Report on the PhD thesis "Perceptual Learning – perceptual changes in learning new categories"

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The general aim of the thesis "Perceptual Learning – perceptual changes in learning new categories" is to identify the important role of perceptual learning and the changes in perceptual representations in the context of categorization. The problem explored in the thesis worth addressing, the approach applied by candidate is original and creative, the whole empirical work and modelling are coherent and integrated.

The results throw light to the nature of categorization and the role of perceptual processes involved. The importance of this issue from the developmental perspective is outlined in the context of current debate on the changes from early perceptual categorization to language-based concept learning. Research shows the progressive increase in the complexity of infant's representation of objects. The involvement of lower level processes with smaller receptive field size has a functional consequence- the increased accuracy in the feature-based representation of objects and causes the developmental shift in categorization behavior from global to local processing of objects. The perceptual processes are influenced by the acquired categories in different ways. Not only in the childhood but as well in the adulthood the visual cortex retains the capacity for experience-dependent changes and neurons rather than having fixed functional properties are dynamically tuned, changing their specificities with varying sensory experience. The presented work provides an additional good and convincing example for the role of the learning at the earlier visual stages in categorization task when short-term changes are manifested in the performance of adult participants.

The second aim of the work is to provide a neural network model for supervised and unsupervised learning assuming the shift of different levels of perceptual pathways in categorization. The model makes a number of contributions. It implements a view that both supervised and unsupervised learning could take place in early vision so that early level representations could be formed and reorganized according to the task requirements and characteristics of categorization. One of the contributions of the model is the possibility to explain a variety of effects in the perceptual learning not only in such higher order tasks but in the simple visual tasks such as Vernier discrimination and orientation feature detection as well.

The first part of the thesis starts with a short introduction to the basic ideas about perceptual learning and its role in the human cognition. Chapter IV presents the review of some of the more complex perceptual learning phenomena that blur the boundary between percepts and concepts and points the evidence for different aspects of categorical influence on the perception. The literature review is comprehensive and up to date, showing excellent understanding of the theoretical context with evidence of critical appraisal of the main hypotheses in this field.

Theoretical assumptions underlying the model of perceptual and conceptual learning outline the interrelationships between these processes in the general cognitive system, that present an evidence for the

plasticity of cortical functions. The manifestation of the functional changes associated with perceptual learning involve both long term modification of cortical circuits during the course of learning and short term dynamics in the functional properties of cortical neurons. These dynamics are subject to top down influences, including that from the conceptual system.

In the chapters III, IV and V the emphasis is on the modelling of changes in categorical and perceptual learning and an extended analysis of previous work done by other authors on modeling the phenomena is proposed. The strengths and weaknesses of symbolic and connectionist models and in-depth analysis of supervised and unsupervised neural networks were presented. The proposed new model is elaborated on the basis of the replication and testing of the predictions of CPLUS model.

Chapter VI presents the **methodology applied** in the work and the description of three experimental studies with analysis of the results. The methodological approach which needs special mention for its originality is consistent to the objectives of the study. It blended the empirical evidences with the conceptual ideas.

The processes underlying the categorization task were investigated within the position transfer paradigm with attempts to link the presence or lack of transfer of learning with the exact level of the cortical structures involved in. The idea is original and it is the applied for the first time with the assumptions about the retinotopic structure of neuronal receptive fields. Certain cautions are related to the fact that the variation of receptive field sizes within each visual area can be rather large despite the overall correlation between brain area and receptive field.

Being the essential part of the experimental procedure the parameters of stimuli are precisely defined as well as the instruction and the viewing distance from the screen. The stimuli and the procedure were tested in the pilot studies, so the number of trials within training and testing blocks has been determined in accordance with the time needed till 90 % of tasks were accomplished. For better control of the factors related to different hemispheric influences the spatial arrangement of two transfer positions on the left and the right side should be taken into account.

From the examples of different stimuli provided (figure 5) it is evident that the exemplars of both categories contain the key element embedded in the figure crossed with an additional line, or without it that could be another source of variation of difficulties. It is supposed that this factor was controlled for in the blocks of stimuli.

The experimental studies 1 and 2 showed the main effect of the position transfer- there is significant difference between conditions and the mean percentage of successful performance decreases when the position is at 4,5 degree of distance from the training one. The same results were obtained for the reaction time. The decrease of successful performance from 97,1% to 92,9% is considered as indicator for partial transfer of learning from the trained to new position. The finding is interpreted as evidence that lower-level visual structures (V2-V4) play a role in the changes that occur during category learning.

The results of the experimental study 3 with more complex stimuli as well as with one additional category repeated the same finding as in Experiment 1- the performance at transfer position is significantly lower in terms of accuracy but still very high. The more stringent quantitative measure of the degree of transfer could be beneficial to approve the expectations that the results would show more position specific learning as the more complex and demanding the learning task was.

Neuronal mechanism of perceptual learning- still there are a lot of unresolved problems and debate about the processes underlying the changes- either the cortical recruitment with increase in amount of cortical territory dedicated to the trained part of the sensory surface or the opposite idea that assumes decrease in the number of neurons responding to the trained stimulus, but sharpening of tuning of V1/V2 neurons. The discovery that long-range horizontal connections in the visual cortex mediate spatial integration and dynamic properties enable us to understand how neurons are dynamically tuned acting as an interactive ensemble in a manner that depends on the conjoint activity within the ensemble. The neurons show differential tuning characteristics according to the task performed and they change to adapt to context specific requirements.

The interaction between top-down information and intrinsic cortical circuits suggests that learned information is based on an interaction between multiple cortical areas, rather than being exclusively represented in a single area. The proposed model makes predictions consistent with this key idea.

In summary, the thesis of Alexander Gerganov reports a body of work that makes a contribution to the subject area and his study goes beyond existing work in providing consistent with theoretical assumptions a neurologically plausible model of perceptual learning. The extent of work amply justifies the award of the PhD degree and I am pleased to recommend that it be approved for accomplishment of this academic degree.

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