Apraxia
Neurology, Neuropsychology and Rehabilitation

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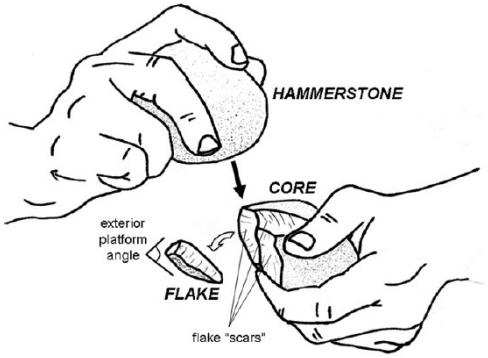
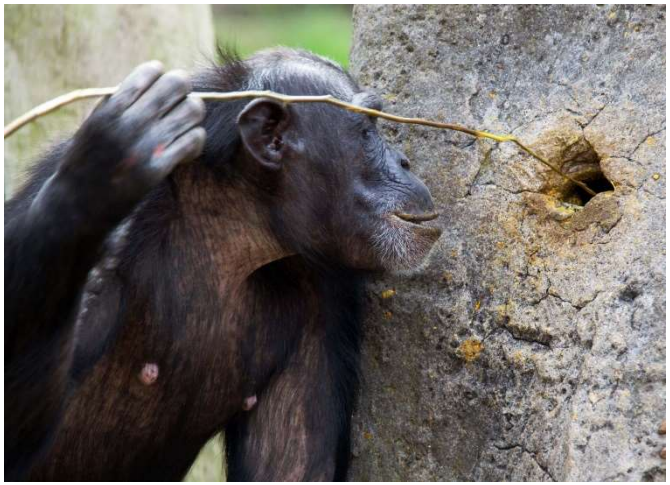
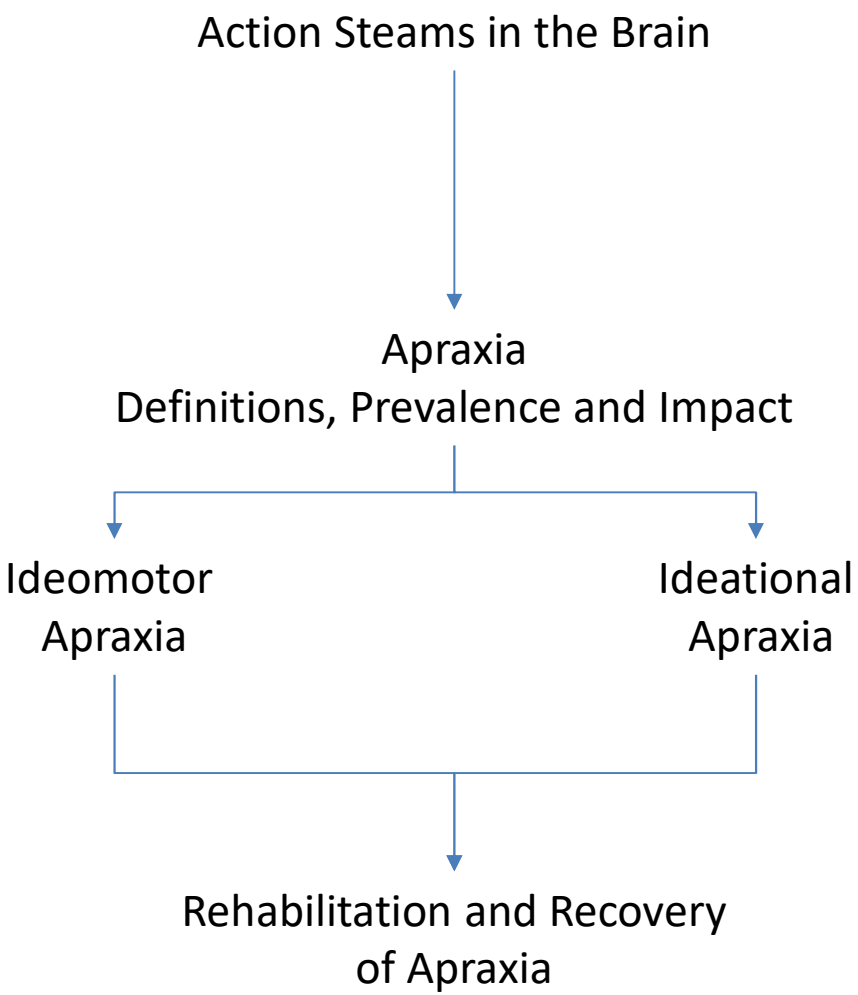
Tool Use



