

SMIL

Connecting the Brain to the Body
from Molecules to Complex Social Behaviors

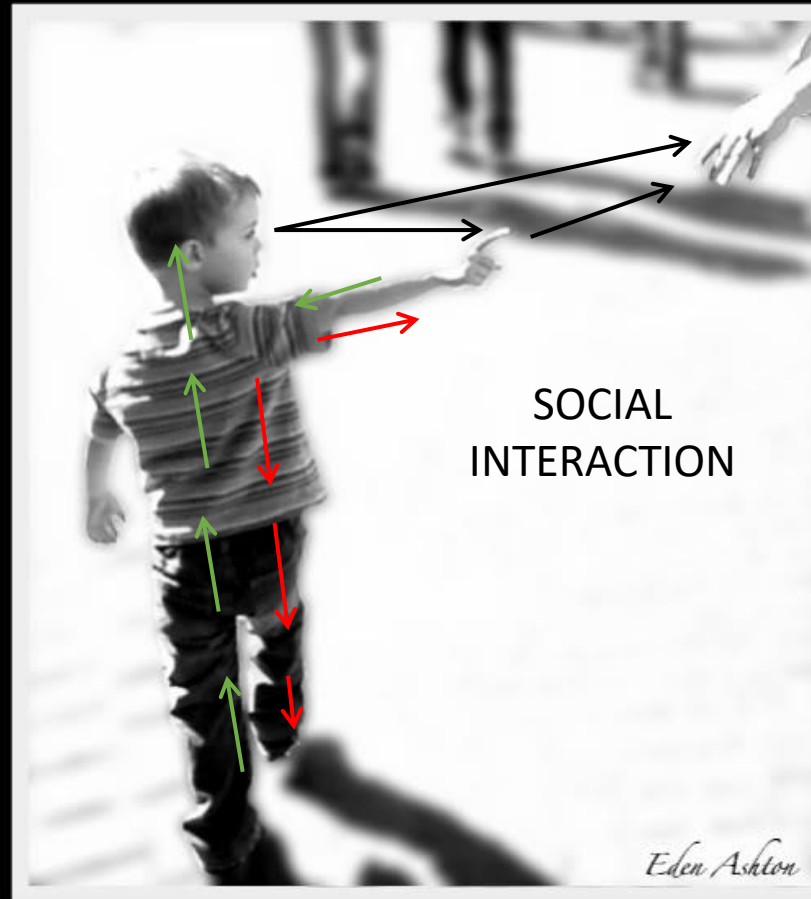
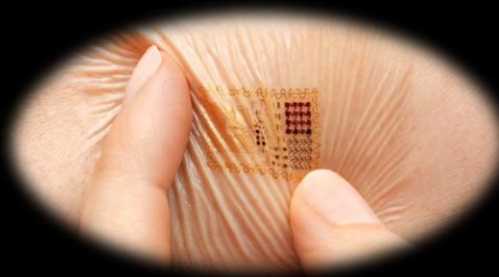


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OBJECTIVES

- Learn about basic ingredients to have agency: e.g. separating mental intent from physical volition
- Learn about kinematics-based indexes derived from complex human motions to quantify the differences between intent and volition
- Learn some more about experimental assays and statistical methods to analyze data
- Learn about patients with different degrees of intent and volition

INTELLIGENT BEHAVIORAL ANALYSES iBA



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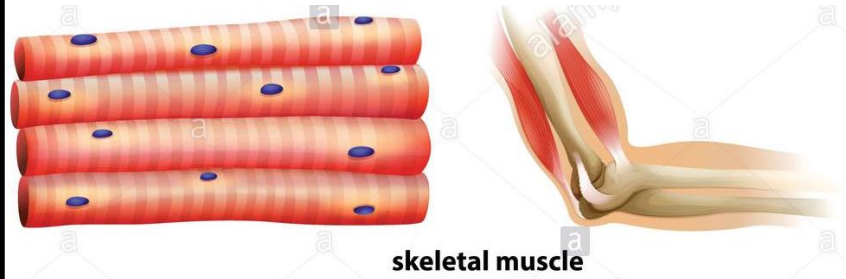


VOLUNTARY

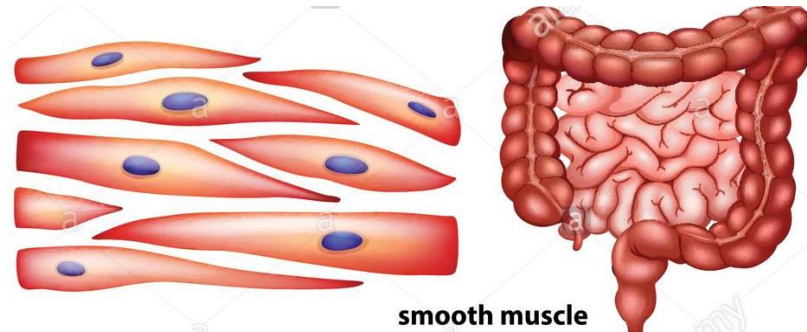
INVOLUNTARY

AUTONOMIC

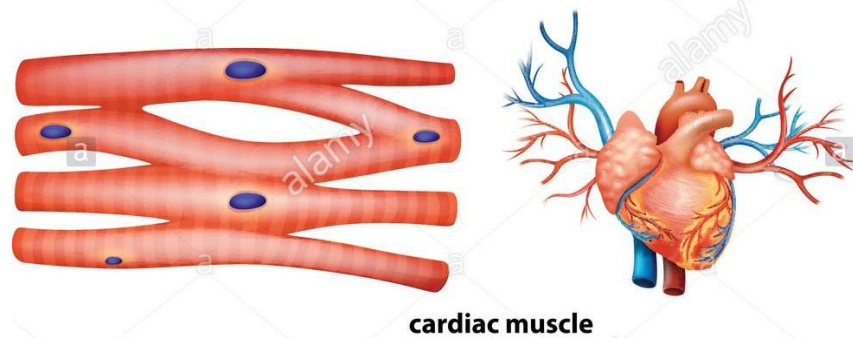
VOLUNTARY



INVOLUNTARY



AUTONOMIC



TOP DOWN



BOTTOM UP

THE PERIPHERAL NERVOUS SYSTEMS

Afferent Fibers

mechanoreceptors

nociceptors

thermal receptors

Socio-Motor Axes

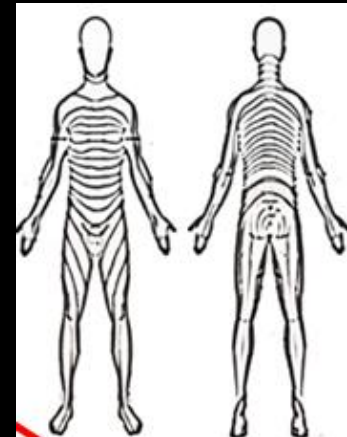
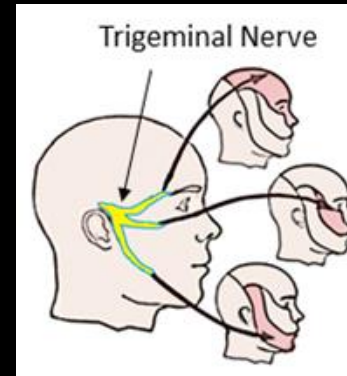
Face

Body

Intended Actions (deliberate, staged, purposeful, goal-directed)

Unintended Actions (spontaneous, supplemental, goal-less, uninstructed)

Inevitable Actions (unintentional beliefs turned intentional)

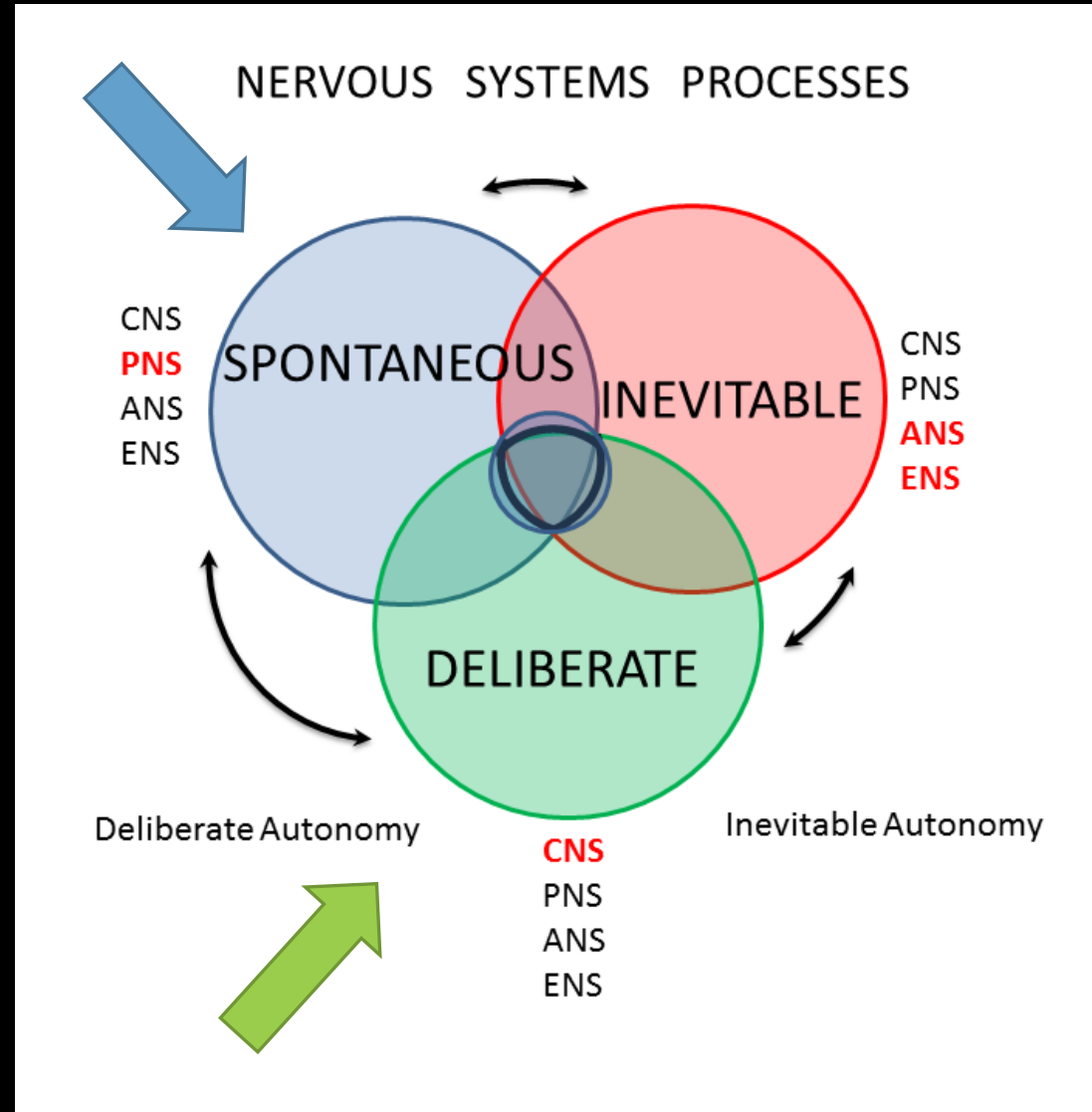


VOLUNTARY

INVOLUNTARY

AUTONOMIC

CHARACTERIZING INTENT THROUGH DIFFERENT TYPES OF PROCESSES

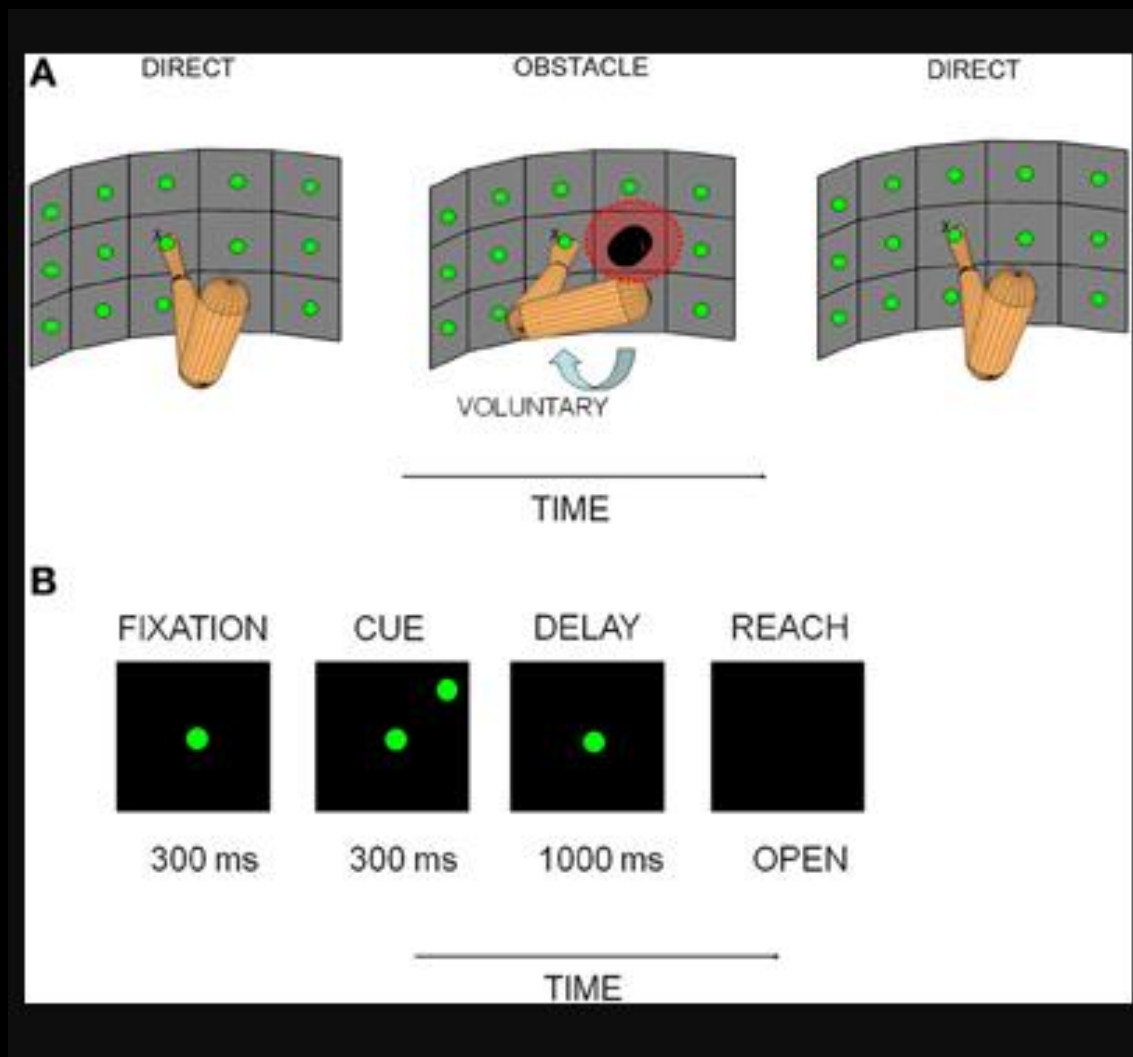


VOLUNTARY

INVOLUNTARY

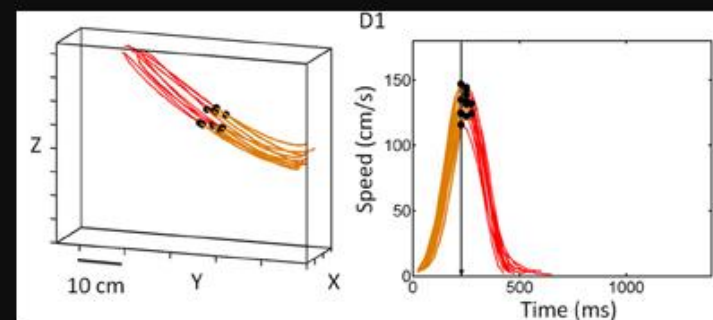
AUTONOMIC

HOW TO RECOGNIZE INTENT?

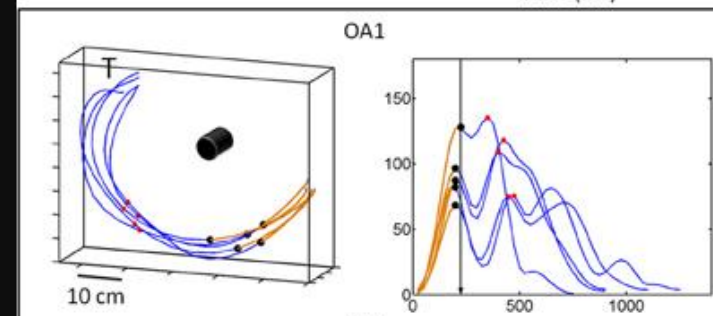


Mental Intent vs Physical Volition

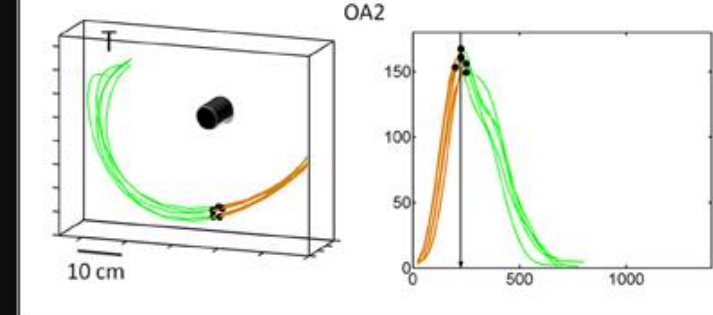
Automatic



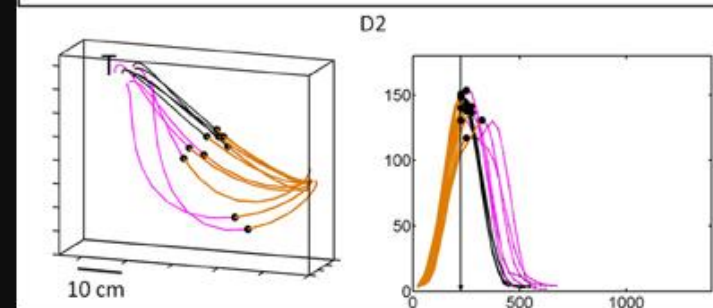
Learning



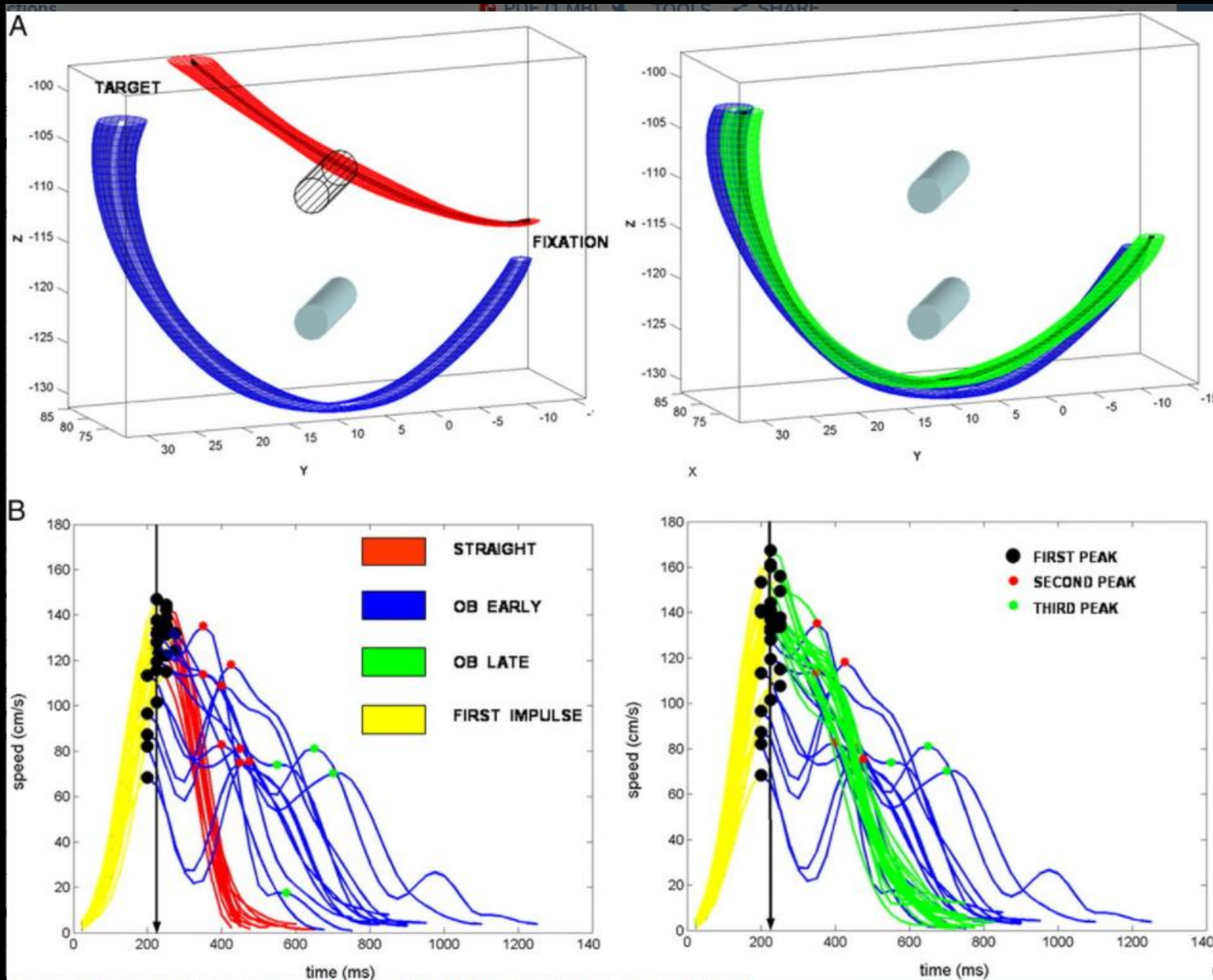
Automatic



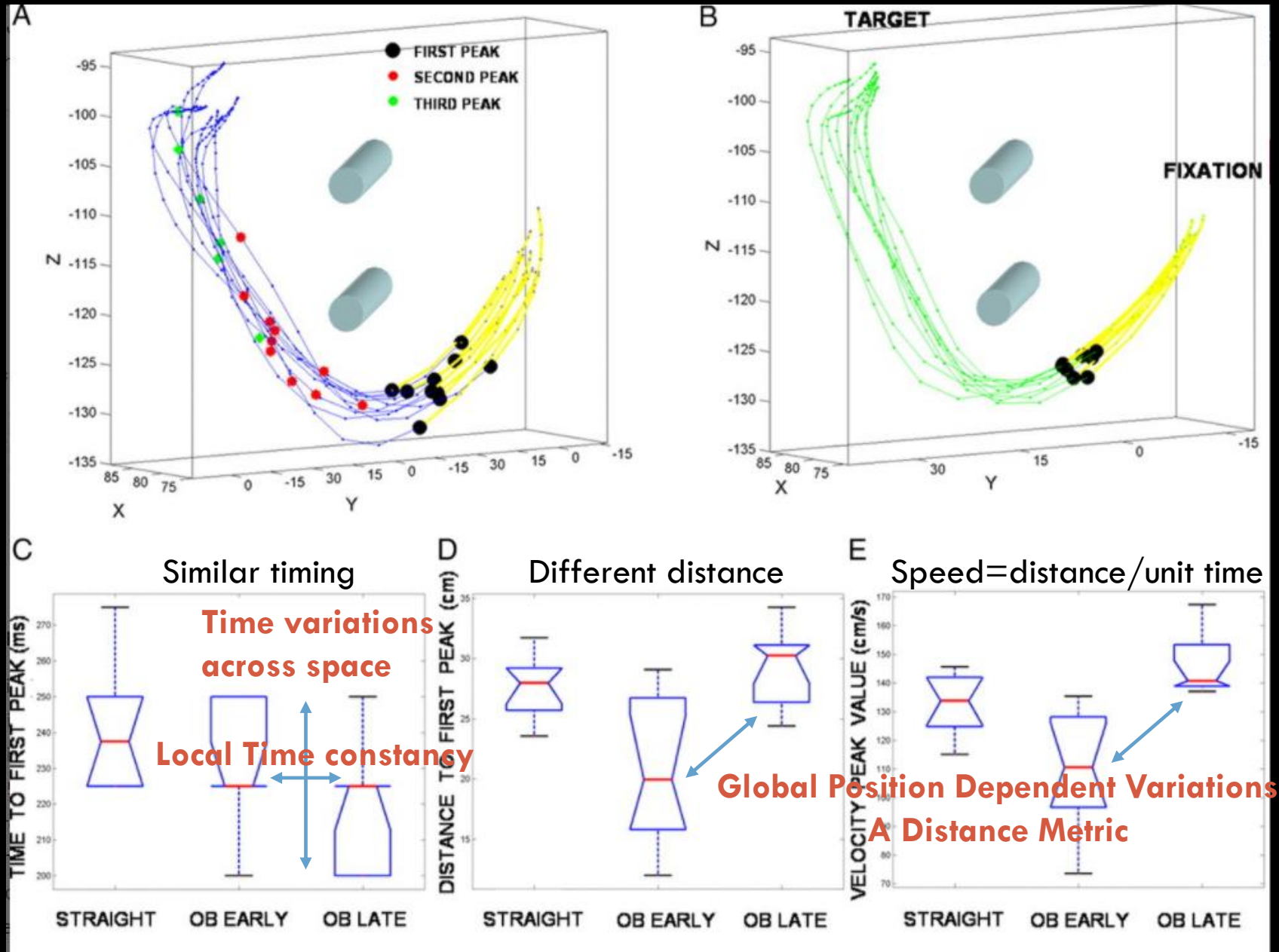
Un-learning
(inevitable)



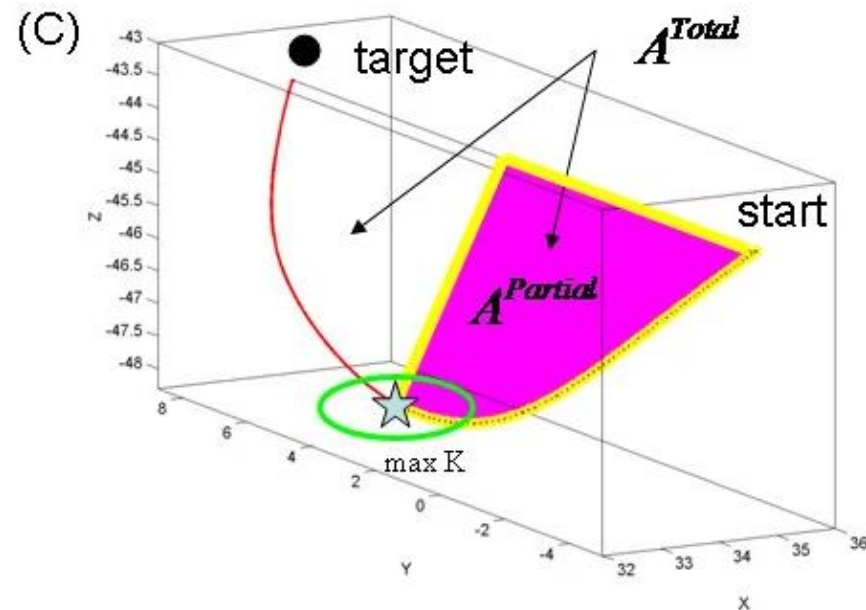
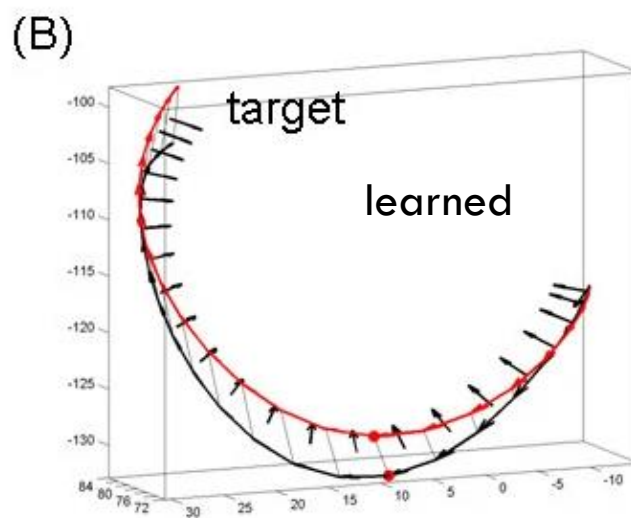
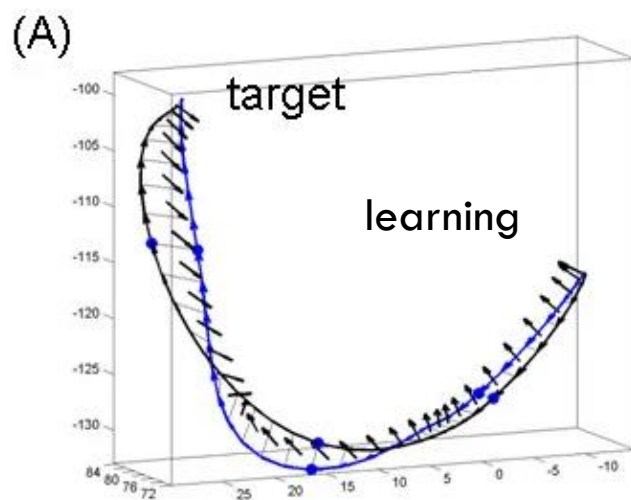
INVARIANCE IN MENTAL INTENT VS VARIABILITY IN PHYSICAL VOLITION



SPACE-TIME SEPARATION OF MENTAL INTENT VS PHYSICAL VOLITION



LOOK AT THE KINEMATICS OF THE MOTION TRAJECTORIES

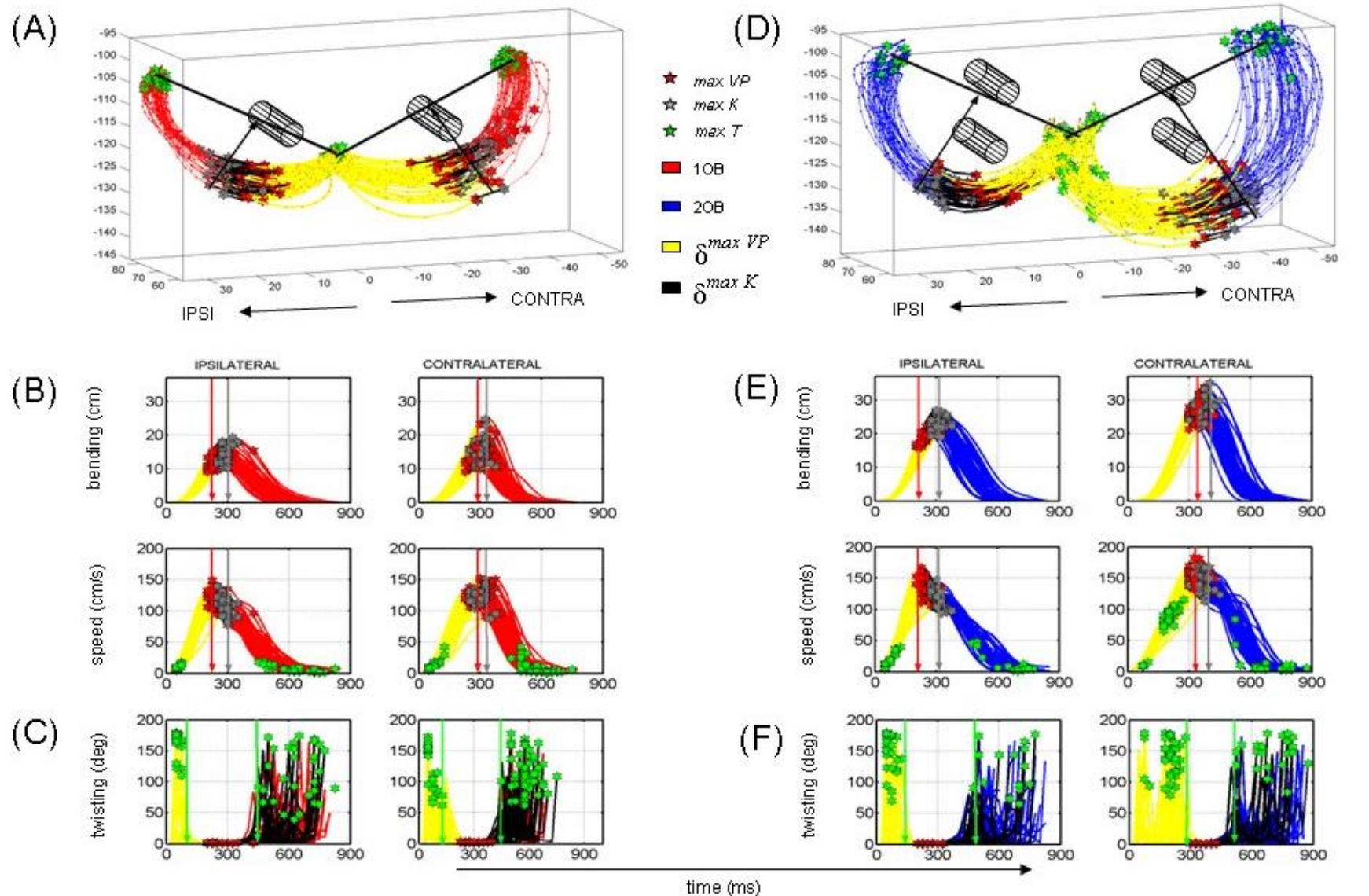


Geometric ratios

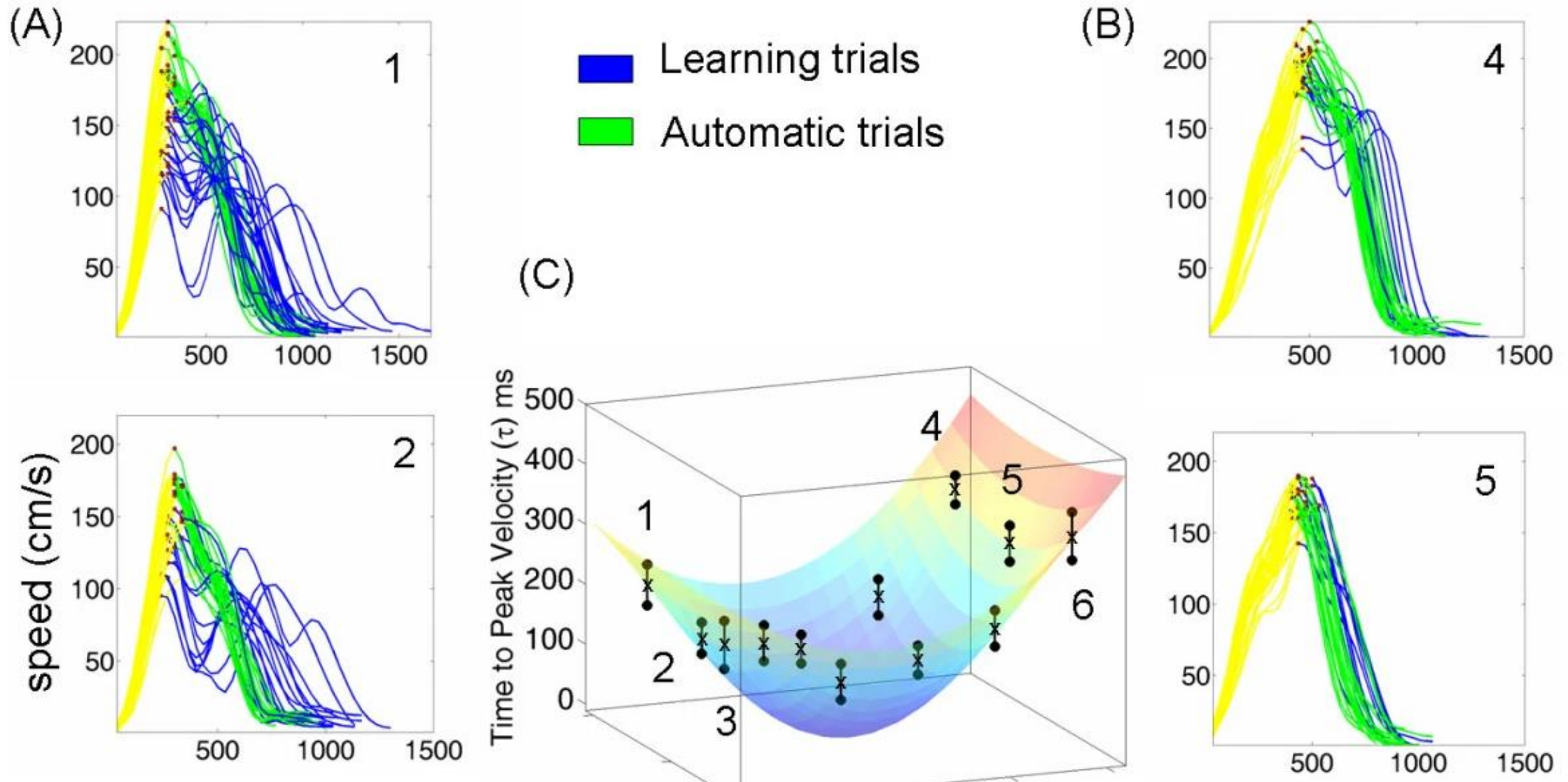
$$\text{Area Ratio} = A^{Partial} / A^{total}$$

