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Konio Pathway: An Instinctive Visual Mechanism for Survival and Decision Making?

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Abstract

Survival is one of the evolutionary priorities for every species on Earth. It is strongly linked to making good decisions, even if these are unconsciously made. In the visual system, interactions between conscious and unconscious processing have been discussed, depending on the main two information flows originating from the retina: the Parvo and Magno pathways. We consider here a possible role of the Konio pathway; less studied and with different characteristics, such as large receptive fields for global complex event detection, and diffuse projections which may allow to quickly inform several areas in the brain of something important present in the visual world. To test these hypotheses, we developed a computational systemic model of the early visual system proposing one type of Konio cells, which respond to certain spectral patterns and change the dynamics of the rest of the system accordingly. When examining the model's responses to static inputs, we observe that the system exhibits desirable reactions, together with time cost and efficiency characteristics. We also discuss the implications of the hypotheses for more complete survival and decision making processes, as the Konio pathway may only be a foundation stone for them in terms of evolution.

Keywords: Konio, visual mechanism, survival, decision making, pathway interplay

1 Introduction & Objectives

Physiologically, in the early visual system, the Parvo and Magno pathways are better understood (Callaway, 2005) than the Konio pathway (Hendry & Reid, 2000). Furthermore, the interactions between these pathways lack understanding. The *standard*

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Magno and Parvo pathways arrive at the primary visual cortex (V1), and the temporal and parietal pathways, via the *core* lateral geniculate nucleus (LGN); whilst the *non-standard* konio pathway projects to several cortical areas, but at the same time to the amygdala via the superior colliculus. The Parvo pathway is associated to details such as color and shapes, whereas the Magno pathway is related to flashing or moving images. The Konio pathway has been found in each of the Old World primates (Hendry & Reid, 2000) and some studies (Yoonesi & Yoonesi, 2011) have proposed that it may be involved with seasonal mood changes (Glickman, Byrne, Pineda, Hauck, & Brainard, 2006) and color consistency mechanism (Yoonesi & Kingdom, 2008)(Paul, Safir, & Tosini, 2009). Whereas these studies propose certain roles, there are 3 Konio layers to consider, and these studies seem to focus on the middle Konio layer, that carries information from central blue cones to superficial color blobs in layer 3 of V1 (Hendry & Reid, 2000). Figure 1 sketches their main features, including the matrix representation in the thalamus for the Konio flow and the thalamic reticular nucleus (TRN) described as a modulator for thalamo-cortical connections. Depending on the characteristics that we implement in our computational systemic model for the Konio pathway, our goal is to investigate how the system changes its dynamics in case the information signaled the presence of an important natural element in the visual world, which might be a predator, a possible sexual partner or food.

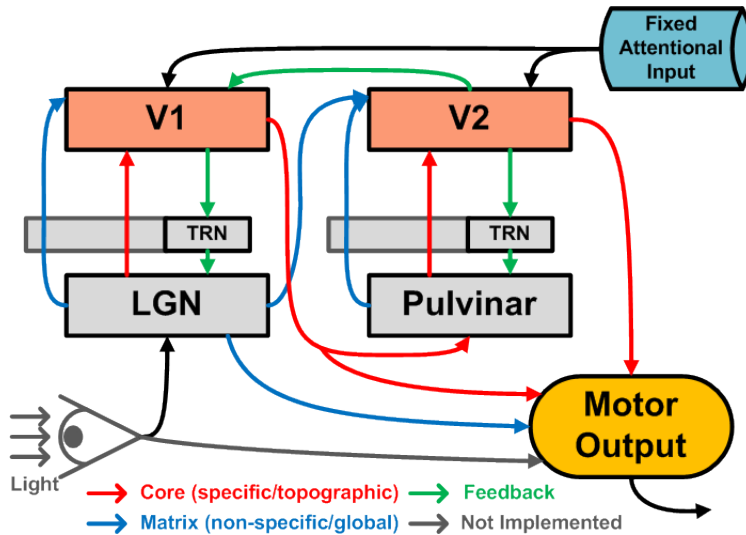


Figure 1: Overview of the model. An implicit hypothesis here is that the matrix part of the pulvinar uses an analogous mechanism to that of the Konio cells in the lateral geniculate nucleus (LGN). Feedback here is considered from cortical layer 6 of V1 and V2 with a relay at TRN for the core pathway, and from V2 to V1 through superficial layers.

2 Methods

We built our model from scratch using Python. Its architecture is inspired from the model proposed by (Rodriguez, Whitson, & Granger, 2004)(Granger, 2006), and con-

siders facts from other studies, including (Callaway, 1998)(Callaway, 2004)(Callaway, 2005)(Sherman, 2007)(Masland & Martin, 2007)(Nassi & Callaway, 2009).