D. Stout, T. Chaminade / Neuropsychologia 45 (2007) 1091–1100

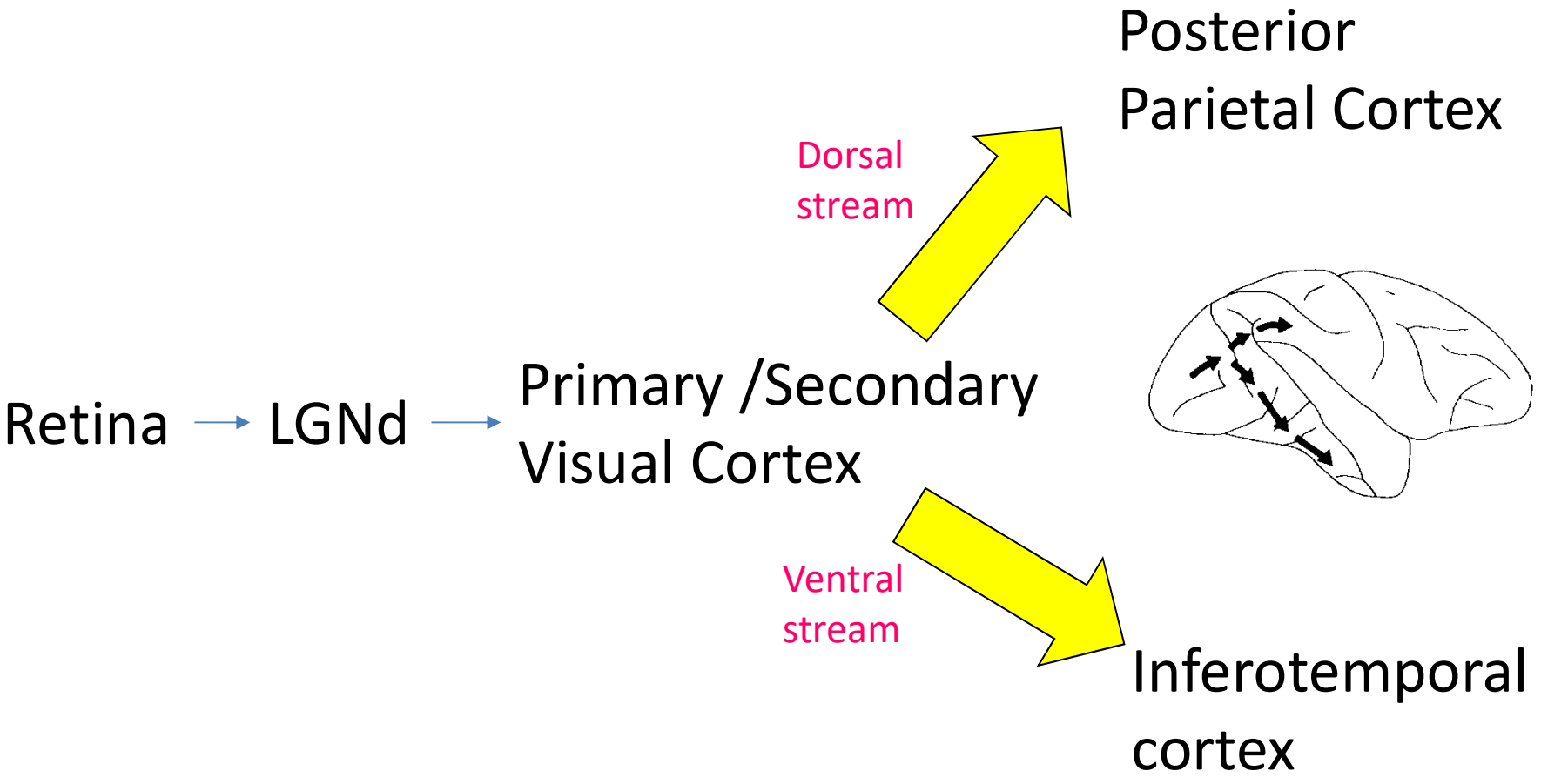


http://www.bradshawfoundation.com/origins/oldowan_stone_tools.php


Action Steams in the Brain
Apraxia
Definitions, Prevalence and Impact
Ideomotor
Apraxia
Ideational
Apraxia
Rehabilitation and Recovery
of Apraxia

