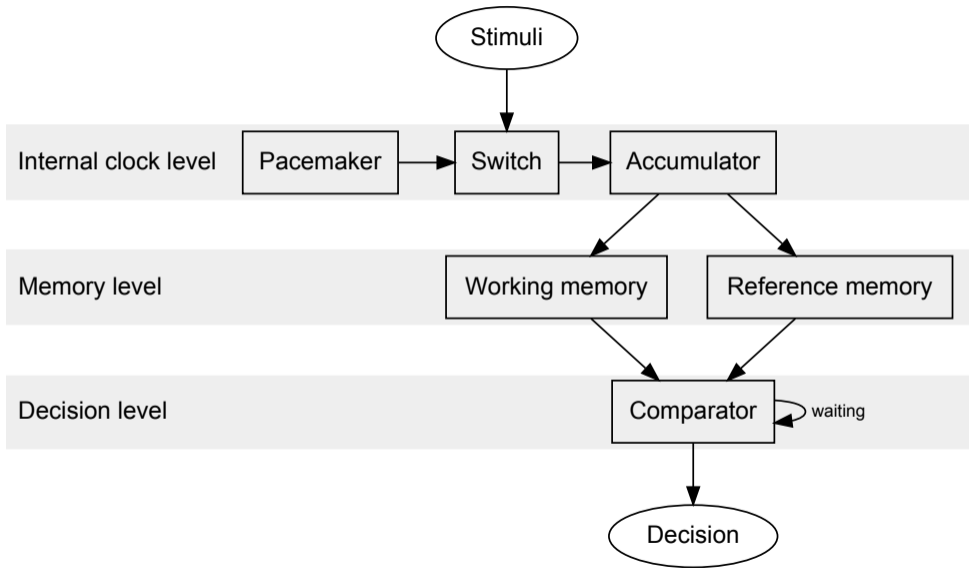
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The clock-counter model – implementation in ANN

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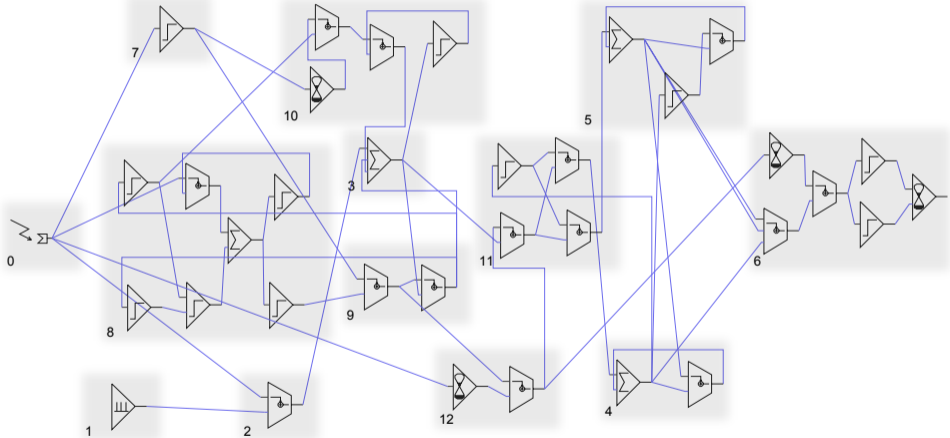
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Inside the network: signal values in time (1)

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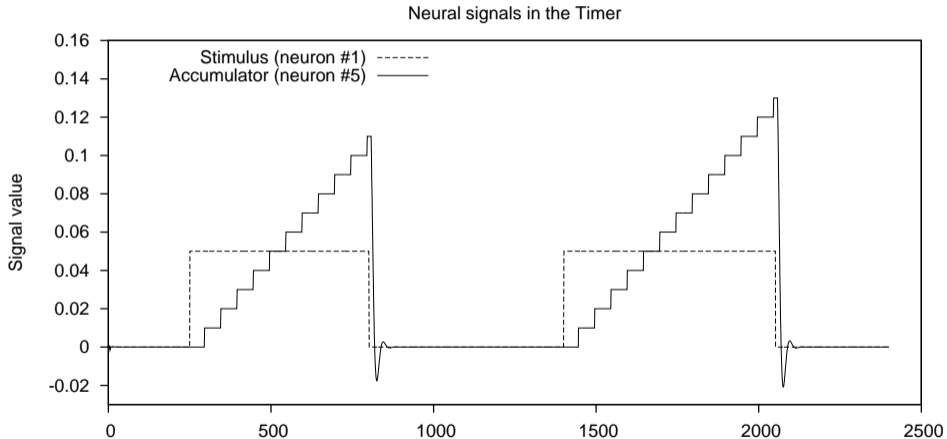
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Inside the network: signal values in time (2)

