Motion Pattern Analysis in Proprioceptive Guidance

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Background

- Proprioceptive guidance assists a human operator to perform goal-directed movement by giving kinesthetic feedback.
- Proprioceptive guidance enhances motor learning when visual feedback is unreliable, the task has complex kinematics, or is difficult to describe.
- These characteristics are present in the surgical and rehabilitation environment, thus making it optimal for training healthcare skills required in Surgery and Rehabilitation.

Objectives

- We aims to characterize the behavior of proprioceptive guidance in storing information for skill learning.
- We hypothesize that a human operator has limited capacity to perceive motor information purely through kinesthetic guidance.
- Task performance will degrade once working capacity has reached its limitation.

Methods

Participants:

- 20 students and staff from the University of Alberta (55 % male; 95 % right-handed)
- Age range: 18 – 39 years, median age = 26 years).

Task:

- The task was performed using a two-dimensional master-slave system built on a wooden board shown in Figure 1.
- Each participant was blindfolded and passively perceived the motion performed by the experimenter over six times, and then reproduced the pattern.
- Figure 2 shows the five different movement patterns performed. The patterns were presented in five different orders and were counterbalanced between subjects.
- On each duplicated pattern, direction of each line was compared to the model pattern. A “0” point was given for each correct direction that matched the one given; whereas a “1” point was counted for the incorrect line direction. These points were then added and the total divided by the number of lines of each pattern (normalized).

Statistical analyses:

- The mean number of errors and task time were compared among the five different patterns using one-way ANOVA; Post Hoc between pairs of patterns were done by Bonferroni test. $p < 0.05$ indicated statistical significance.

Results

- The task performance time increased as the number of lines in the patterns increased ($p < 0.001$).
- Participants successfully recalled the direction of the patterns 96% (768/800).
- In figure 5 (top), the number of errors increases in general with the number of lines in the pattern ($p = 0.044$).
- The directionality of the easiest pattern, pattern 1 with 4 lines, could be perfectly recalled by all the participants. Thereafter, the number of errors increased with the complexity of the pattern.
- The rapid increase in normalized errors from the pattern 2 with 6 lines to pattern 3 with 8, and the drop in pattern 4 with 10 lines still exists, indicating that the line location of the mean error was independent of the type of pattern ($p = 0.076$) and there was no interaction between the type of line and pattern ($p = 0.061$).
- Post Hoc revealed difference presented between lines 1 - 8 ($p=0.002$), lines 2 - 8 ($p=0.002$), lines 3 - 8 ($p=0.006$), lines 4 - 8 ($p=0.006$), lines 1 - 9 ($p=0.036$), and lines 2 - 9 ($p=0.036$).