Action Streams in the Brain

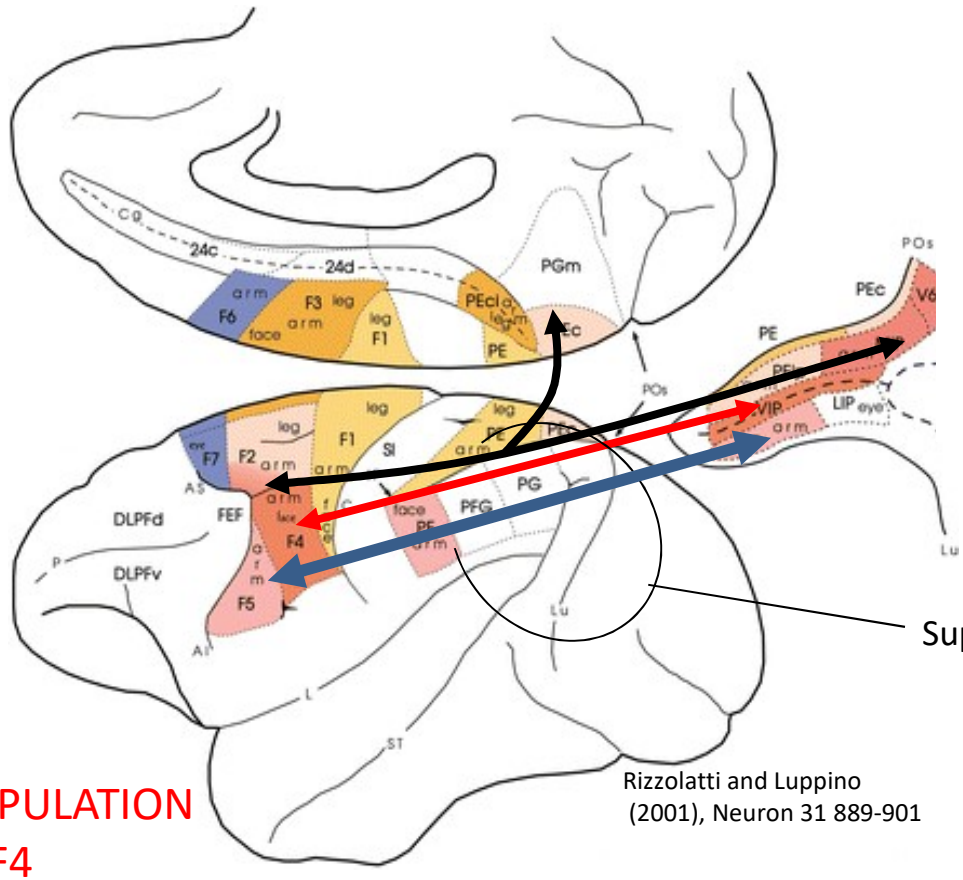
What and How in the Visual System



Goodale et al (1996) In Hand and Brain.