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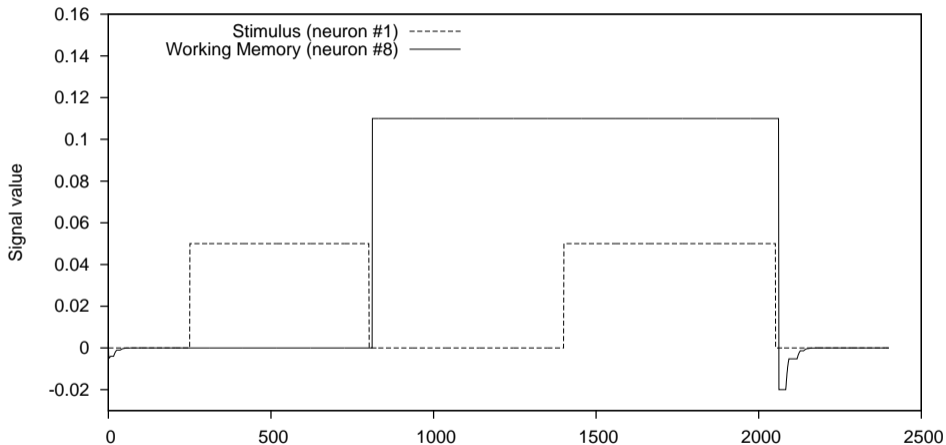
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Inside the network: signal values in time (3)

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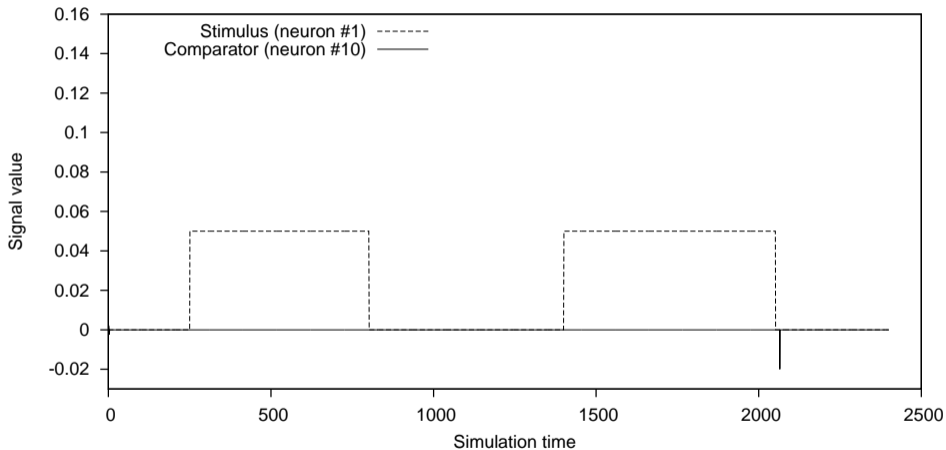
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When comparing two subsequently presented stimuli...

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Jamieson and Petrusic, 1975, “The dependence of time-order error direction on stimulus range”:

- ... stimuli in the range of tens to hundreds of milliseconds: people overestimate the first one relatively to the second one
- ... stimuli in the range of seconds: people overestimate the second one relatively to the first one
- ... the gap between stimuli is relatively long: in each case the magnitude of this effects decreases

There are also many more findings concerning TOE and findings on timing accuracy, different modalities engaged in timing tasks, different tasks in general, etc.

Measures of the time-order error (TOE)

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$$TOE = P(\text{CorrectAnswer}|\text{LongShort}) - P(\text{CorrectAnswer}|\text{ShortLong}) \quad (1)$$

$$TOE = P(\text{FirstReportedLonger}|\text{BothIdentical}) - 0.5 \quad (2)$$

Measure of the time-order error – example

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A person compared several times two stimuli lasting 70 and 100 ms (in both orders – equally frequently). It came out that:

- when the shorter stimulus was presented before the longer one (*ShortLong*), the probability of the correct response was 0.77
- when the shorter stimulus was presented after the longer one (*LongShort*), the probability of the correct response was 0.66

According to the formula (1),

$$TOE = 0.66 - 0.77 = -0.11$$

TOE is negative, that is, the second stimulus was overestimated relatively to the first one.