$$\text{Perimeter Ratio} = p^{Partial} / p^{Total}$$

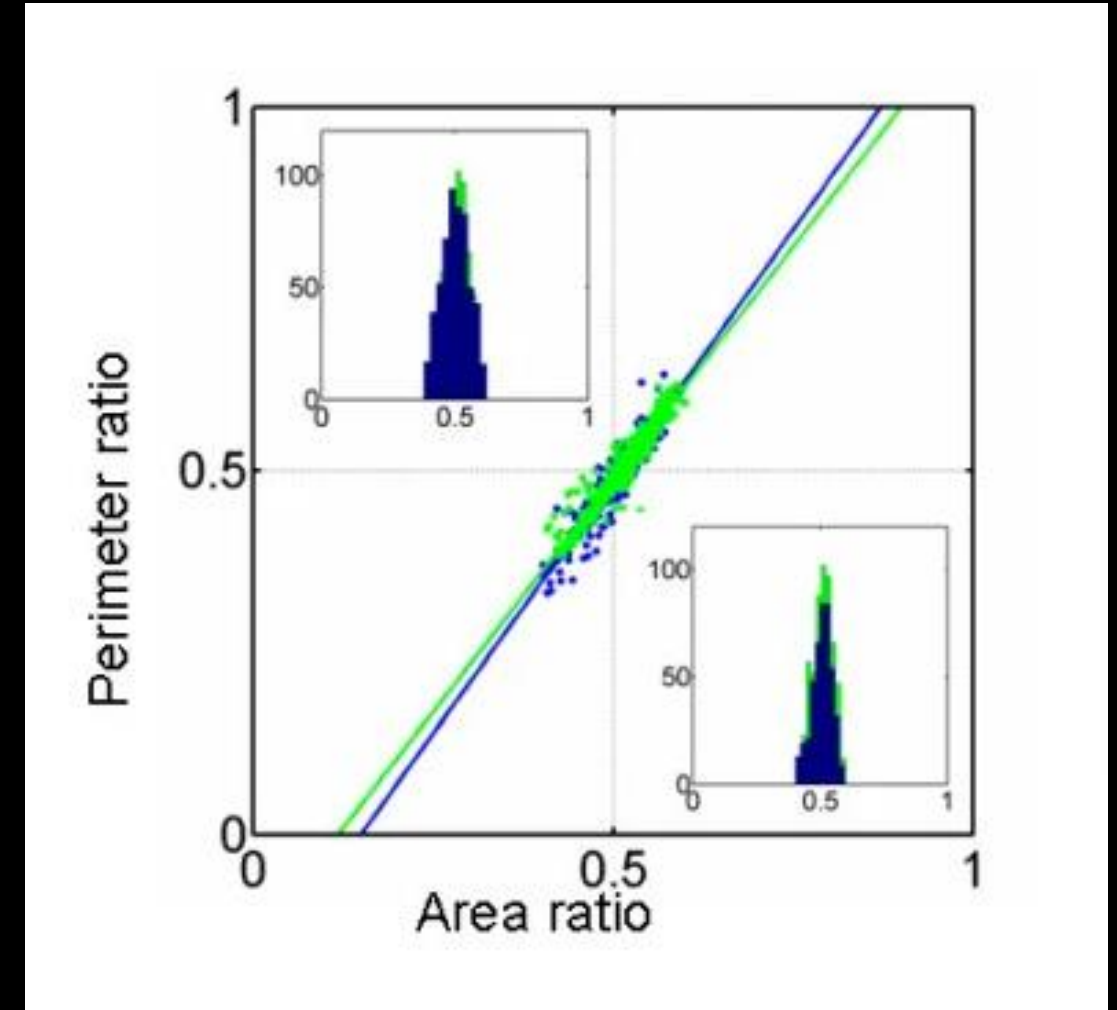
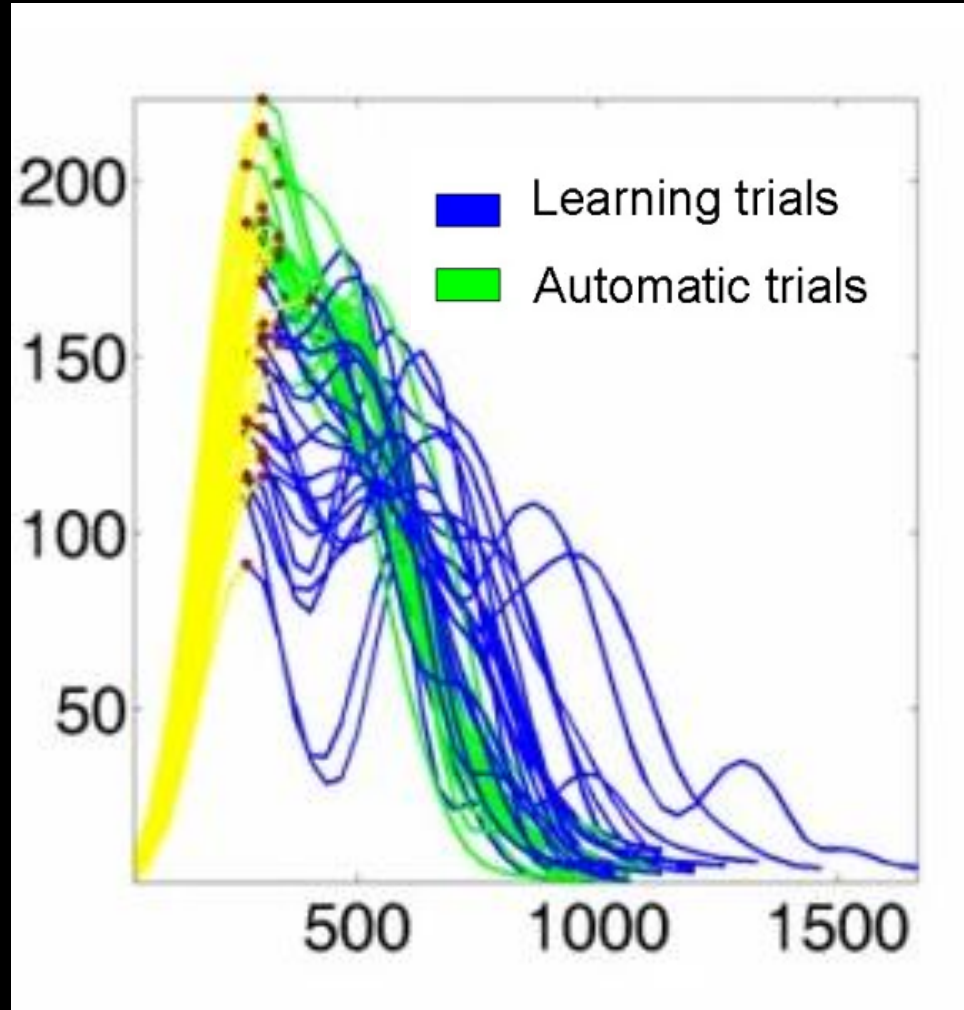
LOOK AT INVARIANCES IN THE CURVES



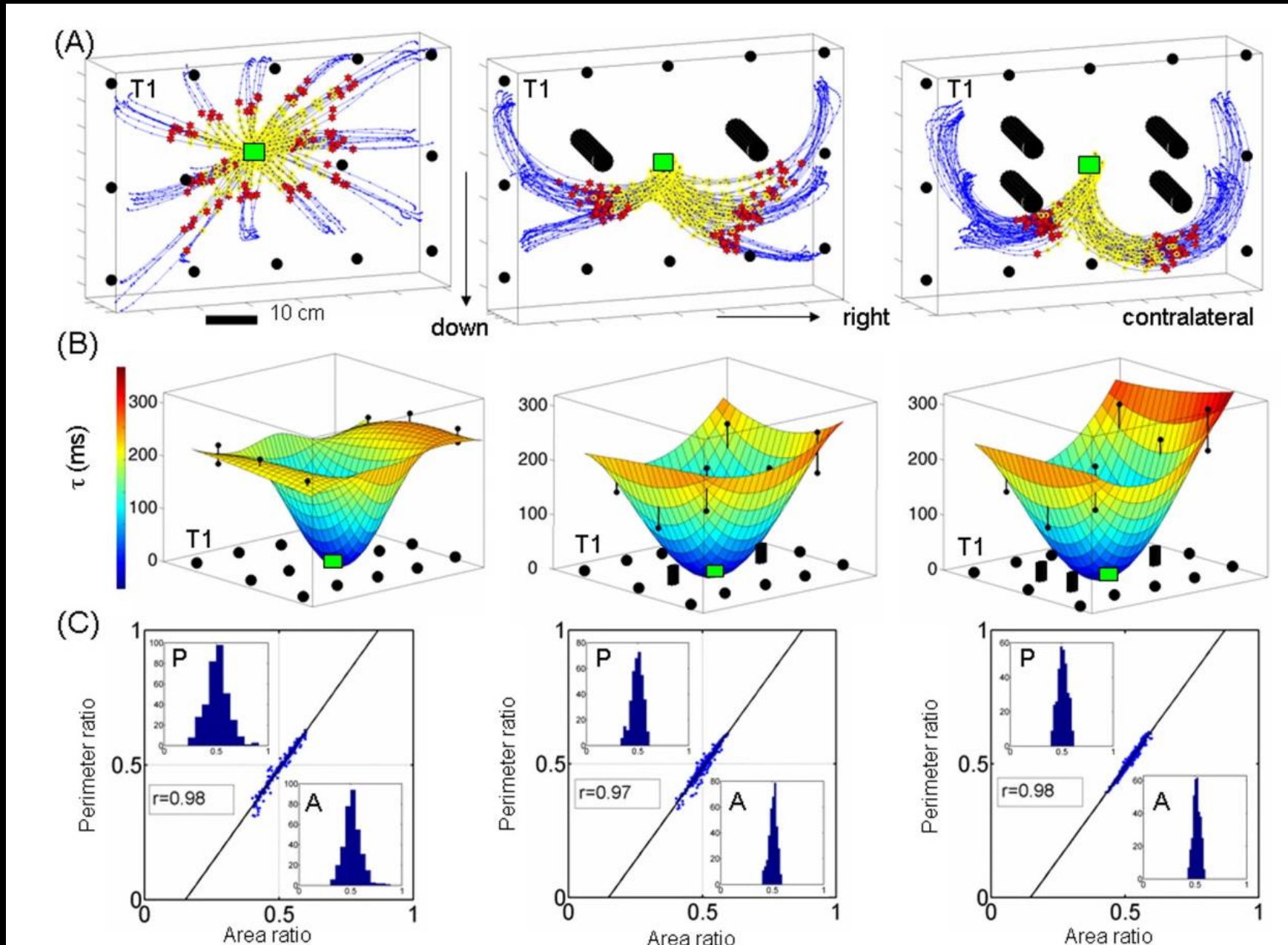
SPACE MAP OF TIME-TO-FIRST HAND VELOCITY PEAK



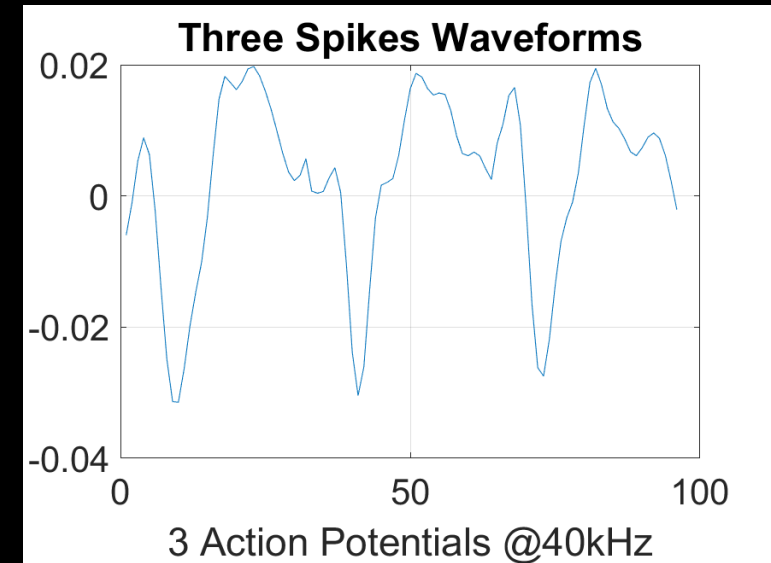
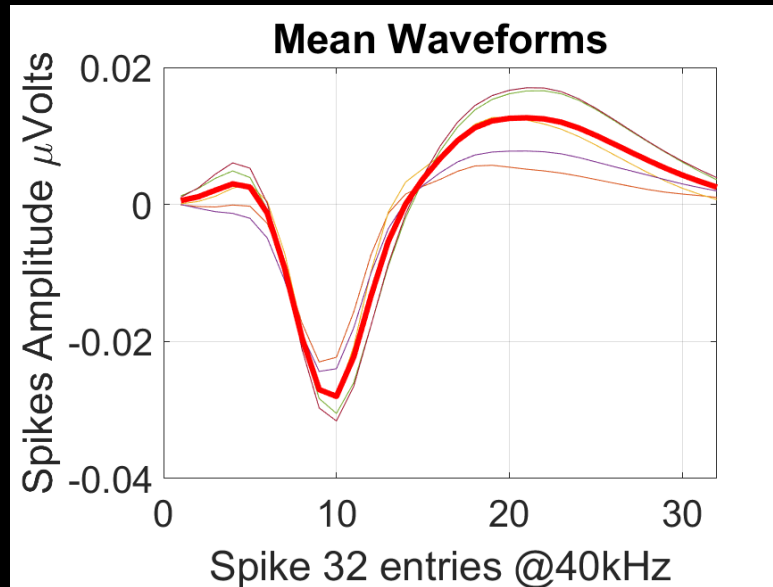
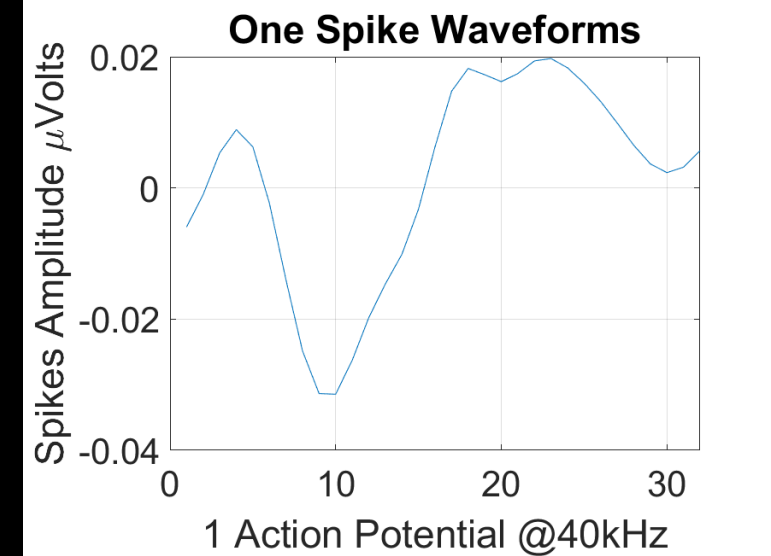
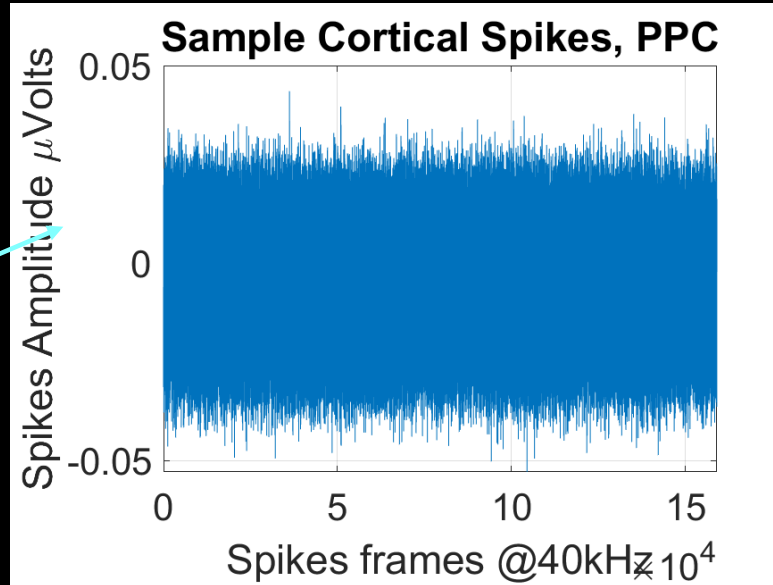
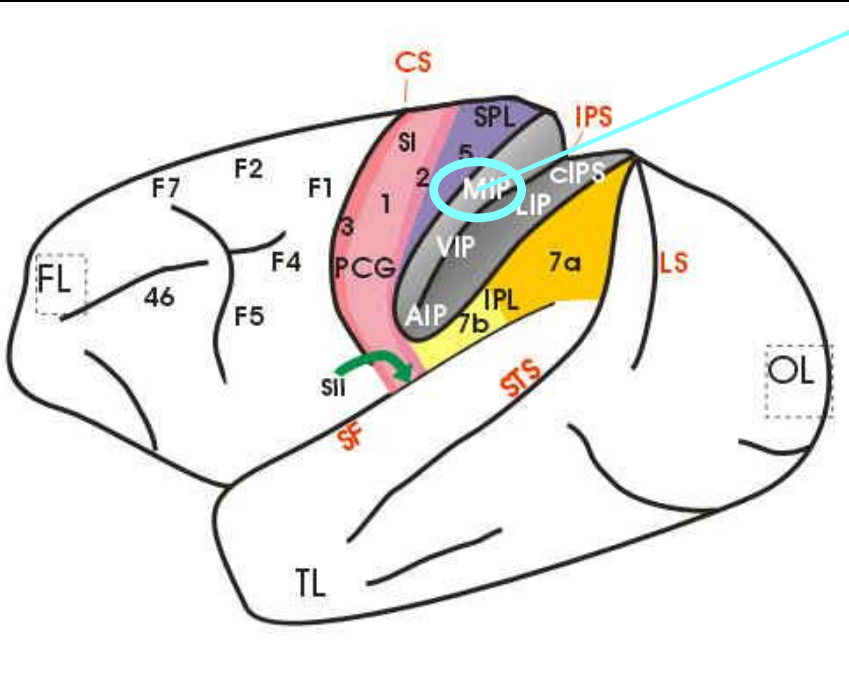
INTENTIONAL HAND MOTIONS TO AVOID OBSTACLES



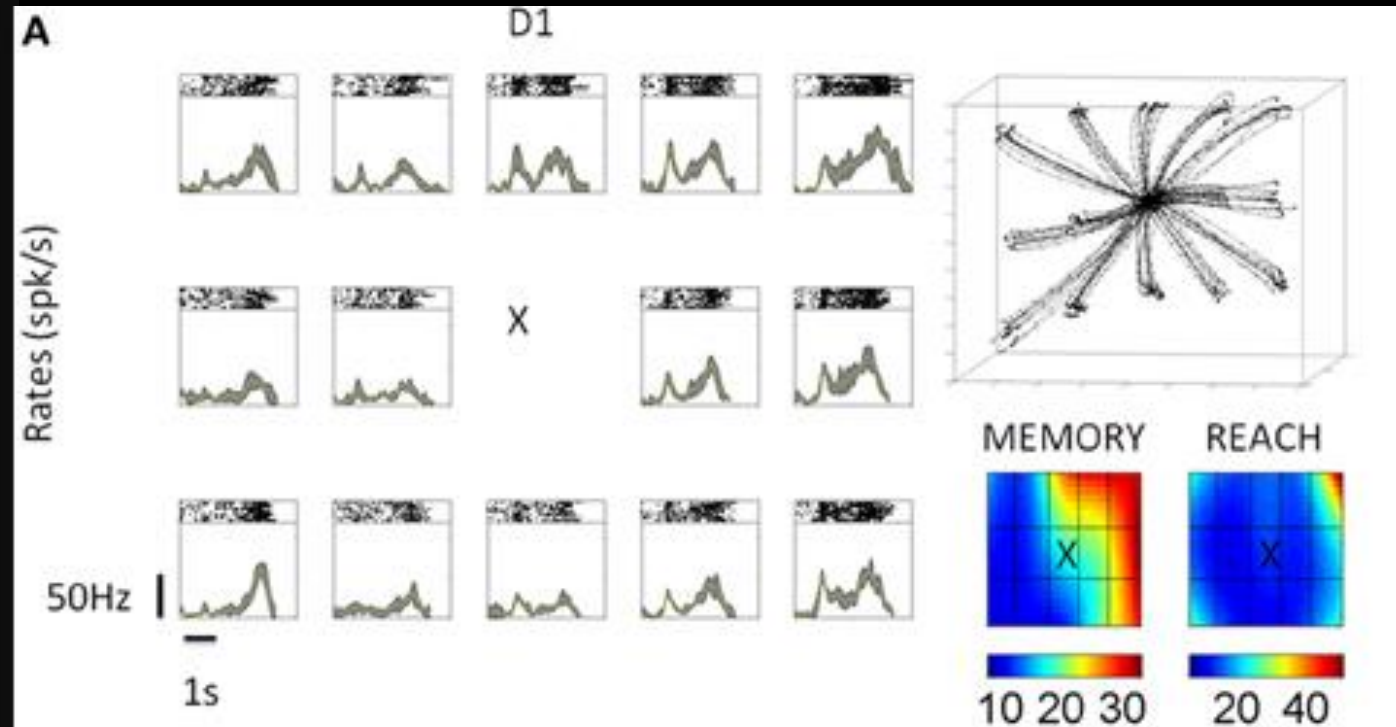
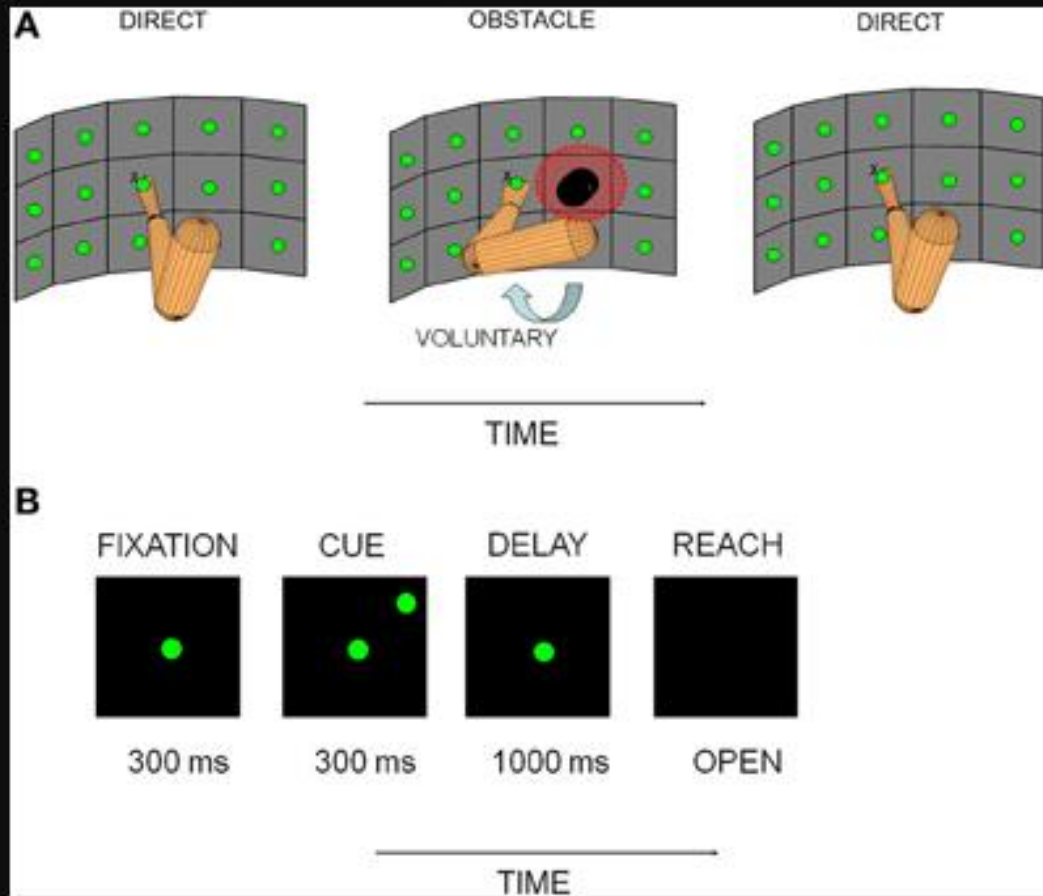
DYNAMICS INVARIANTS IN THE PLANNING OF INTENDED TRAJECTORIES



CORTICAL SPIKES

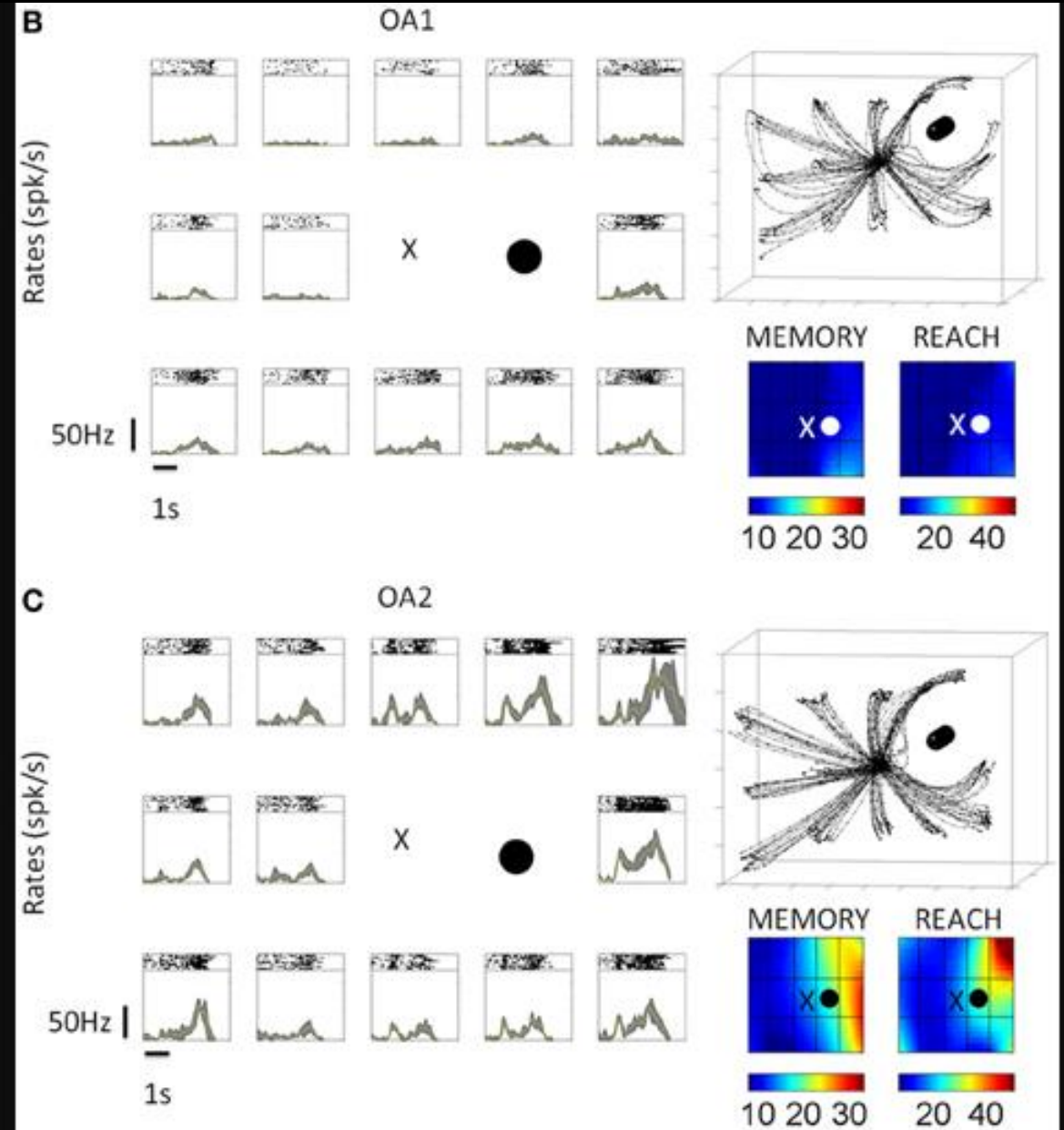
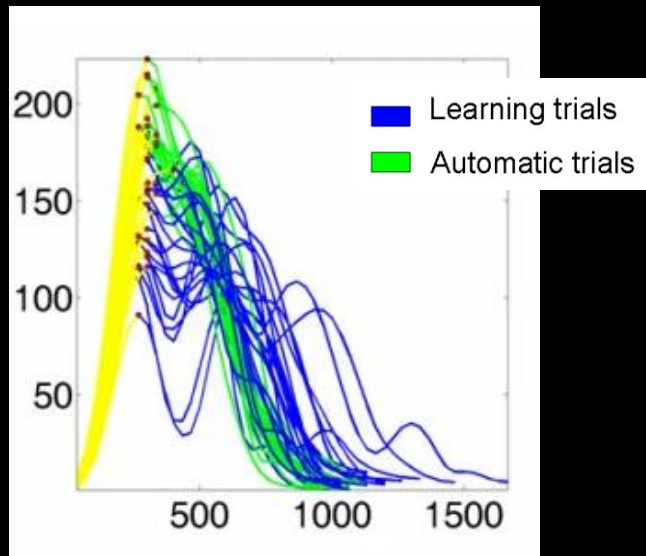
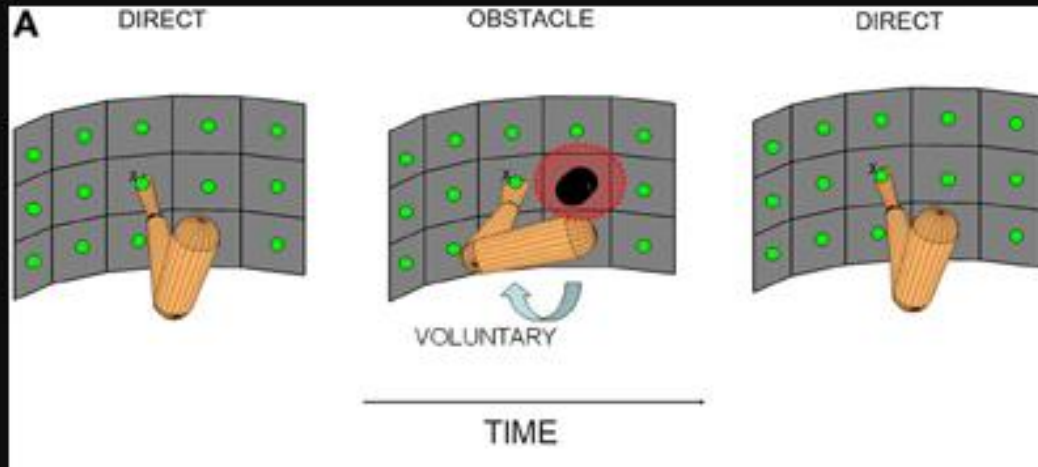


