RAPID GRIP FORCE ADJUSTMENTS INTERACT BETWEEN THE HANDS INDEPENDENTLY OF THE MANIPULATED OBJECT

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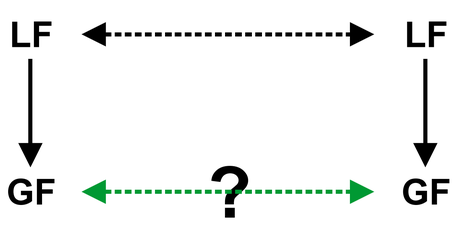
INTRODUCTION

- In voluntary manipulation tasks, humans adjust grip forces (GF) in anticipation of load forces (LF) arising from weight and inertia of an object.
- In case of load force perturbation, grip force must be reactive in order to prevent slippage.
- In **bimanual** object manipulations, LF are transmitted through the object.



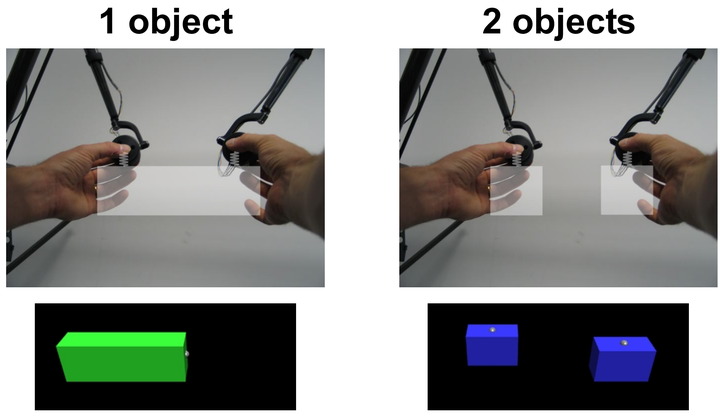
For optimal feedback control, we predict that:

(1) Grip forces **are coupled** when manipulating 1 object
(2) Grip forces **are uncoupled** when manipulating 2 objects

