W24: Neural Modeling: HW-9 Tricking Cerebellum - Motor Noise

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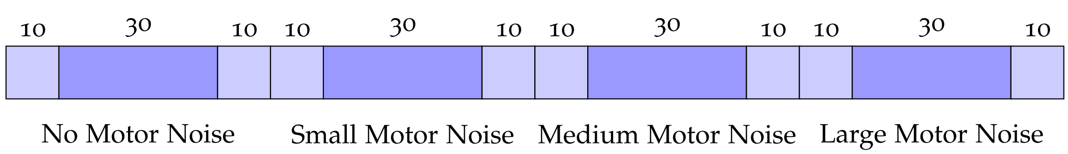
Deadline: ***06.02.2024 - 1:59 pm***

Code Availability

See the full code listing here: TheBavarianGame_ex4.py (GitHub permalink).

Experimental Design

Figure 1: Experimental Setup: We apply four blocks with each block increasing the amount of motor noise, in the colored blocks of 30 trails we apply an additional sudden perturbation that the subject is not aware of and adapts to. Additionally for each succeeding block we apply an additional reduction in friction of the surface to model the beer getting lighter.



TASK 1: Implementation of motor noise

1. Implement motor noise as additional perturbation.

   Answer:

2. Display the text 'Drinking beer' and light up the yellow in the beer pint after the motor noise has been increased.(and/or increase the volume of bavarian music after drinking beer :)).

Answer: We varied the color of the pint from `YELLOW` to `WHITE` to indicate the decrease in *friction*.

3. Design your own experiment to test effect of motor noise.

   Answer: In our experiment, we systematically manipulated motor noise to evaluate its effect on movement performance. The experiment was structured into multiple blocks, each characterized by different noise parameters (`noise_mean`, `noise_std`). Initially, in the first block, no additional motor noise was introduced (`noise_mean = None`, `noise_std = None`).

   Subsequent blocks gradually introduced increasing levels of motor noise:

   - **Low noise condition** (`noise_mean = 0.1`, `noise_std = 1.5`): Small random deviations were added to simulate minor motor inaccuracies.
   - **Medium noise condition** (`noise_mean = 2`, `noise_std = 3`): Increased variability in motor execution to test adaptation capabilities.
   - **High noise condition** (`noise_mean = 4`, `noise_std = 6`): Significant movement variability was introduced to assess the upper limit of motor learning.

   Additionally, friction was progressively reduced in later blocks to model the effect of environmental instability. A secondary experiment introduced approximate end position feedback, in which participants received feedback with increased uncertainty. This setup allowed us to analyze how feedback precision interacts with increasing motor noise in shaping motor adaptation and learning.

TASK 2: Analysis of motor noise on unbiased subjects

1. Record the subject performing your own experiment **Group-A**.

   Answer: Recording were collected and placed in the `participant_data` directory.

2. Visualize the effect of increasing motor noise on the subject's performance.

   Answer: Interpretation:

   - The graph shows the trend of mean error as motor noise increases across different feedback blocks.
   - If feedback were ineffective in the presence of noise, we would expect a completely chaotic increase in error without any adaptation.

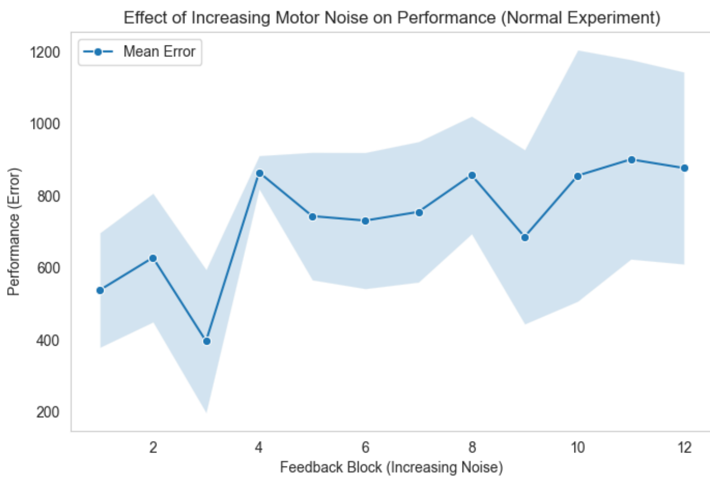


Figure 2: **Motor Noise Mean Error** The trend shows that as noise levels increase, performance deteriorates, indicated by rising error values. However, the presence of feedback appears to help in mitigating the effects of noise, as adaptation can be observed in certain regions where the error plateaus rather than continuously escalating.