Visuomotor Control

REACHING
PE-F2
Directional
Coding to objects
In extra-personal
Space



Superior Longitudinal Fasciculus

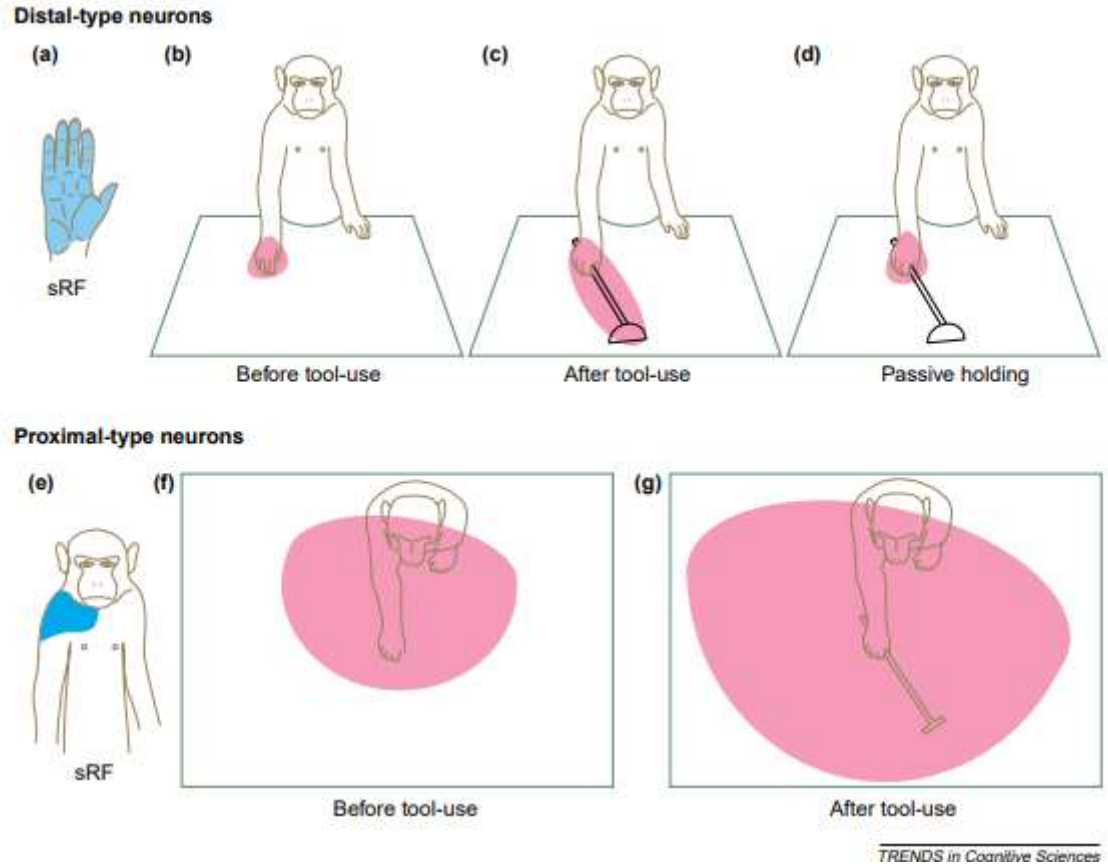
Rizzolatti and Luppino
(2001), Neuron 31 889-901

GRASPING
AIP-F5
Transforming visual
intrinsic
Object attributes into
Motor commands

