Fitts' with a Twist:
An Exploration of Scale Effects using a New Experimental Paradigm

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Introduction

Fitts' law, a classical theme in human movement science, states that the time it takes a human to point at a target of width W, located at distance D is linearly related to the logarithm of their ratios, or more specifically the tasks Index of Difficulty (ID).

Mathematically it is formulated as:

$$MT = a * \log_2(D_e/W_e+1) + b,$$

where $ID = \log_2(D_e/W_e+1)$.

Operationally this means that for every given task, each level of ID has a corresponding MT (μ_T) that is scale invariant.

However, Fitts' himself acknowledged in his 1954 paper that this was true only within a "certain range". The limits of this range have though not received much attention in Fitts' law literature.

We investigated the effects of scale in a Fitts' type pointing task. We separated scale into visual and manual and manipulated either one at a time or both simultaneously.

We utilized a new experimental paradigm, the Time/Error trade-off paradigm. This paradigm differs from the traditional experimental approach in several ways. •Task tolerance is manipulated via instructions to the participants (ranging from "maximum speed" to "maximum accuracy" with three intermediate levels). •Relative Variable Error (RVE = σ_A/μ_A) is used to quantify target performance. • A min-min trade-off between RVE and μ_T is assumed. A trade-off is a mutual dependency between two utilities that conflict with each other because they draw on the *same limited resource pool*. Figure 1 demonstrates this trade-off.

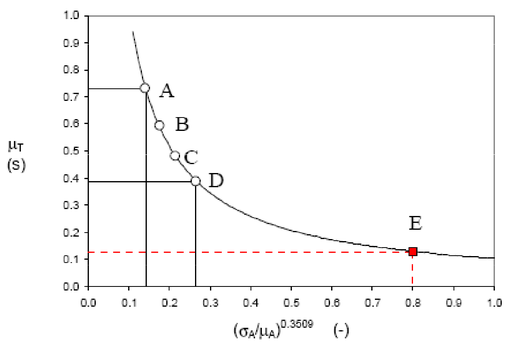

Figure 1. An example of the trade-off between Mean MT and RVE from Fitts' tapping data.

The relationship between μ_T and RVE can be modeled as a power function, thus: $\mu_T = q*RVE^p$ and $q = \mu_T * RVE^{-p}$ where q indicates the amount of resources available.

Methods

Due to the size of the project we divided it into four different experiments, depending on which scale was manipulated. Figure 2 shows the organization of the four experiments. Here are only presented results from experiments 2,3 and 4.

All experiments were performed using a digitized tablet with a stylus and a computer screen. Participants performed a sliding movement on the tablet while looking at the screen which displayed the respective task.

Exp 2:
•Task size on Tablet : 150 mm
•Task size on Screen : 150, 75, 37.5, 18.75 & 9.375 mm

Exp 3:
•Task size on Tablet: 150, 75, 37.5, 18.75 & 9.375 mm
•Task size on Screen: 150 mm

Exp 4:
•Task size on Tablet & Screen: 150, 37.5, 18.75 & 9.375 mm

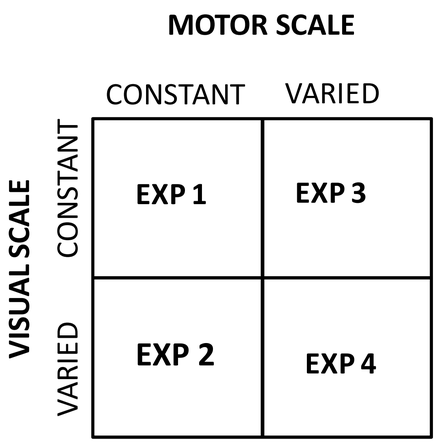

Figure 2. The experimental series.