MENTAL INTENT VS PHYSICAL VOLITION

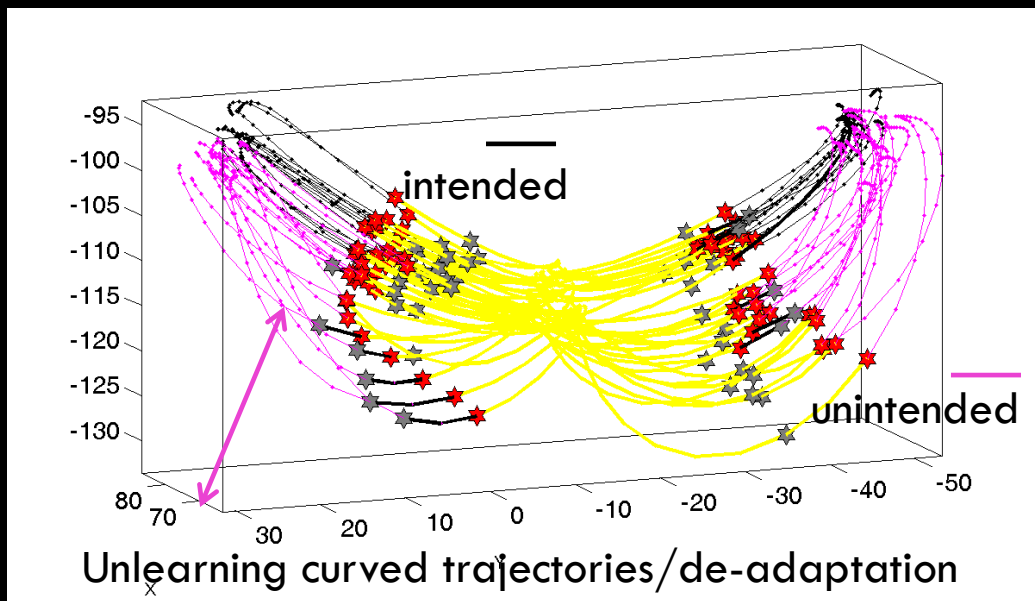
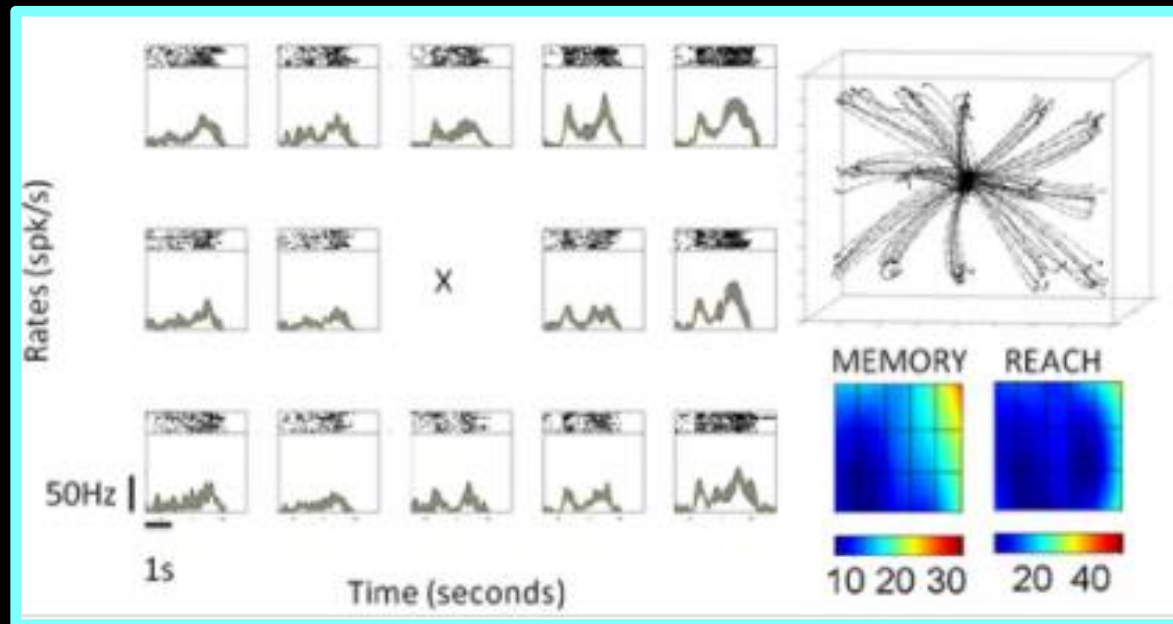
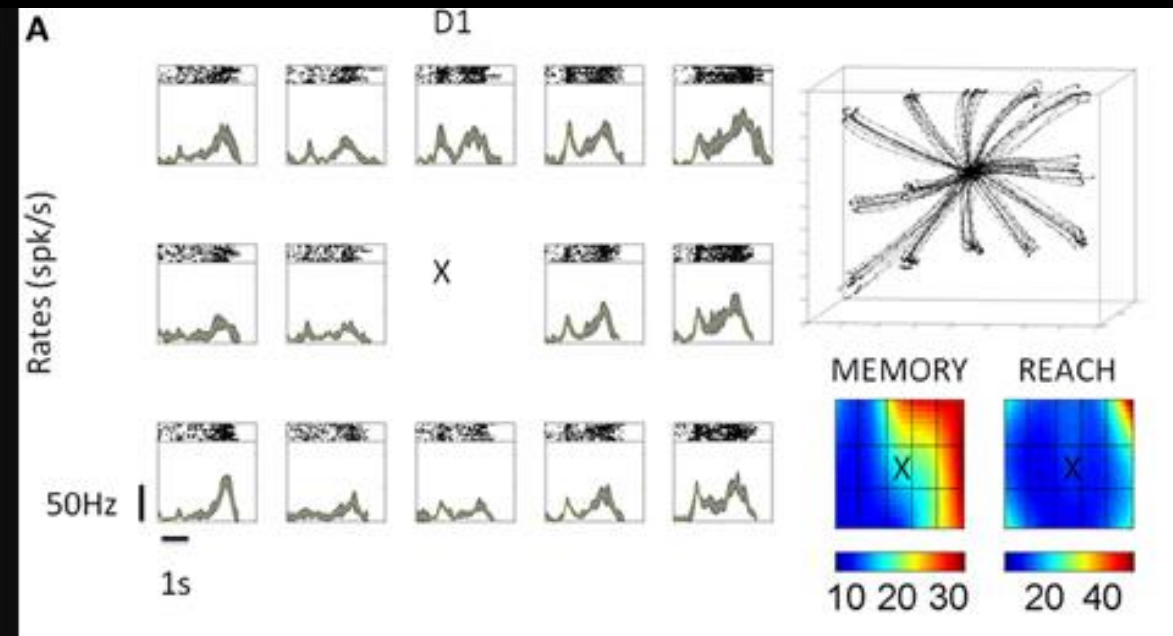
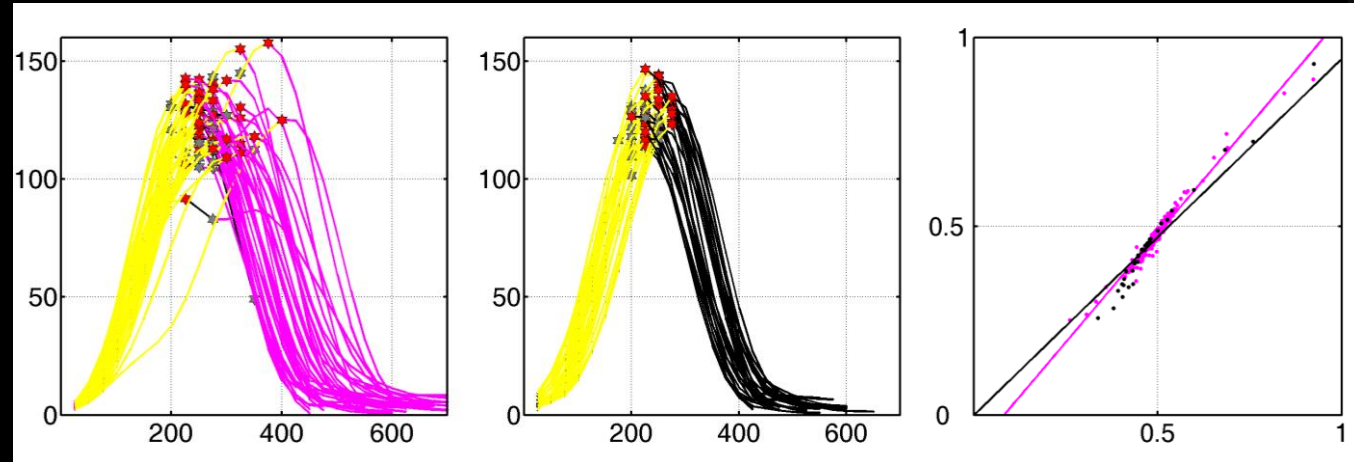


MENTAL INTENT VS PHYSICAL VOLITION

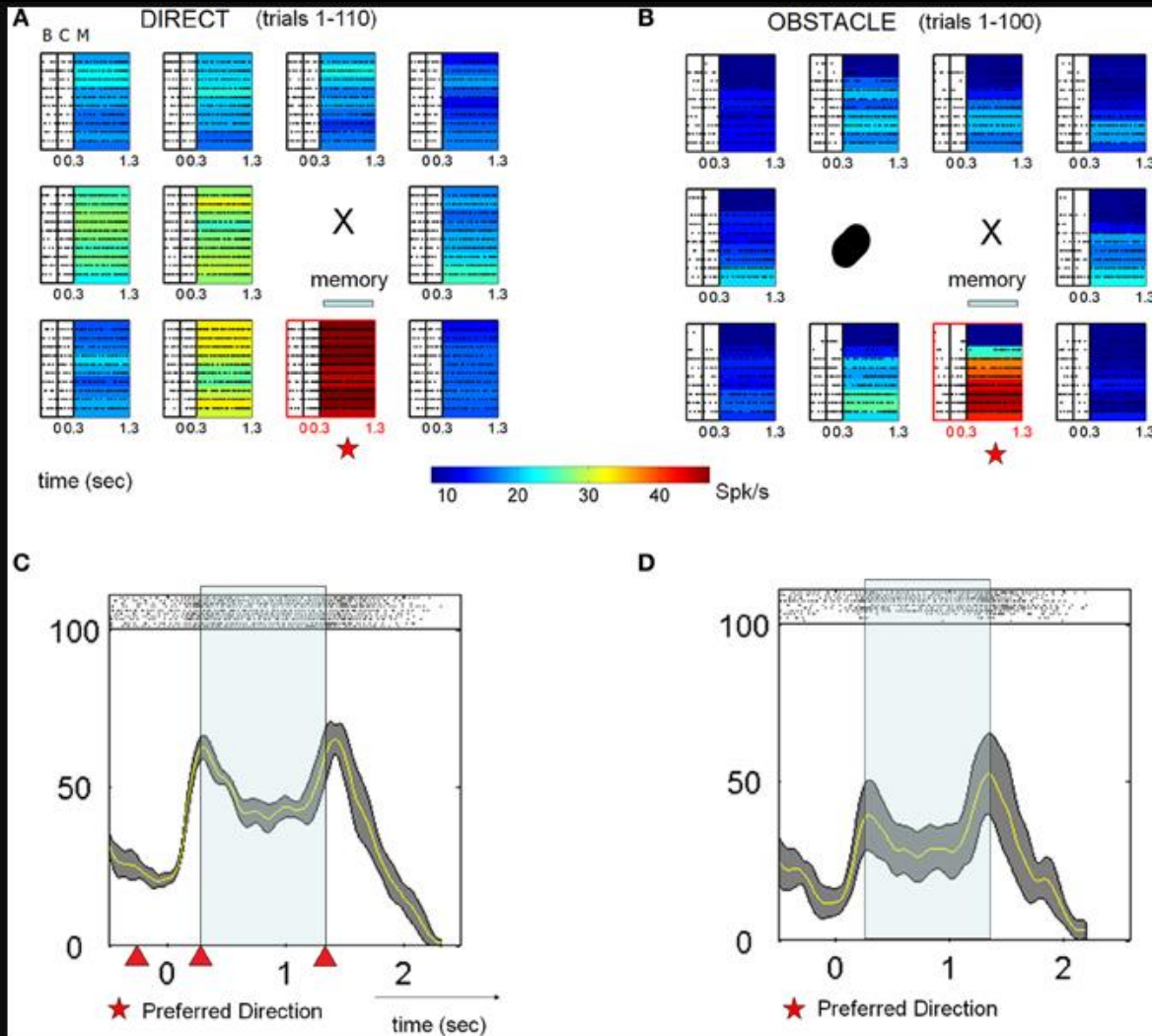
Experimental Assay to Probe Intent



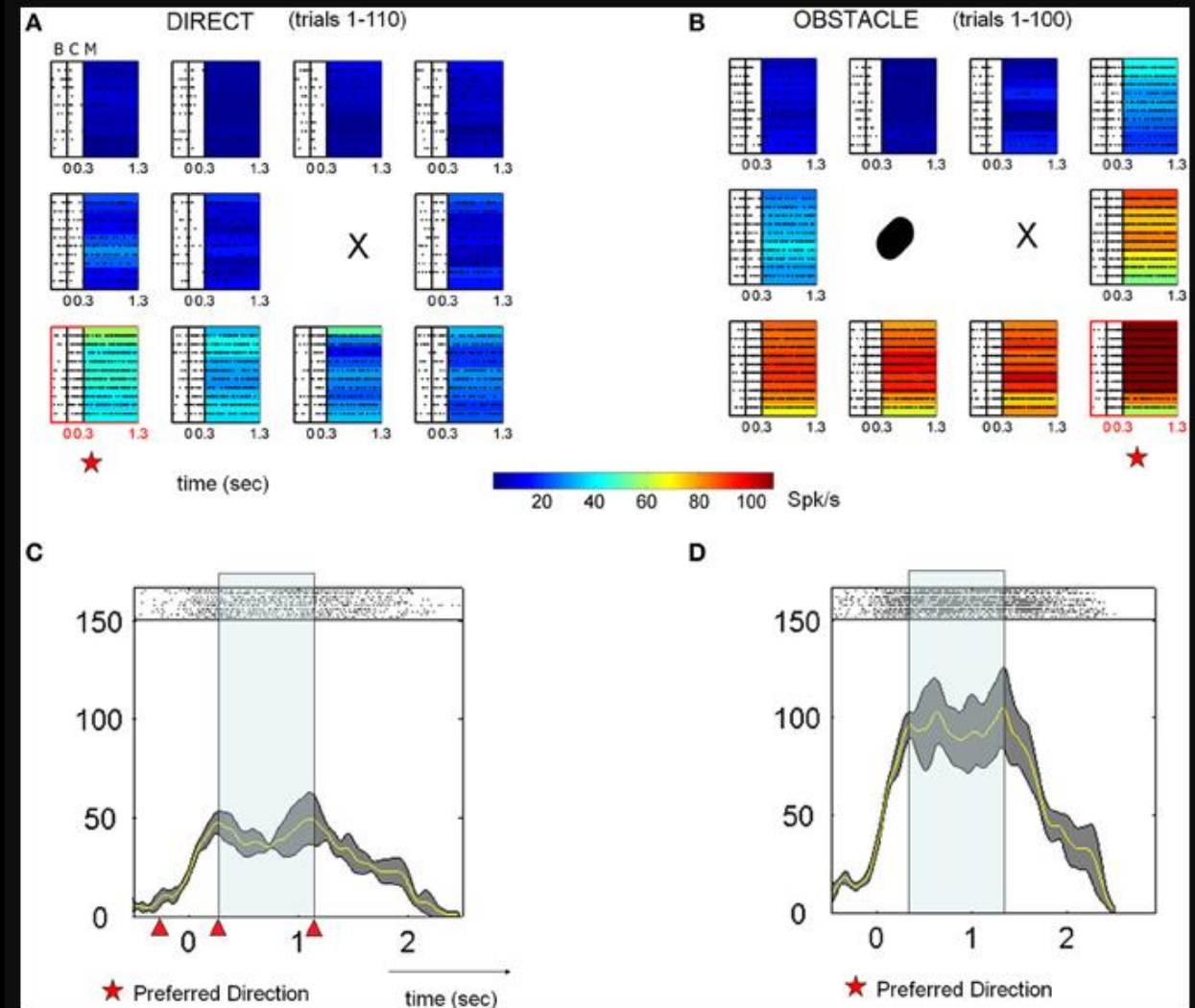
MENTAL INTENT VS PHYSICAL VOLITION



TWO CLASSES OF CELLS BASED ON FIRING RESPONSES

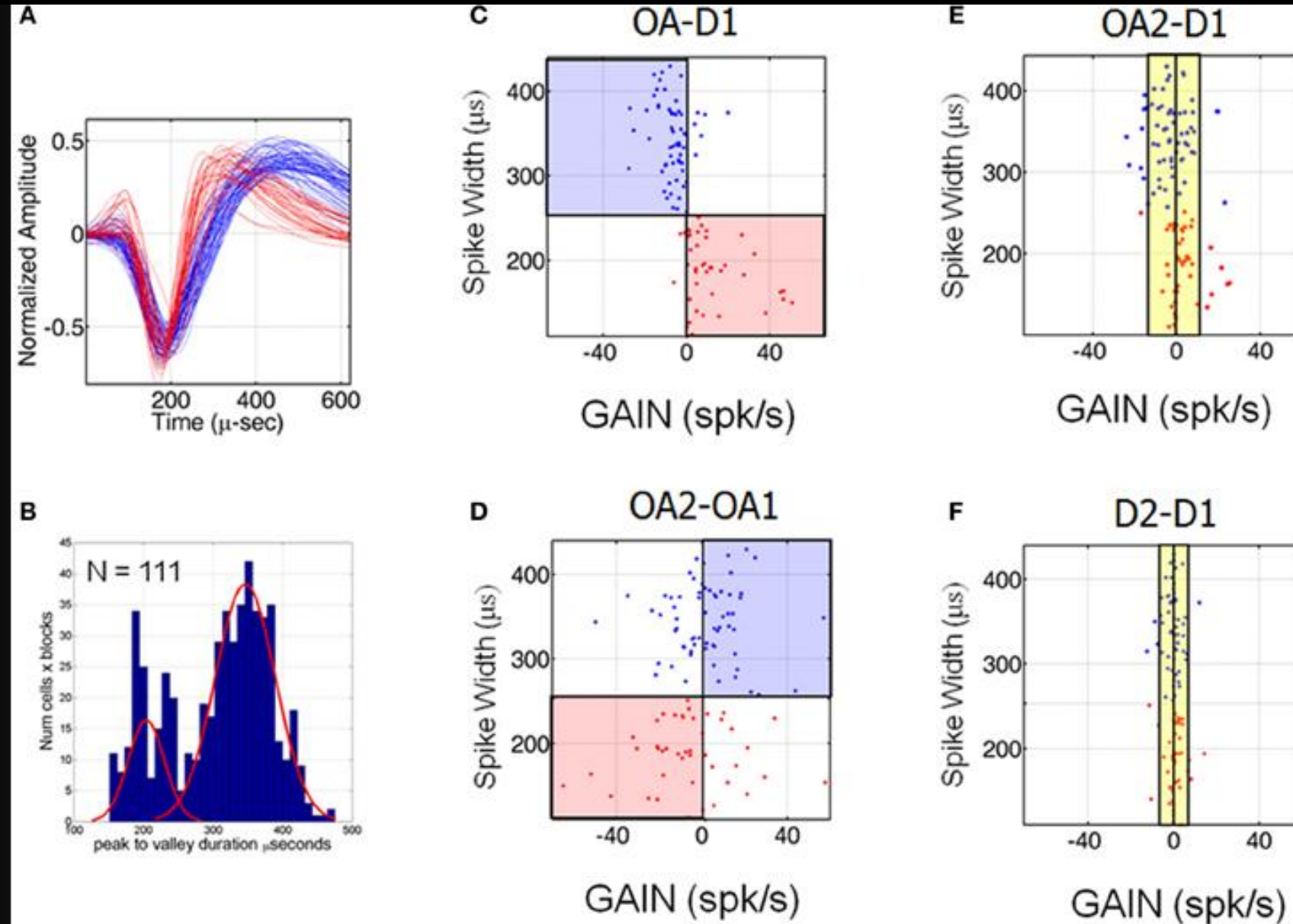


SUPRESS ACTIVITY

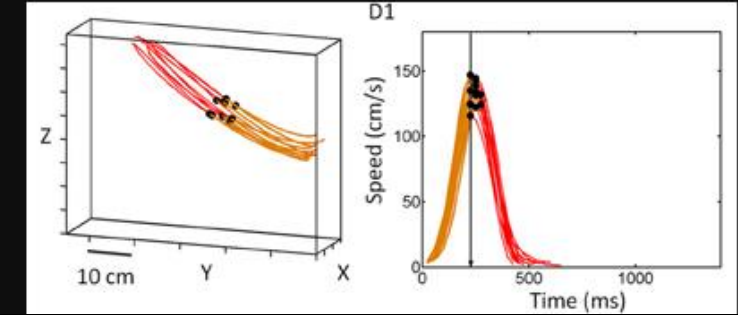
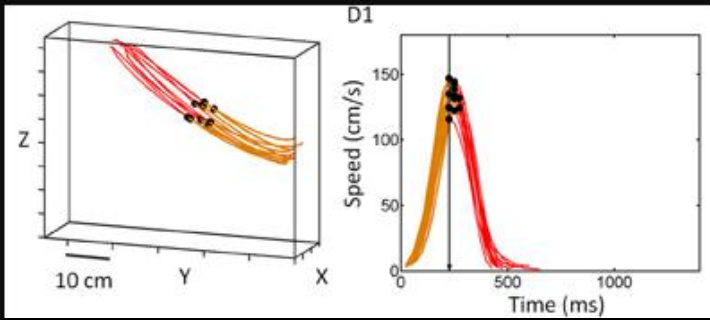


ENHANCE ACTIVITY

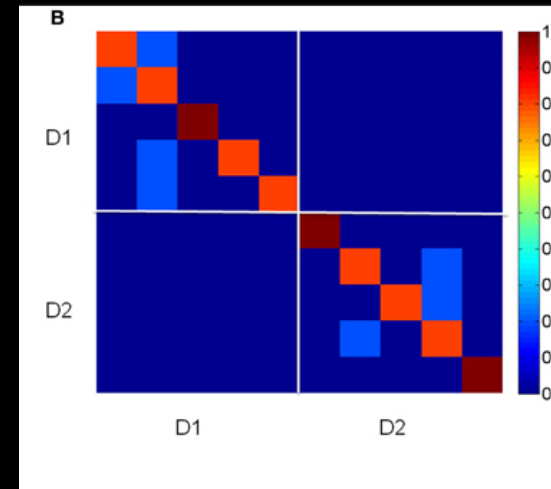
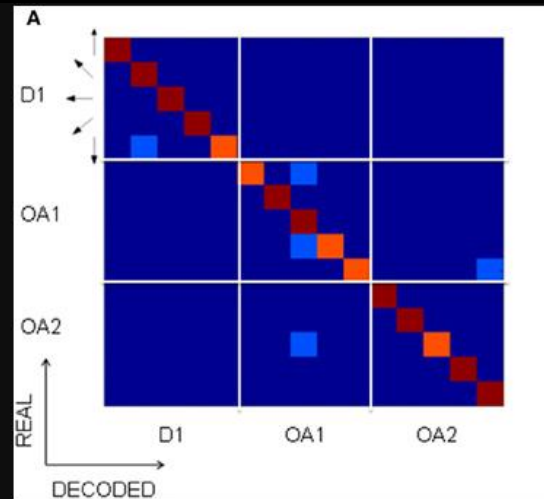
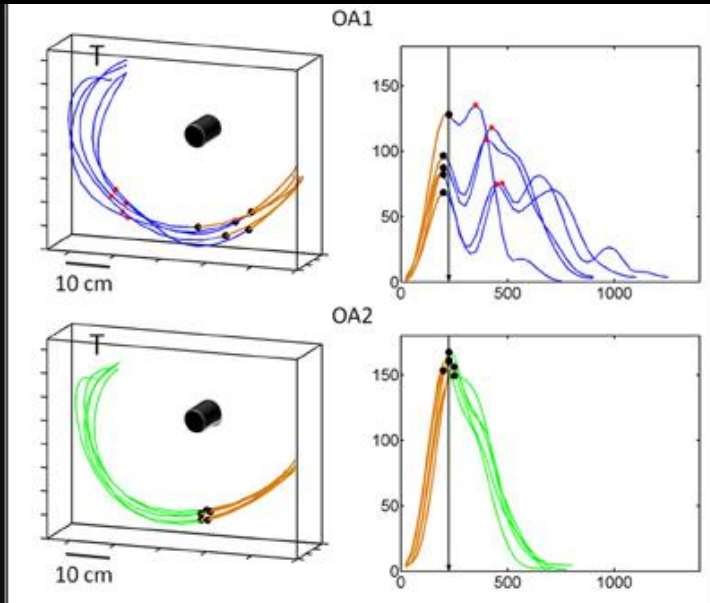
A PATTERN OF MENTAL INTENT IN TWO CELL CLASSES



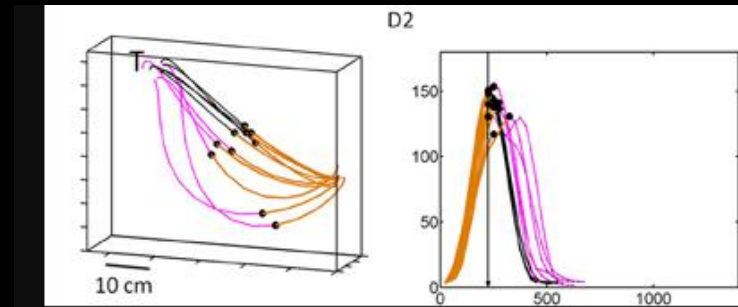
MIXING NEURONS PLANNING ACTIVITY PREDICTS IMPENDING SPEEDS ACROSS LEARNING AND DE-ADAPTATION



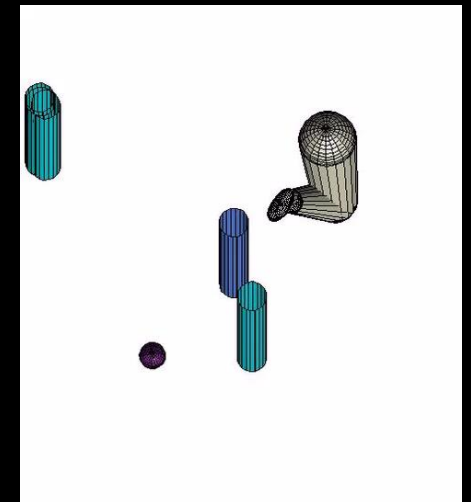
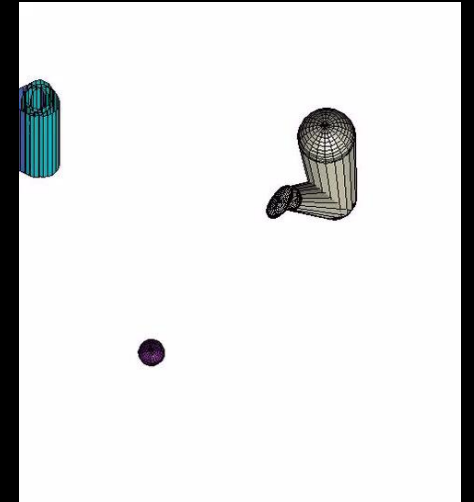
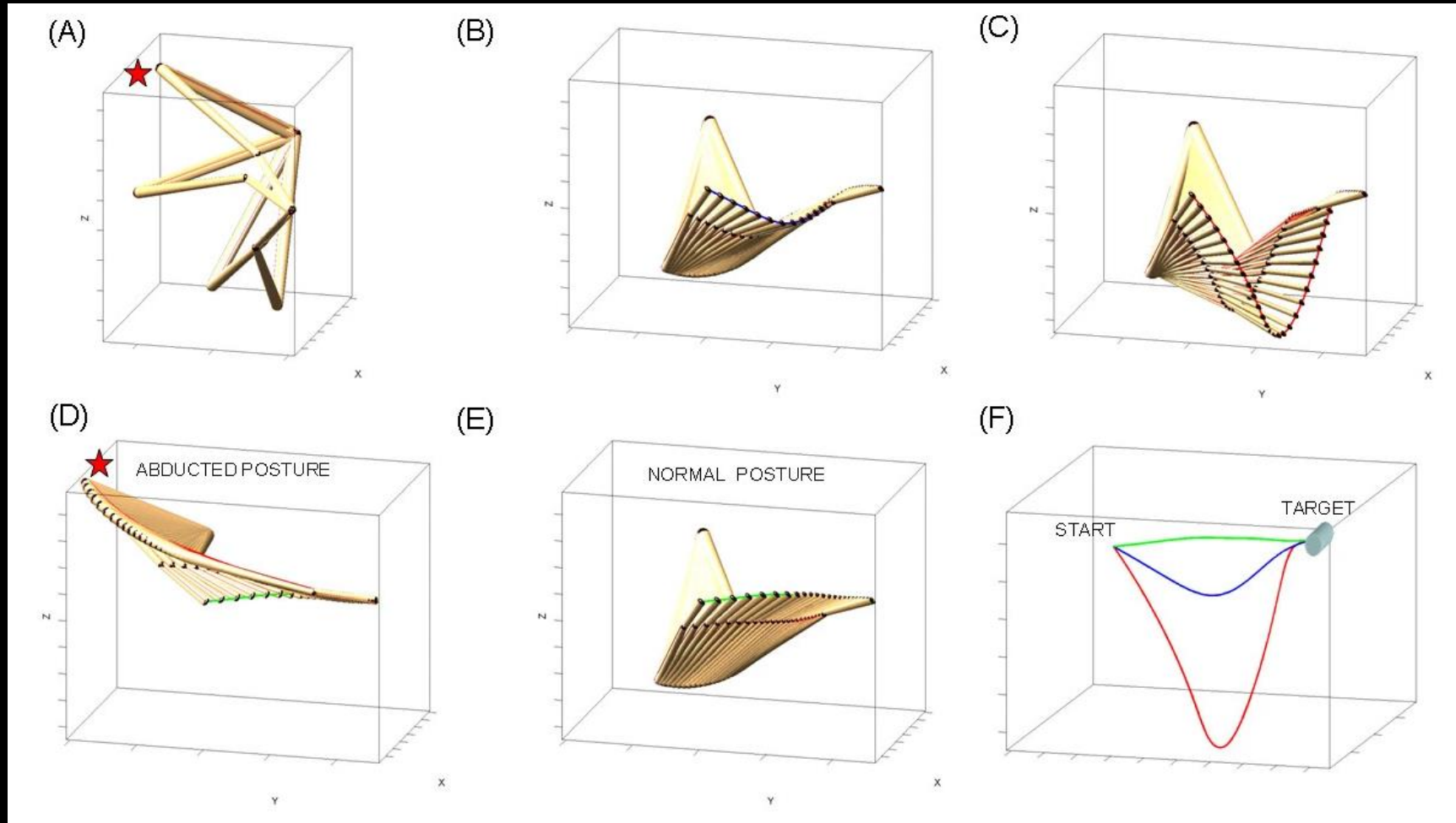
INTENTIONAL LEARNING



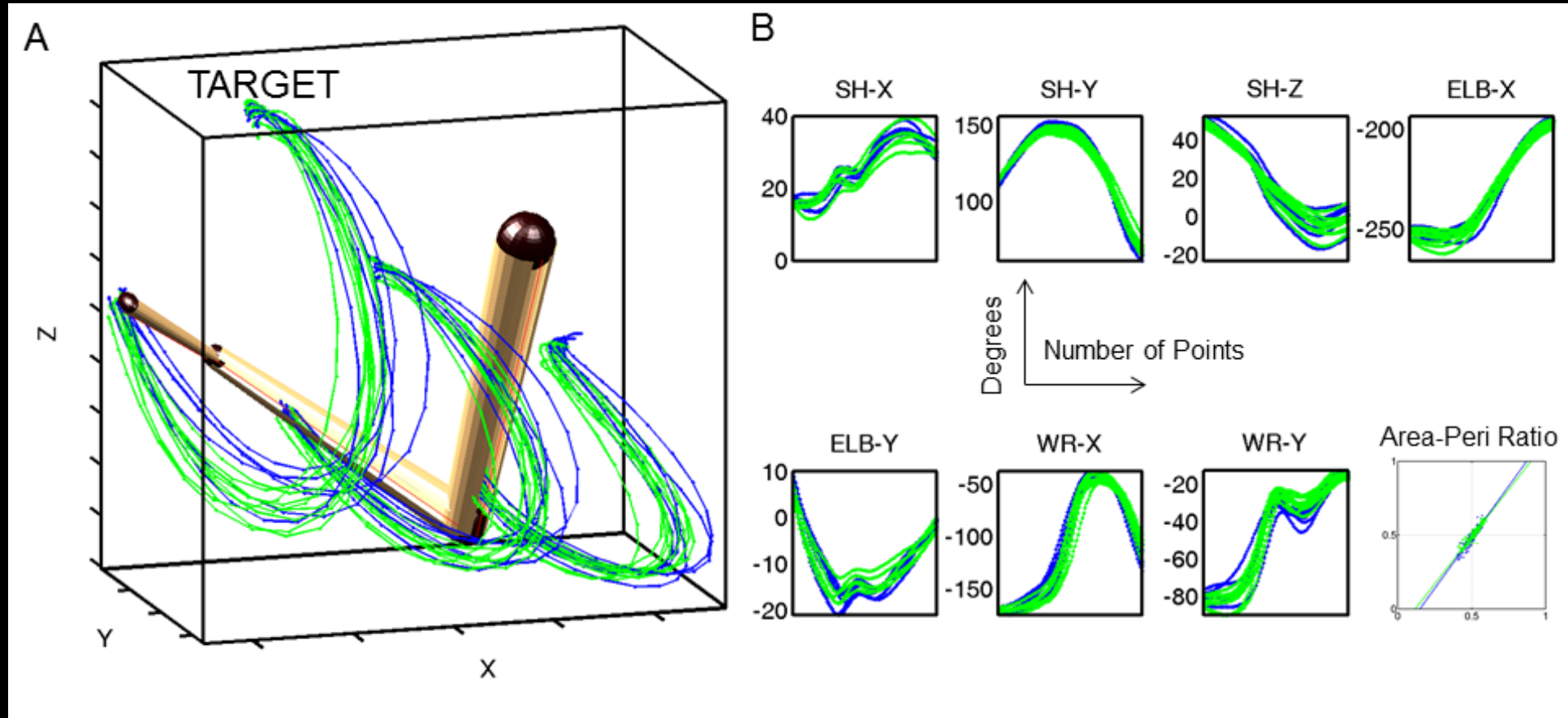
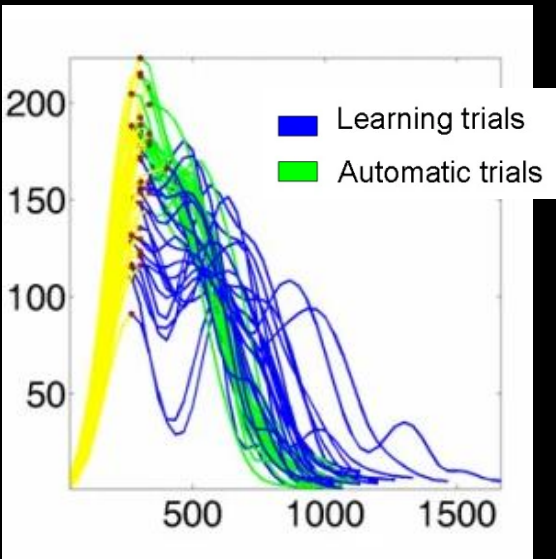
UNINTENTIONAL DE-LEARNING