TOOL MANPULATION
VIP-F4
Bimodal receptive fields
RF altered by tool use

Sensorimotor Transformation
in Parieto-Frontal Circuits

Modification of Body Schema by Tools



Visual receptive Field

Somatosensory Receptive Field

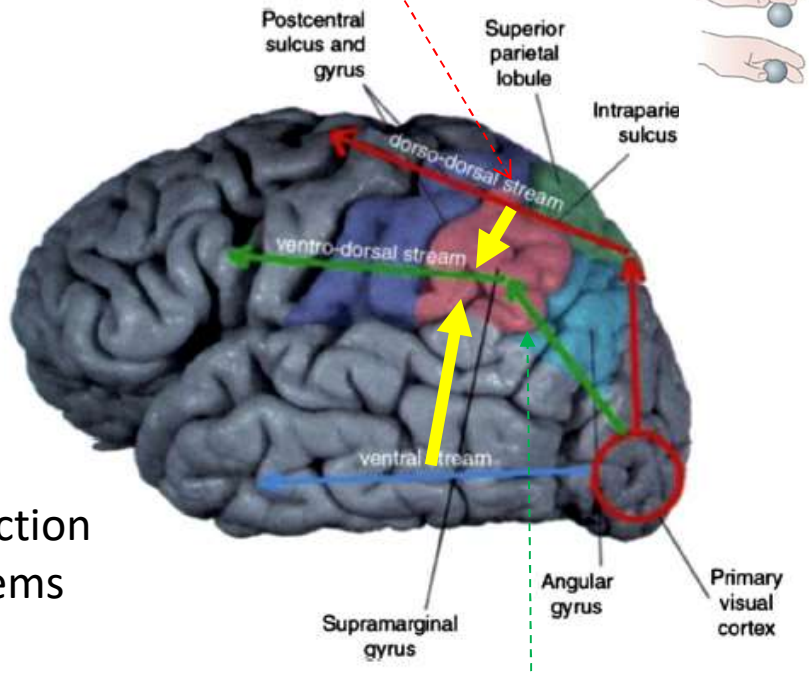
Inter-parietal Neurons

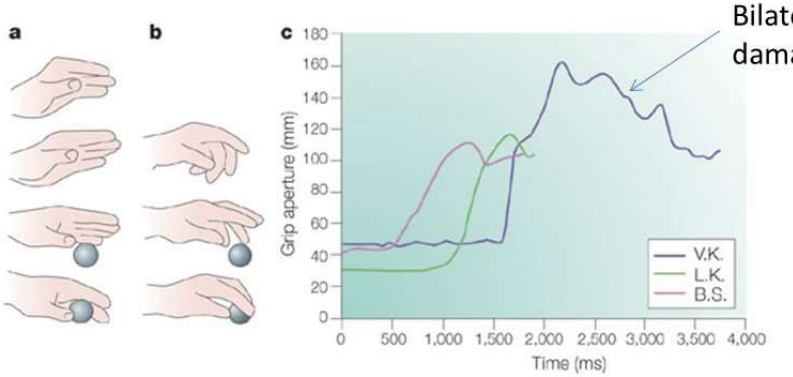
Maravita and Iriki 204 TICS 79-86

Action Streams in the brain

Bilateral Dorso-dorsal system

"Grasp" (actions to visual targets)



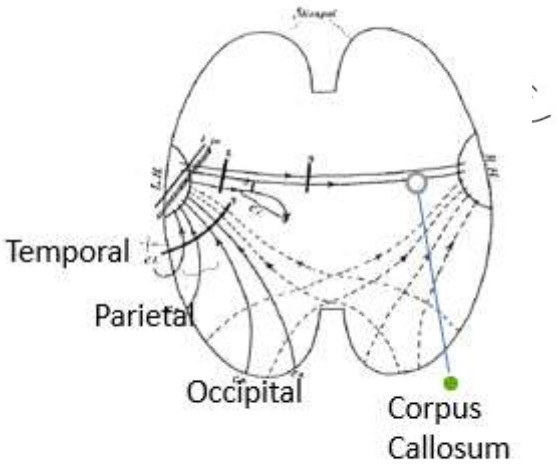


Bilateral occiptoparietal damage

X2 action systems
Vs
ventral and dorsal stream Interaction

Left lateralised Ventrodorsal system

"Use" devoted to skilled functional object use



Adapted from Liepmann 1920

Binkofski et al 2013 Brain and Language 127 22-229

Sirigu et al 1995 Cortex 31 41-55

What Is Apraxia
Definitions, Prevalence and Impact

What is Apraxia?

A disorder of skilled movement characterized by:

- an inability to perform purposeful skilled movements
- an inability to pantomime and/or imitate gestures
- difficulties in recognizing actions
- Not due to weakness, incoordination, somatosensory loss, or by poor comprehension of or inattention to commands

Bienkiewicz et al 2014 Front Psychol 23 353

What is Apraxia?: Prevalence

Stroke

25% all strokes

28-51% of left hemisphere lesions

6% Right hemisphere lesions

Can see with subcortical stroke

Zwinkels et al 2004
Donkervort et al 2000

Multiple Sclerosis

26.3% associated with EDSS / Progressive Forms

Kamm et al 2012

Parkinsons Disease & MSA

27% in PD

MSA: apraxia related to cognitive decline

Uluduz et al 2010

Corticobasal Degeneration

Severe Apraxia

Related to atrophy of pre-motor and parietal Cortex

Burrell et al 2014

Alzheimers Dementia

35% mild, 58% moderate,

98% severe dementia

Edwards et al 1991

What is Apraxia?: Impact

Poor Prognostic Indicator Post Stroke

Symptoms of Ideomotor Apraxia often less when using an object (somatosensory feedback and affordances)

