Review

on “Perceptual Learning – Perceptual Changes in Learning New Categories”, a thesis submitted by Alexander Enchev Gerganov in partial fulfillment of the requirements for PhD degree in Psychology

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Every experienced researcher knows that subjects in perceptual experiments need training to achieve best performance. In the scientific literature the term “learning” is used. Perceptual learning is an important human (and not only human) ability. Learning is an important field in the study of the cognitive processes, in particular in the field of vision science.

Gerganov presents a 158 pages thesis with 140 pages text, 47 figures and tables, and a literature list of 101 items. The first 37 pages are introductory. The introduction is somewhat too wordy, but it is written with a lot of competence. Gerganov correctly outlines the basic paradigms. He distinguishes between “low-level” learning, which may be due to progressive changes in the early visual pathways and “high-level” learning in which higher cognitive processes may be involved. He adopts the standpoint that the low-level learning is (1) implicit i.e. the subject is not able to explain why and how her performance has improved during the training time, and (2) the low-level learning is position-specific, i.e. training with stimuli on a certain location on the retina cannot be transferred on a different location. On the other hand, the high-level learning should be almost completely transferrable from one to another retinal location and the subject should be able to explicitly explain the benefits of the training. This standpoint of Gerganov is shared by many authors (but not by all) and to my opinion it may provide a meaningful basis for a PhD study.

The thesis consists in two relatively separate parts. In the first of them, efforts of several authors aimed at modelling different aspects of the learning process are considered. A model, created by Gerganov is presented. In the

second part of the thesis experiments are described that are aimed at studying the effects of learning on the performance of categorization tasks. Basically, the presence of transfer of learning from one retinal location to another is investigated. If I understand the text correctly, the model developed by Gerganov in the first part of the thesis does not deal with position specificity or invariance of the categorization task, therefore my claim that the two parts are relatively independent.

In the first part of the thesis a thorough review of several computational models of the learning process is presented. Gerganov critically evaluates the strong and weak features of the models. Moreover, he presents simulations with the model CPLUS, developed by Robert Goldstone. The next step of Gerganov is to develop his own, more successful, model. This model consists of three simultaneously acting learning mechanisms. Some of the ideas incorporated in the model are similar to the Integrated Reweigthing Theory (Dosher et al., 2013; Petrov et al., 2005), but with important new developments. The output layer in the model is interpreted as a mid-level perceptual layer which integrates activation from low-level units though selective read-out from lower-level representations. This is achieved through feedforward Hebbian connections. The output layer can receive top-down signal that influences learning. Low-level local representations are built by horizontal connections that lead to the formation of meaningful parts composed of several competitive units. In this way the horizontal connections are responsible for the formation of more global perceptual representations.

Results of two simulations, with supervised and unsupervised learning are presented. They show that the model is very successful and that it provides an important step in the further study of the characteristics of the learning process.

The empirical part of the thesis consists of several experiments; some of them being labelled as “pilot” and “control”. I consider them as “normal” experiments, despite the low number of participants who have been able to successfully finish the tasks.

In the first “pilot” experiment, the task is discrimination between two categories of visual picture stimuli with noise added to the pictures. The categories are unknown to the subjects; they have to discover the categorization rule during a learning phase of the experiment. The task appears to be extremely difficult and about only 1/3 of the subjects are able to complete it. Here incomplete transfer of learning is evident.

In the second “pilot” experiment, the secret that there is some categorization rule is revealed to the subjects, but the rule is not explicitly formulated. Again some transfer of learning is obtained, but it is partial, an increase in the response times is obtained at one of the transfer positions.

Experiment 1 is carried out with 24 subjects. Here the strategy employed in pilot Experiment 2 is used: the subjects are informed that there will be a categorization rule without to reveal it explicitly. The subjects are asked to discriminate between two alternatives. The results are that performance, measured as percent correct responses as well as response time, deteriorated when the stimuli are presented in the transfer positions. Again, no full transfer of the learning is obtained.

The task of the subjects is changed in Experiment 2; here a yes-no procedure is applied, in which the subjects are asked to detect the presence of a stimulus containing a characteristic element. The subjects are explicitly informed about the categorization element before the experiment. The results show again that the accuracy remains practically the same in the training and in the transfer positions, but the response time increases in the 4.5 transfer position. Moreover, the overall speed of performance in this experiment is much better than that in Experiment 1.

Experiment 2 is labeled by Gerganov as “control” experiment. The rationale of this experiment consists of speculations about the potential involvement of selective attention in the task performance. This point needs clarification, in particular, how attention was manipulated by the change in the procedure (two-alternative identification in Experiment 1 to yes-no in Experiment 2).

In Experiment 3 a more difficult task than that in the previous experiments is employed. In one condition the categories of response are not explained. In another condition, hints about the categories are given to the participants. Moreover, the number of responses is increased to three. The increase in difficulty is a meaningful strategy, since it may be suspected that some ceiling effects may have occurred in the previous experiments. As expected, the performance of the subjects is much lower as compared to that in the previous experiments. The hint about the categories does not help to improve performance. A clear decline of the performance in the two transfer positions is obtained.

The experiments demonstrate that transferable learning effects can be obtained when the subjects have to perform identification and detection of rather complicated stimulus material. The degree of transfer seems not to be affected by the level of implicitness of the task but it may be severely affected by its difficulty. The transfer of learning on the rightmost, 4.5 degree position seems lower than the transfer on the 2 degrees position. This may be explained by hemispheric effects on the performance. Gerganov cautiously discusses this possibility. Anyway, the results show that the transfer is only partial. They may support the hypothesis that "low-level" (presumably non-transferable) learning processes are involved even in this kind of "high-level" learning.

My criticism is basically on the presentation of the data and their treatment.

Two dependent variables are measured: percent correct responses, P(C), and response time, RT. Gerganov basically concentrates on P(C); my feeling is that he considers RT as auxiliary variable. No effort has been done to analyze the speed-accuracy trade-of. For example, in Experiment 2 the P(C) for the 2 deg position is lower than for the control, but the RT is shorter. Which performance is better here? Calculations of simple index like d'/RT would be very instructive for all experiments. I do not believe that such analysis would change the final results cardinally, but the thesis would become much more conclusive and elegant. Here I do not want be petty-minded, but it seems strange, that on pg. 97 Gerganov writes that "d' is a

more reliable performance index than percent correct" but we see only percentages in the tables. Also, ANOVA tools are more suitable for data given in d' units rather than in percentages.

No data are given about the development of the performance in time during the learning phase of the experiments. How many blocks or trials are necessary to achieve the predetermined accuracy of 90% correct responses? Did the learning time correlate with the accuracy? Data about task performance at the beginning of the learning phase would give an idea what kind of results may indicate a "total lack of transfer", a term used by Gerganov.

Some technical remarks:

Each individual RT seems to have been calculated by averaging the RTs from a block of 20 trials. Was there some type of censoring of the RT distributions applied, e.g. trimming? With this relatively small number of trials, the presence of outliers may severely bias the mean values.

The caption of fig 6 is incorrect – the classes of stimuli are determined by the spatial frequency parameters of the gratings rather than by the shapes of square, circle and triangle.

Conclusion

Despite my critical remarks, my overall opinion about the thesis is very good. Gerganov demonstrates deep knowledge and competence in the field of the mechanisms of learning. He is particularly strong in analyzing and constructing neural networks. His model is definitely a contribution in the field of cognitive science. Gerganov clearly demonstrates the incomplete positional invariance of the categorical learning. His results support the hypothesis that "low-level" (presumably non-transferable) learning processes are involved even in this kind of "high-level" learning. This is plausible result, since the "low-level" stage is unavoidable in any visual process. At the end of the thesis Gerganov presents useful ways for further developments of his network model.

The basic results of thesis are presented at the Conferences of the Cognitive Science Society. The published papers are cited by several authors, thus providing international visibility of the study.

In conclusion, the thesis submitted by Alexander Gerganov meets the requirements for a PhD degree in psychology.

20.05.2015

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