Driving a virtual car with delayed visual feedback

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1 Introduction

Delaying the presentation of information to one sensory modality relative to another drastically impairs performance. Can humans learn to perform complex, real world tasks under such conditions?

It has long been known that wearing prism goggles (producing a disagreement between the seen and felt position of an object) impairs most spatial tasks (e.g., pointing, navigating, reaching, catching). A few minutes of the proper experience, however, allows the sensorimotor system to adapt itself to the new relationship.
Similarly, delaying visual feedback (producing a disagreement between the seen and felt time of occurance of an event) drastically impairs performance on many tasks. Delays as small as 45 ms can be detrimental and delays greater than 1 second essentially eliminate the visual control of behavior (1,2,3). Only recently has it been shown that, contrary to established belief (e.g., 1), a few moments of the proper type of training can improve performance with delayed feedback considerably (4). This improvement was obtained using abstract stimuli and a task with which most subjects have had little prior exposure. Here, we extend this work to more realistic stimuli and a task with which subjects have extensive prior exposure to immediate feedback. Specifically, we employed a driving simulator using high fidelity virtual environment.

2 General Methodology

2a Apparatus

Stimuli: The 3 dimensional virtual world was projected onto a half−cylindrical projection screen (7m diameter, 3.15m height). The stimuli were generated on a Silicon Graphics Onyx 2 Reality Engine.

Input: Subjects maneuvered the virtual car via a custom−designed, forced−feedback steering wheel.

2b Design Philosophy

Constant Velocity: Previous research on the effect of practice with delayed feedback found little or no improvement (1,2). Unfortunately, the subjects in those experiments tended to slow down when exposed to delayed feedback (3) −− a strategy that negates the effects of the delay. For example, in a car with a 1−second delay between the steering wheel and the tires, a driver traveling 36 kph must turn the steering wheel 10 meters prior to reaching an intersection. A driver traveling at the slower speed of 3.6 kph, however, can act as if there were no delay and turn once in the intersection.
Following Cunningham et al.(4), we ensured that subjects were exposed to the delay, and thus had the chance to acclimate to it, by allowing them to control only the direction of travel. The speed of travel was constant for the duration of a single trial, with each subject being exposed to 7 different speeds.

Sensorimotor adaptation paradigm: Exp. 1 was explicitly designed following the earlier work in prism adaptation. Of particular note is that the task was kept as constant as possible throughout (e.g., the same street was used in all sections, see Fig. 1). Exp. 2, following later prism adaptation work, examined the generalization of training (using novel stimuli).

Task: The task was drive to the end of the street, without ever driving on the grass.

3 Experiment 1: Methodology

<u>*Pre−Test:*</u> The 7 speeds were presented 5 times each in random order with immediate visual feedback.

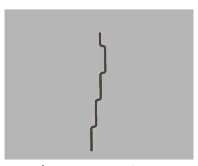


Figure 1: Street used in Exp. 1

<u>*Training:*</u> Visual feedback was delayed by approx. 280ms. Each subject traveled at the slowest speed until one of 3 criteria was met. If the success criterion was met, then subjects moved on the the next faster speed. If either of the other 2 criteria was met, then training ended.
(a) *Success*: They reached the end of the street in 8 of 10 sequential trials;
(b) *Failure*: Subjects left the street 10 times in a row;
(c) *Stalemate*: Neither of the first two criteria was met within 40 trials.

<u>*Post−Test:*</u> Subjects' performance with immediate visual feedback was remeasured. To avoid re−adaptation to immediate feedback, only 10 trials were presented. For each subject, all 10 trials were at the fastest speed that they successfully completed at least 4 of the 5 Pre−Test attempts.

4 Experiment 1: Results and Discussion

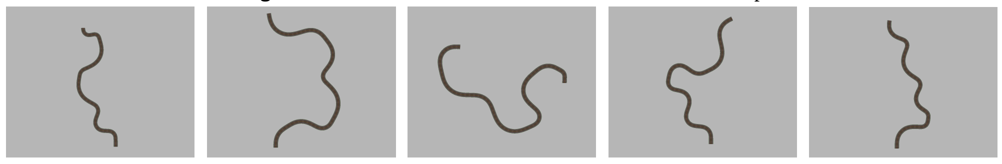
- During training, performance with delayed feedback improved.
- Each subject exhibited a strong negative aftereffect (after training with a delay, performance with immediate feedback decrease by approx. 80%, on average).

These results are consistent with those of Cunningham et al.(4), and demonstrate the robust nature of the ability to acclimate to large feedback delays.

5 Experiment 2: Methodology

<u>*Pre−Test:*</u> Each subject's baseline performance with delayed feedback was measured, using 5 paths (see Fig. 2a) each presented at 4 speeds.

Figure 2a: Streets used in the Pre−Test section of Exp. 2



<u>*Training:*</u> The training was identical to Experiment 1, including the fact that the same street (see Fig 2b) was used for all trials.

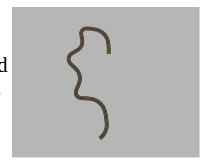
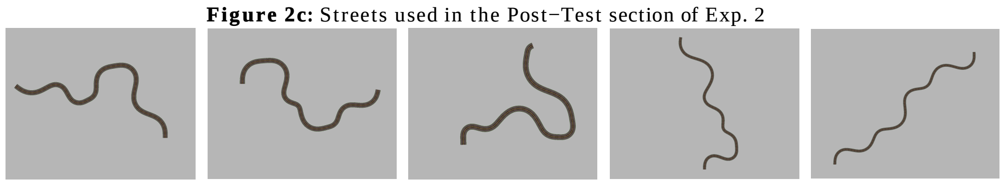


Figure 2b: Street used in the Training section of Exp. 2

<u>*Post−Test:*</u> The post test was identical to the pre−test, with the single exception that 5 new paths (see Fig. 2c) were used.

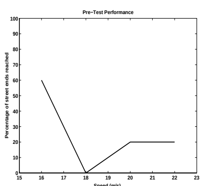
Figure 2c: Streets used in the Post−Test section of Exp. 2



6 Experiment 2: Results and Discussion

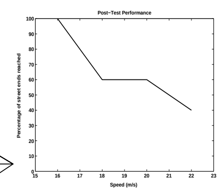
- During training, subjects were able to successfully complete the street at much faster speeds than they could during during the Pre−Test.
- Performance accuracy on the novel streets after training was substantially higher than accuracy before training.

<u>Data from one representative subject.</u>
The number of streets successfully completed is plotted as a function of vehicle velocity



← Baseline performance with delayed feedback.

Performance on novel streets after training with delayed feedback. →



7 Conclusions

- Humans can learn to drive a car with visual delayed feedback by 300 ms.
- Combined with Cunningham et al.'s(4) earlier work, this suggests a general ability to learn to perform complex tasks with delayed feedback.
- The results are suggestive of sensorimotor adaptation to intersensory temporal differences.
- The results are **not** consistent with over−training, cognitive or motoric memorization of the path, or simple behavioral strategies (e.g., simply attempting to turn earlier).

8 References

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