Dexterity problems (eg using/learning to use utensils) higher in apraxics

Gesture imitation associated with errors (accuracy; spatiotemporal) in dexterity tasks

Gesture imitation deficit associated with carer dependency

Gesture imitation important if aphasic

Sunderland and Shinner 2007
Bienkiewicz et al 2014

Wu et al Top Stroke Rehabil 2014 21
211-219

What is Apraxia?: Impact

"Bodily characteristics typical of the apraxia experience".
The Subjective View of Apraxia

- Gap between intention and bodily action
- Fragmented awareness in action
- Peculiar actions and odd bodies
- Intentionality on the loose
- Fighting against tools.

Amtsen and Elstad 2013

Sunderland and Shinner 2007

HUGO LIEPMANN

What is Apraxia?

Ideomotor
Problems with
pantomime and /or imitation
+/- Tool Use

Ideational
Difficulties with conceptual
knowledge of tools
(aka Conceptual apraxia)

Difficulties with sequences
(aka action
disorganisation syndrome)

Bienkiewicz et al 2014 Front Psychol 23 353

Apraxia

Production Component

Space Time representation
Of an action

Ideomotor Apraxia
Spatiotemporal abnormalities in
Gestural pantomime and imitation

Crutch, 2005 ACNR V 5 165-17

Conceptual Component

Semantic Knowledge of Tools and actions

Inference of Function from Structure

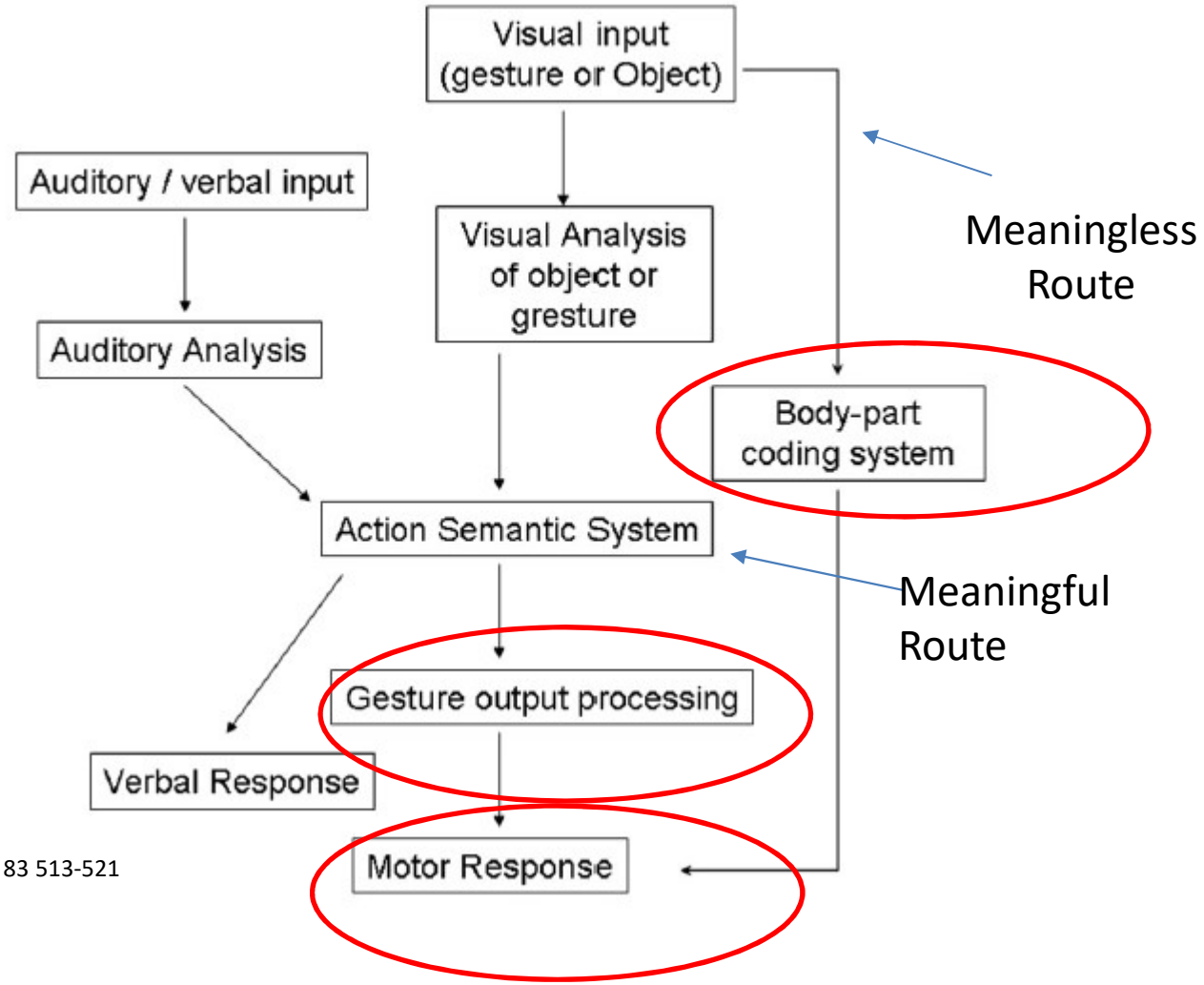
Knowledge of organisation of single actions into a sequence