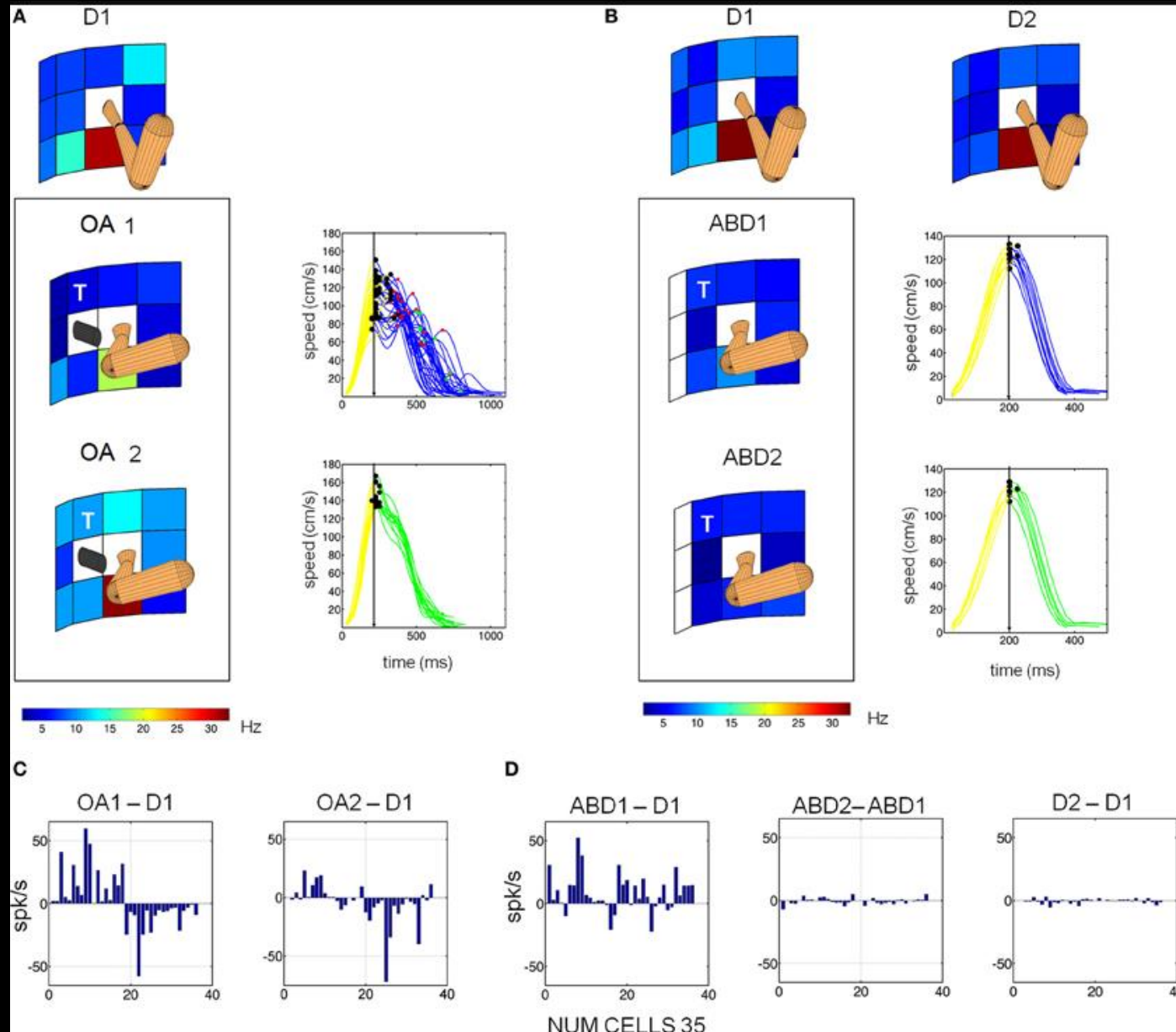
MENTAL INTENT ACROSS MULTIPLE EMBEDDED SPACES



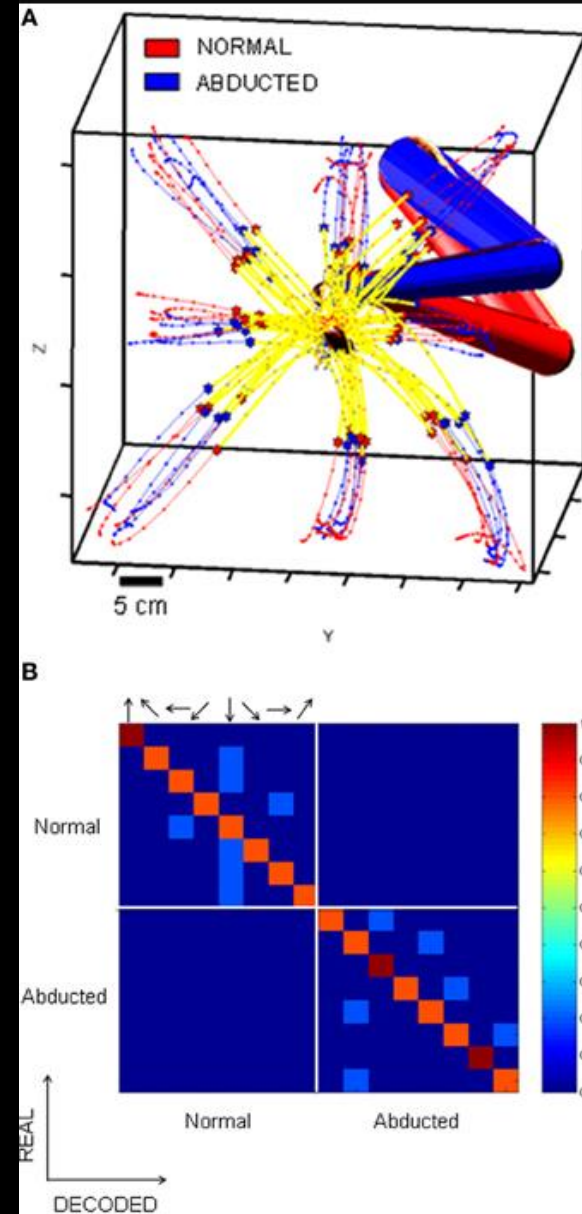
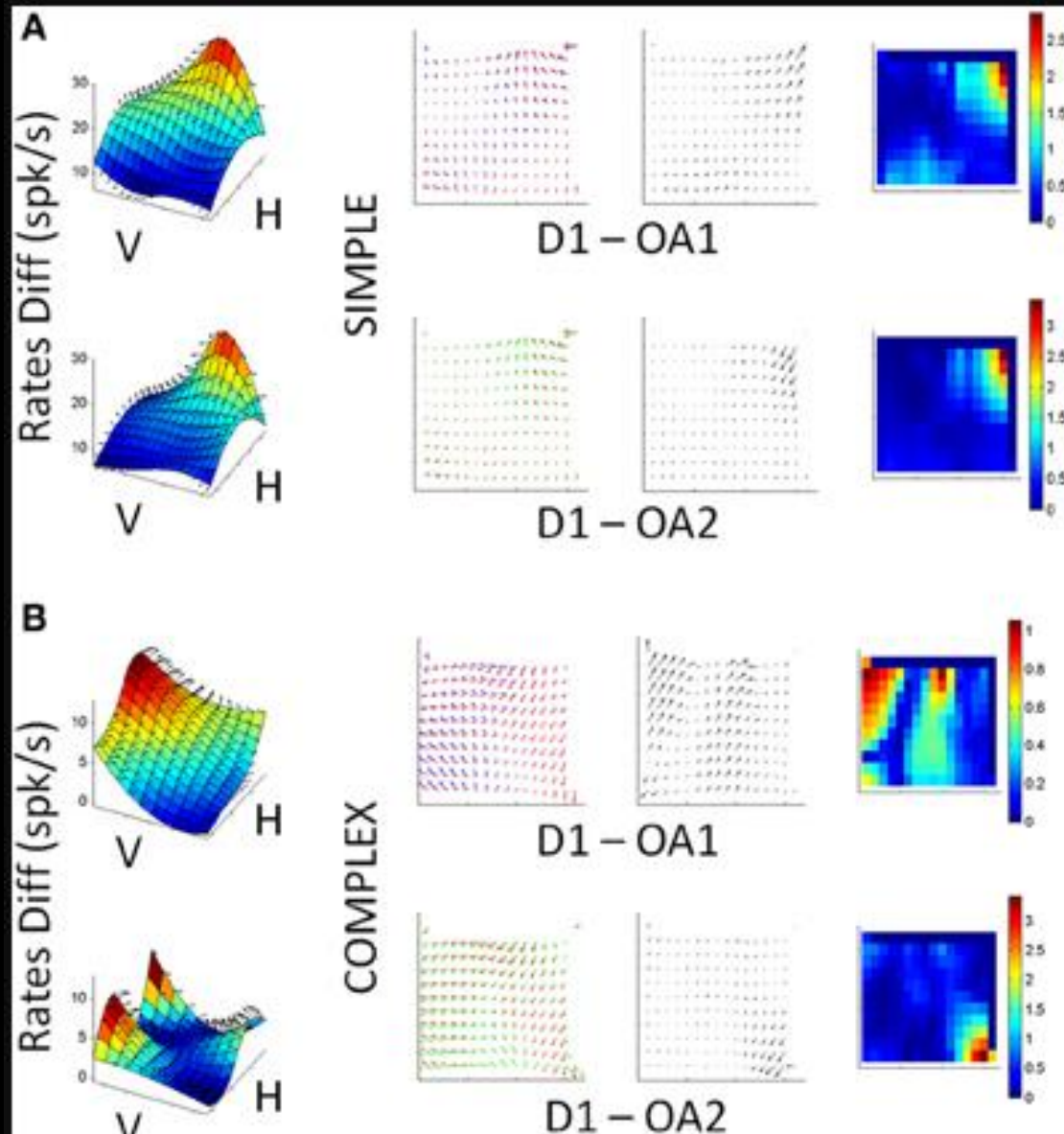
Path Conservation in both Postural Configuration and Hand spaces



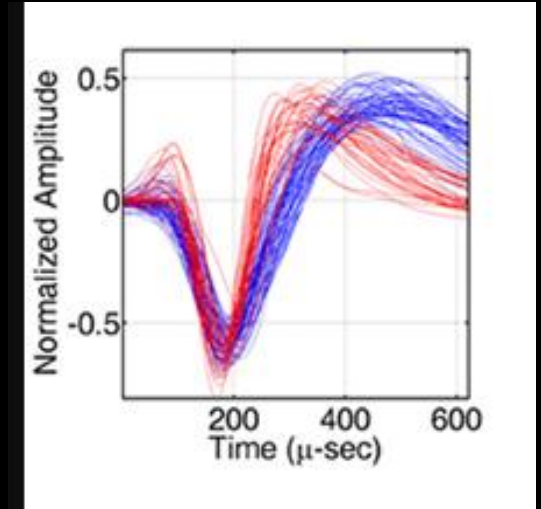
COULD POSTURAL CHANGES BE A PARSIMONIOUS EXPLANATION?

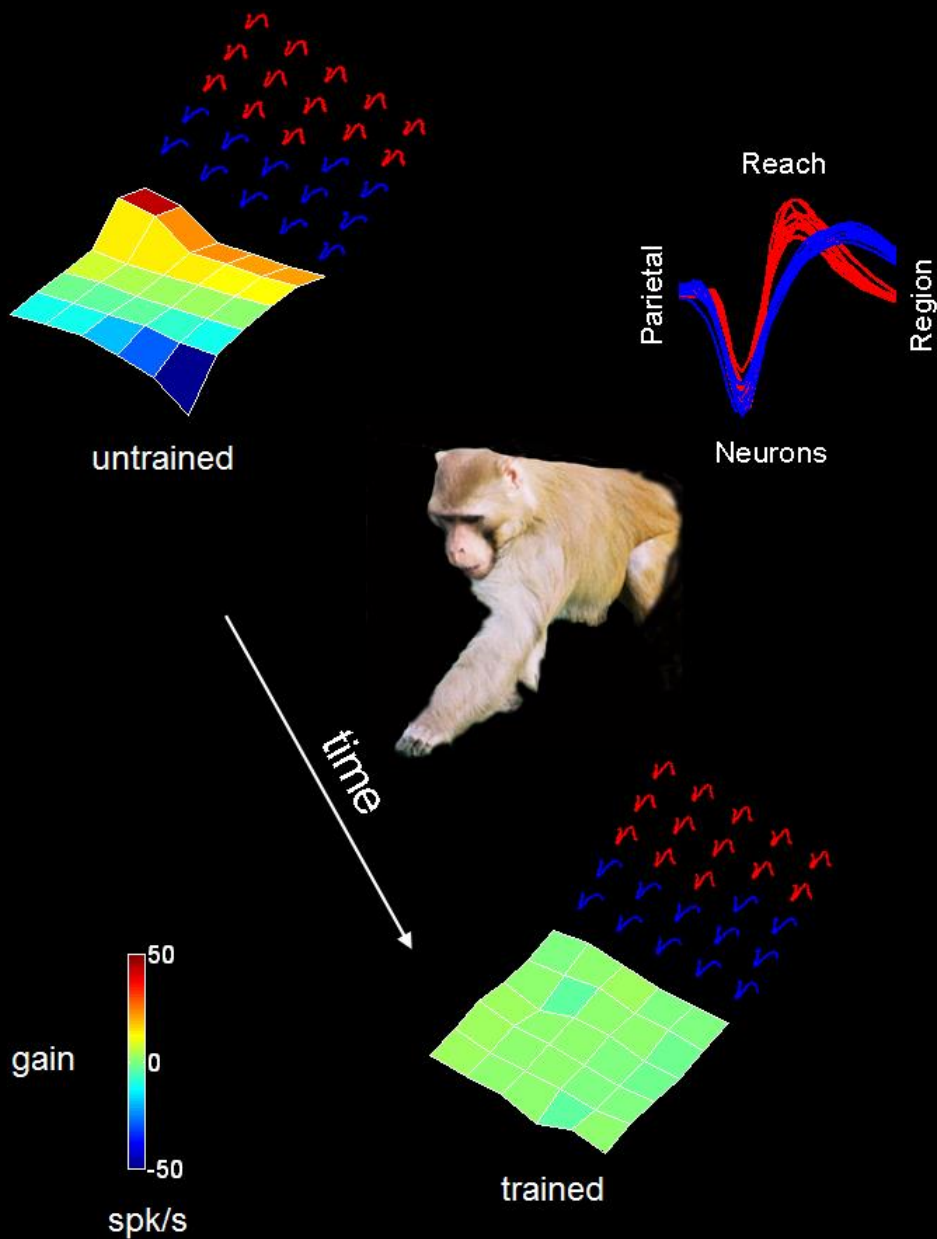


PREDICTING 2 SECONDS AHEAD THE IMPENDING POSTURAL PATHS FROM NEURONAL PLANNING SPIKES



Two Cell Classes





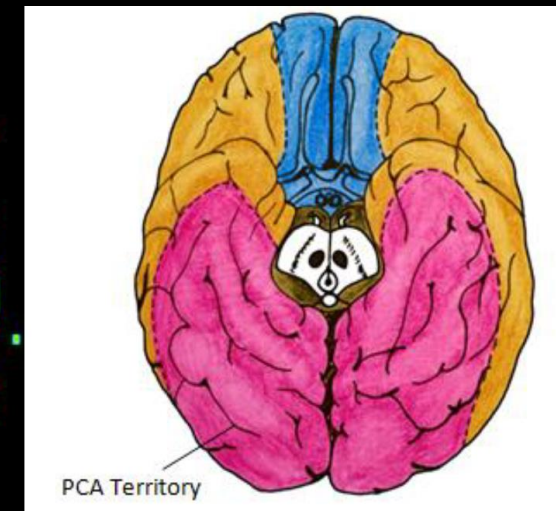
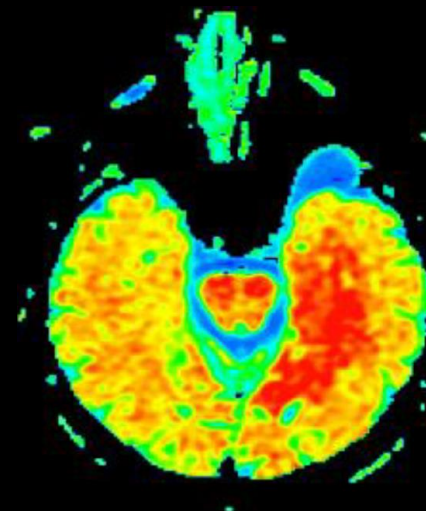
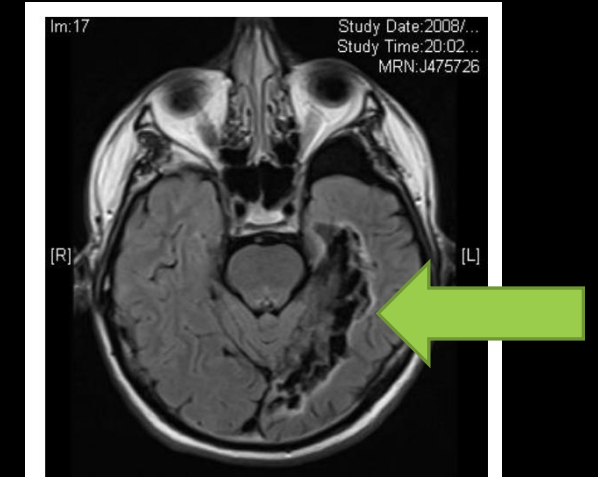
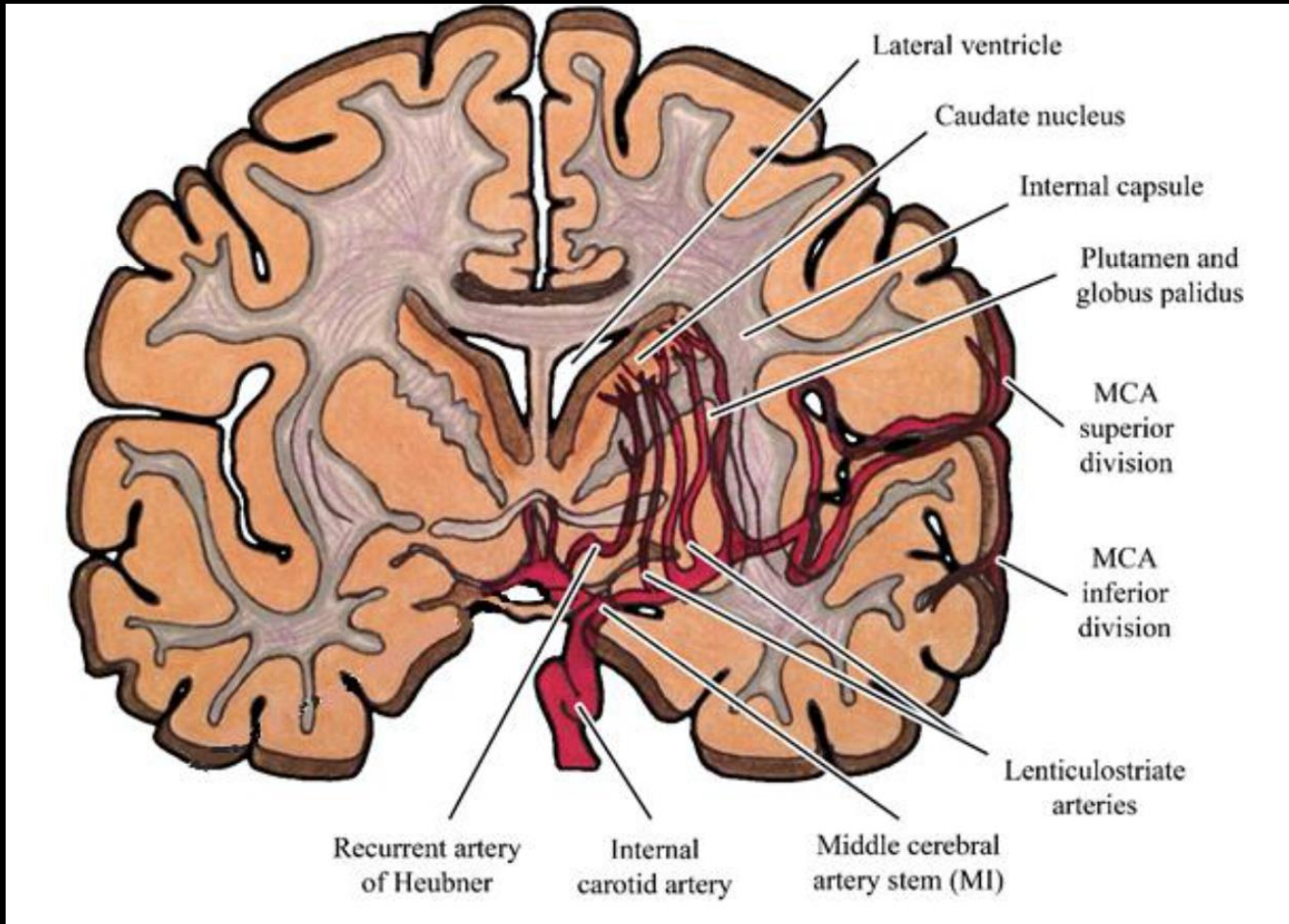
INTENT MAPS IN THE POSTERIOR PARIETAL CORTEX INTEGRATE VISION AND PROPRIOCEPTION

LOSING THE LINK BETWEEN MENTAL INTENT AND PHYSICAL VOLITION

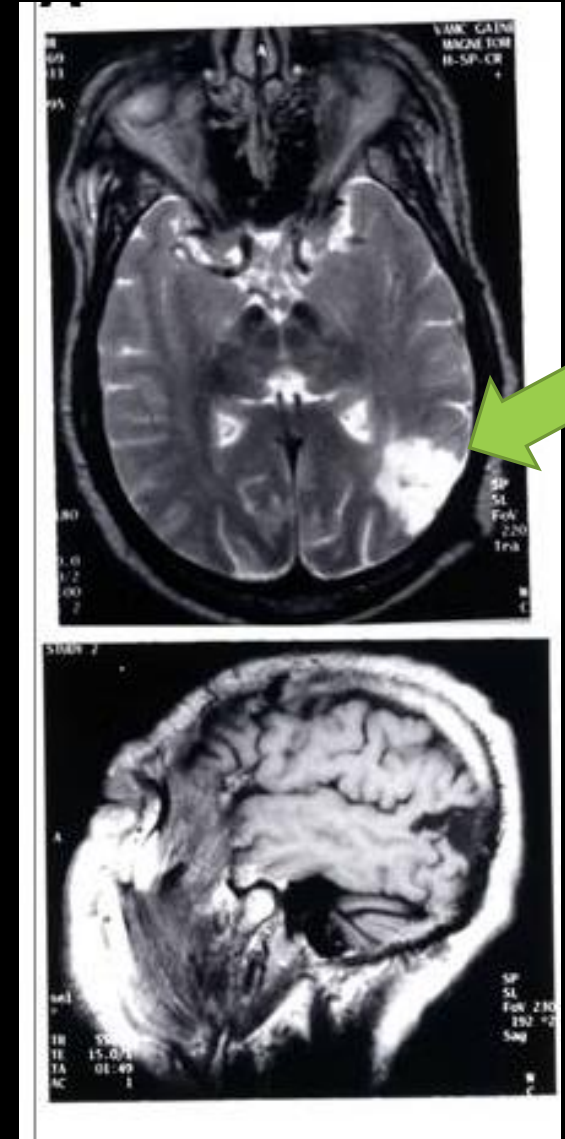
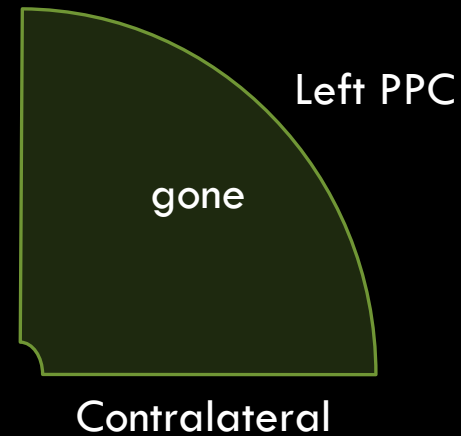
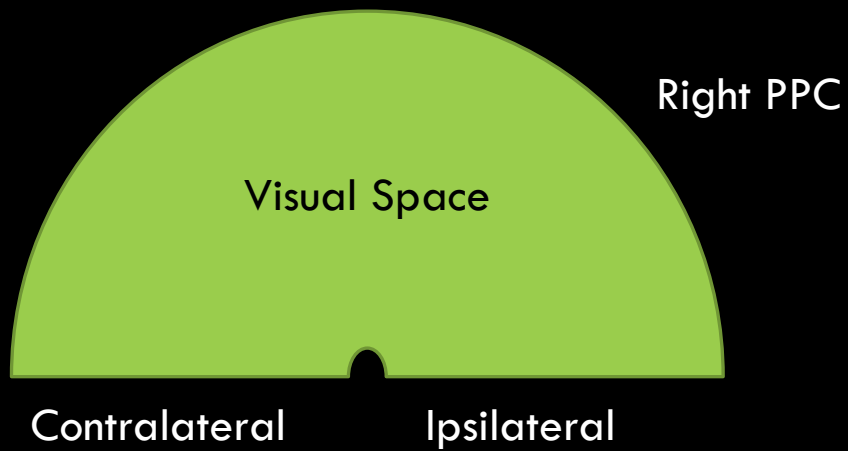
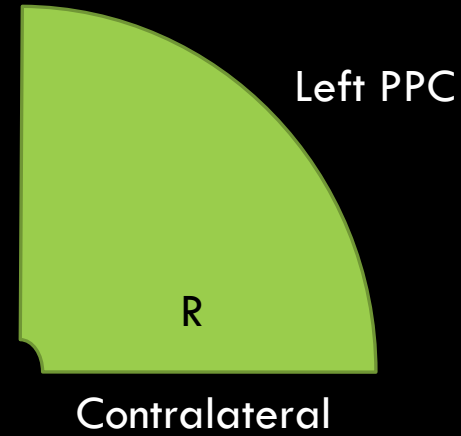
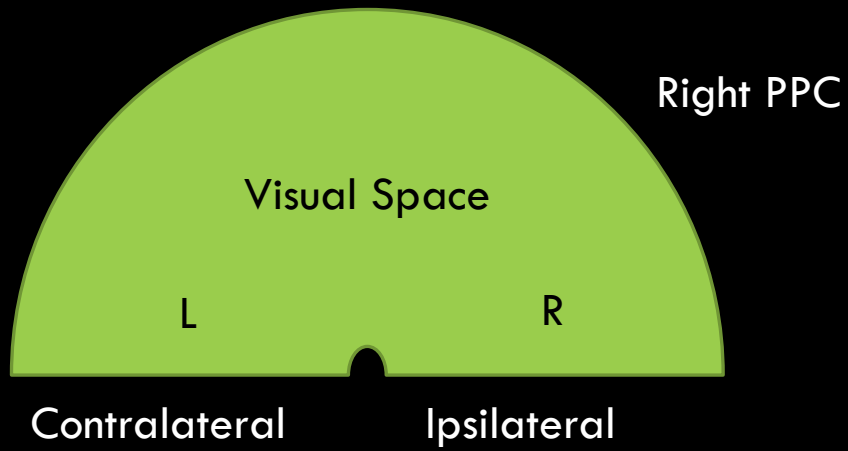
Neurology



PARIETAL HEMISPATIAL NEGLECT: RIGHT PPC STROKE

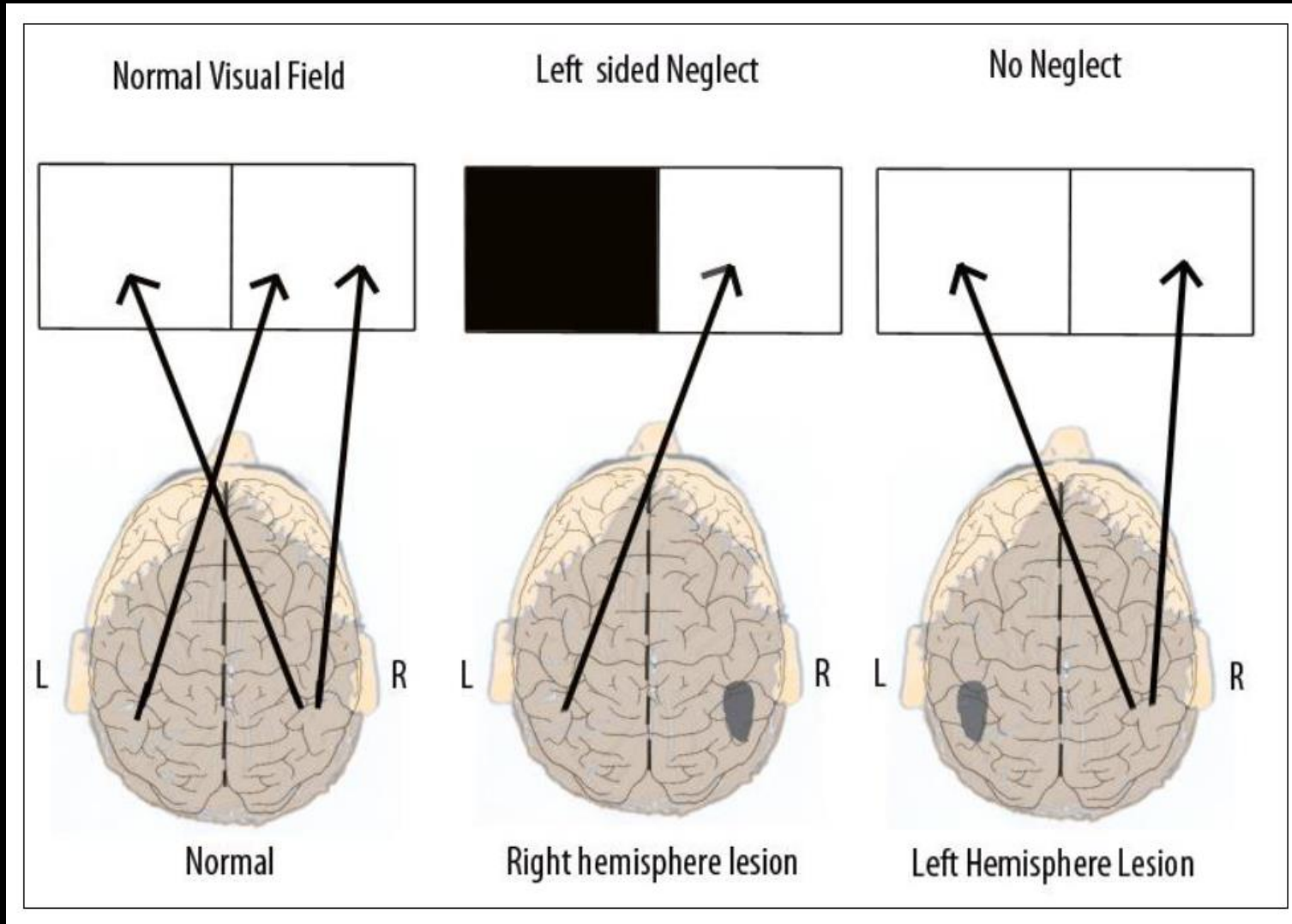


HUMANS POSTERIOR PARIETAL CORTEX SPACE ASYMMETRY



Left PPC involved in numbers (acalculia upon stroke)

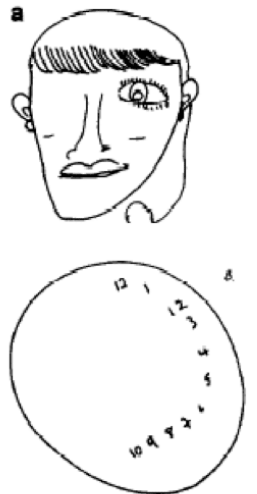
LEFT PPC STROKE NO SPATIAL NEGLECT HOW ABOUT TIME? ACALCULIA - NUMBERS



Copying:



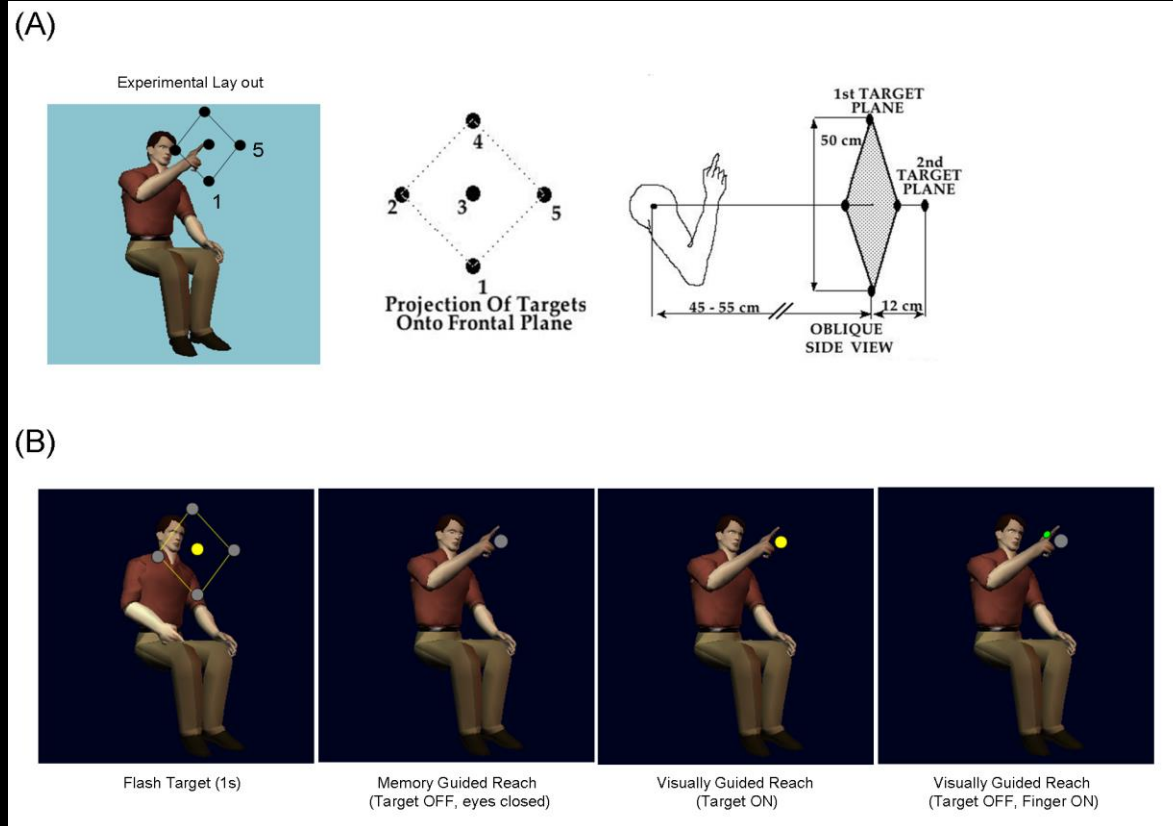
Spontaneous drawing:



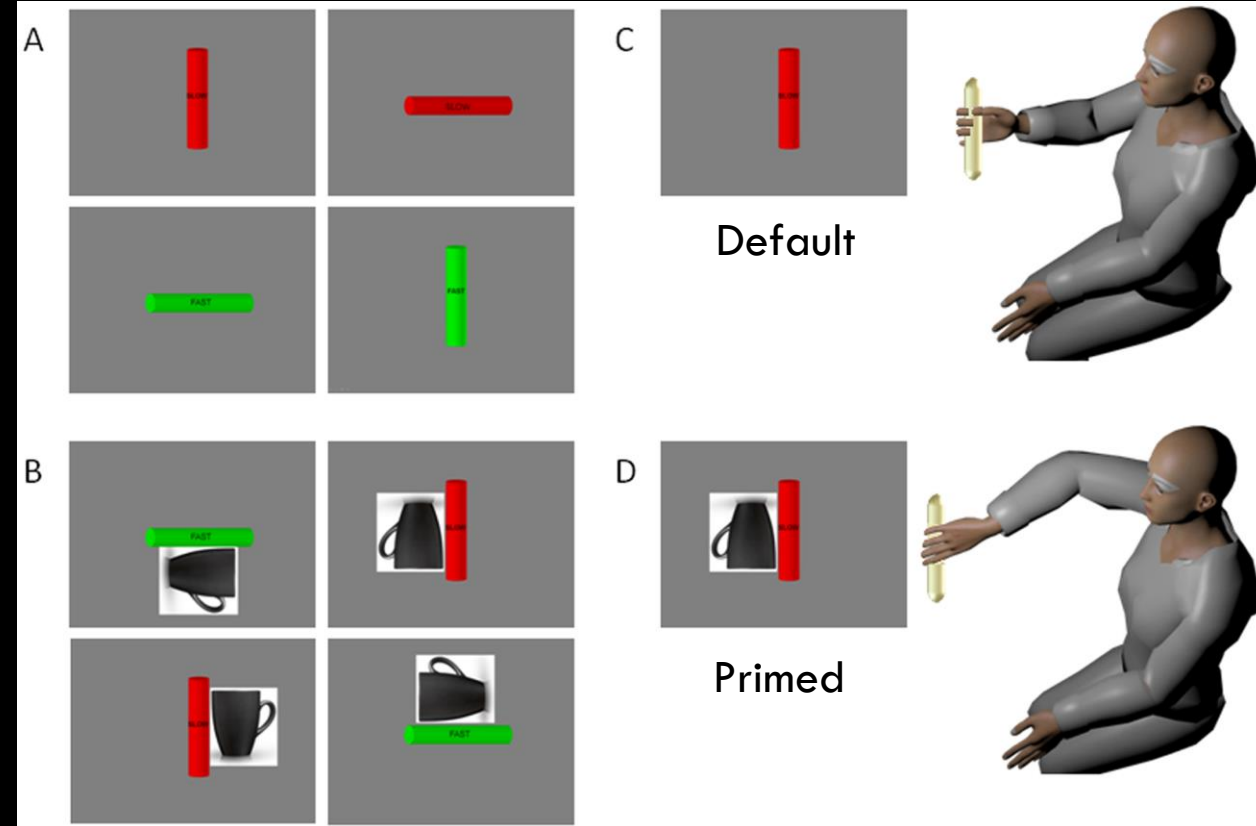
PHYSICAL - INTENTIONAL ACTIONS IN NEGLECT AND PD

Experimental Assays

Pointing



Reach to Grasp

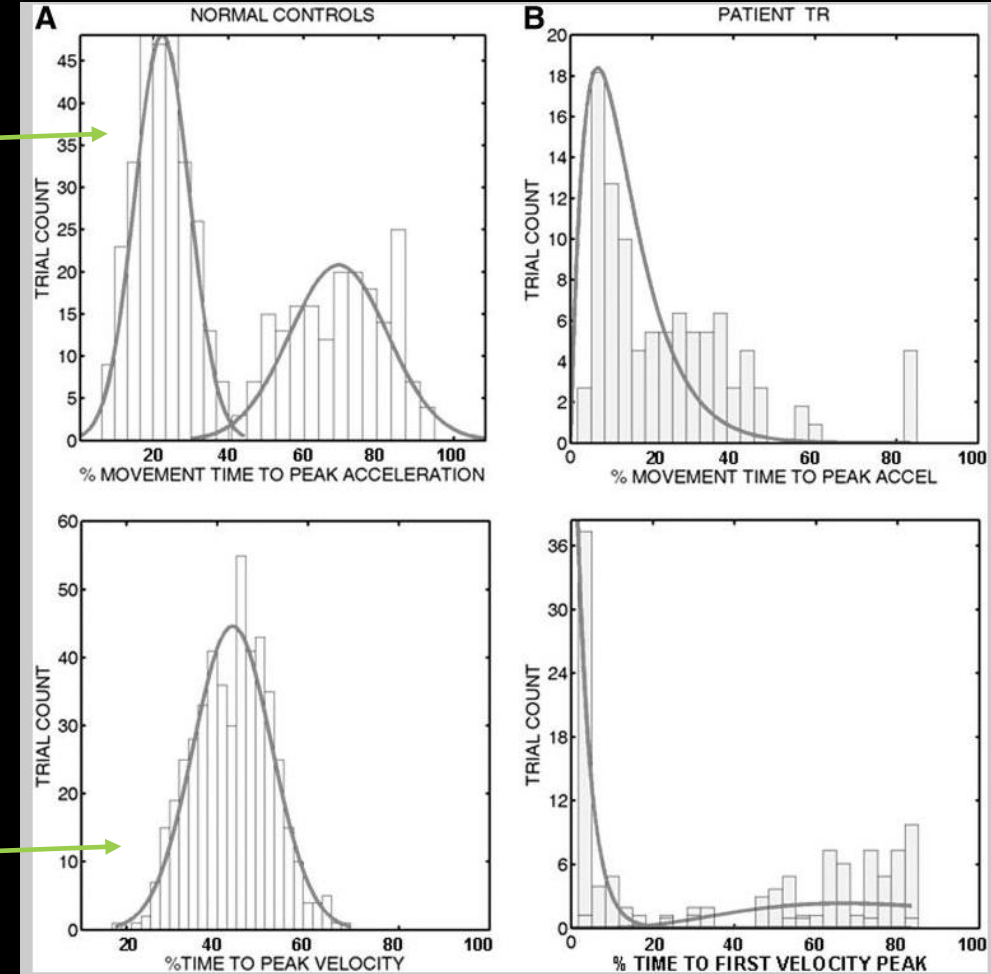
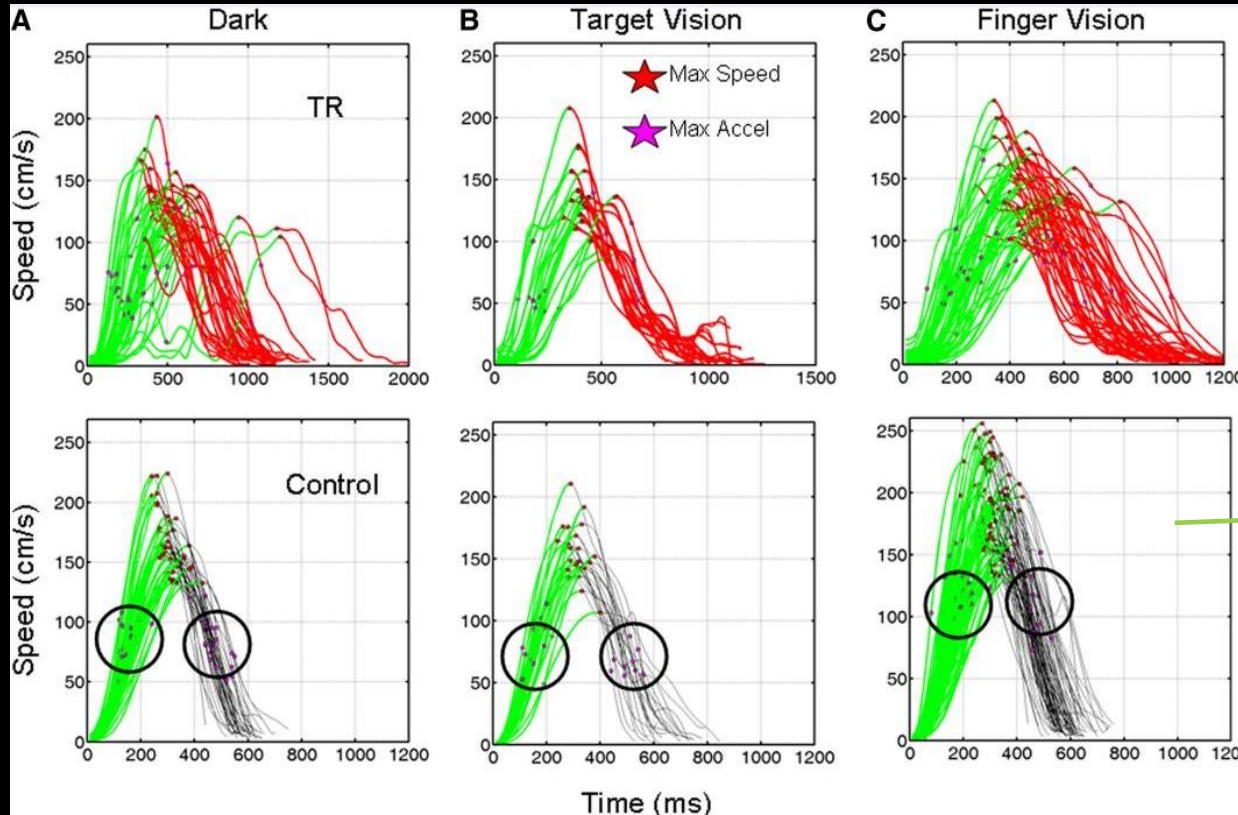
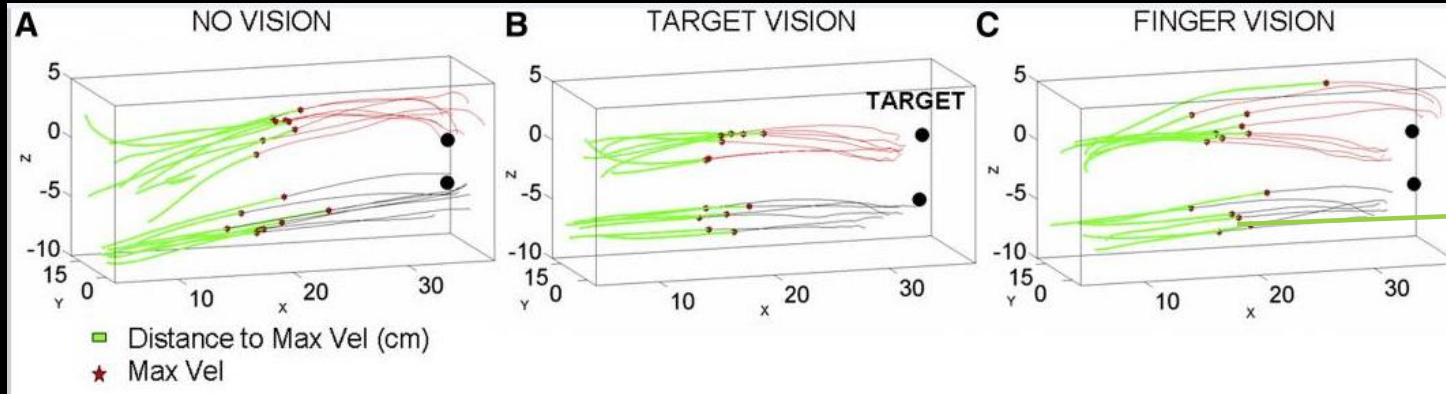


