

Summary

Rapid and accurate interaction with the world requires that we perceive the consequences of our actions. It has been well demonstrated that delaying visual feedback impairs performance on a range of tasks (e.g., 1-4).

We have recently shown that a few minutes of exposure to delayed feedback induces sensorimotor temporal adaptation (5). Temporal adaptation is analogous to prism adaptation. For example, temporal adaptation:

- allows nearly normal performance with the delay.
- seems to alter intersensory perceptual judgments (e.g., after adapting to the delay, the delayed visual stimulus and non-delayed proprioceptive stimulus are perceived as occurring simultaneously).
- subsequent removal of the delay severely impairs performance (negative aftereffect – Figure 1)

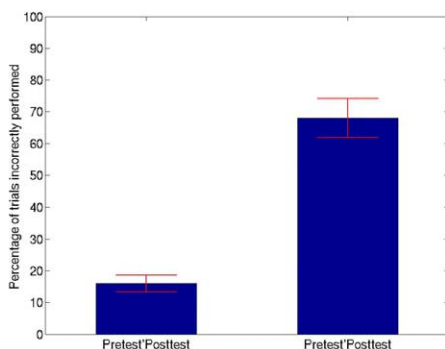


Figure 1: Demonstration of negative aftereffect from previous temporal adaptation work. Error rates on the task with no delay were measured both before Pretest) and after (Posttest) training with delayed visual feedback.

Motivation

As part of an ongoing line of research into how the visual, proprioceptive, and vestibular systems are integrated, we examined the sensitivity and flexibility of the vestibular system to the temporal characteristics of perceptual feedback. Specifically, we asked:

- Does delayed vestibular feedback impair performance?
- If so, is temporal adaptation to delayed vestibular feedback possible?

Methods: Equipment



Figure 2: The motion platform

The vestibular feedback was provided by a motion simulator (Figure 2: the Maxcue platform from Motionbase).

While the platform is capable of motion along all six degrees of freedom, only roll motions (i.e., tilt to the subjective left/right of the subject) were used in this experiment.

Methods: Task

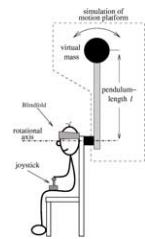


Figure 3: Schematic of the inverted pendulum.

The platform duplicated the motion of an inverted pendulum (Figure 3).

Subjects were asked to stabilize the platform by applying an acceleration to it via a joystick.

To isolate vestibular feedback, subjects wore a blindfold and headphones (which played white noise).

Methods: Design

To help ensure that learning effects did not contaminate the pre- and post-test measures, subjects were trained on the task with immediate feedback several days before the start of the experiment.

The experiment itself was divided into 3 parts:

- **Pre-test:** (2 minutes). Subjects performed the task with immediate vestibular feedback (i.e., the platform responded almost immediately to joystick motions).
- **Training:** (4 blocks, 5 minutes each). During training, vestibular feedback was delayed by approximately 500 ms. Subjects were given a small break (1-2 minutes) between blocks.
- **Post-test:** (2 minutes). Performance with immediate feedback (no delay) was remeasured.

Results

The more difficulty that one has in stabilizing the platform, the more it will oscillate. Accordingly, the standard deviation of the platform position was used as the primary measure of performance.

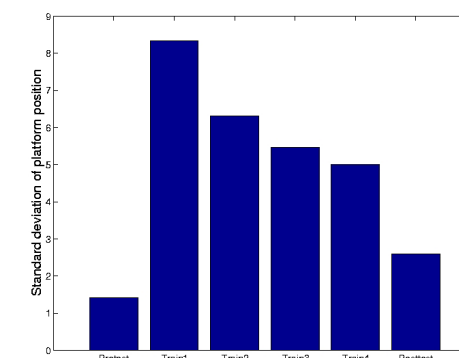


Figure 4: Results of the present experiment, demonstrating both learning and negative aftereffect.

- Subjects did well during the Pre-test (with immediate feedback).
- The introduction of the delay greatly impaired performance.
- Training with the delay improved performance.
- Post-test performance (with immediate feedback) was worse than Pre-test (negative aftereffect).

Conclusions

Delaying vestibular feedback impairs performance on stabilization tasks.

Continued exposure to the delay clearly enables subjects to compensate, at least partially, for the delay.

The pattern of compensation for the delay is consistent with temporal adaptation.

References

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