Ideational / Conceptual Apraxia
Content Errors

Goldenberg and Hagmann 1998 Neurosychologia 3(7) 581-589

Stamenova et al 2011; De Rfenzi et al 1988

Apraxia:
A model of Cognitive Processing



Bikerton et al 2012 JNNP 83 513-521

Stamenova et al 2012

Ideomotor Apraxia:

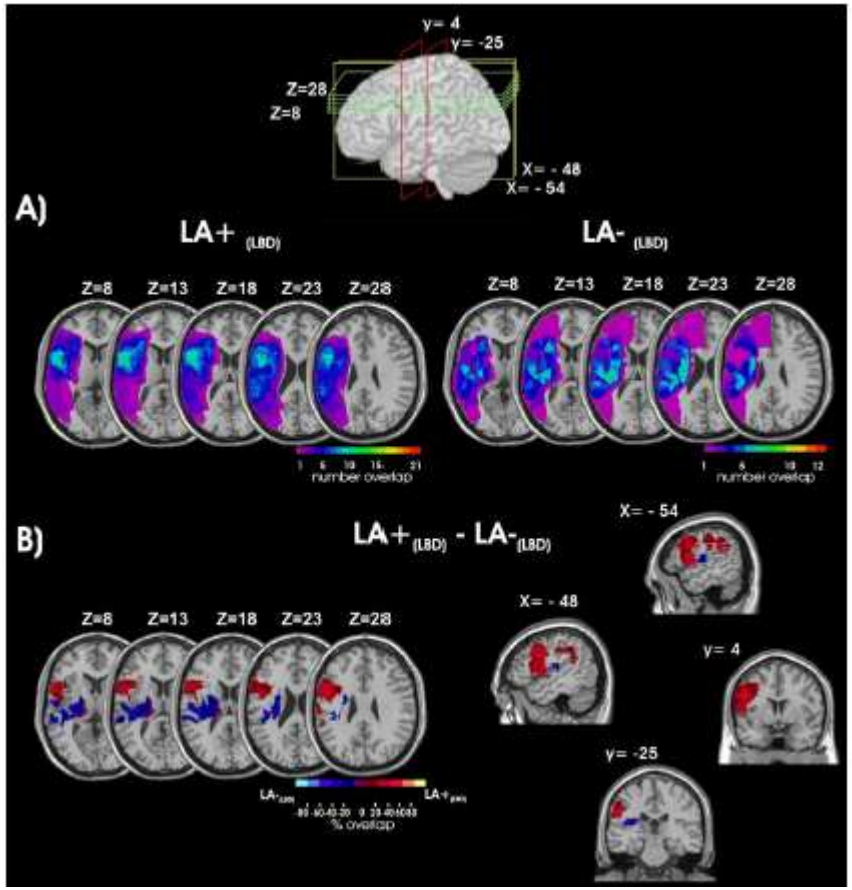
Planning the Right Movement

Ideomotor Apraxia: Lesion Location

LA+ = has limb apraxia LA- Does not have limb apraxia

Areas of Lesion Overlap

Difference between LA+ AND LA- groups



Left
Inferior Parietal cortex

Inferior Frontal cortex

Pazzaglia et al 2008 J Neuroscience 28 3030

Ideomotor Apraxia: Testing

Name patient: **Test date:**
Name examiner:
Diagnosis (incl. lesion localization):