Its implementation is based on three-dimensional Gabor filters for cortical levels, on Difference of Gaussians filters for core thalamic structures, and on a statistical analysis of oriented features for the matrix thalamus. We only worked with horizontal and vertical orientations for simplicity.

The input to the system corresponds to a series of black & white images of 324x324 px, which are treated (in detail) 3 times, as a saccadic movement is done about 3 times per second (Ballard, Hayhoe, Pool, & Rao, 1997) and humans may process complex natural images in about 120[ms] (Thorpe, Fize, & Marlot, 1996)(VanRullen & Thorpe, 2001).

Figure 2 shows how artificial inputs are analyzed by the system topographically by extracting patterns. The global analysis made by the Konio system allows to choose the order of the hierarchical decomposition, whereas the TRN inhibits information already analyzed.

The output of the system is a series of messages that represent a certain motor output (Figure 3). They are based on the result of a pattern recognition from the Konio, V1 and V2 information, and in how critical this pattern is for the system.

3 Results

We have postulated that our system analyzes 3 times a frame, and that we have different criticality parameters for different stimuli. One of the first tests that we did then was to check whether the model could extract the patterns following a certain order given the responses from the proposed Konio cells and how critical this pattern was for the system. For this, we created a fake pattern that contained 3 others, which were the ones interesting for our model. To do this we consider only the cell activation maps¹ at every level rather than to also consider the motor output. It is validated that the system prioritizes critical patterns if found and just then passes to less critical options if found. Already analyzed patterns are inhibited through cortical feedback relaying at the thalamic reticular nucleus to allow for a less costly treatment. Figure 2 shows this process.

Another needed study was noise resistance to test the capability of the system to demonstrate that a more developed system is needed as the processing undertaken by the Konio cells is global and simple so it can arrive at the desired areas without spending too much time at the thalamus. Figure 3 shows this process, where a non-critical pattern is used to reflect the idea that the system allows itself to wait for a more detailed representation as the error at lower visual levels is too high to recognize the pattern as present. This figure also shows that the simulation time for the Konio mechanism proposed here is about 4 times faster than the Parvo mechanism implemented, which was expected as its goals are to communicate a simple information to several areas of the brain, either to trigger a defensive action, or to bias the conscious visual processing as something naturally interesting seems to be present.

¹A map that shows cell activation rather than to show the visual representation at that stage of the system.

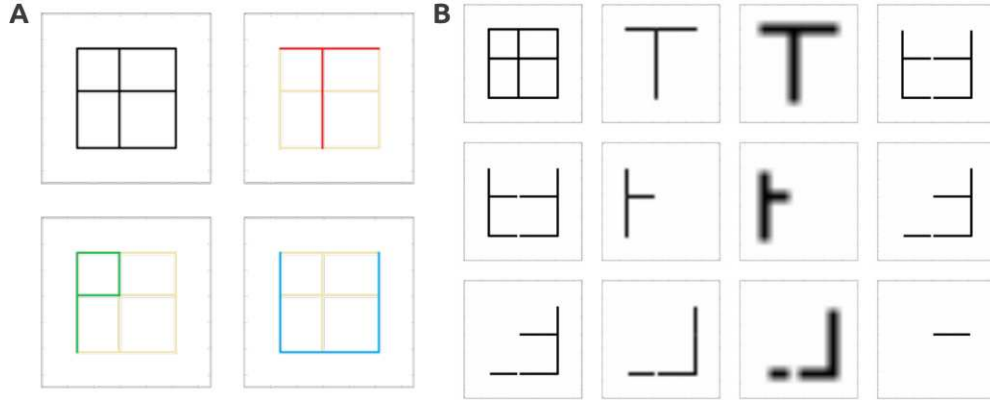


Figure 2: Pattern extraction and hierarchical decomposition. Using 3 konio cells of the proposed type and a fake pattern as input, that contains the 3 interesting sub-patterns, we observe how the model analyzes the frame one pattern at a time (T-P-U here), inhibiting what has been already analyzed at each iteration. **A** The 3 interesting patterns. **B Rows:** Each iteration for the single frame in A. **Columns:** Input, cell mapping at V1 and V2, and the remainder after extracting the analyzed pattern.