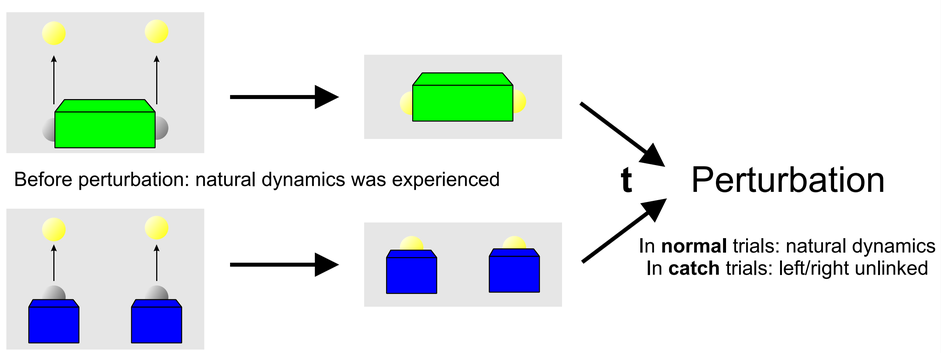
METHODS

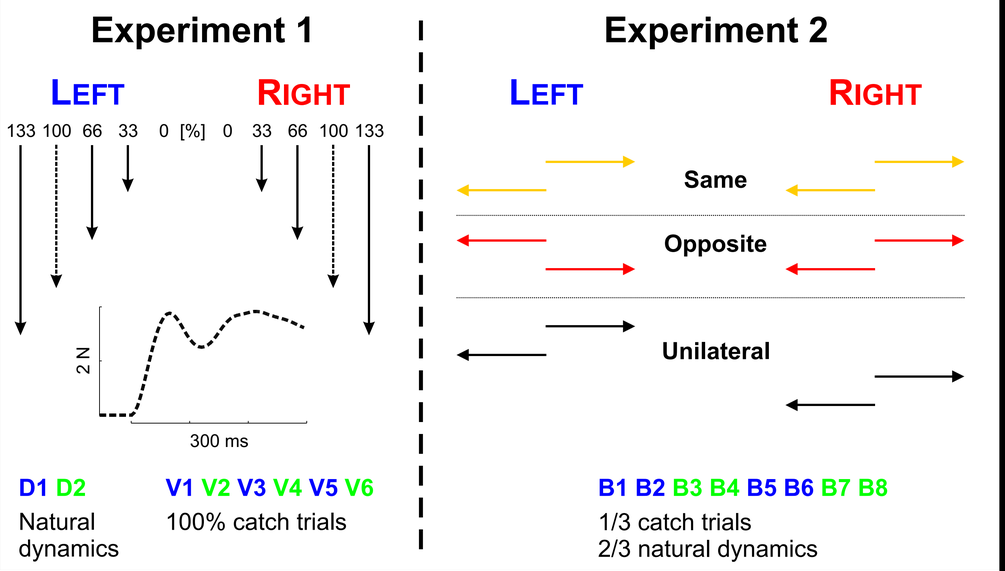
Apparatus

Simulation of object Newtonian dynamics in a 3D virtual environment with 2 robotic devices controlled in closed-loop (Phantom 3.0, Sensable Technologies).

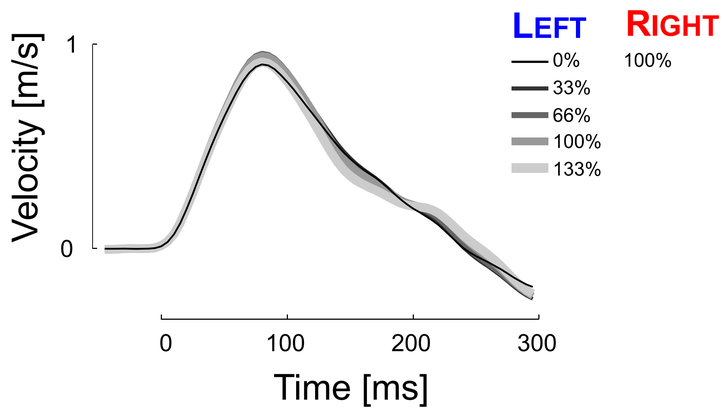


Procedure

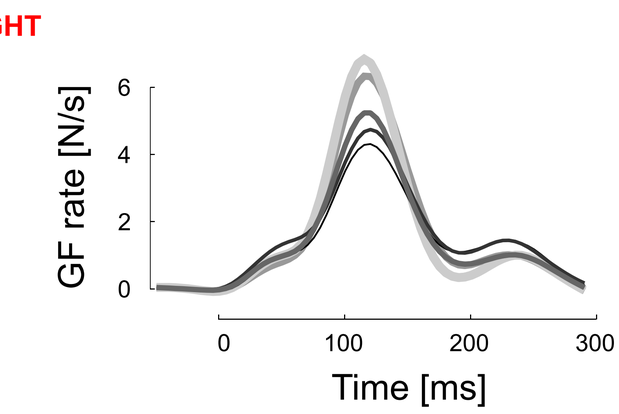




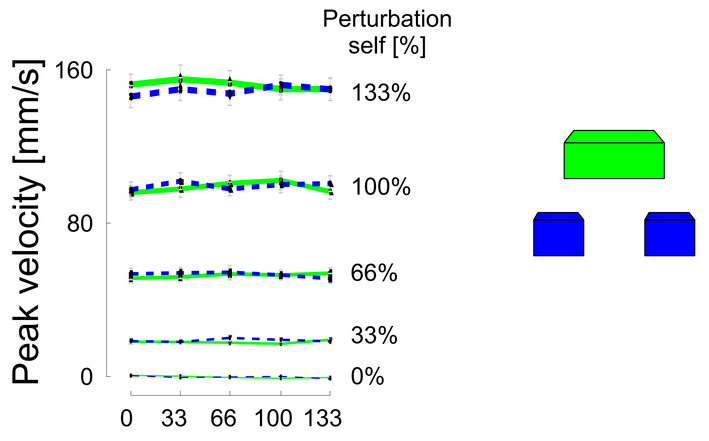
RESULTS: EXPERIMENT 1



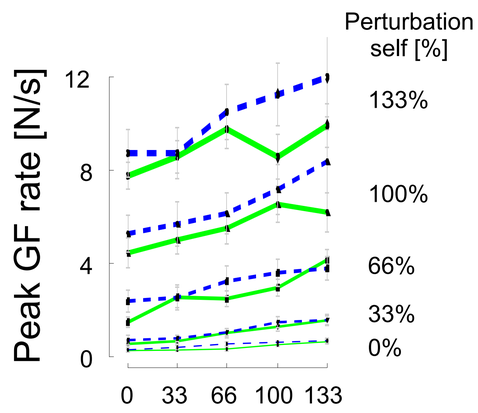
Velocity on the perturbed hand (right) is **independent** of the perturbation of the other hand (left)



Grip force on the perturbed hand (right) **increases** with the perturbation of the other hand (left)



