Learning to Tie Well with Others: Bimanual vs. Intermanual Coordination during Shoe-tying

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Introduction

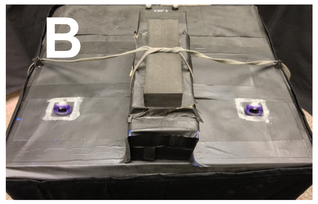
- People coordinate hand movements alone and with others in a variety of settings

Team Lifting
(a familiar task for most people)

Laparoscopy
(a novel task for most people)

- In the context of interacting with everyday objects, people coordinate their hand movements in a variety of ways, called coordination modes
  - Unimanual – one-handed
  - Bimanual – two-handed
  - Intermanual – different people, each using one hand
- Research on coordination modes in novel task environments (e.g., teleoperations; laparoscopy) has shown that
  - Transitioning from one mode to another can cause either an increase (*positive transfer*) or decrease (*negative transfer*) in performance (Gorman & Crites, 2013), depending on the order in which people practice different modes
  - Research has also shown "*mode effects*," such that intermanual tends to be significantly faster than other modes (Gorman & Crites, 2013; Zheng, Swanström, & Mackenzie, 2007)
- However, those studies used novel tasks and novice participants, and those transfer and mode effects disappeared rapidly with practice
- The current study examines the generality of such findings using a familiar manual coordination task, shoe-tying, while examining transfer between coordination modes in terms of learning functions and motor transfer
- We hypothesized that the intermanual mode effect would be absent for this highly-familiar bimanual task and explored whether bimanual skill transfers to intermanual skill and whether intermanual motor learning occurs in terms of transfer to subsequent bimanual performance
- The results of this research may, for instance, inform new strategies to facilitate relearning simple manual coordination tasks, such as tying a shoe, after one loses the use of a hand (e.g., due to paralysis, amputation, or after a stroke)

Shoe-tying Task Environment

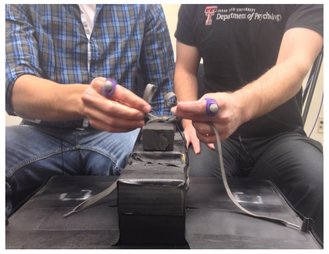


- **A** = Motion Capture Room
- **B** = The "Shoe"
- **C** = Participant wearing Ring with Reflective Marker

Method

- All participants tied the shoe using the same sequence of coordination modes
  - Bimanually; intermanually; and then once more bimanually
- Participants (36 dyads)
  - Tied the shoe bimanually (B1) for 10 trials
  - Then intermanually (Inter) for 20 trials
  - Then bimanually (B2) for 10 trials

An example of the intermanual shoe-tying condition



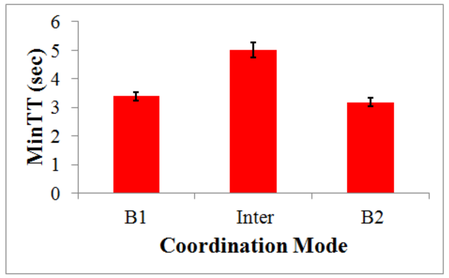
- A predetermined volume of the motion capture space was used to start and stop motion capture analysis for each trial
  - The exact location of the start/stop volume was determined during pilot testing and was located 1 inch above the "home keys" on each side of the shoe
  - The start/stop volume was used to identify the onset and offset of movement duration for each trial, such that movement onset occurred when the first hand entered the volume, on its way to the shoe, and offset occurred when the last hand exited the volume, on its way back to its home key
- Trial time was measured as offset minus onset in seconds
  - Trial times in the bimanual coordination mode were averaged across participants for comparison with the intermanual trials
  - Variability was measured as generalized variance across hands; however, measures of variability are not addressed in this proceedings paper
- Data was analyzed in two ways to investigate
  1. Mode Effects
  2. Learning Functions and Transfer

Mode Effects

- Because performance asymptote occurred prior to the last trial, and because participants were instructed to "tie the shoe as quickly as possible for every trial" in each coordination mode, the minimum trial time (MinTT) was obtained for each dyad across all trials for each level of Coordination Mode
  - MinTT measures the highest level of performance achieved at each level of Coordination Mode
- Not surprisingly, results revealed a significant mode effect, where the familiar bimanual mode (B1 & B2) was *faster* than the novel intermanual mode (Inter)

$F(2, 36.35) = 43.30$, $p < .001$, $\eta^2 = .55$

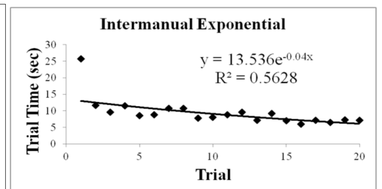
Bonferroni p's < .001

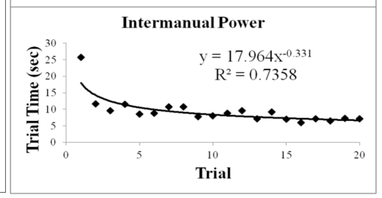


- This illustrates that previously reported mode effects may not be applicable to highly-familiar manual coordination tasks
- Hence, mode effects may be more dependent on prior task experience than previously described

Learning and Transfer

- To assess how people learn a new coordination mode for a familiar task, we fit exponential and power functions to each dyad's trial series in each coordination mode
- Exponential vs. power fits for a dyad during the Inter condition are shown to the right
- Whereas exponential functions describe transitory changes early in learning, a power law tends to describe persistent learning (Stratton et al., 2007)
  - If people are acquiring a new motor coordination skill, then we expect to observe an exponential function
  - If they are transferring persistent, bimanual shoe-tying skill then we expected a power law learning function

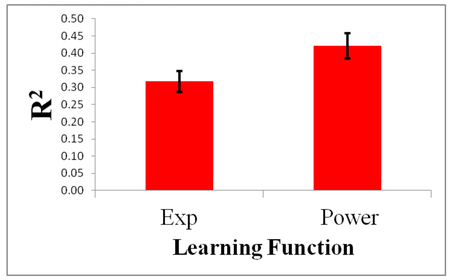




- The amount of variance explained (R^2) was calculated for exponential and power law fits for each dyad at each level of Coordination Mode

Simple effect for Inter

$F(1, 35) = 34.79$, $p < .001$, $\eta^2 = .50$



- As shown in the figure, follow-up analysis of the trial-by-trial Inter data were better fit by a power law learning function

Conclusions

- Dyads were never able to match their baseline level of bimanual performance when completing the task in the intermanual coordination mode
  - This is due either to familiarity of the bimanual task or lack of intermanual practice
- Subsequent analysis (not in the proceedings paper) revealed that initially slower participants sped significantly during the second set of bimanual trials
  - That result suggests motor learning and transfer of intermanual skill to subsequent bimanual performance
- We obtained a better power law fit for the intermanual trials
  - Participants were able to transfer previous bimanual skill to the novel intermanual coordination mode
  - People may be able to transfer their past bimanual experience rather than having to learn an entirely new coordination skill

References

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