- However, while performance (error) generally increases with noise, there are indications that the subject is still able to adapt, as seen in the plateauing of the error in some sections.
- The shaded area (variance) also suggests that while noise increases movement variability, the subject may still be utilizing feedback to some extent to control movement. Thus, while increasing motor noise does impair performance, the trend suggests that feedback still provides a compensatory effect, allowing some level of adaptation.

TASK 3: Discussion of your results

1. Is feedback still helpful even if motor noise is present?

   Answer: Our results indicate that feedback remains beneficial even in the presence of motor noise. The boxplot demonstrates that while movement variability increases with higher noise levels, the deviation remains constrained within certain limits. If feedback were ineffective, we would expect movement errors to grow without bounds. Instead, the data suggest that subjects still attempt to compensate for the noise, indicating that feedback continues to guide performance despite increasing uncertainty

2. How large can the motor noise be until learning no longer takes place ?

   Answer: As noise increases, movement variability grows, suggesting that excessive motor noise might impede motor learning and

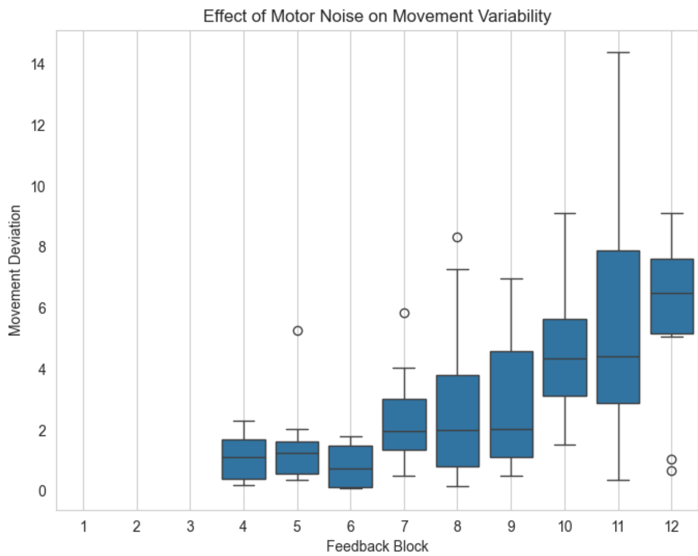


Figure 3: **Noise Impact in Blocks** The boxplot illustrates the effect of increasing motor noise on movement variability across different feedback blocks. As noise levels increase, movement deviation becomes more pronounced, indicating a decline in motor precision. The widening interquartile ranges and the presence of outliers in later blocks suggest greater inconsistency in movement execution, highlighting the impact of motor noise on task performance.

adaptation. The presence of extreme outliers in later blocks further supports the notion that higher noise levels disrupt consistent performance.

TASK 4: Something on our Own

We introduced another set of blocks called **endpos_approx**: Approximate end position provides the approximate end position. The subject infers his end position by estimating the center of a scaled final position. See Figure **??** for the final screen visible to the subject.

The results suggest that as motor noise increases, performance error also rises, indicating a decline in motor precision. However, a notable trend is the presence of adaptation phases where performance stabilizes temporarily despite increasing noise. The variability in performance also grows with noise, demonstrating greater movement inconsistency. These findings imply that while feedback allows some compensation for noise, higher uncertainty in end position feedback leads to amplified performance degradation compared to standard conditions.

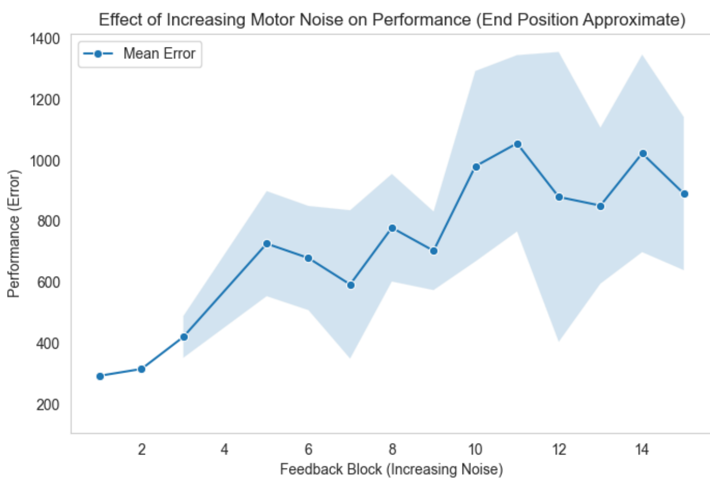


Figure 4: **EndPos Approximate Block** The figure illustrates the effect of increasing motor noise on movement performance under the "End Position Approximate" feedback condition. The y-axis represents performance error, while the x-axis corresponds to different feedback blocks, where noise levels progressively increase. The solid blue line indicates the mean error per block, and the shaded region represents the variability (standard deviation) in performance