### **Preemptive Action**

Accelerating human reaction using electrical muscle stimulation without compromising agency

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#### Core question for today's talk:

## can we accelerate reaction time without compromising agency?

## 1. related work the sense of agency

## sense of agency

: feeling of control over actions and their consequences

this is fundamental to the way we interact in the world:

- 1. it is linked to self-awareness [Gallagher, '02]
- 2. its disruption is linked to neurological disorders [Frith, C, '92]
- 3. It is a core value in our community [Shneiderman's rule#7]

Frith, C. (1992). The Cognitive Neuropsychology of Schizophrenia. Gallagher, S. (2002). Experimenting with introspection. Trends Cogn. Sci Shneiderman, B., and Plaisant, C. (2004). Designing the User Interface: Strategies for Effective Human-Computer Interaction









# **2. Our approach** delay the actuation timing



#### experiment #1

## On-screen Target

#### **EMS Device**

#### experiment #1: design



#### experiment #1: design



#### experiment #1: results



#### experiment #1: results











#### **Preemptive Action : generalized model**





#### experiment #2: design



same apparatus + added control conditions

preemptive EMS (80 ms)
Relax EMS. (80 ms)
user moves + EMS tingles (80ms)
preemptive EMS (240 ms)

Participants were not aware of four conditions

#### experiment #2: results

finding#1: human intention was not responsible for speed up



#### experiment #2: results

finding#2: ... but agency score is much better with 80 ms preemption.



#### experiment #2: results

finding#3: EMS tingling drops agency slightly, but time and movement is more important



## **3. implications**









## 4. applications

#### application #1: pen-drop

EMS preemptive gain: 80ms

### application #2: high-speed photography

/SUS

D'Hami

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## Finger Actuation









## **5. conclusions**

### conclusions: summary

Voluntary

Action

### 1. human/machine must have aligned intentions

Preemptive

Action

## 2. relationship between agency and preemptive gain is not linear (or binary



### conclusions: open questions

1. alternative methods for **measuring agency** (intentional binding)

- 2. complex situation (cognitive loaded , complex motion, incongruent intention)
- 3. how to weigh in other factors (e.g., context, attention, priming, etc.)

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Accelerating Human Reaction using Electrical Muscle Stimulation Without Compromising Agency

... thanks, questions?

p.s.: come to our demo at SIGGRAPH' 19 eTech



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## Comparator model

Blakemore et al., 2002



central error monitoring

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figure modified after Frith et al., 2000; Blakemore et al., 2002; Wolpert and Flanagan, 2001).

Goal

Desired

state

Controllers

(perception to movement)

Motor

\_\_\_\_\_

feedback error monitoring

.....

Hierarchical model M. Synofzik et al, 2008





The sense of agency

#### It's Not My Fault: Postdictive Modulation of Intentional Binding by Monetary Gains and Losses

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#### Abstract

Sense of agency refers to the feeling that one's voluntary actions caused external events. Past studies have shown that compression of the subjective temporal interval between actions and external events, called intentional binding, is closely linked to the experience of agency. Current theories postulate that the experience of agency is constructed via predictive and postdictive pathways. One remaining problem is the source of human causality bias; people often make misjudgments on the causality of voluntary actions and external events depending on their rewarding or punishing outcomes. Although human causality bias implies that sense of agency can be modified by post-action information, convincing empirical findings for this issue are lacking. Here, we hypothesized that sense of agency would be modified by affective valences of action outcomes. To examine this issue, we investigated how rewarding and punishing outcomes following voluntary action modulate behavioral measures of agency using intentional binding paradigm and classical conditioning procedures. In the acquisition phase, auditory stimuli were paired with positive, neutral or negative monetary outcomes. Tone-reward associations were evaluated using reaction times and preference ratings. In the experimental session, participants performed a variant of intentional binding task, where participants made timing judgments for onsets of actions and sensory outcomes while playing simple slot games. Our results showed that temporal binding was modified by affective valences of action outcomes. Specifically, intentional binding was attenuated when negative outcome occurred, consistent with self-serving bias. Our study not only provides evidence for postdictive modification of agency, but also proposes a possible mechanism of human causality bias.

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RESEARCH ARTICLE

#### The Sense of Agency during Continuous Action: Performance Is More Important than Action-Feedback Association

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Copyright: © 2015 Wen et al. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are Abstract

The sense of agency refers to the feeling that one is controlling events through one's own behavior. This study examined how task performance and the delay of events influence one's sense of agency during continuous action accompanied by a goal. The participants were instructed to direct a moving dot into a square as quickly as possible by pressing the left and right keys on a keyboard to control the direction in which the dot traveled. The interval between the key press and response of the dot (i.e., direction change) was manipulated to vary task difficulty. Moreover, in the assisted condition, the computer ignored participants' erroneous commands, resulting in improved task performance but a weaker association between the participants' commands and actual movements of the dot relative to the condition in which all of the participants' commands were executed (i.e., selfcontrol condition). The results showed that participants' sense of agency increased with better performance in the assisted condition relative to the self-control condition, even though a large proportion of their commands were not executed. We concluded that, when the action-feedback association was uncertain, cognitive inference was more dominant relative to the process of comparing predicted and perceived information in the judgment of agency.

## **Outcome bias**

'the sense of agency depends on a retrospective comparison between expected or desired action outcomes and actual outcomes' [Wegner and Wheatley, 1999] [Blakemore et al., 2002]

Wegner, D. M., and Wheatley, T. (1999). Apparent mental causation. Sources of the experience of will. Am. Psychol. Blakemore, S. J., Wolpert, D. M., and Frith, C. D. (2002). Abnormalities in the awareness of action. Trends Cogn. Sci



#### **BEYOND** tapping test ----- cognitive loaded task

**Stroop Test – cognitive loaded task** 



#### Reaction time > 500ms / sometime human makes mistake