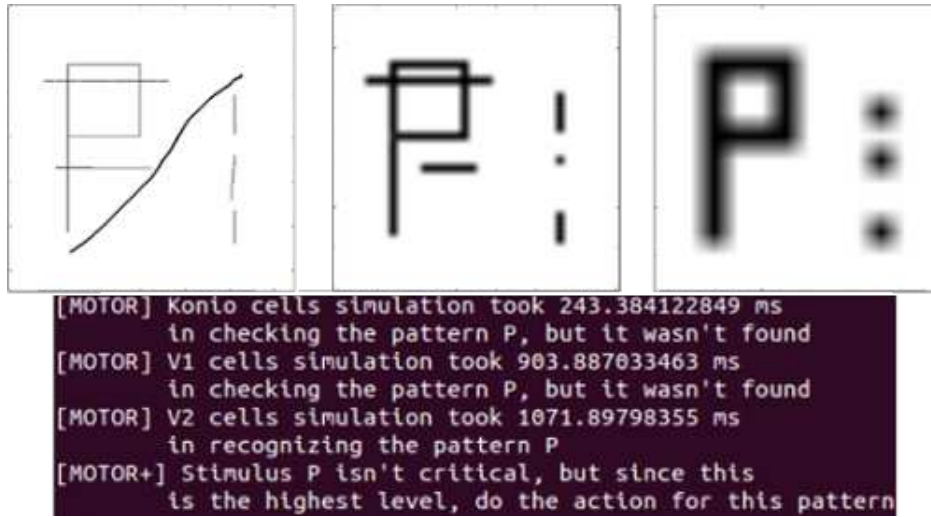


Figure 3: Detail & Motor output. The system recognizes the pattern and triggers an action depending on how critical the pattern is. *Top:* Input and cell activation mapping at V1 and V2. *Bottom:* Reduced set of messages produced by the motor output block.

4 Discussion

The Konio pathway has been found in each of the Old World primates (Hendry & Reid, 2000). It projects to higher cortical stages and to the amygdala via the superior colliculus. This connection is relevant as the superior colliculus has a role in responses to events and emergencies (Dean, Redgrave, & Westby, 1989), and the amygdala (LeDoux, 2008) is involved in several cognitive and behavioral functions, such as attention, explicit and emotional memory, and decision making (Gupta, Kosciuk, Bechara, & Tranel, 2011). We have not yet addressed these structures nor their links, but we're keen to study them as the Konio pathway is just one starting point for them.

5 Conclusions and Perspectives

Our model shows that architectural and functional characteristics of the Konio system can bring flexibility to a local and hierarchical analysis of the perceptive world. These properties could be replicated at higher levels of the matrix system, like in the pulvinar. It might be also important to consider other crucial extra-cortical inputs like the ones stemming from the superior colliculus or the amygdala.

Perspectives

- Work with natural images.
- Extend the model to higher cortical areas and the Magno pathway to account for motion.
- Include the path to the amygdala to exploit, e.g., higher level decision making processes.
- Enhance the model to further study the interactions between pathways and the role of the other layers of Konio cells.
- Examine other stages of the food chain: how a predator would be helped by such a prewired network, and the duality (being and having predators).
- Explore different disorders (Yoonessi & Yoonessi, 2011) to which the visual pathways (Parvo, Magno and Konio) are related, such as multiple sclerosis (Murav'eva, Deshkovich, & Shelepin, 2009)(Thurtell et al., 2009), schizophrenia (Delord et al., 2006)(Butler & Javitt, 2005), Parkinson's (Silva et al., 2005) and Alzheimer's (Guo, Duggan, & Cordeiro, 2010)(Sartucci et al., 2010) disease, and many others (Gutowski, Heron, & Scase, 1997)(Papia et al., 2010).