Torres et al 2010, J of Neurophysiology

Torres et al 2013, J of Neuroscience

Yanovich et al 2013, PLoS

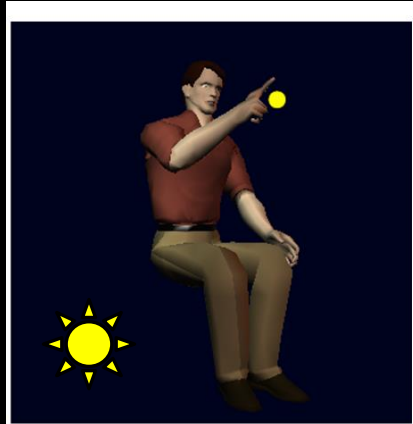
SPACE – TIME KINEMATICS PARAMETERS OF POINTING TRAJECTORIES



THERAPEUTIC EFFECTS RECOVERING NORMALCY



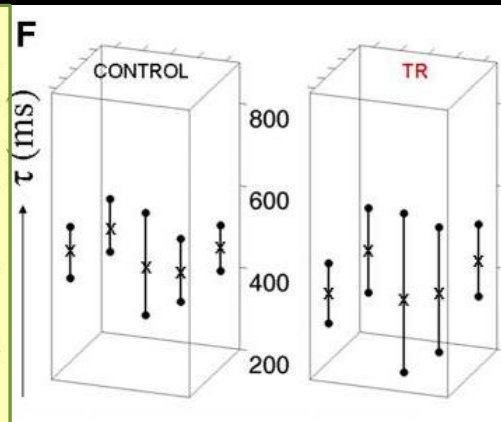
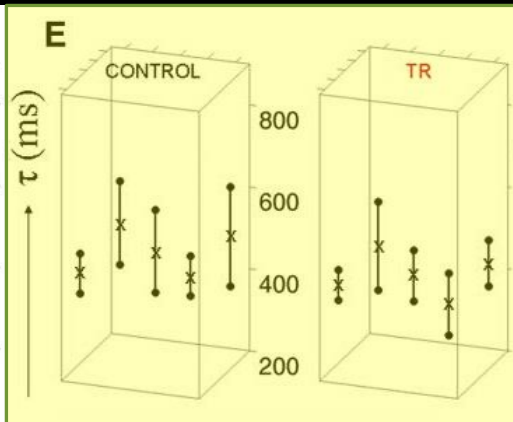
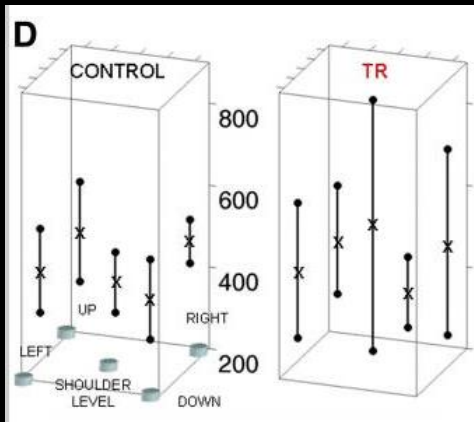
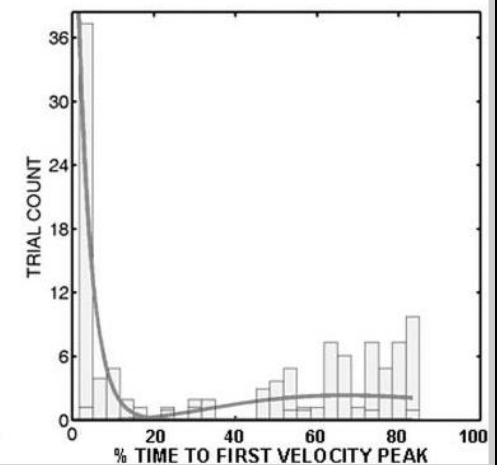
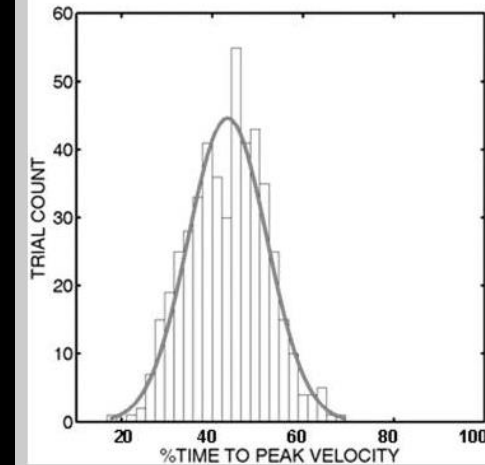
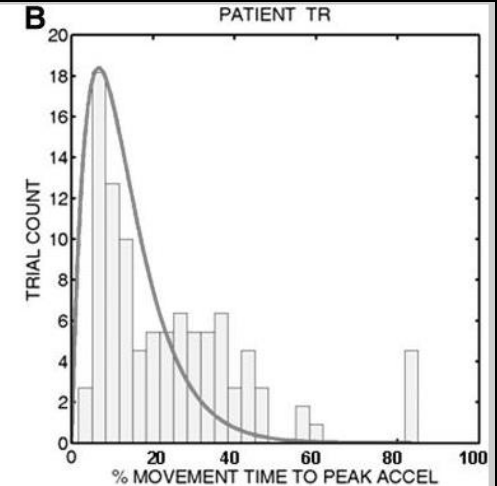
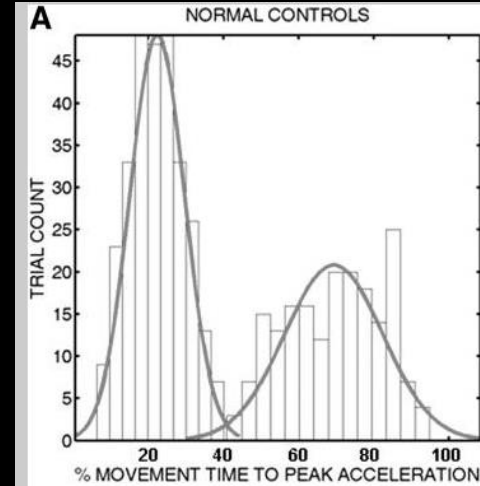
Memory Guided Reach
(Target OFF, eyes closed)



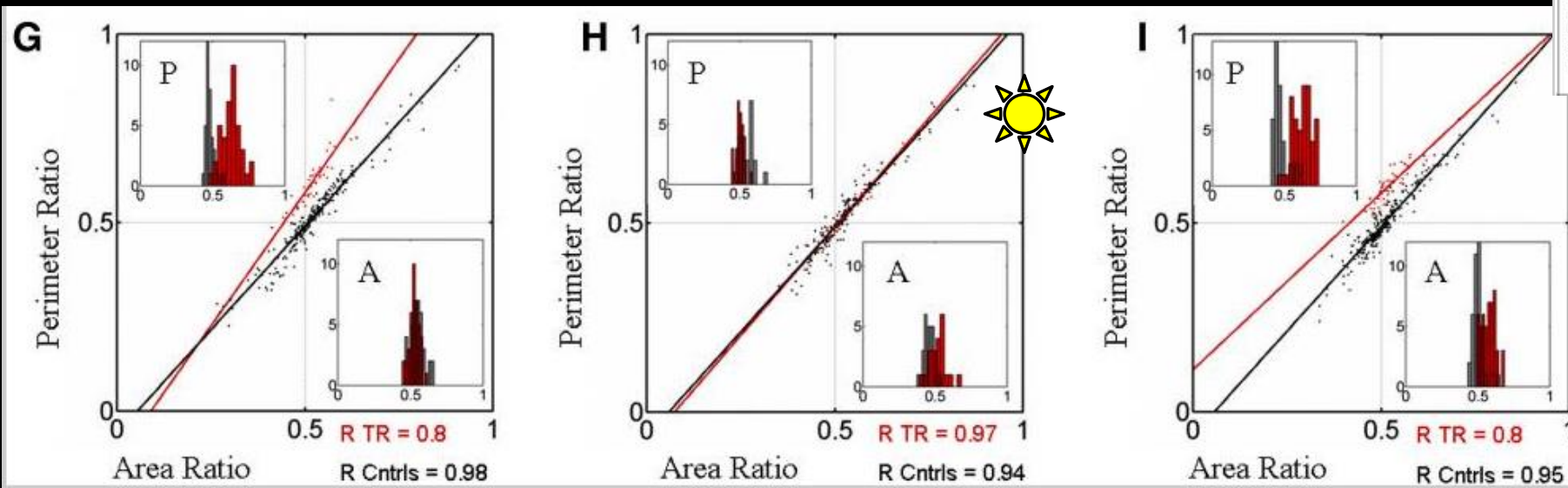
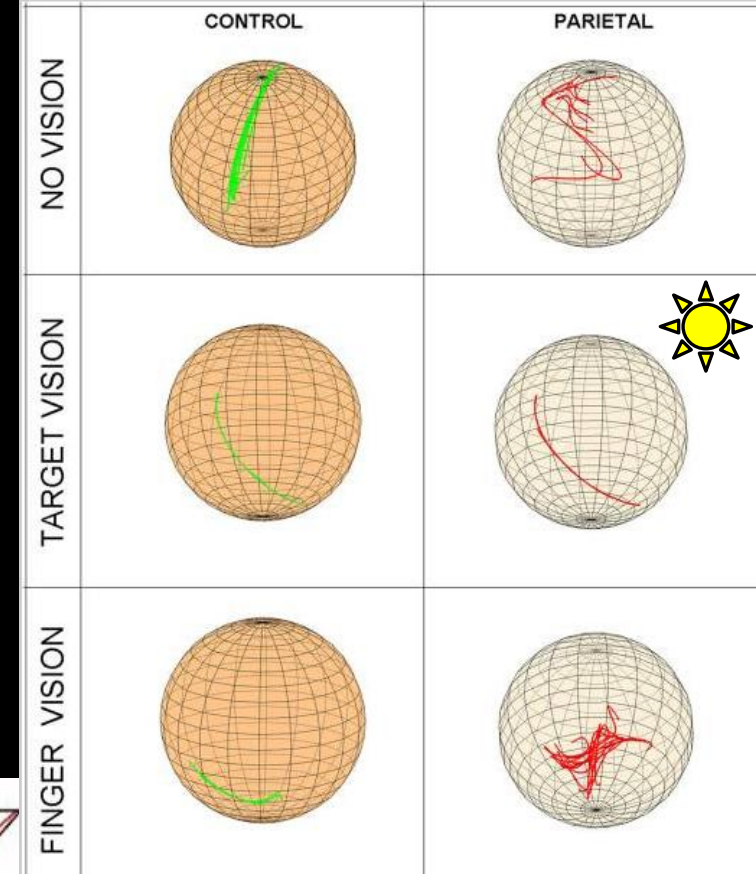
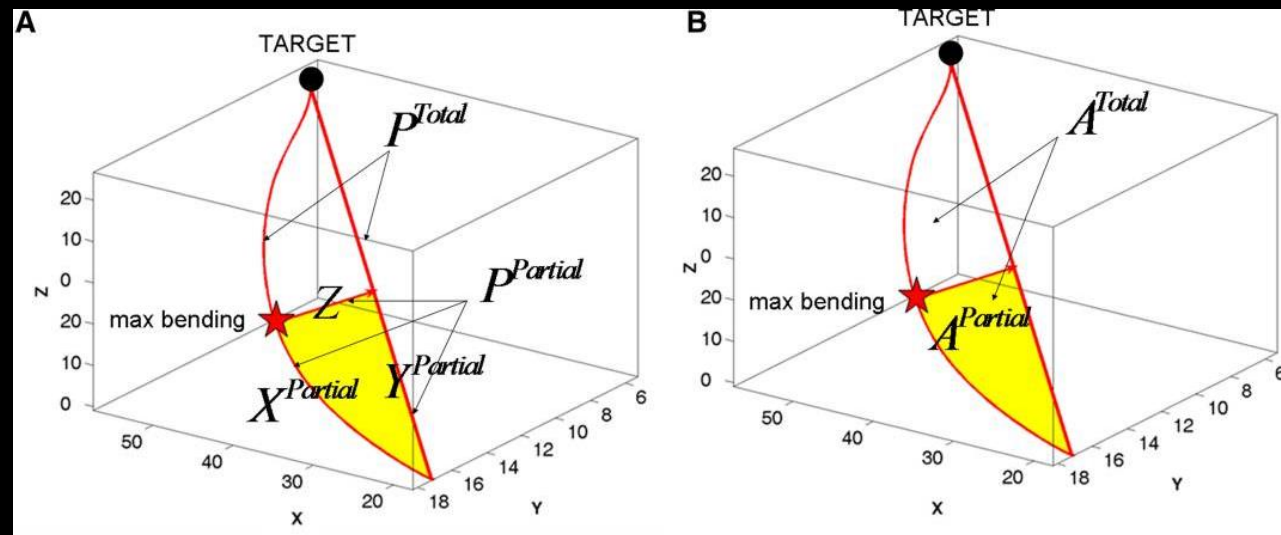
Visually Guided Reach
(Target ON)



Visually Guided Reach
(Target OFF, Finger ON)



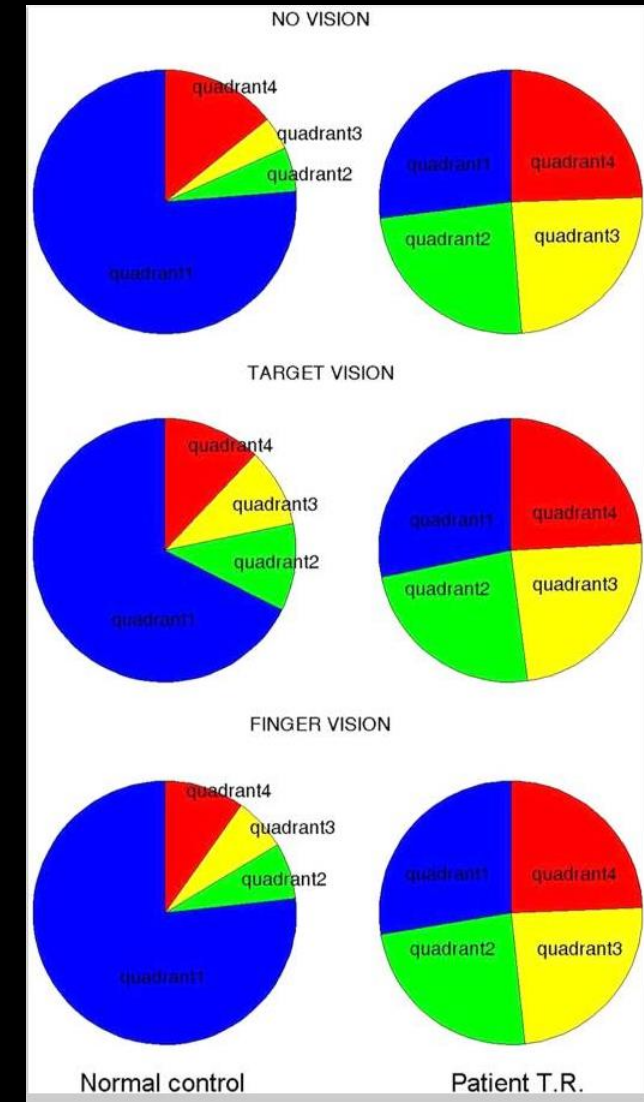
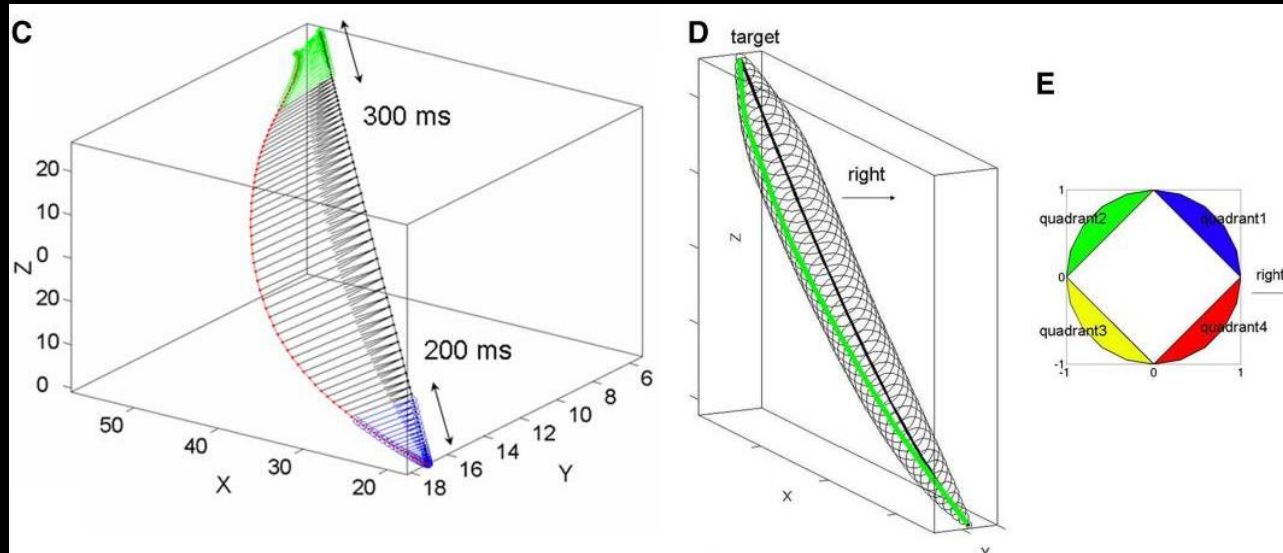
DIFFERENT SPACES AFFECTED



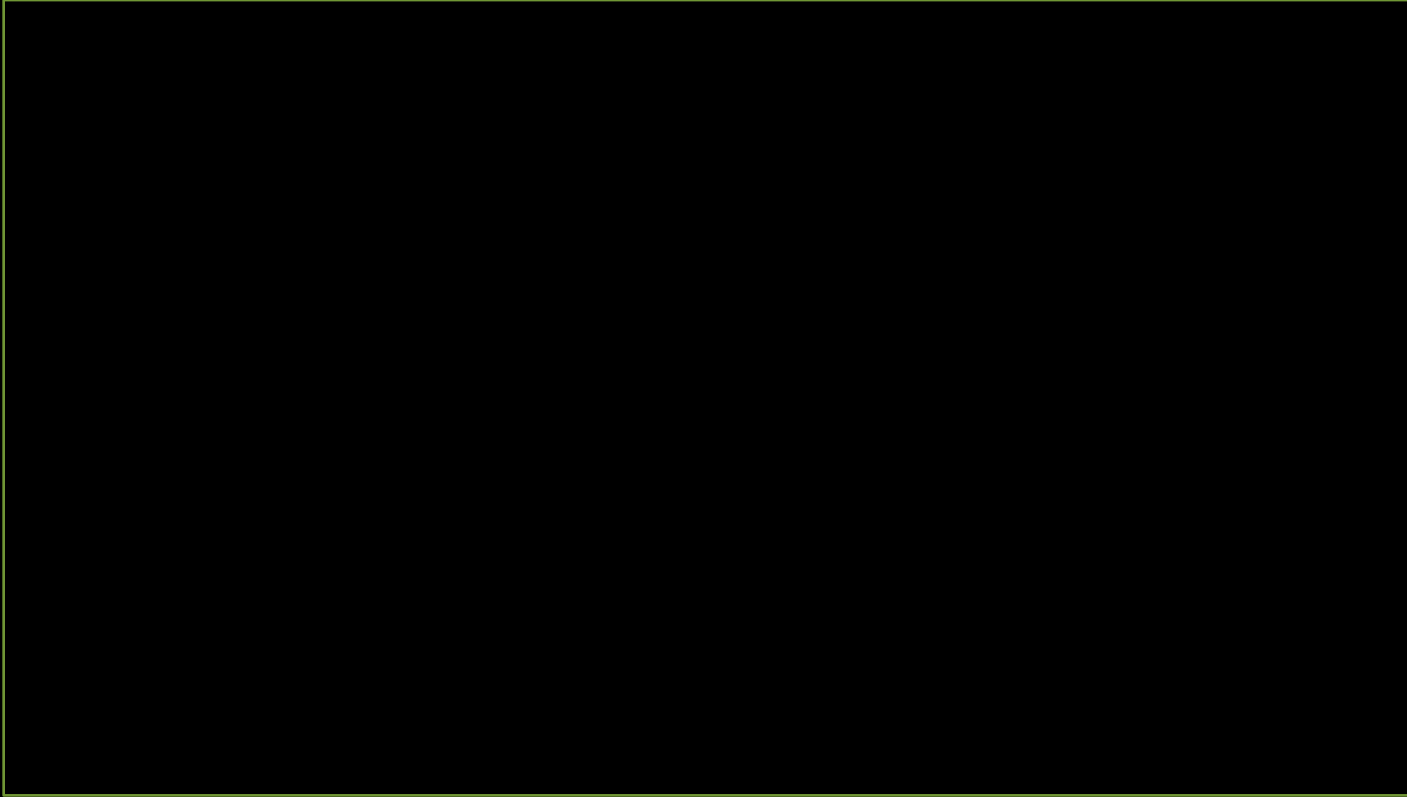
Internal Posture Space

External Hand Space

A DIFFERENT FORM OF NEGLECT IN LEFT PPC STROKE



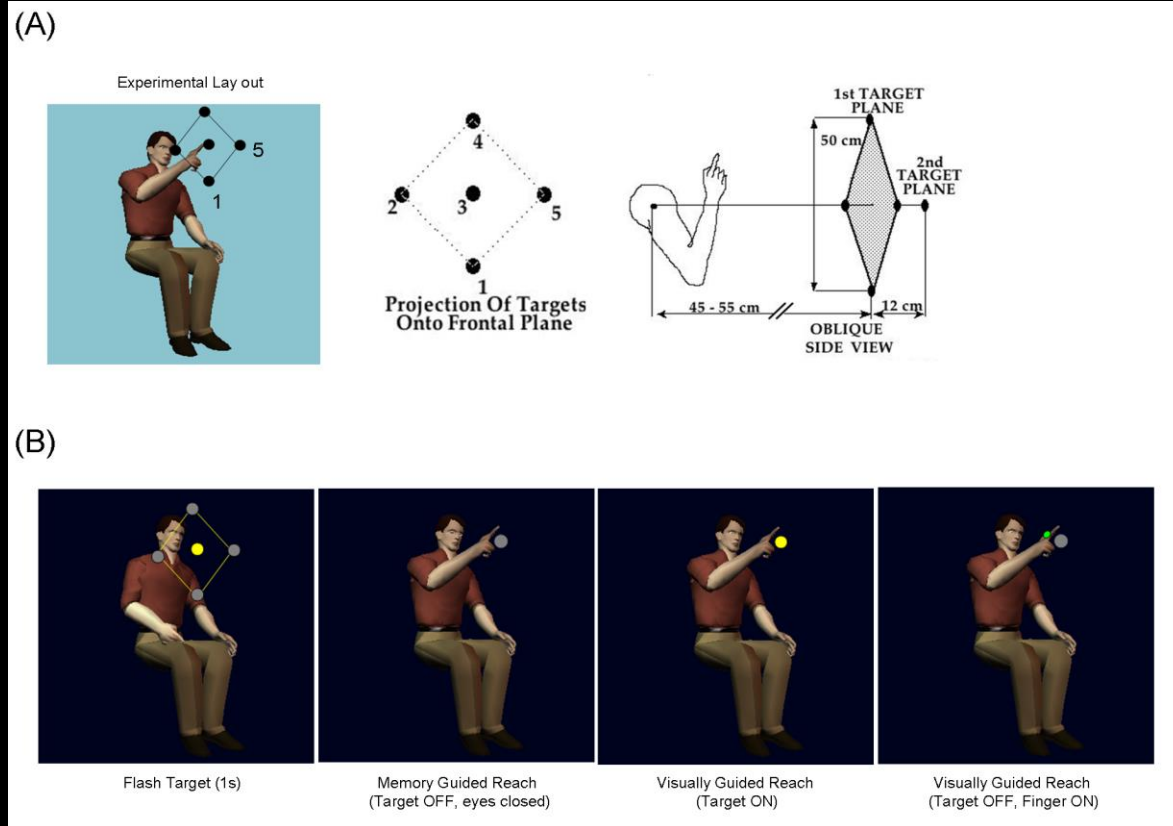
RETURNING TO IAN WATERMAN: INTENT



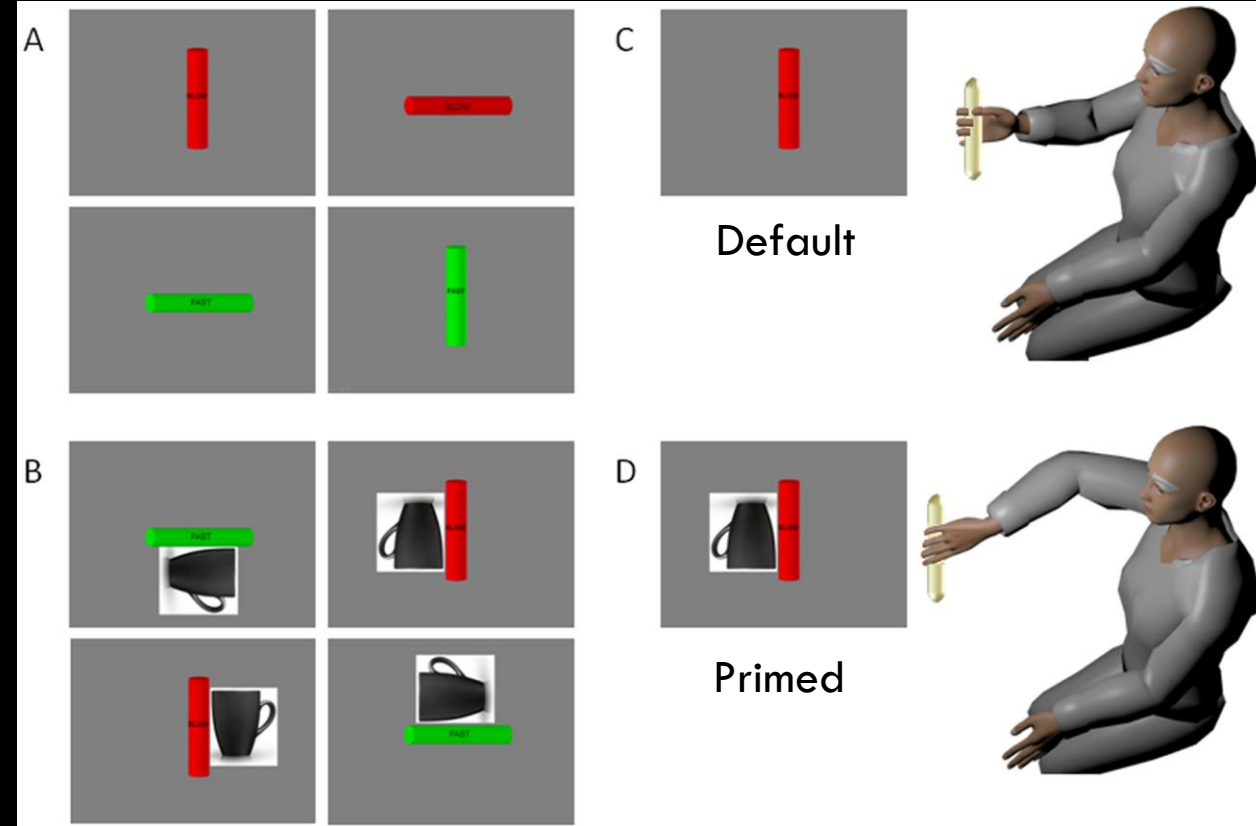
<https://www.pbs.org/video/brain-david-eagleman-episode-3-clip-1/>