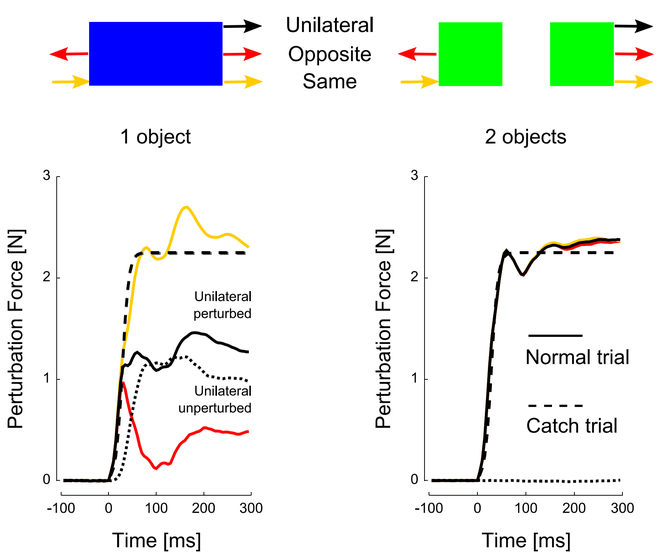
- Velocity increases with perturbation self
- Velocity is independent of object and perturbation other



- Positive slopes reflect grip force coupling
- Slopes increase as a function of perturbation self
- No difference across objects

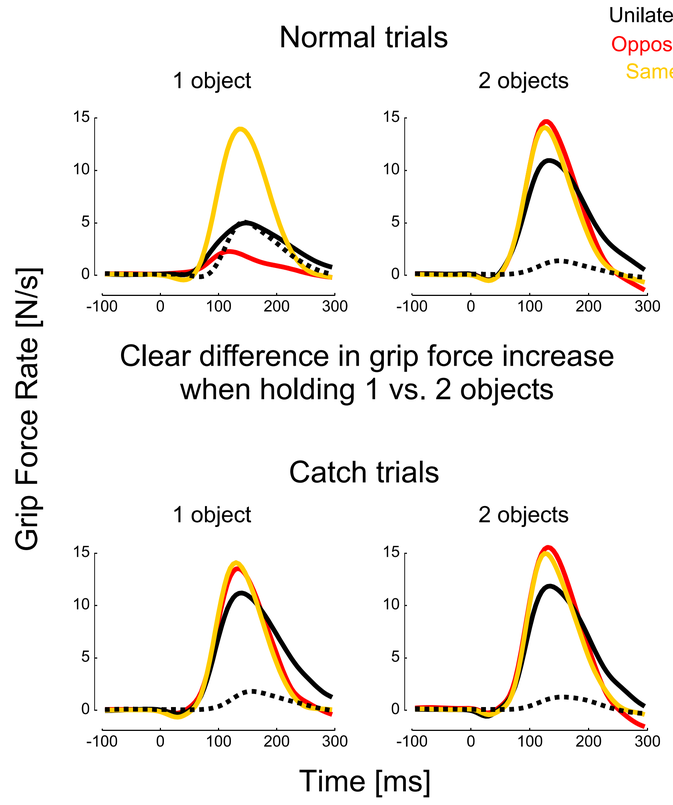
Unexpectedly, **we found a stronger grip force coupling in the 2-object condition...**
Maybe because load forces were **always decoupled**, or because load force pulses were **vertical => Exp 2**

RESULTS: EXPERIMENT 2



1-object condition:
Forces are transmitted through the object in normal trials

2-object condition:
Catch trials and normal trials are identical



Clear difference in grip force increase when holding 1 vs. 2 objects

No difference in grip force in bilateral perturbations

CONCLUSIONS

- Grip forces are coupled even when load forces are physically uncoupled at the perturbation. Grip force responses were independent of the nature of the object and of the direction of the perturbation. This contrasts with reactions to force field perturbations in reaching (Diedrichsen, 2007) and load forces in a restraining task (Okhi et al., 2002).
- However, for high bilateral perturbations, grip force increased more rapidely when holding 2 separate objects. The cost of loosing grip on a single object held in one hand is more severe than that of loosing one side of one object, because the other hand can help to restore stability.
- Together these findings suggest a relatively low-level and inflexible mechanism of reactive grip force coupling that has matured during evolution to ensure stability during bimanual object manipulation.

This research was supported by grants from Biotechnology and Biological Sciences Research Council (BB/E009174/1), FSR (Belgium) and the NCM 2008 Scholarship Program.