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References

- Ballard, D. H., Hayhoe, M. M., Pool, P. K., & Rao, R. P. N. (1997). Deictic codes for the embodiment of cognition (with commentary). *Behavioral and Brain Sciences*, *20*(4), 723–767.
- Butler, P. D., & Javitt, D. C. (2005). Early-stage visual processing deficits in schizophrenia. *Current Opinion in Psychiatry*, *18*(2), 151–157.
- Callaway, E. M. (1998). Local circuits in primary visual cortex of the macaque monkey. *Annual Review of Neuroscience*, *21*, 47–74.
- Callaway, E. M. (2004). Feedforward, feedback and inhibitory connections in primate visual cortex. *Neural Networks*, *17*(5-6), 625–632.
- Callaway, E. M. (2005). Structure and function of parallel pathways in the primate early visual system. *Journal of Physiology*, *566*(Pt 1), 13–19.
- Dean, P., Redgrave, P., & Westby, G. W. (1989). Event or emergency? two response systems in the mammalian superior colliculus. *Trends in Neurosciences*, *12*(4), 137–147.
- Delord, S., Ducato, M. G., Pins, D., Devinck, F., Thomas, P., Boucart, M., et al. (2006). Psychophysical assessment of magno- and parvocellular function in schizophrenia. *Visual Neuroscience*, *23*(3-4), 645–650.
- Glickman, G., Byrne, B., Pineda, C., Hauck, W. W., & Brainard, G. C. (2006). Light therapy for seasonal affective disorder with blue narrow-band light-emitting diodes (leds). *Biological Psychiatry*, *59*(6), 502–507.
- Granger, R. (2006). Engines of the brain: the computational instruction set of human cognition. *AI Magazine*, *27*(2), 15–32.
- Guo, L., Duggan, J., & Cordeiro, M. F. (2010). Alzheimers disease and retinal neurodegeneration. *Current Alzheimer Research*, *7*(1), 3–14.
- Gupta, R., Kosciak, T. R., Bechara, A., & Tranel, D. (2011). The amygdala and decision making. *Neuropsychologia*, *49*(4), 760–766.
- Gutowski, N. J., Heron, J. R., & Scase, M. O. (1997). Early impairment of foveal magno- and parvocellular pathways in juxta chiasmal tumours. *Vision Research*, *37*(10), 1401–1408.
- Hendry, S. H., & Reid, R. C. (2000). The koniocellular pathway in primate vision. *Annual Review of Neuroscience*, *23*(1), 127–153.
- LeDoux, J. E. (2008). Amygdala. *Scholarpedia*, *3*(4), 2698.
- Masland, R. H., & Martin, P. R. (2007). The unsolved mystery of vision. *Current Biology*, *17*(15), R577–R582.
- Murav'eva, S. V., Deshkovich, A. A., & Shelepin, Y. E. (2009). The human magno and parvo systems and selective impairments of their functions. *Neuroscience and Behavioral Physiology*, *39*(6), 535–543.
- Nassi, J. J., & Callaway, E. M. (2009). Parallel processing strategies of the primate visual system. *Nature Reviews: Neuroscience*, *10*(5), 360–372.
- Papia, M. F., Burke, M. W., Zangenehpour, S., Palmour, R. M., Ervin, F. R., & Ptito, M. (2010). Reduced soma size of the m-neurons in the lateral geniculate nucleus following foetal alcohol exposure in non-human primates. *Experimental Brain Research*, *205*(2), 263–271.
- Paul, K. N., Safir, T. B., & Tosini, G. (2009). The role of retinal photoreceptors in the

- regulation of circadian rhythms. *Reviews in Endocrine and Metabolic Disorders*, 10(4), 271–278.
- Rodriguez, A., Whitson, J., & Granger, R. (2004). Derivation and analysis of basic computational operations of thalamocortical circuits. *Journal of Cognitive Neuroscience*, 16(5), 856–877.
- Sartucci, F., Borghetti, D., Bocci, T., Murri, L., Orsini, P., Porciatti, V., et al. (2010). Dysfunction of the magnocellular stream in alzheimer’s disease evaluated by pattern electroretinograms and visual evoked potentials. *Brain Research Bulletin*, 82(3-4), 169–176.
- Sherman, S. M. (2007). The thalamus is more than just a relay. *Current Opinion in Neurobiology*, 17(4), 417–422.
- Silva, M. F., Faria, P., Regateiro, F. S., Forjaz, V., Januário, C., Freire, A., et al. (2005). Independent patterns of damage within magno-, parvo- and koniocellular pathways in parkinsons disease. *Brain: A Journal of Neurology*, 128(Pt 10), 2260–2271.
- Thorpe, S., Fize, D., & Marlot, C. (1996). Speed of processing in the human visual system. *Nature*, 381(6582), 520–522.
- Thurtell, M. J., Bala, E., Yaniglos, S. S., Rucker, J. C., Peachey, N. S., & Leigh, R. J. (2009). Evaluation of optic neuropathy in multiple sclerosis using low-contrast visual evoked potentials. *Neurology*, 73(22), 1849–1857.
- VanRullen, R., & Thorpe, S. J. (2001). The time course of visual processing: from early perception to decision-making. *Journal of Cognitive Neuroscience*, 13(4), 454–461.
- Yoonessi, A., & Kingdom, F. A. A. (2008). Comparison of sensitivity to color changes in natural and phase-scrambled scenes. *Journal of the Optical Society of America A*, 25(3), 676–684.
- Yoonessi, A., & Yoonessi, A. (2011). Functional assessment of magno, parvo and koniocellular pathways; current state and future clinical applications. *Journal of Ophthalmic and Vision Research*, 6(2), 119–126.