PHYSICAL - INTENTIONAL ACTIONS

Pointing

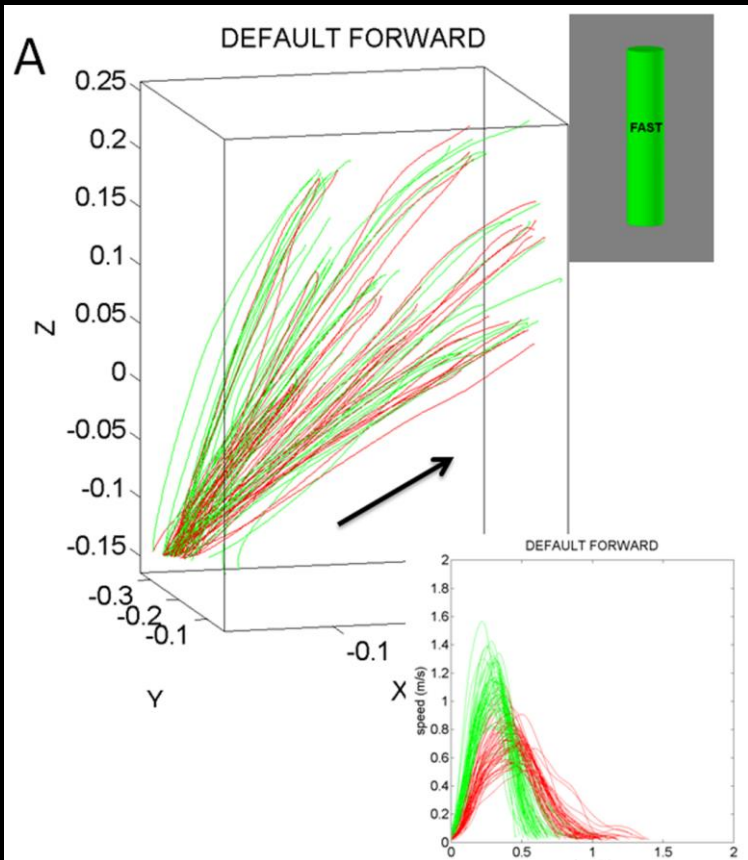


Reach to Grasp

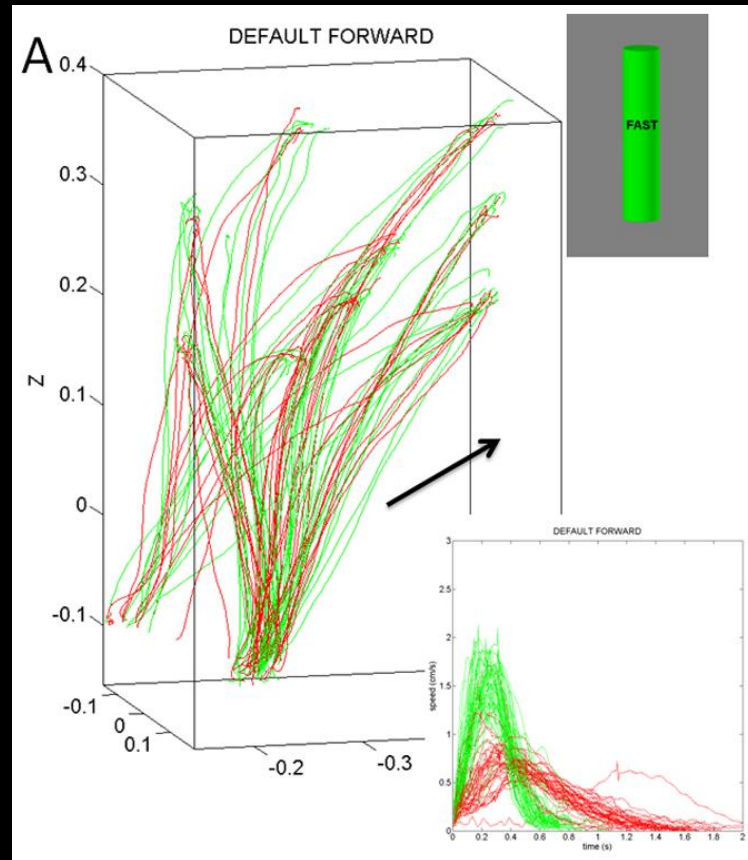


PHYSICAL INTENT IN PD IS IMPEDED BY PRIMING

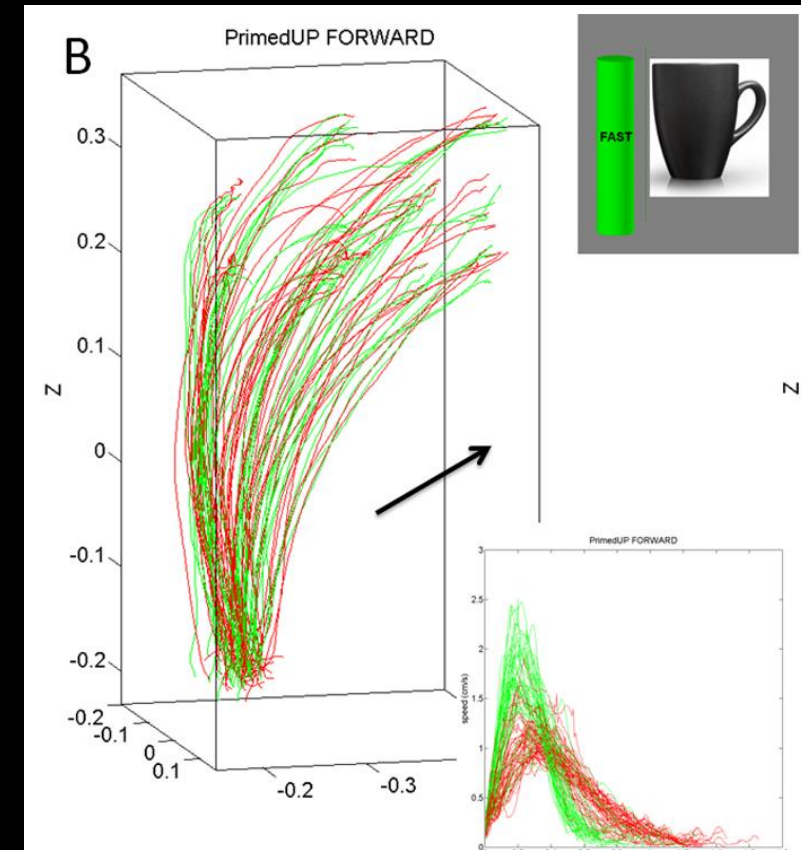
Control



PD

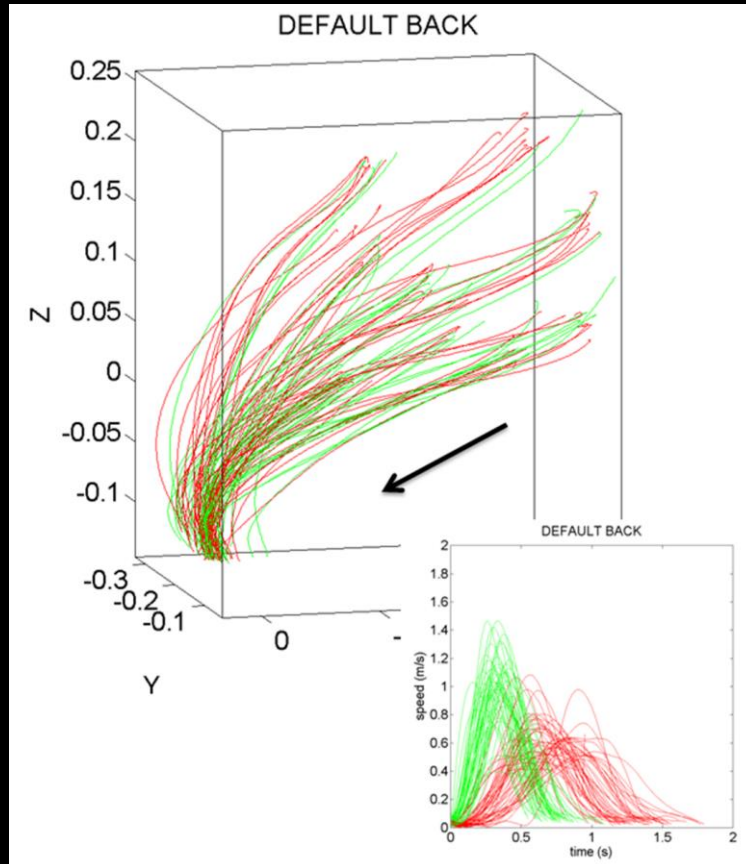


PD Primed

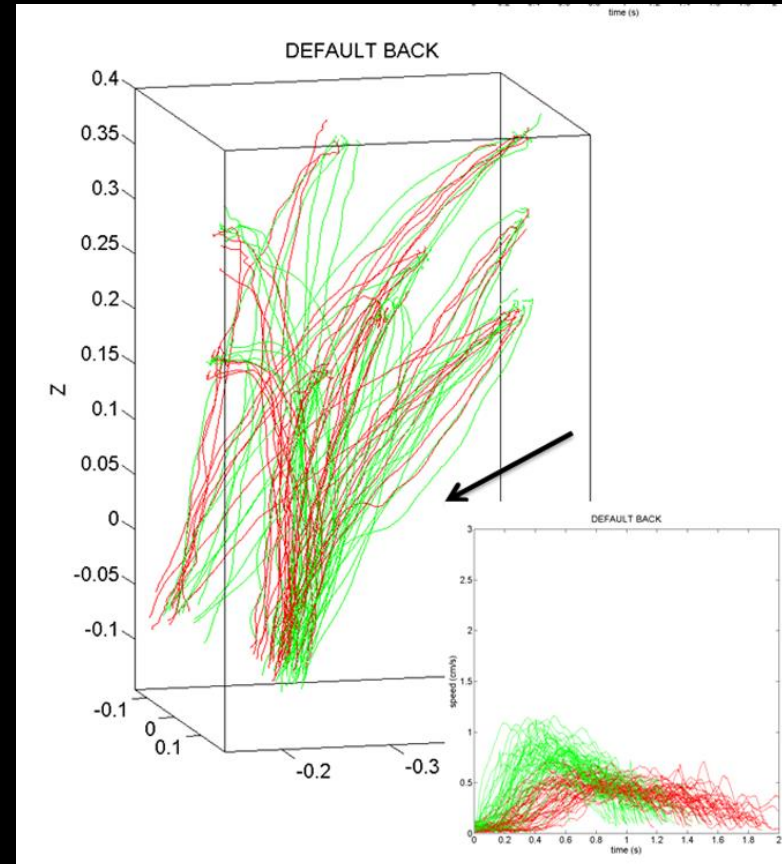


SPONTANEOUS RETRACTION IN PD ARE EVEN MORE IMPEDED THAN INTENTIONAL FORWARD MOTIONS

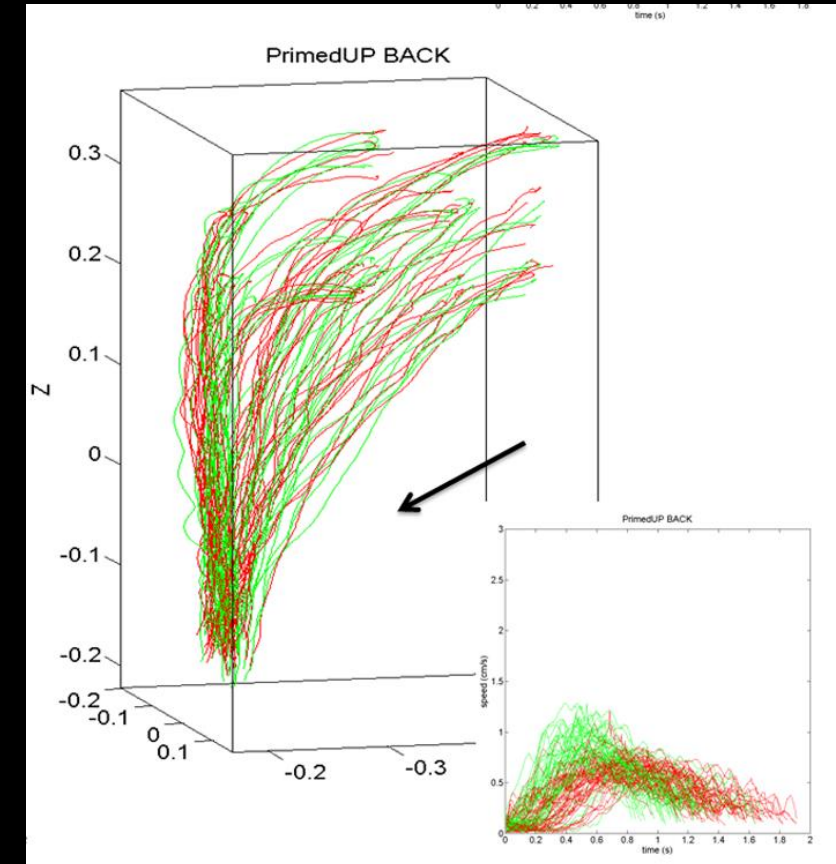
Control



PD

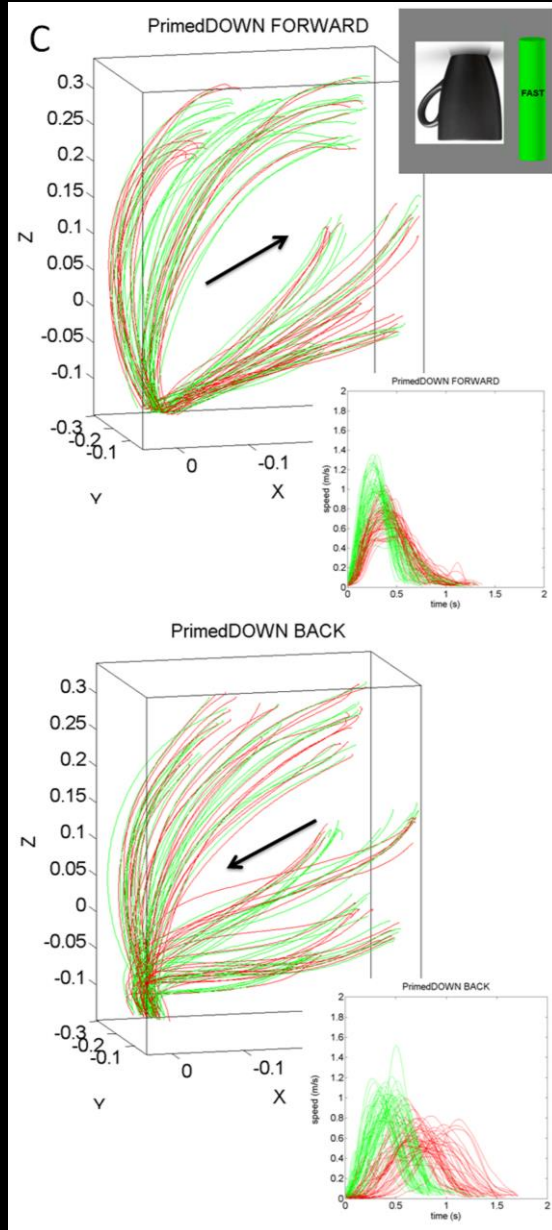


PD Primed

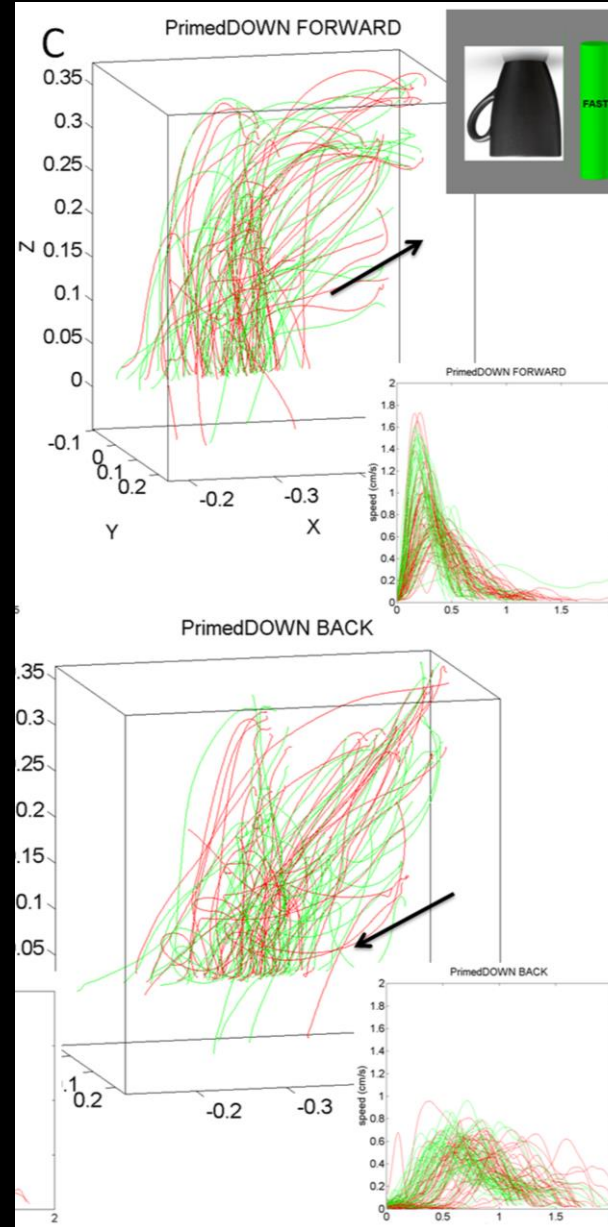


PRIMING IMPEDES INTENTIONAL PHYSICAL MOTIONS IN PD

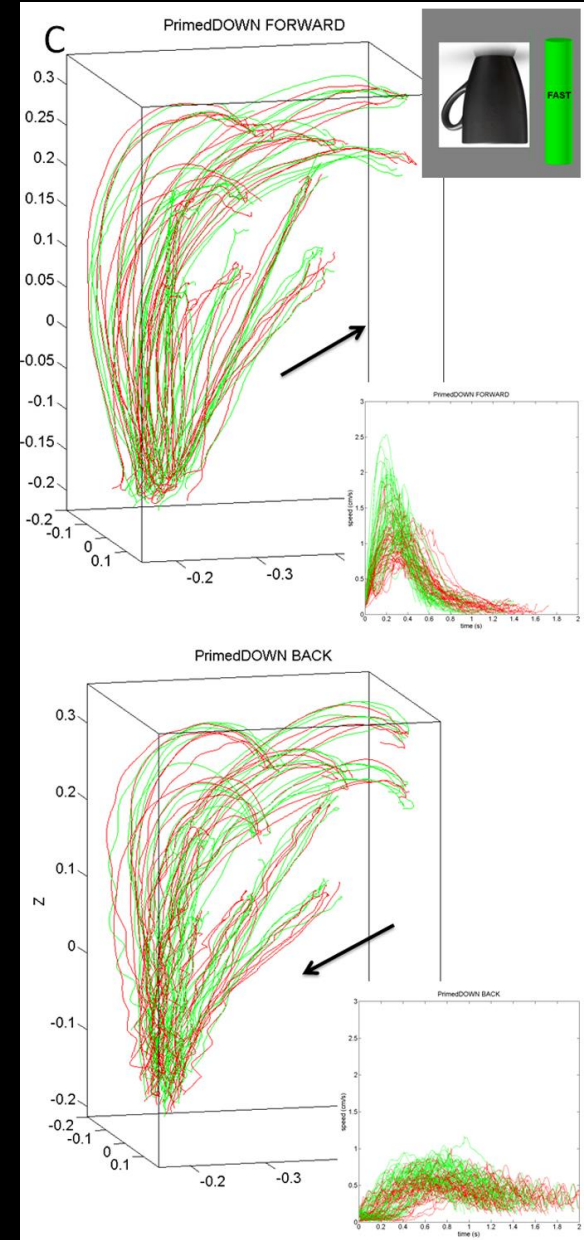
Control



Mild PD

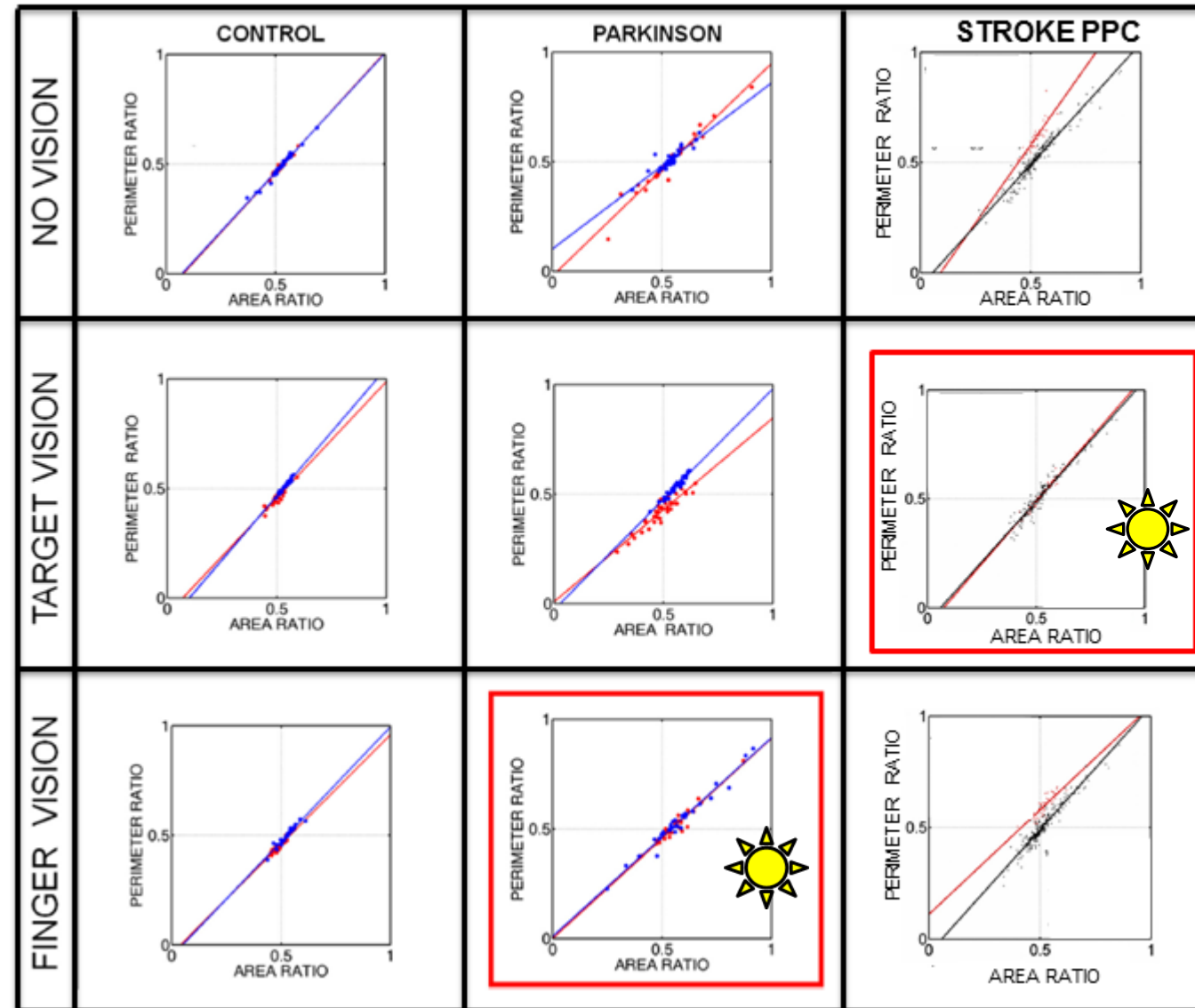


Severe PD



THERAPEUTIC VALUE

A



HAND POINTING MOTION TRAJECTORIES DEAFFERENTED IW

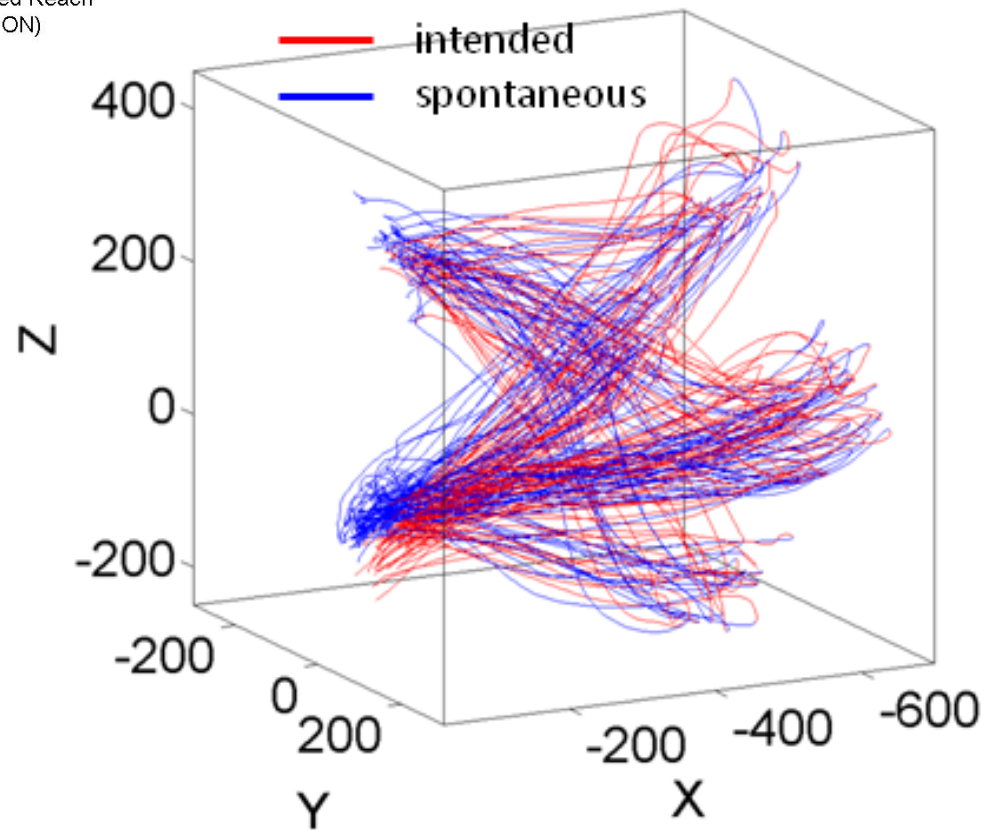


Visually Guided Reach
(Target ON)

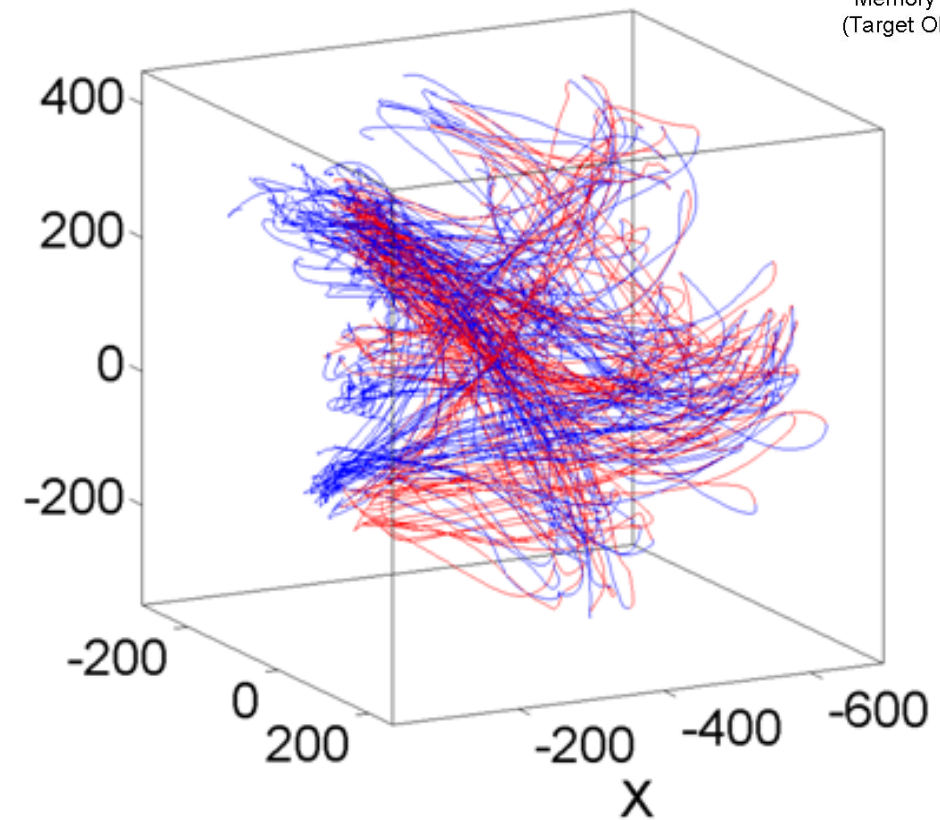


Memory Guided Reach
(Target OFF, eyes closed)

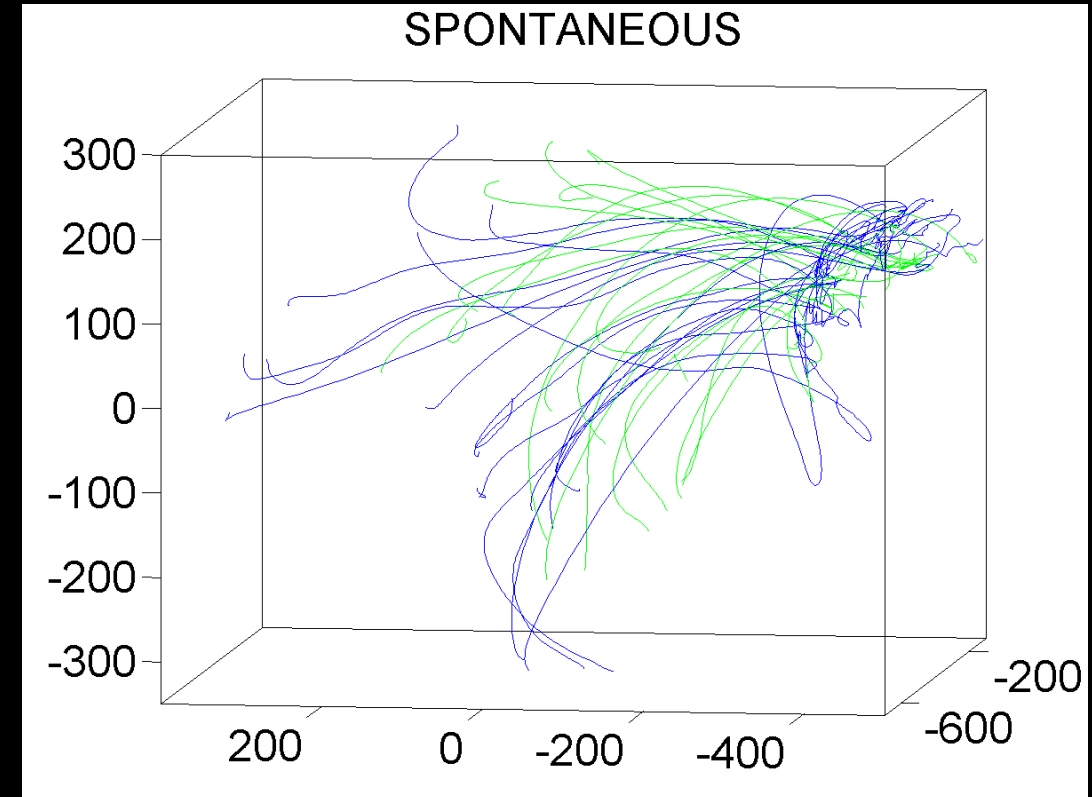
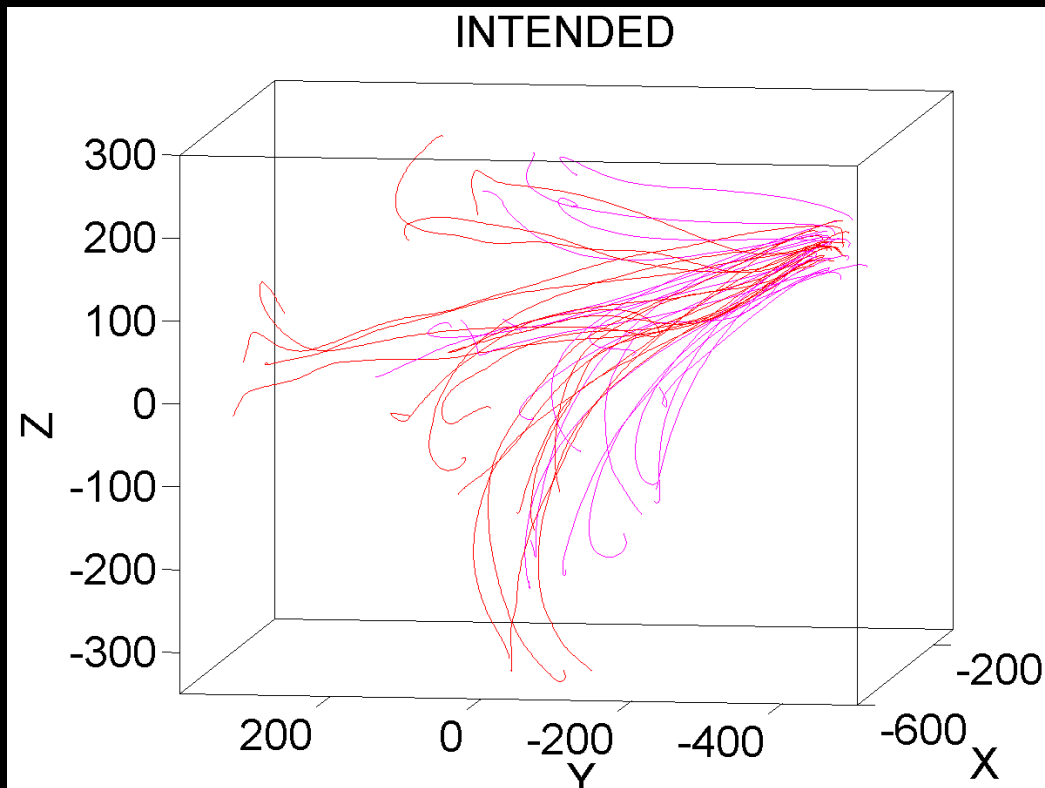
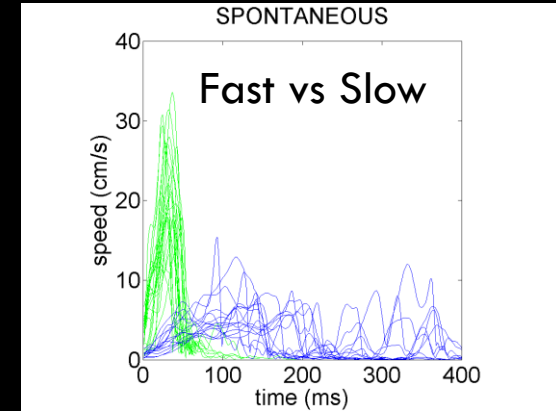
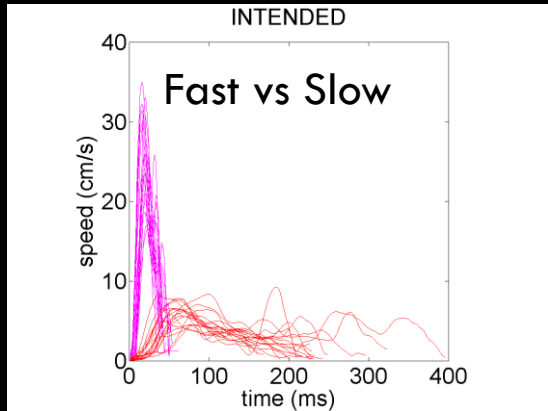
LIGHT
VISUALLY GUIDED