Figure 1. Guidance device

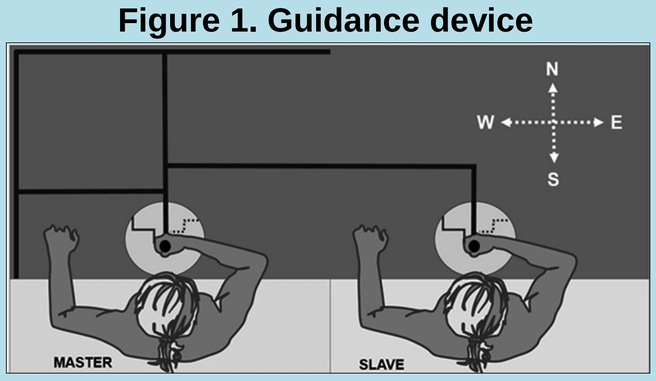


Figure 2. Model patterns

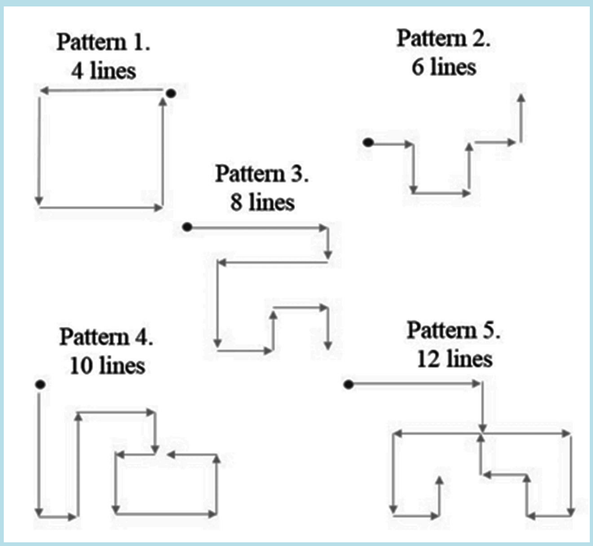


Figure 3. Counted errors per pattern

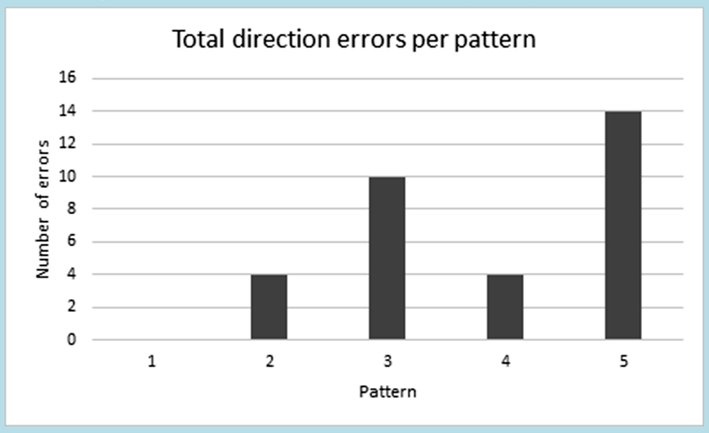
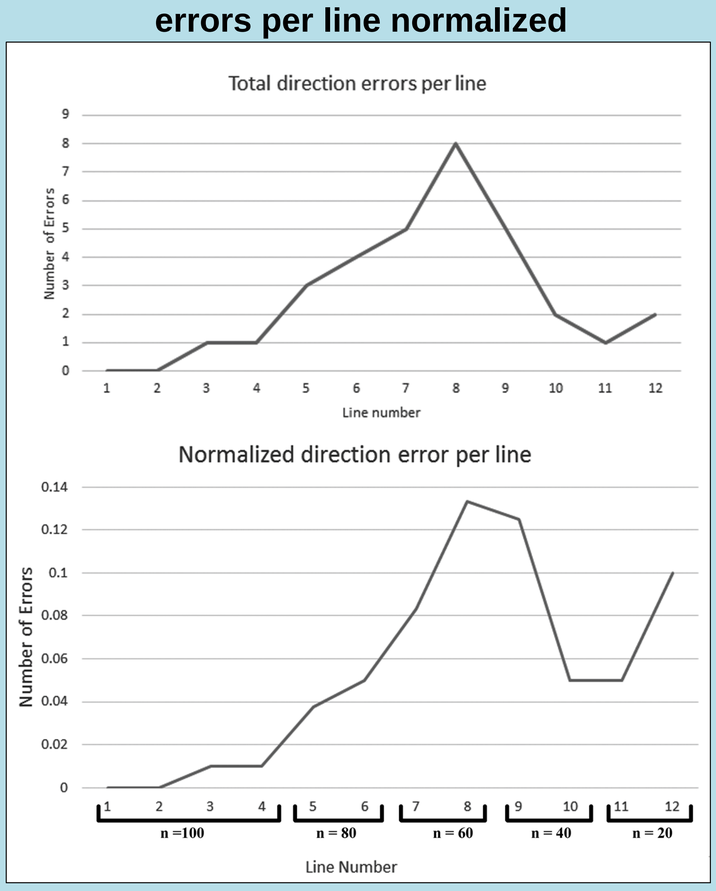


Table 1. Error count, rate of error in pattern, and rate of error per line in direction

	Pattern 1	Pattern 2	Pattern 3	Pattern 4	Pattern 5
Error count	0	4	10	4	14
Rate of error pattern	0	0.020	n = 20 0.50	0.020	0.70
Rate of error line	Line 4 n =100 0.010	Line 6 n =80 0.050	Line 8 n =60 0.133	Line 10 n =40 0.050	Line 12 n =20 0.100

Figure 5. Top: Total number of errors per line number. Bottom: Total number of errors per line normalized



Discussion

- Our hypothesis was confirmed. With increased number of movements, errors and completion time incremented.
- The complexity level of the patterns was determined by the number of steps in the patterns, and by the degree of randomness in the direction of the movements. Saturation point of the working memory was observed around the 6th line.
- In complex patterns, a chunking strategy was used by participants to decrease the number or errors.
- Direction recalling behaviour demonstrates high accuracy at the beginning and the end of each pattern. This phenomenon may be explained by the *serial position effect* whereby recalling a step is affected by its position on a list of steps.
- This is the first experiment in a exclusive haptic realm in which both *primacy* and *recency* effects are observed.

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