Optimizing four key parameters of the ANN to meet TOE

(Human data from Allan, 1977: “The time-order error in judgments of duration”)

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Scanning the 4D parameter space:

- The generator mean period
- Reset rate of the accumulator
- The accumulator initial value
- Loading rate of the accumulator

Fitting ANN to human behavior: MSE

(2D slices of a 4D parameter space)

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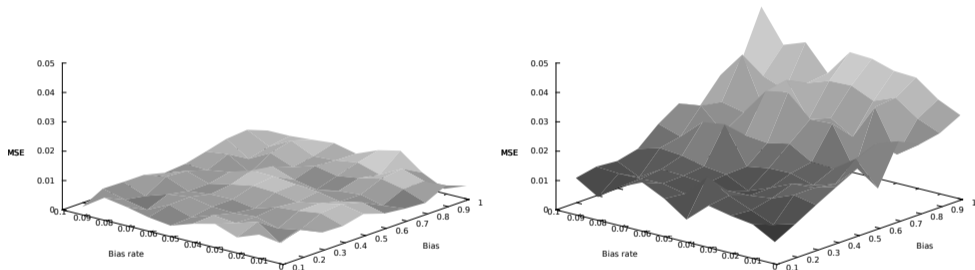


Figure: Left: Period=10, Reset rate=0.0016.

Right: Period=20, Reset rate=0.002.

Fitting ANN to human behavior: TOE

(2D slice of a 4D parameter space)

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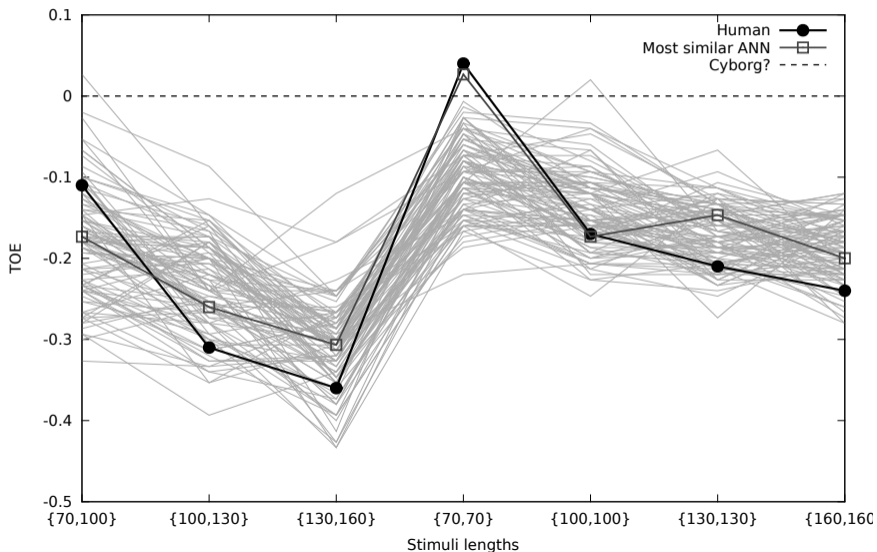
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Fitting ANN to human behavior: TOE(70,100)

(2D slice of a 4D parameter space)

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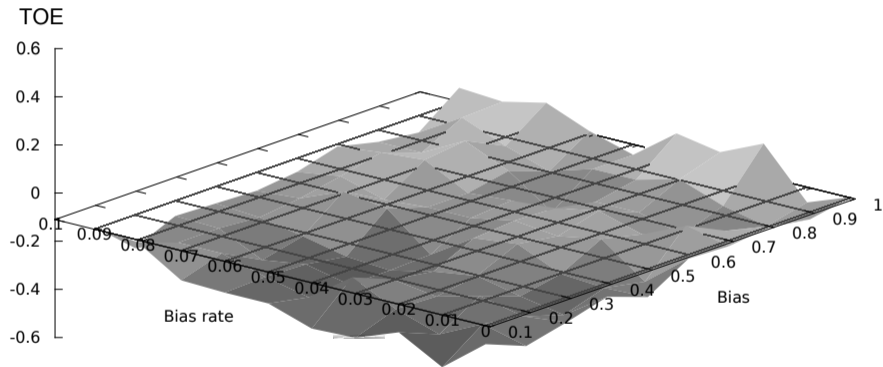


Figure: Period=10, Reset rate=0.0016, as these parameters yielded low MSE.

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Now that we have the ANN implementation of the model, we can

- include additional, experimentally proven phenomena in the implementation,
- increase biological adequacy of the components of the implementation,
- verify the implementation in a simulated environment where fitness depends on time perception.

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- [KK15] Maciej Komosinski and Adam Kups. “Time-order error and scalar variance in a computational model of human timing: simulations and predictions”. In: *Computational Cognitive Science* 1.3 (2015), pp. 1–24. DOI: [10.1186/s40469-015-0002-0](https://doi.org/10.1186/s40469-015-0002-0).