



## REVIEWER'S OPINION OF FINAL THESIS

### I. IDENTIFICATION DATA

<b>Thesis name:</b>	<b>Application of Predictive Coding for Visuo-Tactile Sensory Integration</b>
<b>Author's name:</b>	<b>Adrián Pitoňák</b>
<b>Type of thesis :</b>	bachelor
<b>Faculty/Institute:</b>	Faculty of Electrical Engineering (FEE)
<b>Department:</b>	Department of Cybernetics
<b>Thesis reviewer:</b>	Jean-Paul Noel, Ph.D.
<b>Reviewer's department:</b>	Center for Neural Science, New York University

### II. EVALUATION OF INDIVIDUAL CRITERIA

<b>Assignment</b>	<b>ordinarily challenging</b>
<i>Evaluation of thesis difficulty of assignment.</i>	
<p>The assignment asked to become familiar with the multisensory, peri-personal space, and predictive coding framework. Then, the student had to modify an existing neural network to include the tactile modality and generate a dataset that could be used to train and evaluate the modified network. Lastly, the assignment asked to compare properties of the trained model with properties known about peri-personal space and multisensory integration. I think the assignment was very well defined, represented a tractable yet complete problem to be solved. The assignment was far from trivial, yet also provided the student with all the support needed – a great Bachelor's thesis assignment.</p>	

<b>Satisfaction of assignment</b>	<b>fulfilled with minor objections</b>
<i>Assess that handed thesis meets assignment. Present points of assignment that fell short or were extended. Try to assess importance, impact or cause of each shortcoming.</i>	
<p>I find the thesis to adequately summarize existing literature and the problem at hand. I also find it very well structured and easy to follow, even for a non-expert in neural networks. For this, I commend the author. The implementation of the dataset and the modification to the model seem adequate. The author provides some very sound firsts experiments. These are needed, and thus through the process we have all learned. However, the thesis falls short in providing insight as to whether a predictive coding based neural network behaves similarly to how the brain encodes peri-personal space. That is, for example, it would have been incredibly interesting to know if tactile predictions occur earlier when the velocity of the ball increases. Of course, this is where the thesis was headed, just seems to have ran out of time while still debugging the implementation of this last experiment, or how to modify either the model, their inputs, or the dataset to allow for this experiment. The thesis has provided the foundational work and I look forward to see future developments.</p> <p>I really liked the visualization showing predictions vs. actual positions of the ball and tactile stimulation. However the visualization of the error was less appropriate. It is hard to read tables and these could have easily been replaced with histograms for example. Another nice visualization would have been to show ball positions, directions, and velocities when the first prediction of touch was made – like this the author could have depicted the peri-personal space surrounding the robot.</p>	

<b>Method of conception</b>	<b>correct</b>
<i>Assess that student has chosen correct approach or solution methods.</i>	
<p>I believe the student chose the correct methods and suggested good error measures. He also suggested thoughtful future directions.</p>	

<b>Technical level</b>	<b>B - very good.</b>
<i>Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.</i>	
<p>The thesis reads as a first phase – pilot or debugging phase – for an eventual contribution to the published literature on neural networks of peri-personal space. Most psychologists/neuroscientists within the field would agree that foundationally peri-personal space is a computation of impact prediction, but there has been little formal work in this domain. I believe this thesis can be the foundation for future published work that, 1) introduces the extended model to include the tactile</p>	



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modality and thus represents peri-personal space, and 2) conducts an array of experiments to study how peri-personal space changes due to different factors according to the model (e.g., velocity of incoming ball, size of ball, size of body, direction of movement, reliability of the visual stimuli, what if there are multiple objects?, etc.). Lastly, if the model is made biological-plausible (maybe less applicable here) one could examine the inner workings of the 'neurons' within the model, to make biological predictions. In summary, I believe most of the knowledge gained in the current thesis is in 'know-how' and this will allow for exciting future work.

### Formal and language level, scope of thesis

**A - excellent.**

*Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.*

The thesis is well written and as I commented above, very well structured.

### Selection of sources, citation correctness

**A - excellent.**

*Present your opinion to student's activity when obtaining and using study materials for thesis creation. Characterize selection of sources. Assess that student used all relevant sources. Verify that all used elements are correctly distinguished from own results and thoughts. Assess that citation ethics has not been breached and that all bibliographic citations are complete and in accordance with citation convention and standards.*

The references are appropriate and the student is very clear in indicating what was given to him and where his modifications came into play. Further, the student links to online repositories where the code is made available. That is very nice to see and a great example of being a good member of the scientific community.

### Additional commentary and evaluation

*Present your opinion to achieved primary goals of thesis, e.g. level of theoretical results, level and functionality of technical or software conception, publication performance, experimental dexterity etc.*

N/A

### III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION

*Summarize thesis aspects that swayed your final evaluation. Please present apt questions which student should answer during defense.*

Overall I find the thesis to have successfully implemented a version of the neural network model where vision is used to predict touch. I find that the student did a good job at designing and developing an experiment within the neurorobotics platform. The thesis does not yet make a contribution to the field of peri-personal space, as there has to be more extensive analyses of the behavior of the model given different environmental conditions, but definitely sets the stage for this contribution.

Questions for the student;

- What do you think was the main issue with the velocity experiments? Are there modifications to the model that could be made, or is the solution is how input was given and/or the number of frames? How would you go about solving this issue to be able to compare the timing of touch predictions given different velocities of the ball?
- Can you discuss the biological plausibility of the model implemented? One of the main advantages of doing neural network modeling vs. e.g. experiments in humans is that you can now "open up" any "box" (i.e., neural area) you want. Within the model, which components would you examine to gain insight as to the implementation of peri-personal space and multisensory integration in the brain?

I evaluate handed thesis with classification grade **B - very good.**

Date: **22.5.2020**

Signature: