MSc Human and Biological Robotics

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Human Neuro-Mechanical Control and Learning: Tutorial 4: Nonlinear control and learning

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1 Question 1

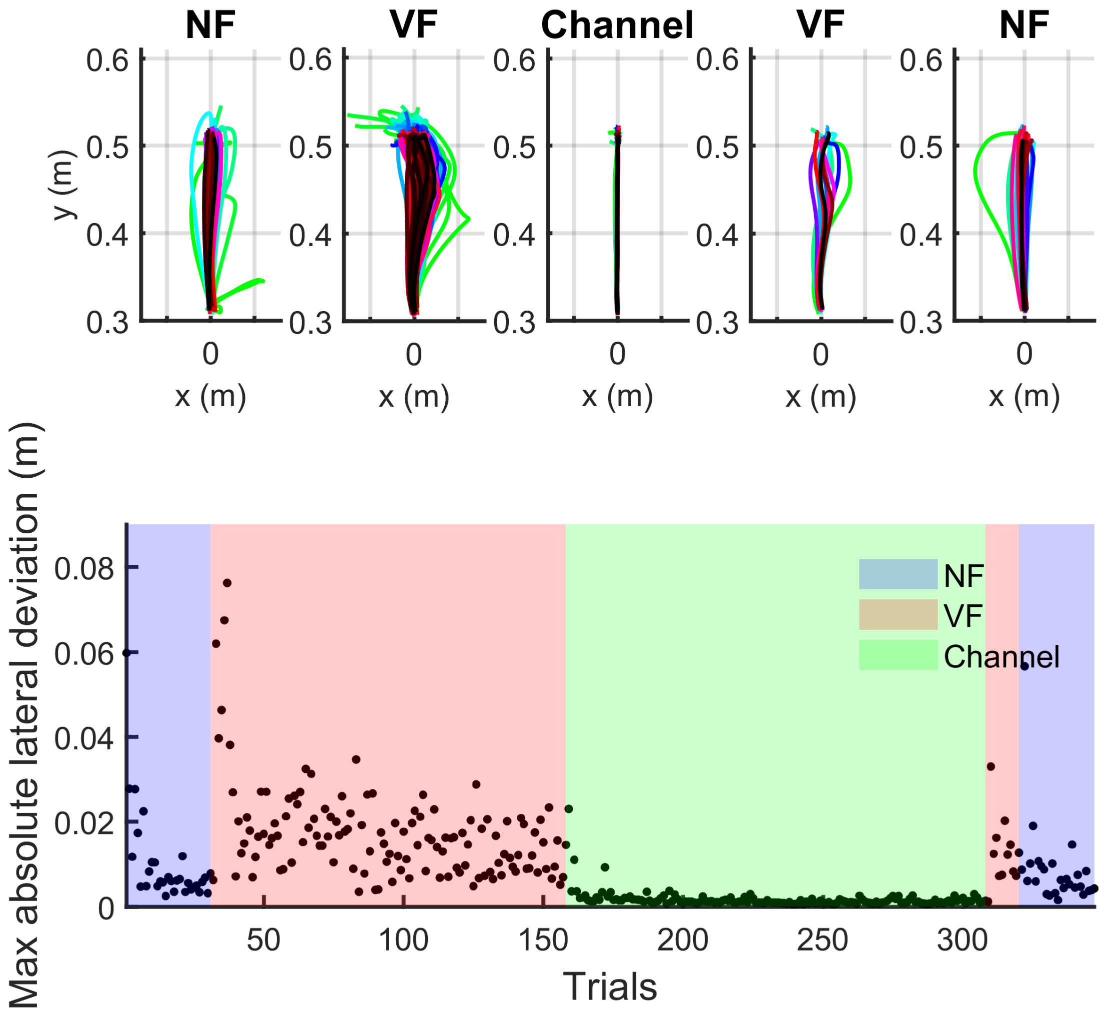

Figure 1: Top: Paths in repeated reaching arm movements in five different phases with different force fields. Bottom: maximum absolute lateral deviation during these phases.

Figure 1 shows the path and maximum error of the movement. Over the series of reaching movements during the VF phase before the channel phase the maximum deviation is steadily reduced. The deviation begins at around 8cm and reduces monotonically and asymptotically to around 2cm. After the channel phase, the maximum deviation commences at 4cm, again reducing asymptotically. This reduction is almost immediate and to a level equal to or less than the 2cm error seen at the end of the first VF phase. The fact that the initial error is reduced after the channel points to the fact that there is retention in the motor adaptation. However, since the the initial error post channel phase is larger than that of the end of the original VF phase suggests that the channel phase somewhat hinders the retention. Nonetheless, it is noted that the rapid decline of the error in the VF washout indicates that the motor adaptation is indeed retained in the wake of the channel phase.

2 Question 2

2.1 Part A

Figure 2 shows the path and maximum error of the movement for the simulations where motor command learning is implemented with $\alpha = 0.08$ and $\gamma = 0.001$. In the last NF force field, for the original data, the error is sporadic, with a downward trend. In the simulation, the error is of the same amplitude, in general, however its trend is monotonically decreasing which implies learning of the motor task over time. This difference can be seen in the displayed paths (figure 1 (top) and figure 2 (top)) where the colour of the consecutive reaching movements goes from green to black and in the maximum deviation data (figure 1 (bottom) and figure 2 (bottom)).

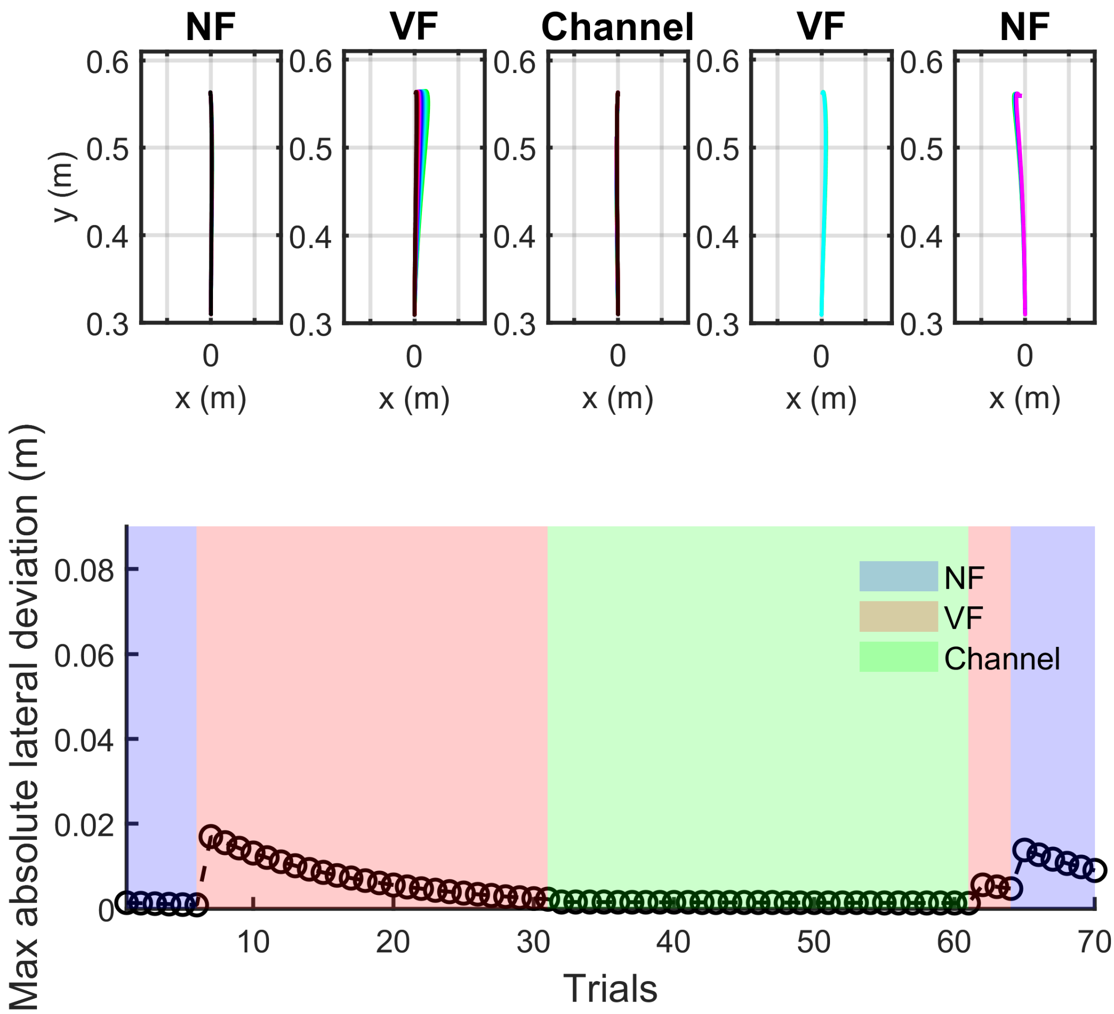

Figure 2: Feedforward motor command learning, $\alpha = 0.08$, $\gamma = 0.001$. Top: Paths in repeated reaching arm movements in five different phases with different force fields. Bottom: maximum absolute lateral deviation during these phases.

2.2 Part B

Figure 3 displays, on the same plot, the performance of the motor command learning as the values of α and γ are varied. The impact of α and γ in this section is looked at with reference to the first VF phase. In Question 2: Part C, the effect of α and γ is looked at in the context of a null force.

By comparing the blue circled data with the red crossed data the effect of changing α can be investigated. It is evident that increasing the value of α causes the maximum deviation to reduce at a faster rate. From this it can be said that the α term represents a rate of learning from the feedback of the previous error.

By comparing the blue circled data with the yellow stared and purples squared data the effect of increasing the value of γ can be investigated. It is evident that by increasing the value of γ the error value which the learning asymptotically tends to is increased. When $\gamma = 0.001$ the error tends to around 0m, when $\gamma = 0.1$ the error tends to around 0.1m. From this it can be said that the value of γ represents the long term limit of the maximum deviation. This occurs since 1-γ is your feedforward learning rate, thus for small γ values, you'll have a large learning rate.

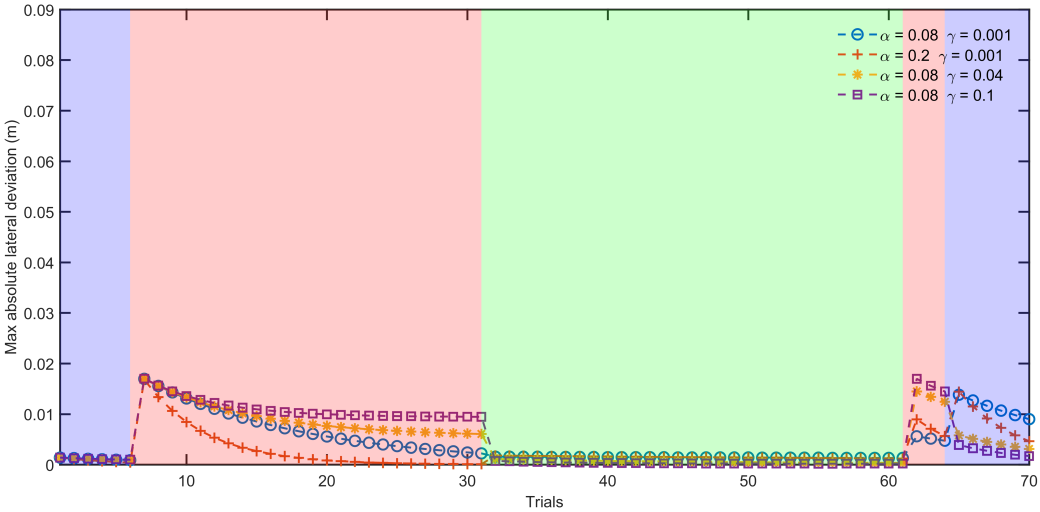

Figure 3: Feedforward motor command learning, varying α and γ. Top: Paths in repeated reaching arm movements in five different phases with different force fields. Bottom: maximum absolute lateral deviation during these phases.

2.3 Part C

As previously mentioned, the maximum absolute deviation in the data is much more sporadic compared with the simulation - this is also true in the NF washout phase. The magnitude (excluding some outliers in the data) are of the same magnitude and have the same downward trend.

From figure 3 it can be seen that the value of γ has a large effect on the maximum deviation during the washout NF phase. When $\gamma = 0.001$, as in the blue circled and red crossed data, the inital maximum deviation in the NF washout phase increases compared with the end of both VF phases. When γ is increased, the difference between the maximum deviation at the end of the VF phases and the start of the NF washout phase decreases. From this it can be noted that while γ appears to be linked with the long term limit of the maximum deviation in the VF phase, it also has an effect on the retention of the model which was learned and its generalisation to different force fields (including null).

The apparent difference in the effect of γ on the maximum deviation depending on the force field (velocity or null) is ingrained in the idea that the learning associated with the VF phase is a learning of a new model and is remembered in a 'short term' fashion which has been learned over a short time (i.e. as a result of recent activity - fatigue - or environment - a windy day). Contrarily, the model utilised in the null phase is one which has been committed to a 'long term' memory which has been learned over a long time (i.e. your whole life and only adapted for change occurring over long duration - increased strength, heavier limbs etc.).