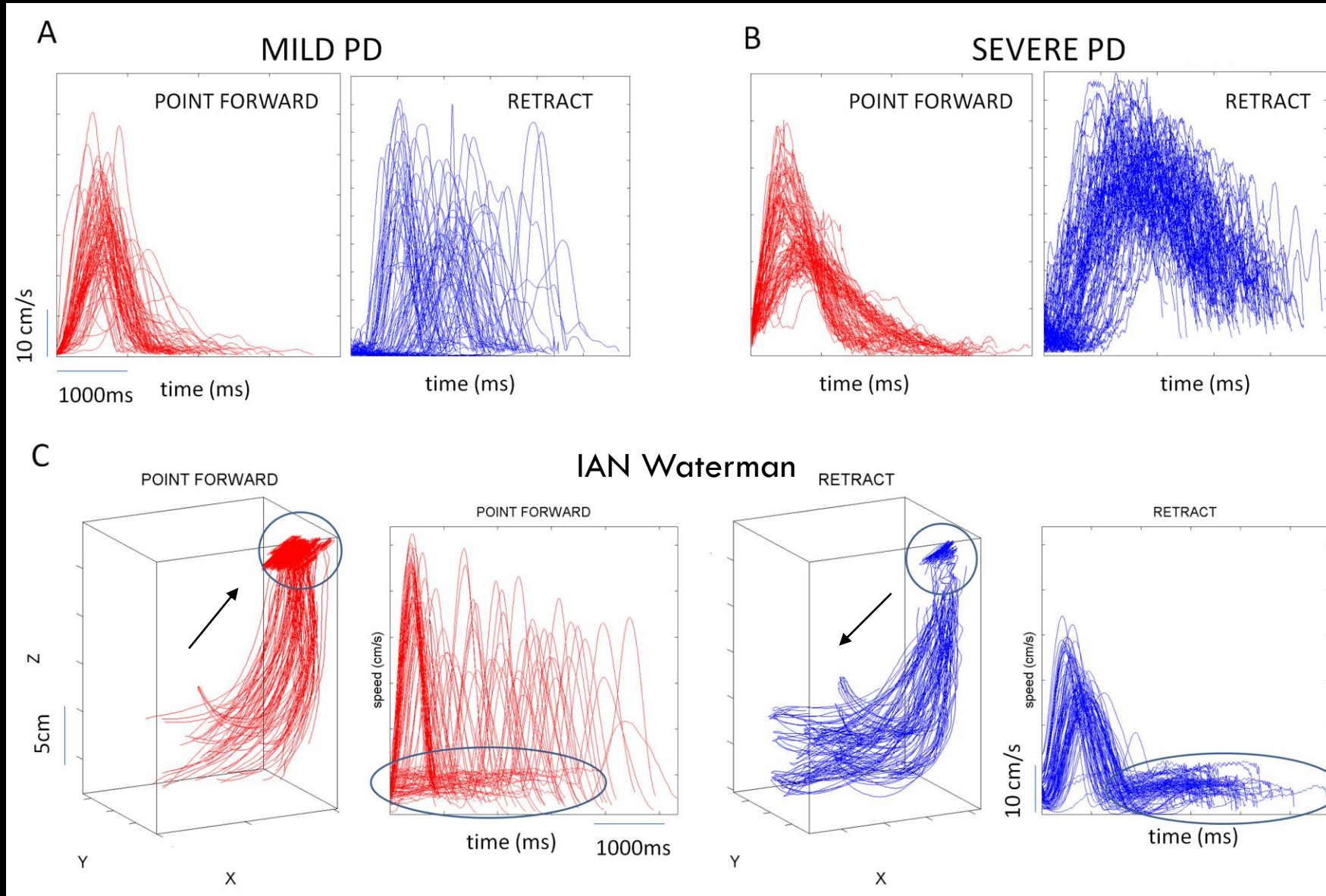
B
DARK
IMAGINED



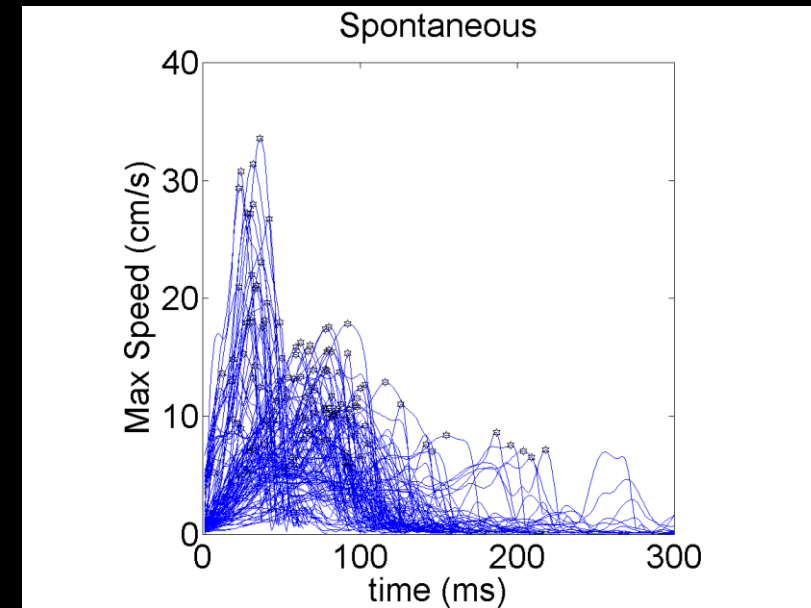
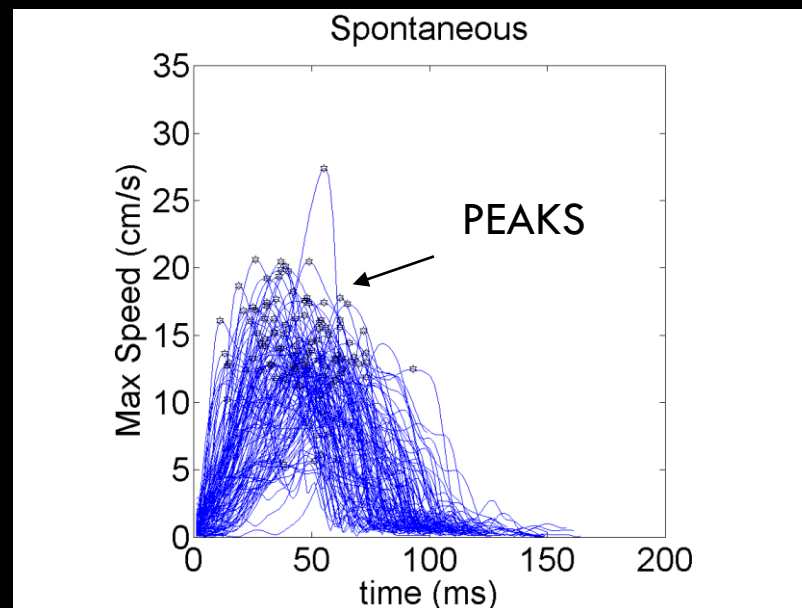
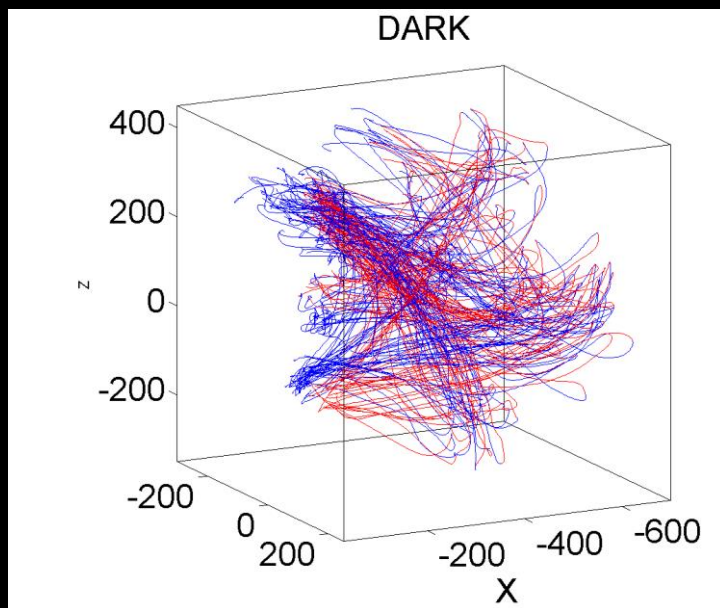
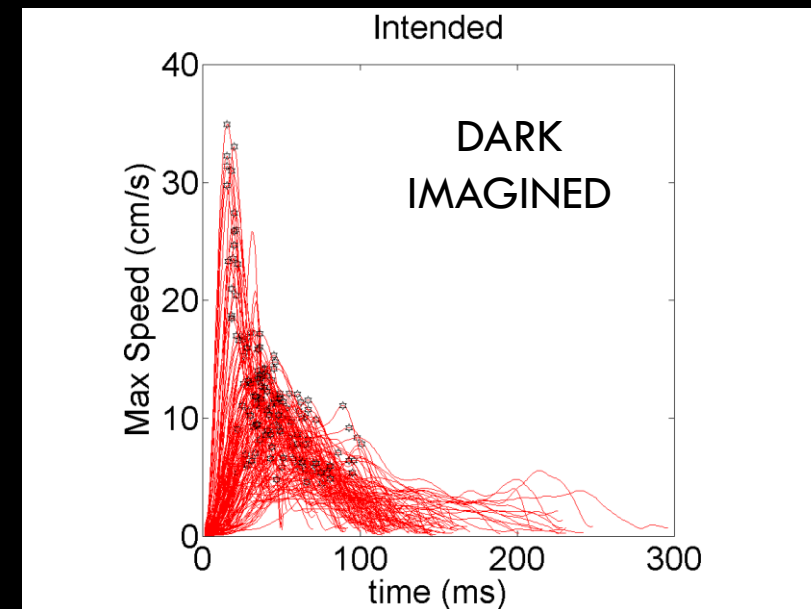
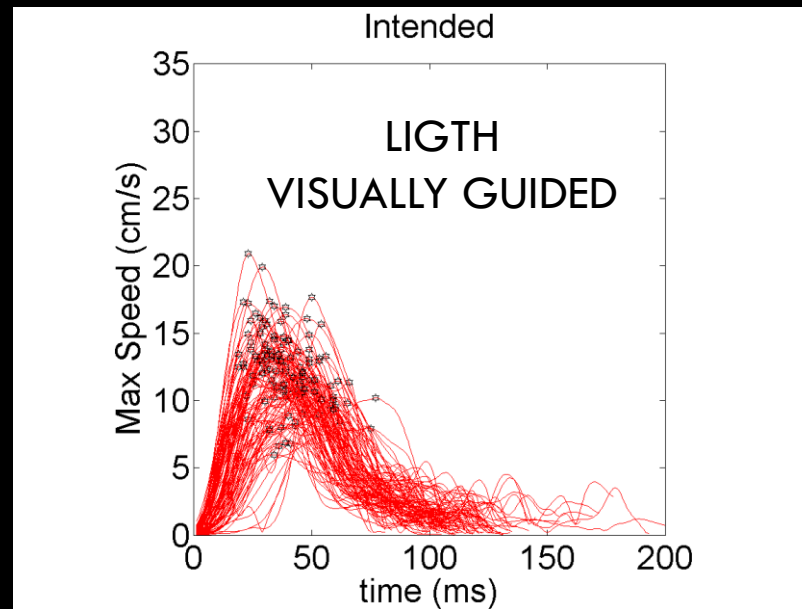
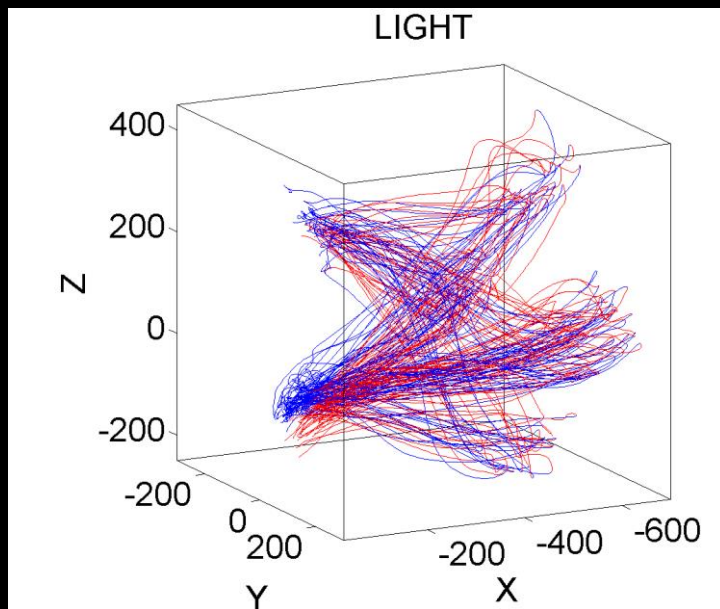
DEAFFERENTED TRAJECTORY PRIMING SPEED IW



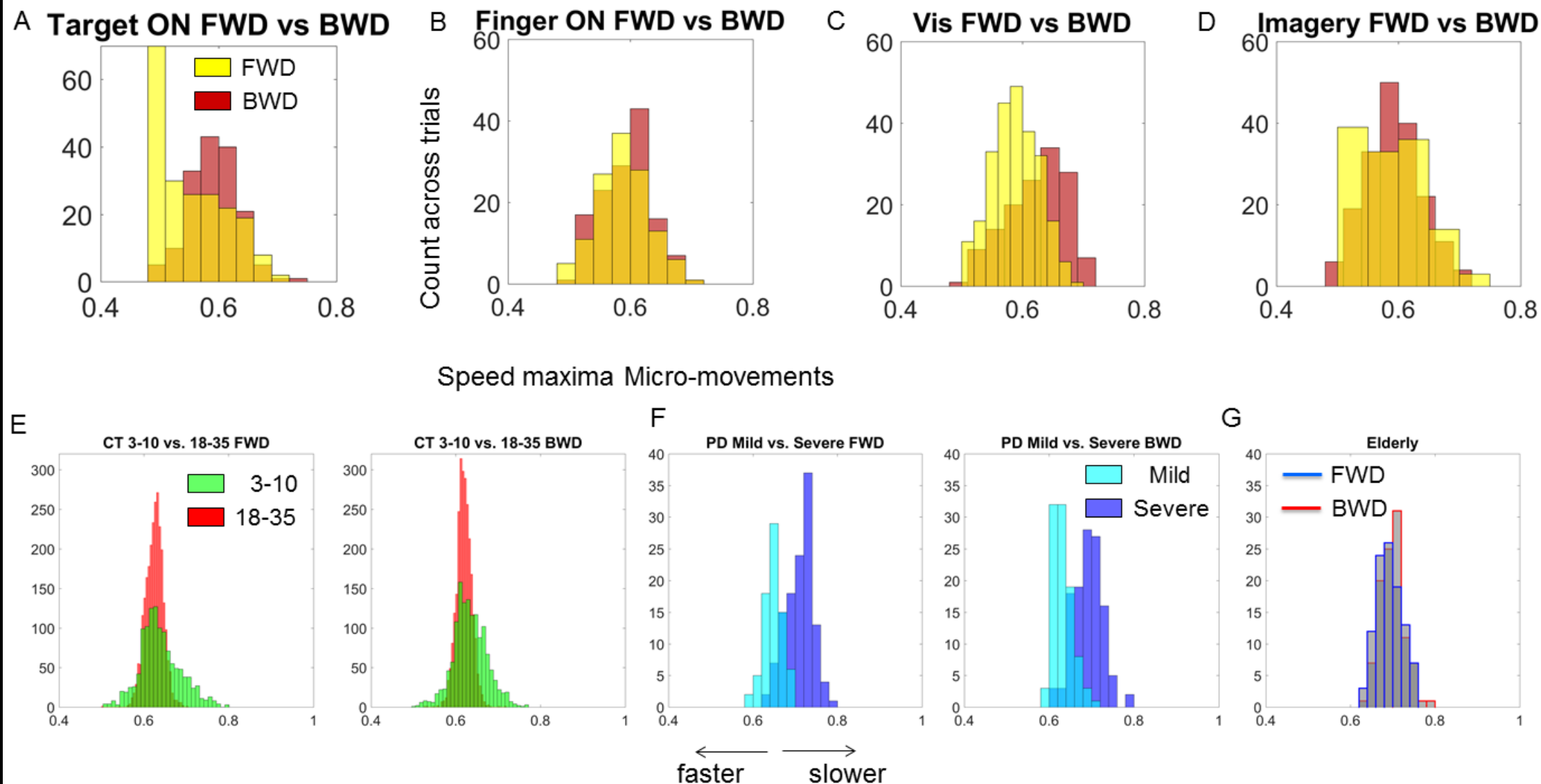
COMPARED TO PATIENTS WITH PD



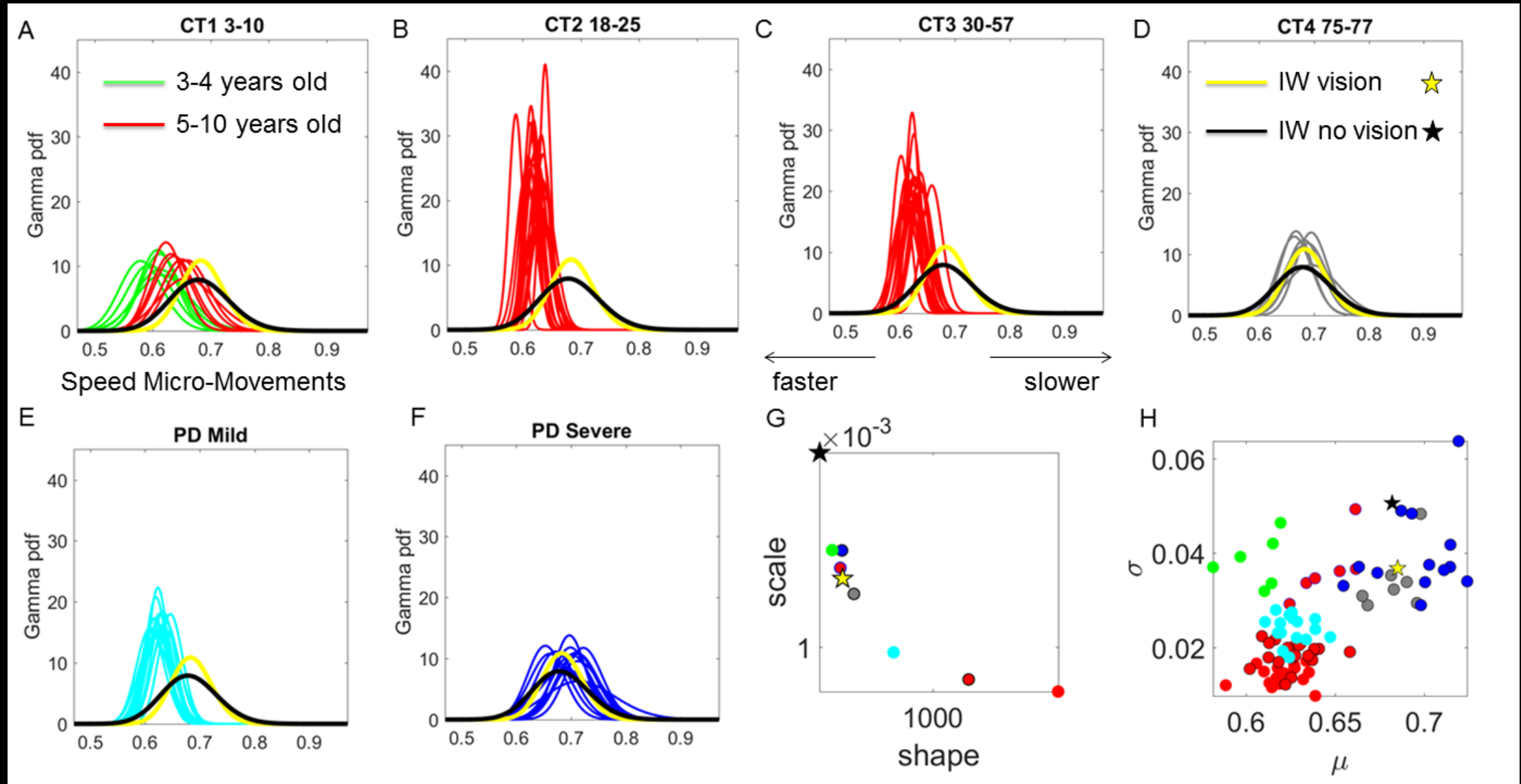
HAND MOTION TRAJECTORIES VISUAL GUIDANCE EFFECTS



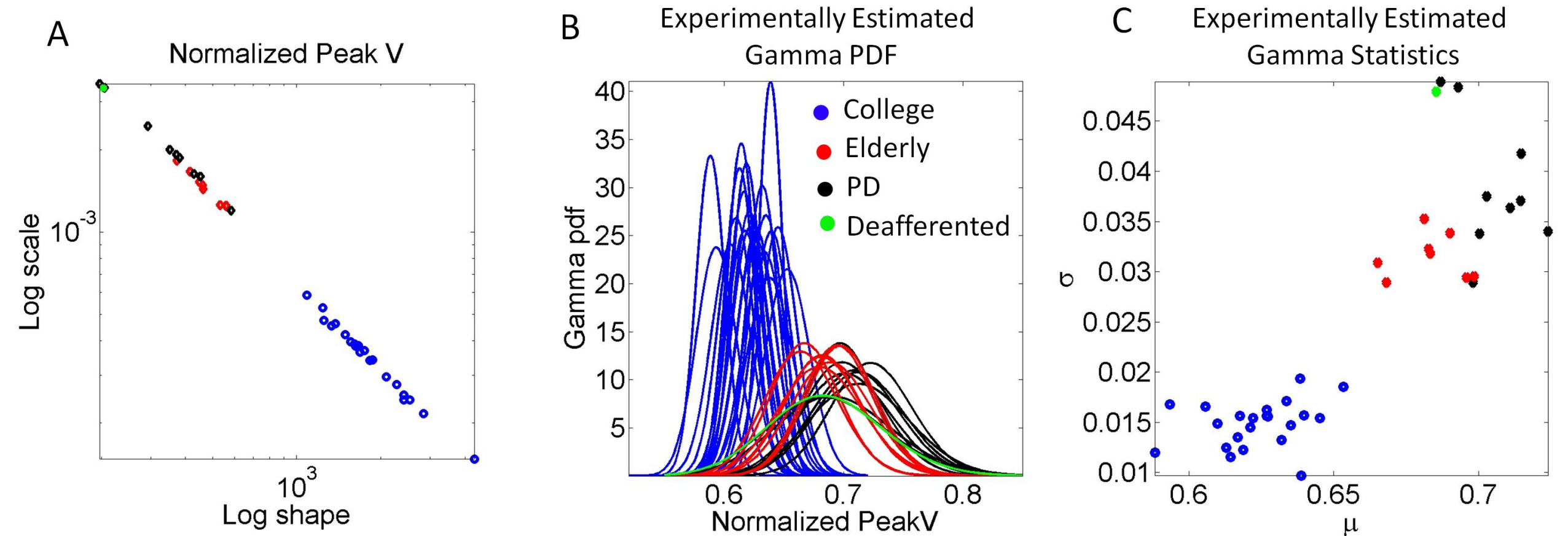
PROBING PREFERENCES: IW VS CONTROLS



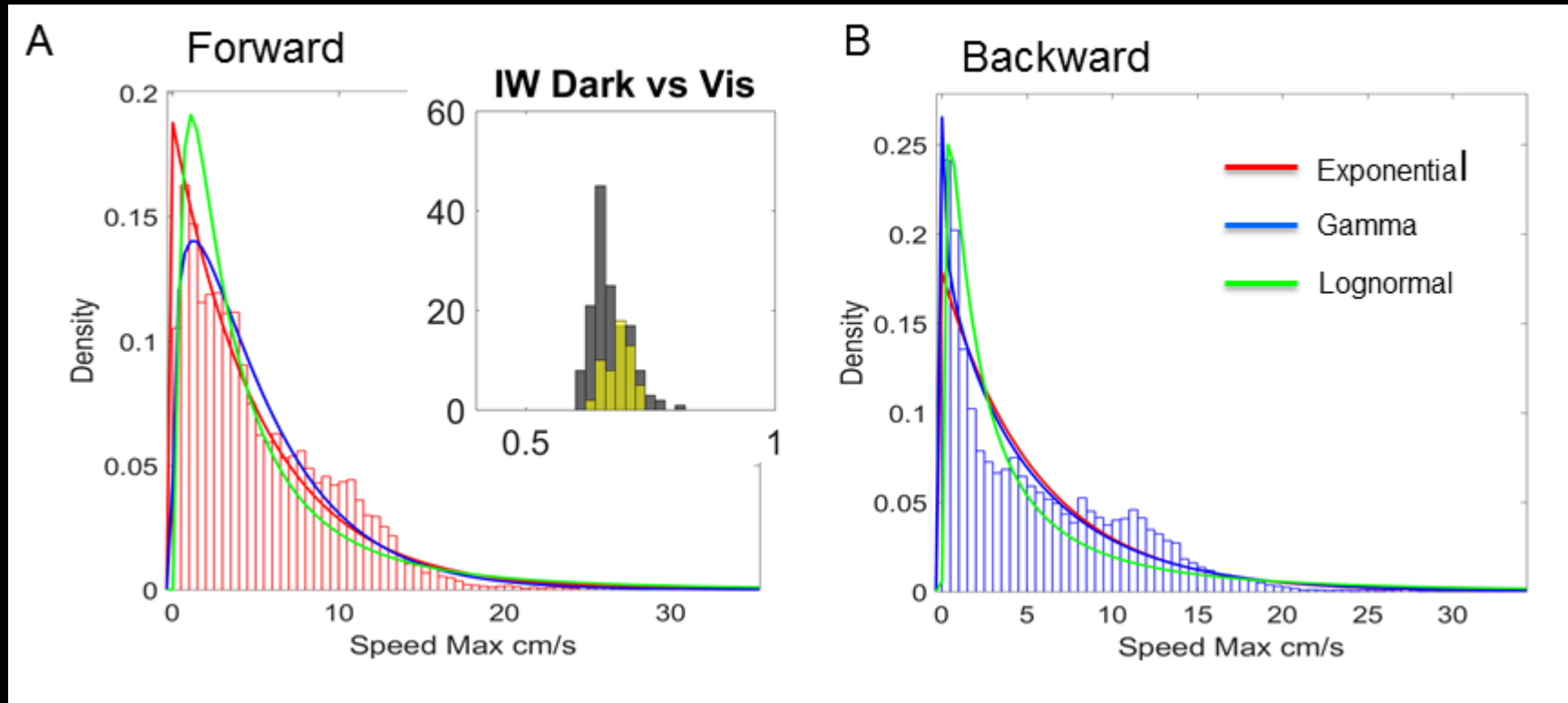
POPULATION POINTING STOCHASTIC SIGNATURES



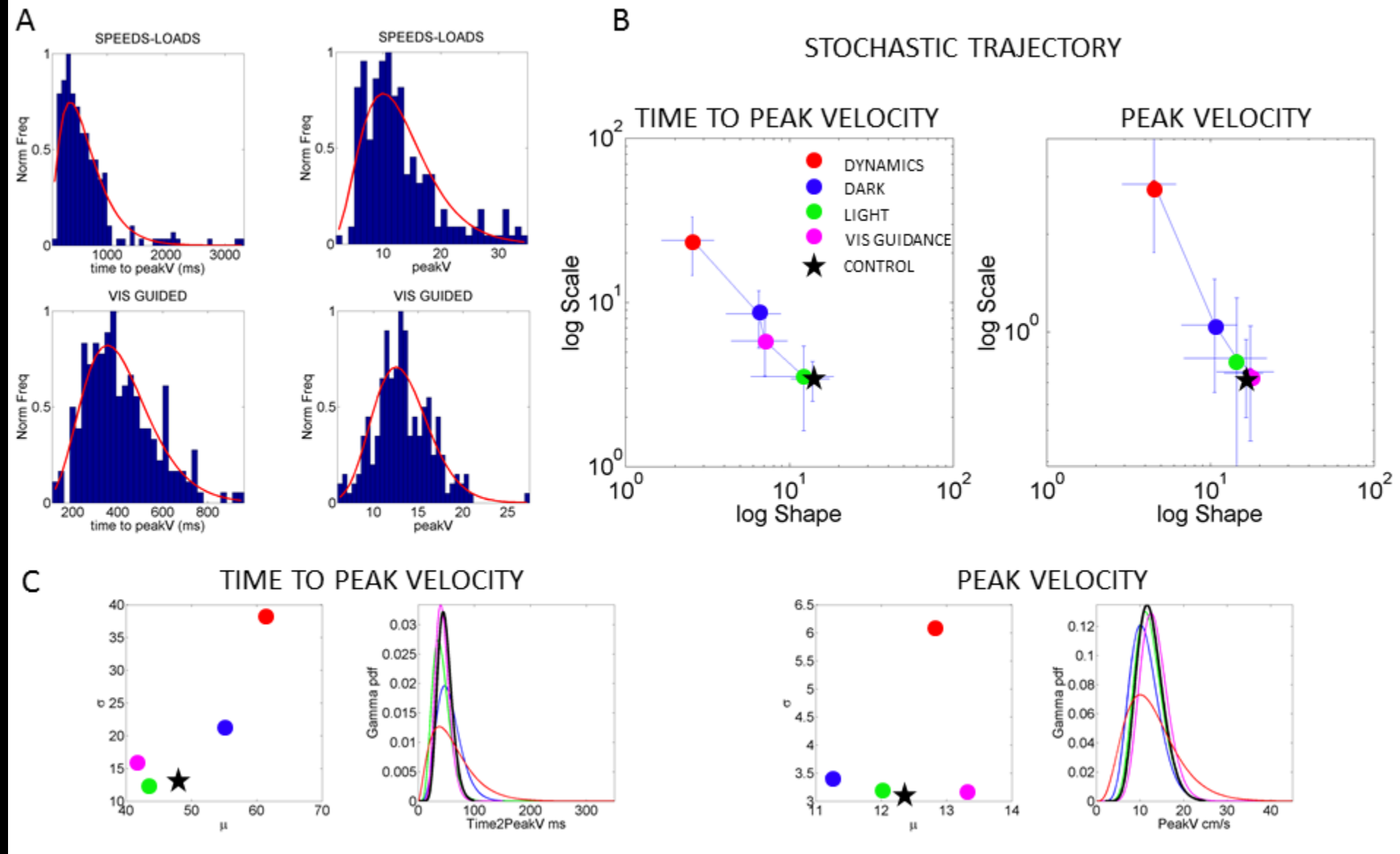
SPEED MAXIMA AS A NATURAL CLASSIFIER



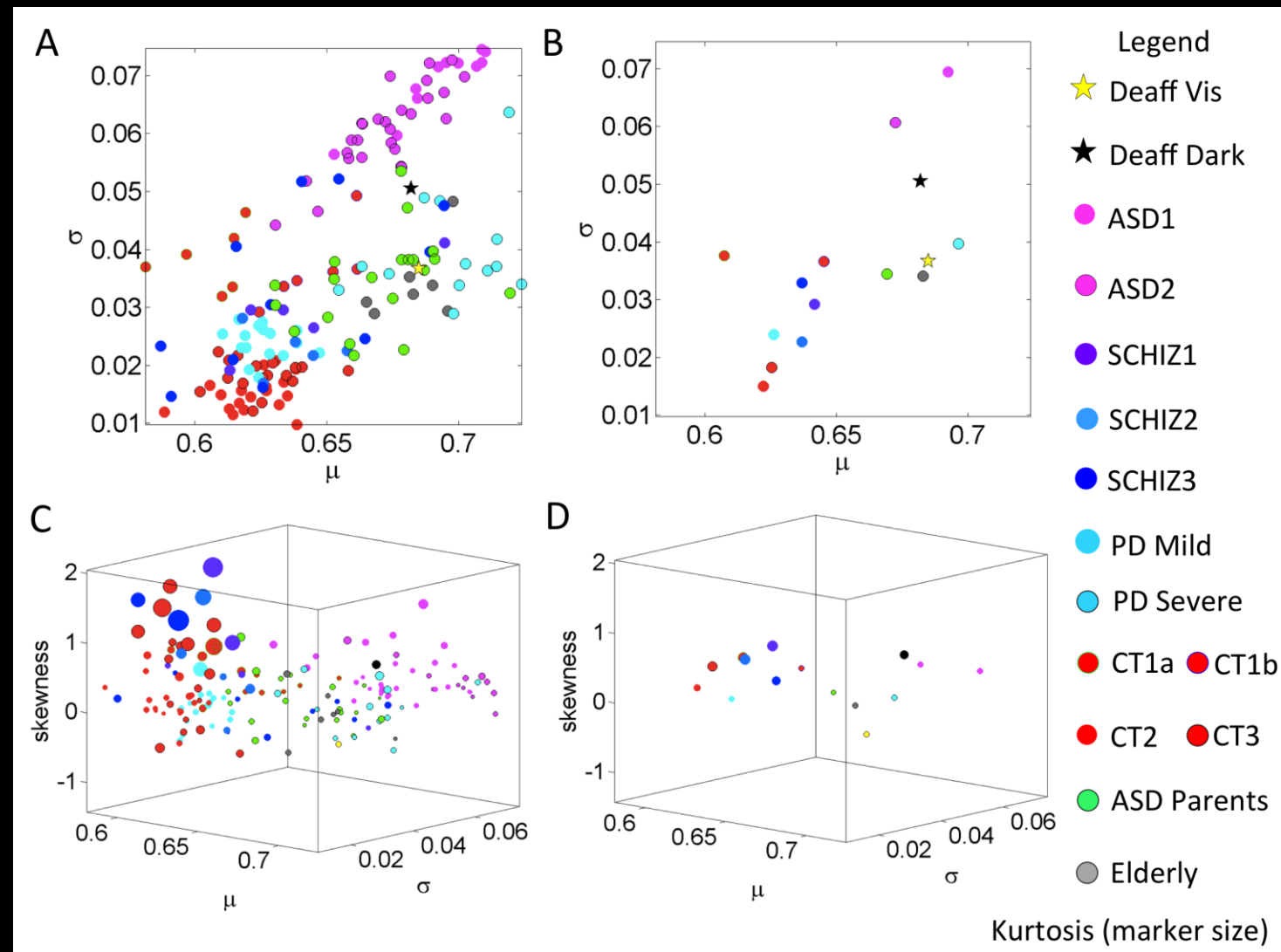
IAN WATERMAN MOTIONS UNDER SENSORY SUBSTITUTION



IAN WATERMAN SIGNATURES VS CONTROLS



APPLICATION: MAP OF NEUROLOGICAL DISORDERS



MENTAL INTENT VS PHYSICAL INTENT

Movement Intention After Parietal Cortex Stimulation in Humans

Michel Desmurget,^{1,2} Karen T. Reilly,^{1,2} Nathalie Richard,^{1,2} Alexandru Szathmari,³ Carmine Mottolese,³ Angela Sirigu^{1,2*}

Parietal and premotor cortex regions are serious contenders for bringing motor intentions and motor responses into awareness. We used electrical stimulation in seven patients undergoing awake brain surgery. Stimulating the right inferior parietal regions triggered a strong intention and desire to move the contralateral hand, arm, or foot, whereas stimulating the left inferior parietal region provoked the intention to move the lips and to talk. When stimulation intensity was increased in parietal areas, participants believed they had really performed these movements, although no electromyographic activity was detected. Stimulation of the premotor region triggered overt mouth and contralateral limb movements. Yet, patients firmly denied that they had moved. Conscious intention and motor awareness thus arise from increased parietal activity before movement execution.

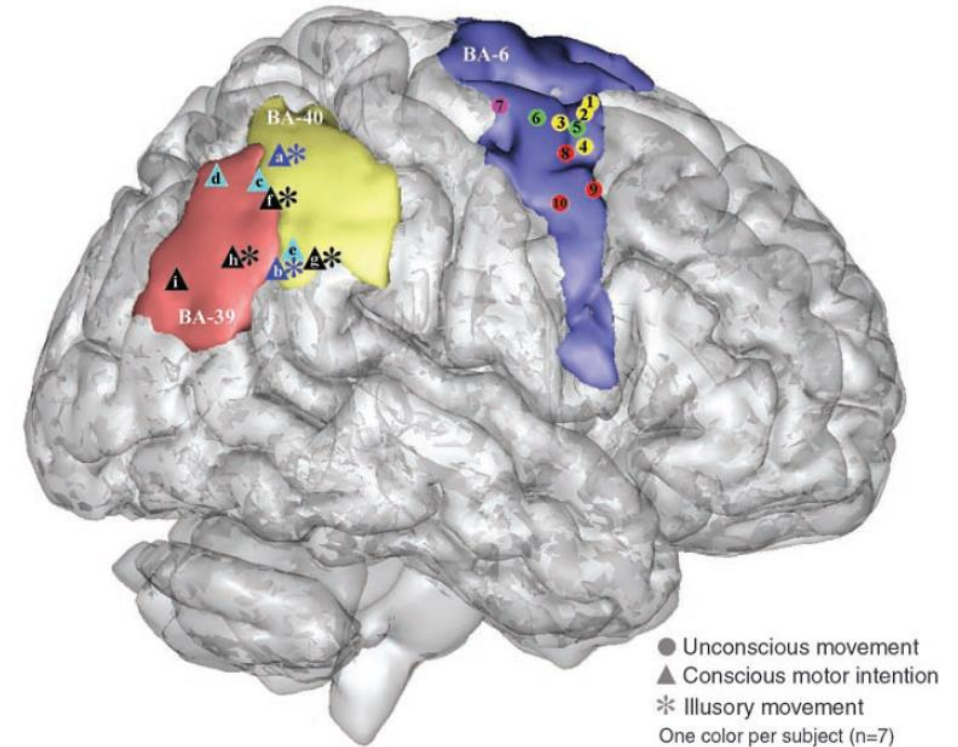


Fig. 1. Premotor and parietal responsive sites shown after registration of the individual MR image to the MNI template. Left stimulations have been reported on the right hemisphere. Colored areas define the anatomical boundaries of BA 40 (yellow), BA 39 (orange), and BA 6 (blue).