Results

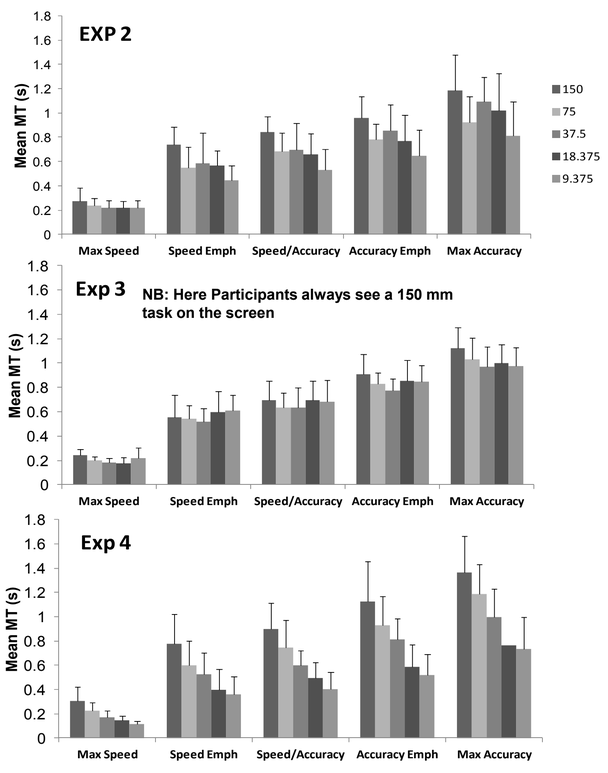

Figure 3. Mean MT in all three experiments as a function of instruction and scale (task size).

•In all experiments and for all scale changes MT increased with increasing emphasis on accuracy (Figure 3)
•Exp 2 and 4, significant main effects of Scale but not for Exp 3.
•Exp3:P's performed the task on the screen in the same time by moving faster on tablet with increasing scale.
•Exp2: Tablet velocity was not invariant to scale even though tablet task size was constant.

•General: RVE decreases with increasing accuracy as expected.
•Larger RVE for smaller tasks except in max speed condition of exp 2.

•Significant effects of scale (task size) in Exp 2 and 4 on q.
•Resource available decreases with task size (scale).

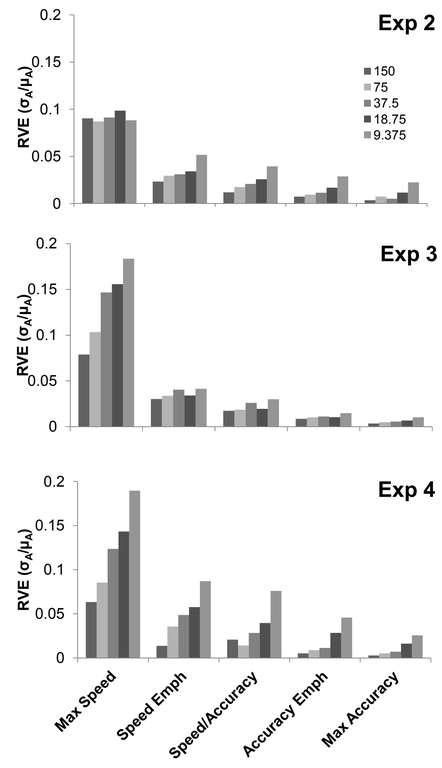

Figure 4. Relative Variable Error (σ_A/μ_A) as a function of instruction and scale (task size)

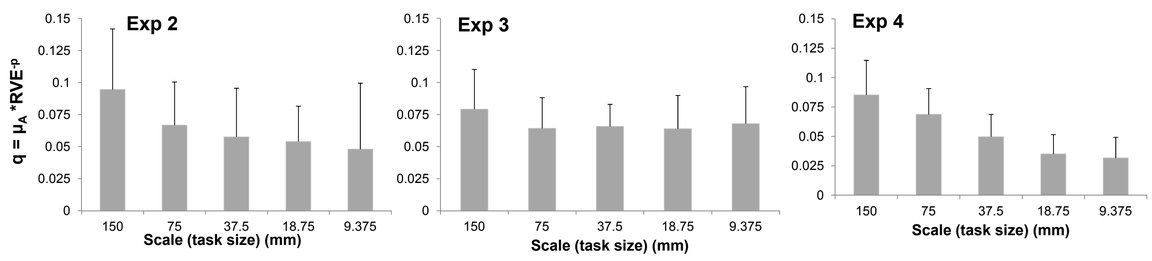

Figure 5. Index of resources (q) as a function of task scale in the three experiments.

Conclusion

The analysis of these experiments is still a work in progress. MT results of Exp 3 show the same trend reported by Bohan et al. (2010) but are not significant.

Results of the Time/Error trade-off analysis revealed order of q values in line with what was previously found by Guiard et al. (2011) but further work is needed.

References

Bohan, M., McConnell, D.S., Chaparro, A. &Thompson, S.G. (2010). The effects of visual magnification and physical movement scale on the manipulation of a tool with indirect vision. *Journal of Experimental Psychology*. 16, 33-44.

Fitts, P.M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology.* 47, 381-391.

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