Sensorimotor control and linear visuohaptic gain

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1 Introduction

Our direct interactions with the environment are performed through the sense of haptics. Touch and kinesthesia are used to extract objects properties' as well as to control our motion relative to them. The effectiveness of this sensorimotor control is a key question in the field of Human-Computer Interaction to enhance user performance. This is notably the case when we use a touchpad to control a visual cursor on a separate screen (e.g., a laptop). The control of these graphical interfaces is configured through a mapping between the motor space (e.g., the touchpad) and the visual space (e.g., the screen) called Transfer Function (TF). When we use the touchpad to control the cursor on the screen, the motion is compounded of a preprogrammed phase performed at high speed, and a following homing phase, performed at low speed and based on visuohaptic feedbacks (Elliott et al. 2010). Some operating system TFs (e.g., Windows, OS X) are based on this principle with a visuomotor gain during the preprogrammed phase which is high while it is low during the homing phase to reduce the Movement Time (MT). Such TFs have been shown to enhance performance with this increasing visuomotor gain (Casiez et al. 2008; Casiez and Roussel 2011). However, the reasons of this improvement are not totally elucidated, notably because the prescribed gains are *non-linear*. Here we analyzed the kinematics of a pointing task with a *linear* velocity-based TFs to assess how we plan and control our movement based on vision and haptics (i.e., touch and kinesthesia involved in motion perception). We compared two non-linear increasing and decreasing TF with constant gain TFs.

2 Methods

Eleven participants performed a Fitts' task in the horizontal plan on a MacBook Pro Retina (OS X 10.11.6 El Capitan) with a screen of 13.3 inches (1280 x 1024 pixels) refreshed at 60 Hz and a touchpad with a resolution of 400 CPI sampling at 125 Hz. Raw data from the pointing device and transfer functions were handled using libpointing (Casiez and Roussel 2011) while we used an application written using C++/Qt to provide the instructions and stimuli. Participants were asked to point the target as precisely and as accurately as possible with a smooth movement: they had to avoid stopping outside the target. The target distance was 8 cm and the width 2 cm, 0.5 cm or 0.125 cm, corresponding to the index of difficulty (ID; (Fitts 1954)) 3, 5 and 7, respectively. Four TF were applied from the pad velocity to the visual cursor velocity: i) a constant gain of 1 (CG1), ii) a constant gain of 3 (CG3), iii) an increasing gain (IG) from 1 (at motor velocity of 0 $cm.s^{-1}$) to 3 (at motor velocity of 10 $cm.s^{-1}$), iii) a decreasing gain (DG) from 3 (at motor velocity of 0 $cm.s^{-1}$) to 1 (at motor velocity of 10 $cm.s^{-1}$). Twelve blocks with thirty successive trials of each TF and ID were performed, and only the last 20 were analyzed to avoid post-effect of TF change.

3 Results and Discussion

A repeated-measures Anova on the pointing movement time (MT) showed a main effect of TF ($F_{3,20}$=18.1 p<.001), and ID ($F_{2,20}$=125.4, p<.001) as well as an interaction between both factors ($F_{6,60}$=2.5, p<.05; Fig. 1). Post-hoc Newman-Keuls further revealed the following statistical differences: The CG1 induced a longer MT than the CG3, regardless the ID. In addition, participants were as fast with CG3 than with the IG. Finally, while the DG induced longer MT for ID3, it was no longer the case for ID7 where CG3, IG and DG were not different. Overall, a high visuomotor gain appeared necessary to be fast even for the smallest target (ID7). Surprisingly, MT were not shorter for the CG3 than for the IG even at ID7.Therefore, the visuomotor gain of IG was reduced at low motor velocity and would have been helpful for an accurate sensorimotor control near the target ((Woodworth 1899)). A possible explanation of such absence of MT shortening might be that even if the low gain at low motor velocity allowed a better ending control, it might also be detrimental at the beginning of the motion because it delayed the time to reach the peak of visual velocity. This hypothesis is supported by the profile of the operating system TF: starting with a relative high gain and exponential at low speed. Further kinematic analyses will be conducted to assess how we use vision and haptics to control our motion regarding the manipulated visuomotor gains and task complexity.

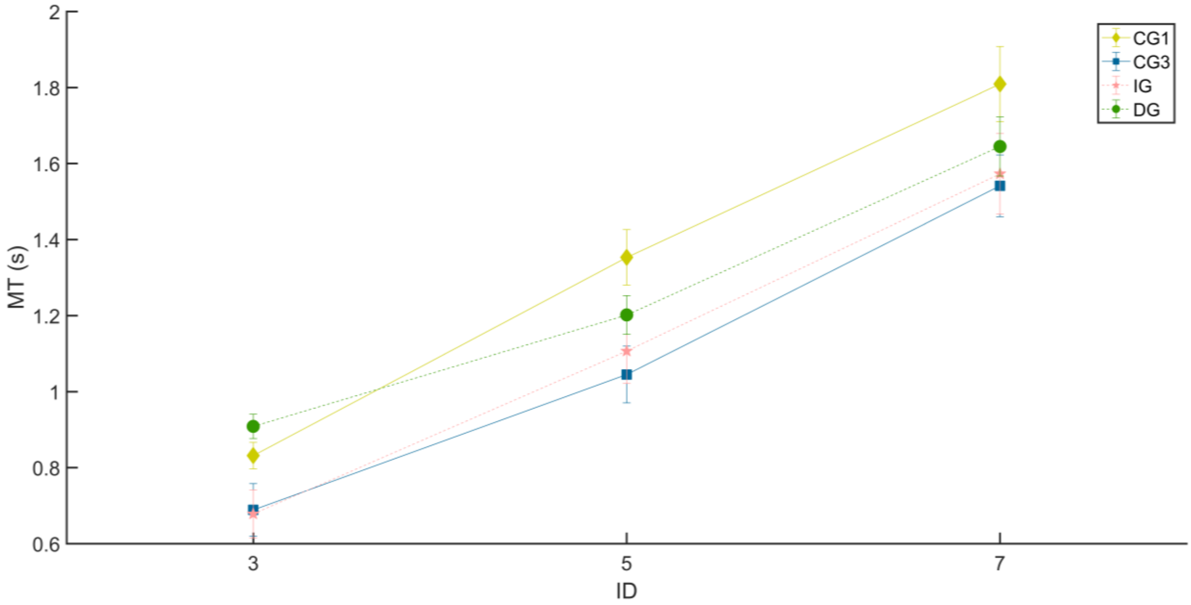

Figure 1: Movement Time as a function of ID and TF. CG1: Constant Gain of 1; CG3: Constant Gain of 3; IG: Increasing Gain; DG: Decreasing Gain. Error bars denote standard error.

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