RESPONSES TO BRAIN (CORTICAL) STIMULATION

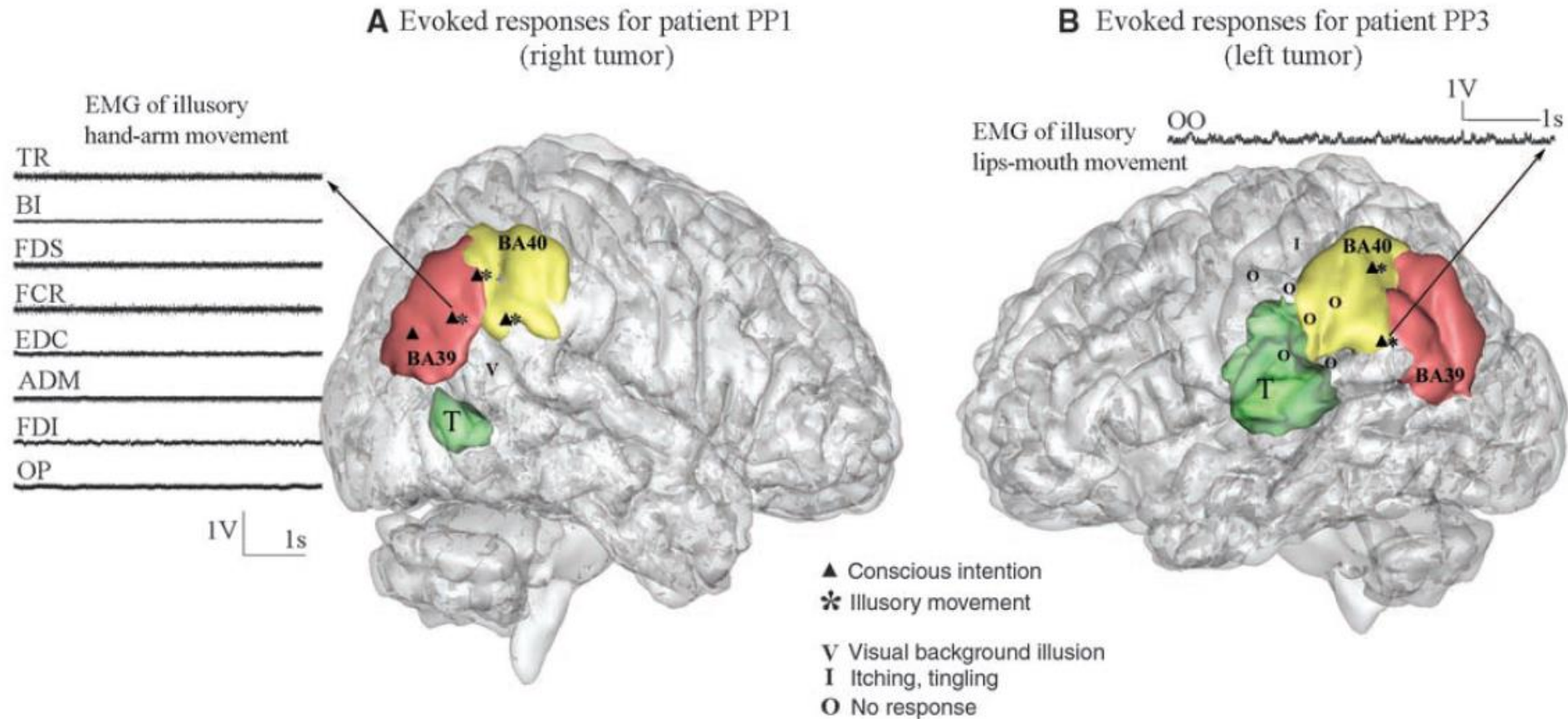
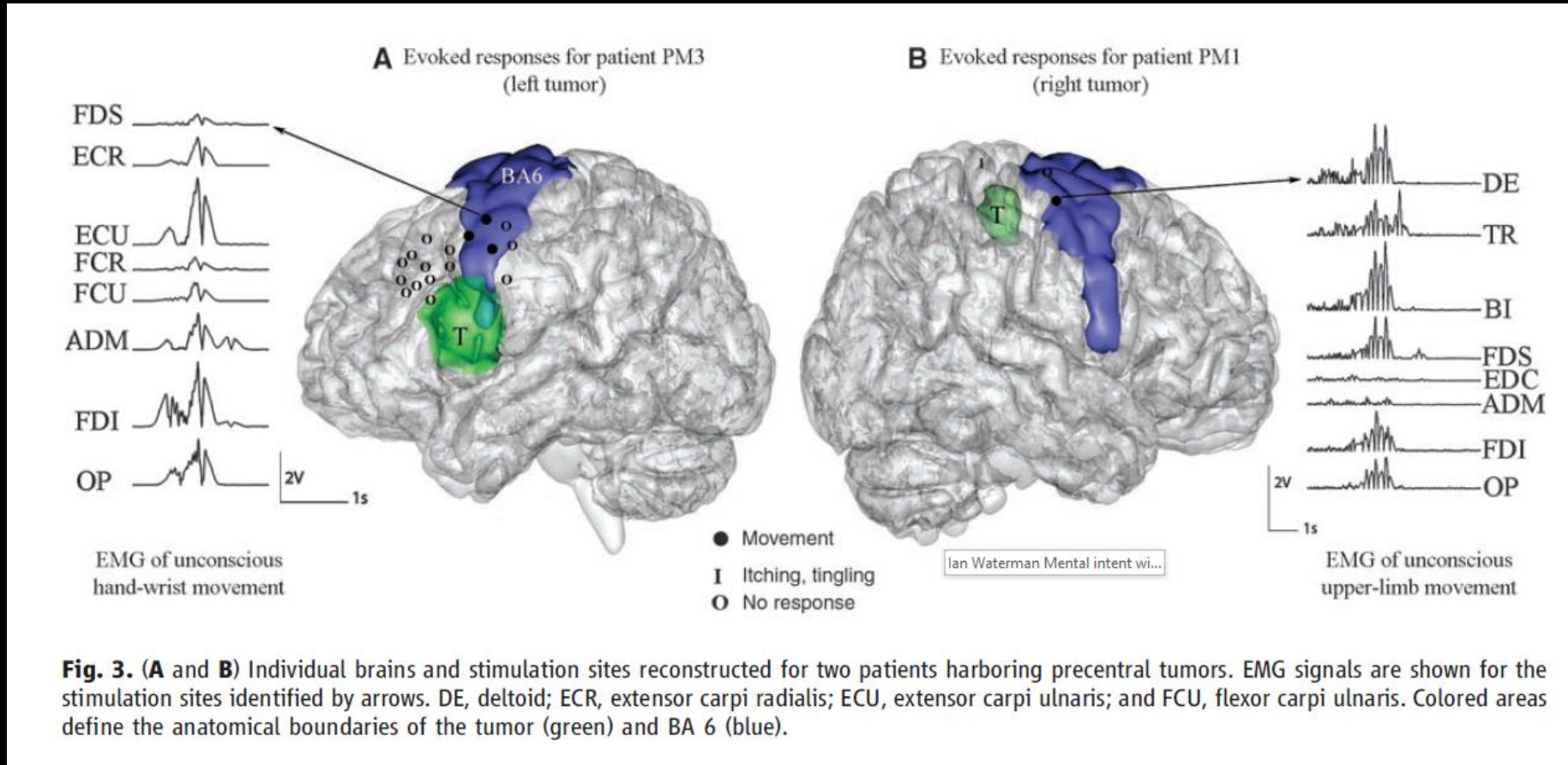


Fig. 2. (A and B) Individual brains and stimulation sites reconstructed for two patients harboring postcentral tumors. EMG signals are shown for the stimulation sites identified by arrows. T indicates tumor; TR, triceps; BI, biceps; FDS, flexor digitorum superficialis; FCR, flexor carpi radialis;

EDC, extensor digitorum communis; ADM, abductor digiti minimi; FDI, first dorsal interosseous; OP, opponens pollicis; and OO, orbicularis oris. Colored areas define the anatomical boundaries of the tumor (green), BA 40 (yellow), and BA 39 (orange).

EVOKED RESPONSES FROM BRAIN STIMULATIONS



Movement Intention After Parietal Cortex Stimulation in Humans

Michel Desmurget,^{1,2} Karen T. Reilly,^{1,2} Nathalie Richard,^{1,2} Alexandru Szathmari,³ Carmine Mottolise,³ Angela Sirigu^{1,2*}

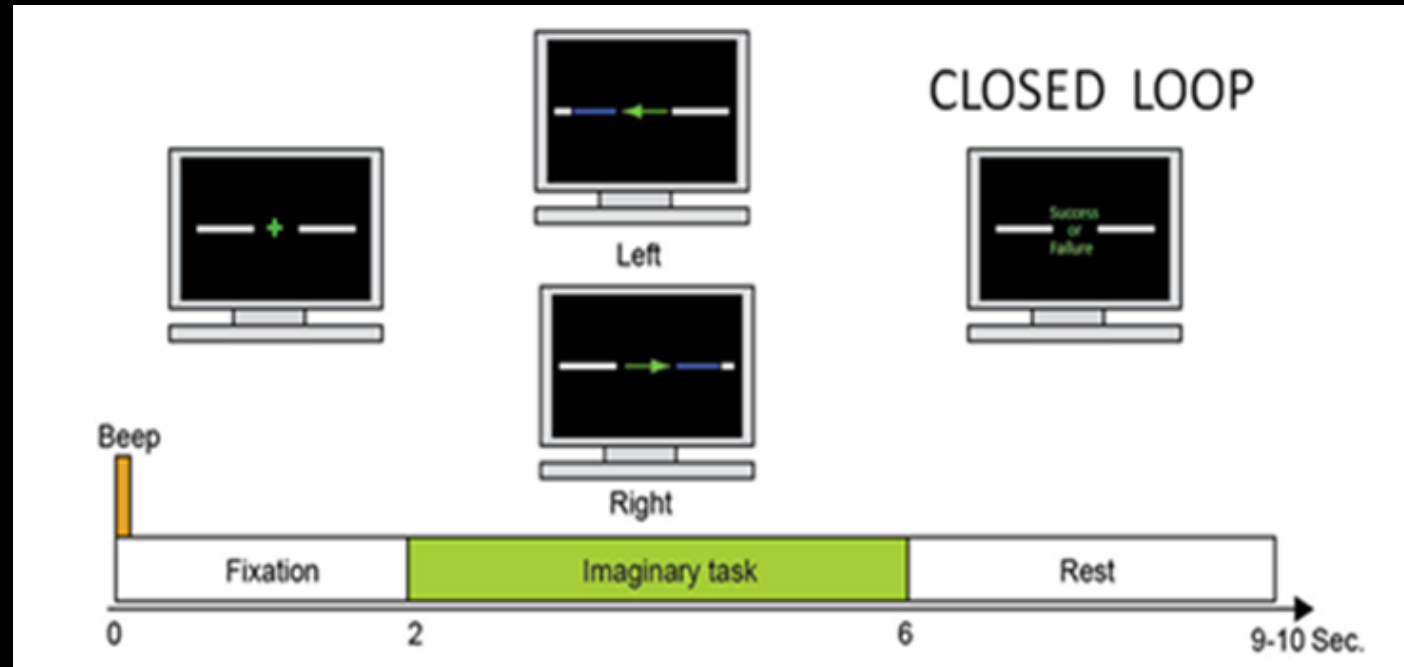
Our study suggests that motor intention and awareness are emerging consequences of increased parietal activity before movement execution. The subjective (and potentially illusory) feeling that we are executing a movement does not arise from movement itself, but it is generated by prior conscious intention and its predicted consequences.

WHAT ABOUT IAN WATERMAN'S MENTAL INTENT?

HOW IS MENTAL INTENT MANIFESTED IN THE BRAIN OF IW?

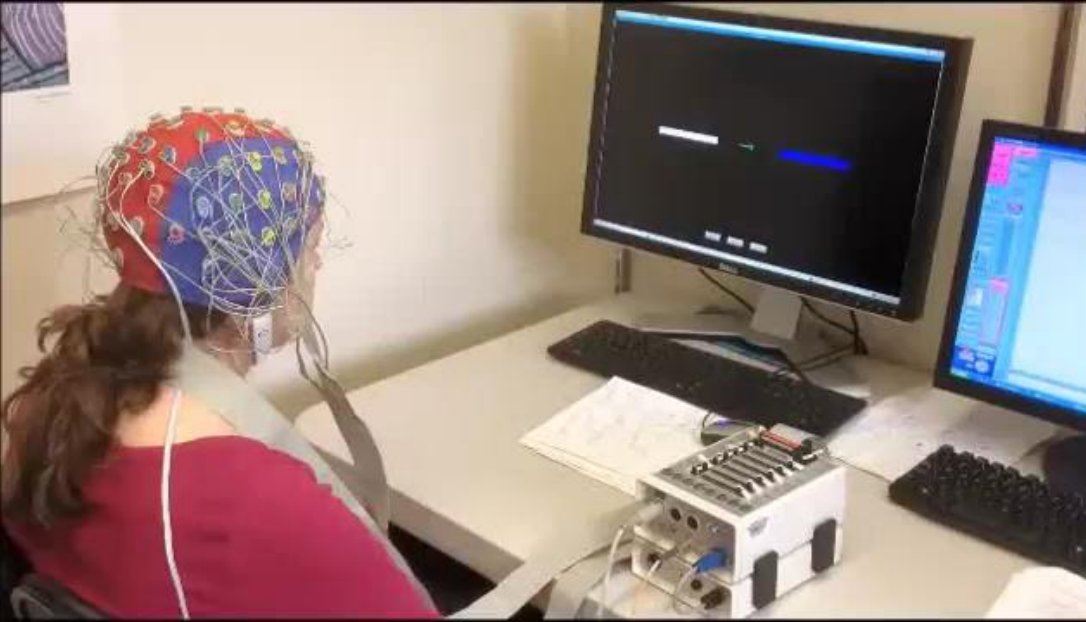
IAN WATERMAN

MENTAL INTENT WITHOUT KINESTHETIC REAFFERENCE



EEG - CLOSED LOOP BRAIN-MACHINE INTERACTIONS

INTENT IS AN ABSTRACT SIGNAL

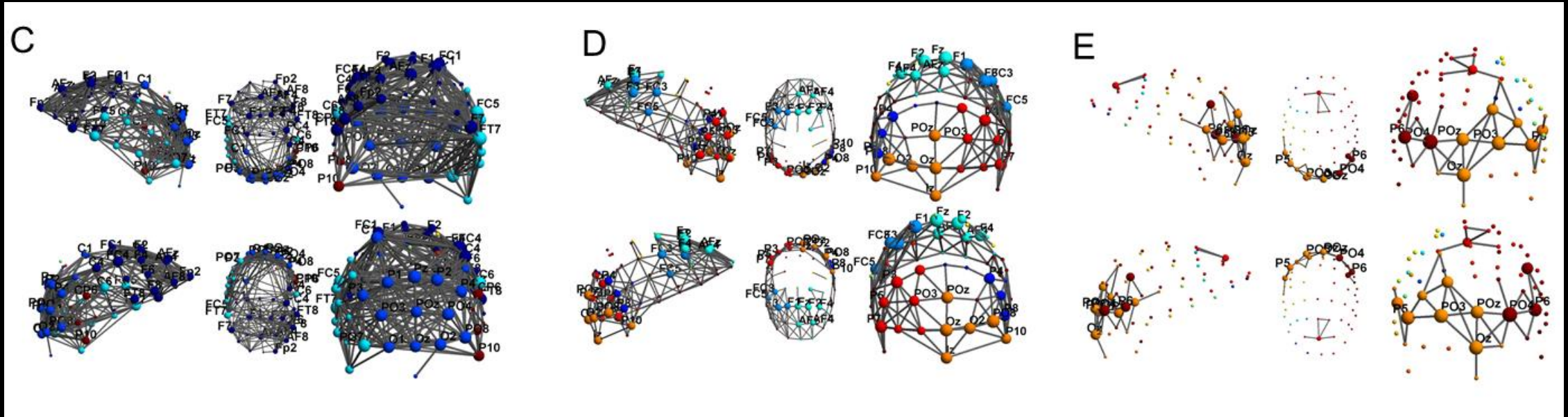


VISUAL-AUDITORY CONTROL: AUTOMATIC TRANSFER

AUTOMATIC TRANSFER OF INTENT TO AUDITORY DOMAIN



COGNITIVE EFFORT MEASURED THROUGH CONNECTIVITY MAPS



Ian Waterman

Biologist

Mathematician

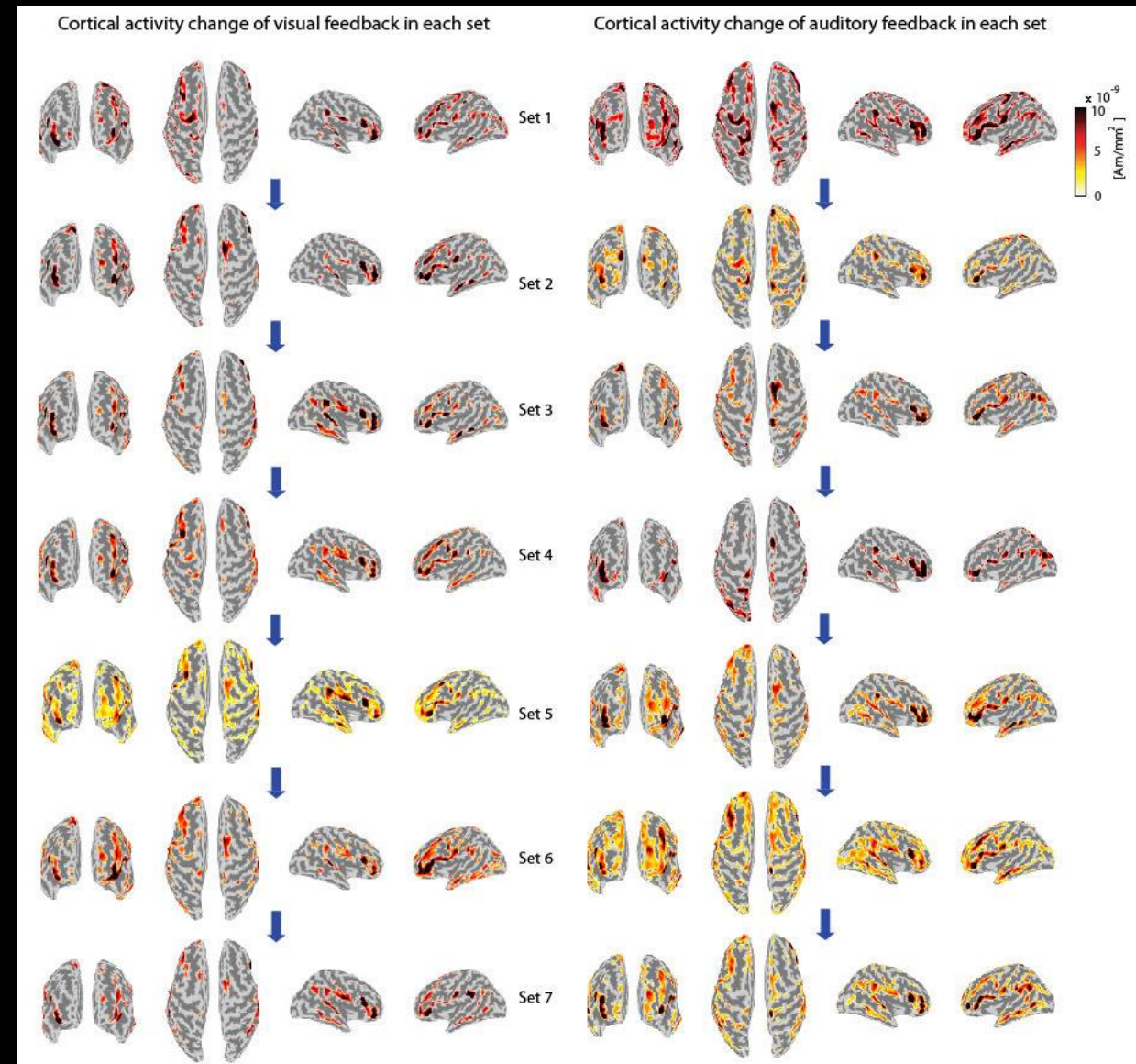
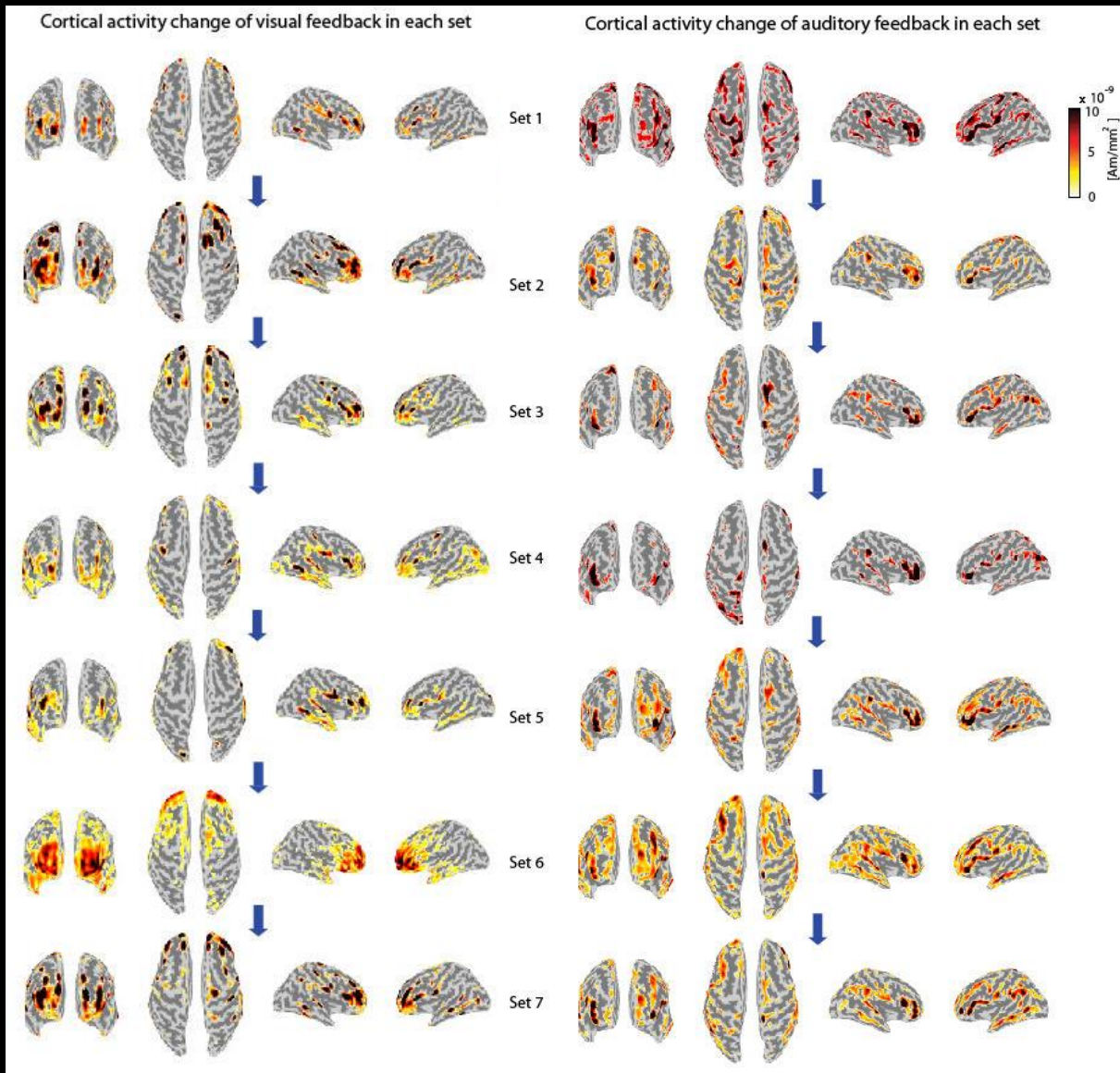
AUTOMATIC TRANSFER OF INTENT FROM VISUAL TO AUDITORY – IN DEAFFERENTED PARTICIPANT IW



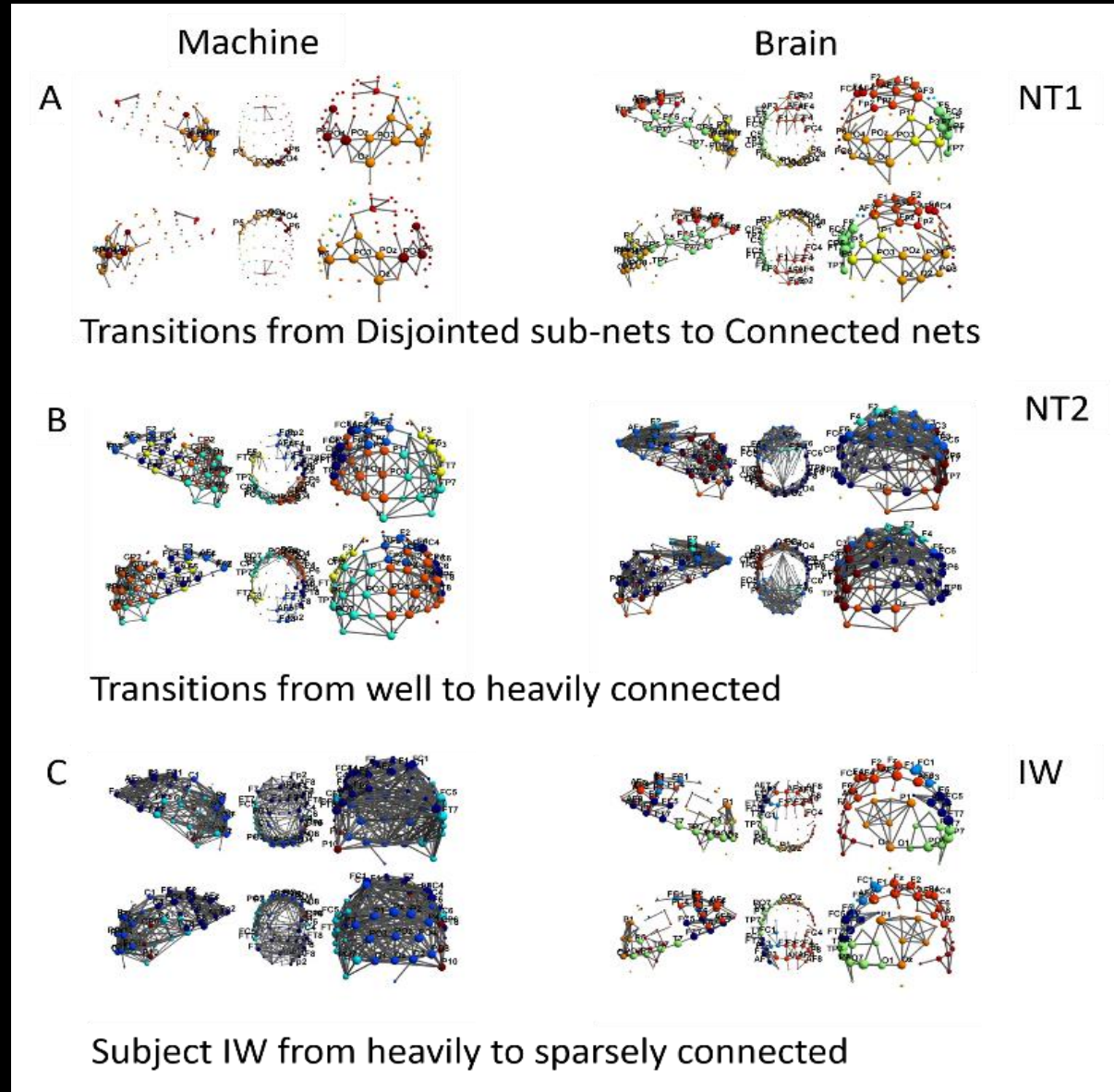
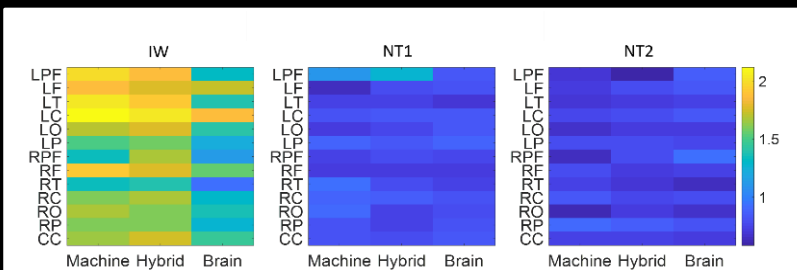
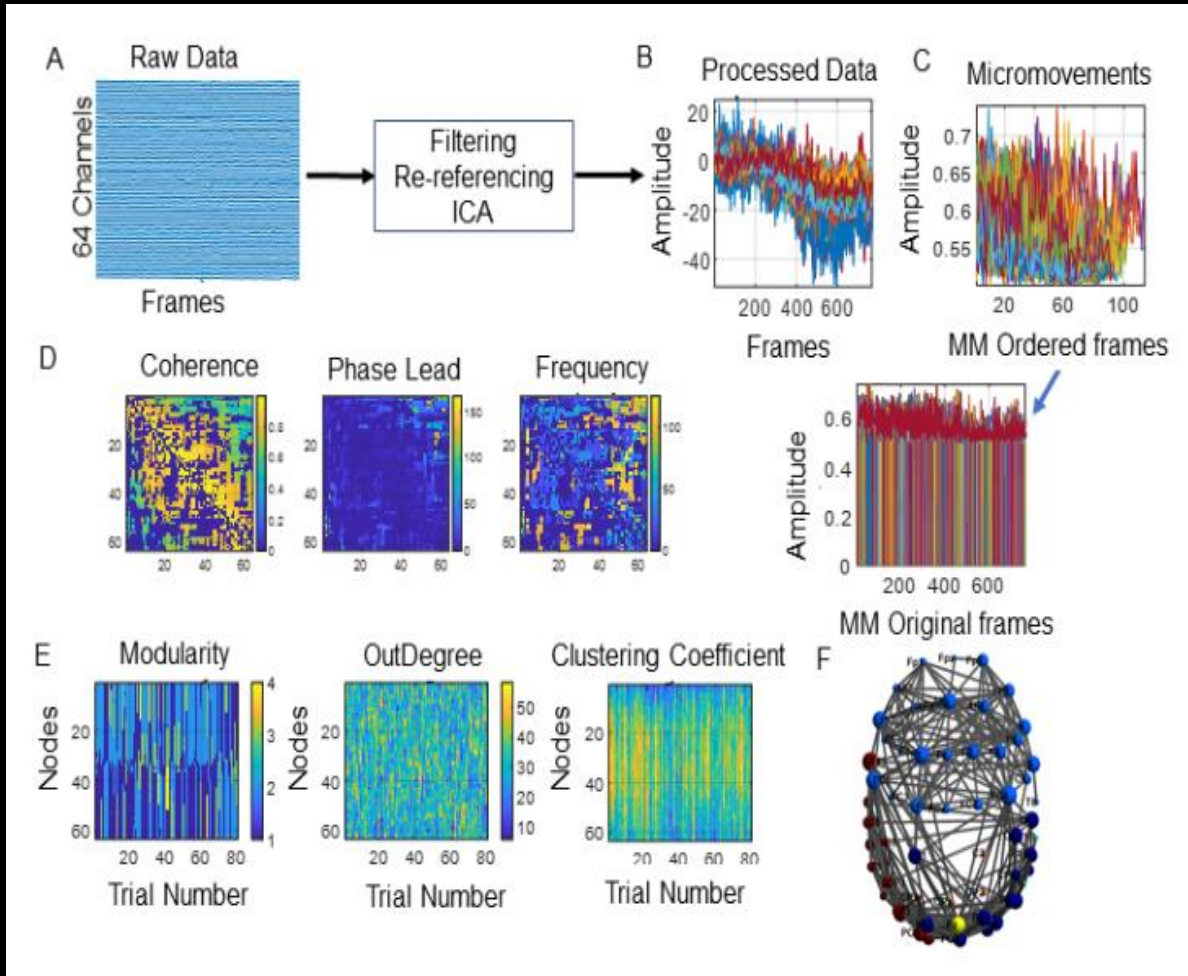
CORTICAL ACTIVITY SHIFTS

CONTROLS

IW



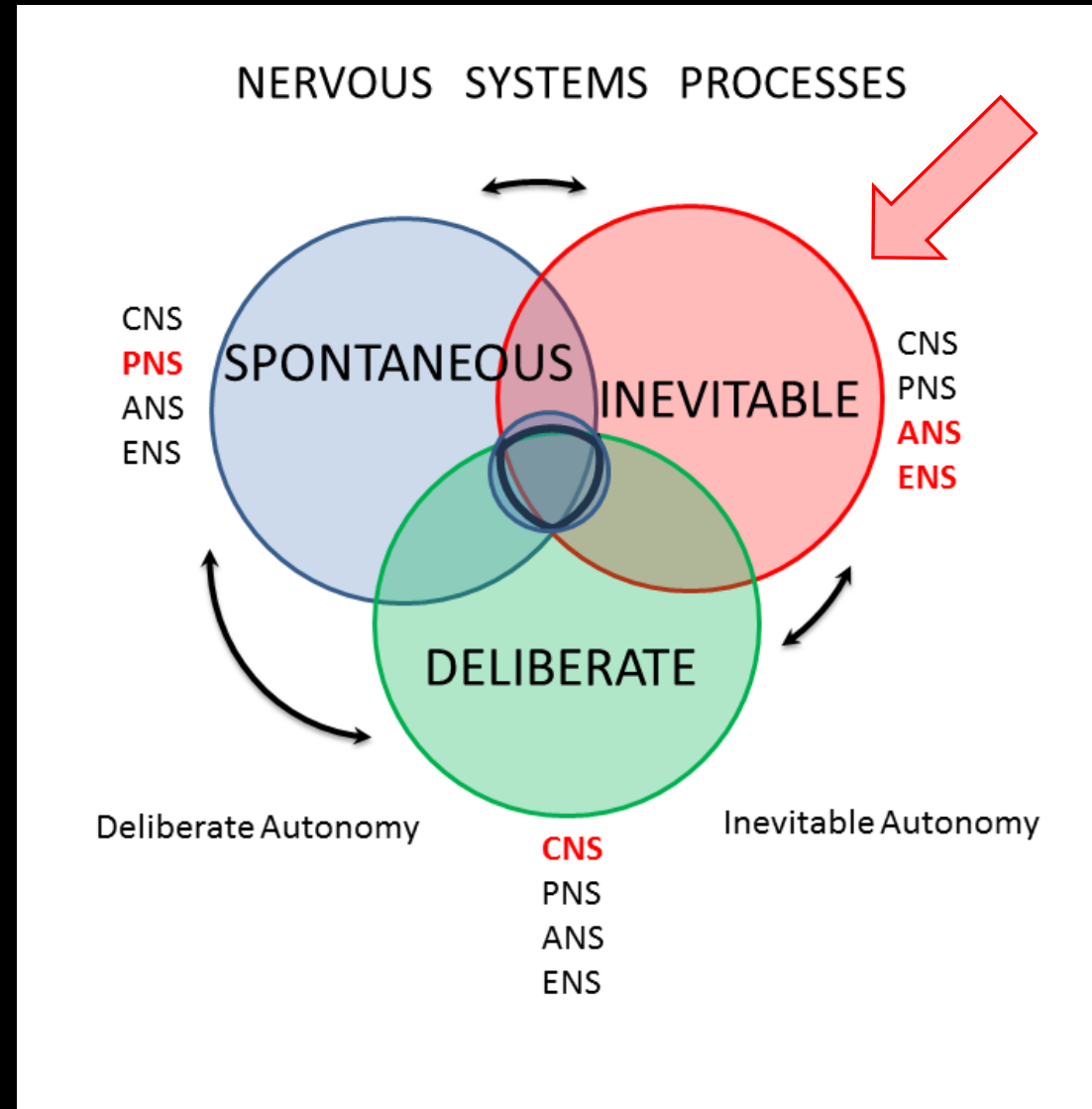
EVOLUTION OF MENTAL INTENT IN BCI - NEUROFEEDBACK



SUMMARY

- Intent is quantifiable in mental activity
- Intent is abstract and transfers across senses
- Physical intent is separable from Mental intent (deafferentation, absence of movement, pressure and touch feedback but pain temperature present)
- How to differentiate intentional physical action from unintended acts?
- Is motor reafference separable from pain-temperature reafference?

CHARACTERIZING INTENT THROUGH DIFFERENT TYPES OF PROCESSES



A THIRD TYPE OF OUTCOME: THE INEVITABLE



NEXT CLASS: SEPARATING INTENT IN AUTONOMIC SIGNALS FROM INTENT IN KINEMATICS SIGNALS

The screenshot shows the MDPI website interface. At the top, there's a navigation bar with links for Journals, Information, Author Services, Initiatives, and About, along with Sign In / Sign Up and Submit buttons. Below this is a search bar with fields for Title / Keyword, Author / Affiliation, Journal of Personalized Medicine, and All Article Types, with Search and Advanced buttons. The breadcrumb trail indicates the article is in Journals / JPM / Volume 10 / Issue 3 / 10.3390/jpm10030076. On the left sidebar, there's the Journal of Personalized Medicine logo and buttons for Submit to this Journal, Review for this Journal, and Edit a Special Issue. Below this is an Article Menu with links to Abstract, Open Access and Permissions, Share and Cite, and Article Metrics. The main content area displays the article title 'The Autonomic Nervous System Differentiates between Levels of Motor Intent and End Effector' by Jihye Ryu and Elizabeth Torres. It includes their affiliations, a note about correspondence, the journal citation 'J. Pers. Med. 2020, 10(3), 76; https://doi.org/10.3390/jpm10030076', and the publication timeline: Received: 25 May 2020 / Revised: 28 July 2020 / Accepted: 28 July 2020 / Published: 31 July 2020. A note at the bottom states the article belongs to the Special Issue 'Precision Medicine in Neurodevelopmental Disorders: Personalized Characterization of Autism from Molecules to Behavior'. On the right, there are social sharing icons.

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The Autonomic Nervous System Differentiates between Levels of Motor Intent and End Effector

by Jihye Ryu¹ and Elizabeth Torres^{2,*}

¹ Psychology Department, Rutgers University Center for Cognitive Science, Rutgers University, Piscataway, NJ 08854, USA

² Psychology Department, Rutgers University Center for Cognitive Science, Computational Biomedicine Imaging and Modeling Center at Computer Science Department, Rutgers University, Piscataway, NJ 08854, USA

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J. Pers. Med. **2020**, *10*(3), 76; <https://doi.org/10.3390/jpm10030076>

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