Imitation
General instruction: "Seven gestures are demonstrated in a mirror fashion, imitate them as precisely as possible"

	right	left
1. Bring thumb extended on forehead, other fingers point upwards		
2. Wipe dust from shoulder		

Additional instruction: "For the next five gestures, imagine holding a tool or an object in hand, don't use your fingers as a tool"

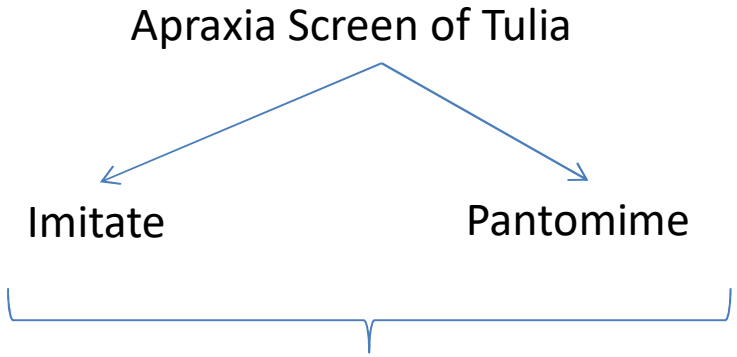
3. Drink from a glass		
4. Smoke a cigarette		
5. Use a hammer		
6. Use scissors		
7. Use a stamp to postmark		

Pantomime
General instruction: "Now gestures are asked. Listen very carefully and perform them as precisely as possible"

8. "Show as if someone is crazy" *		
9 . "Make a threatening sign" **		

Additional instruction: "Again, imagine holding a tool or an object in hand, don't use the fingers"

10. "Brush your teeth"		
11. "Comb your hair"		
12. "Use a screwdriver"		
Total Score		



May involve different pathways

Vanbellingen et al 2011

Ideomotor Apraxia: Testing

Intransitive
Gestural

Verbal +/- Imitate

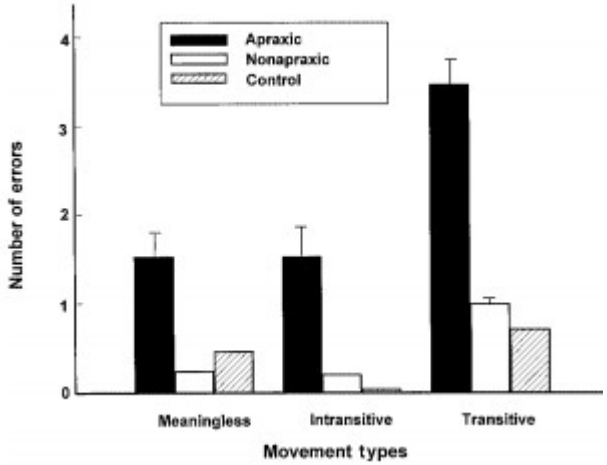
Transitive
Object Use

Visual Verbal Tactile

Meaningful
"Salute like a Soldier"

Meaningless
"Hand under your chin"

Eg
Show me how you would use a ..
Hammer
Comb
Toothbrush



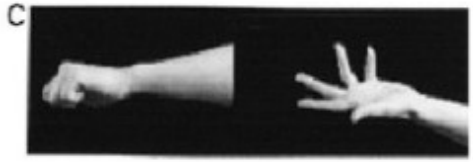
Haaland et al 2000 Brain 123 2306-2313

Ideomotor Apraxia: Errors

Hand Position and Movement Errors

Imitate writing

Healthy Control “Flip a coin”



Patient “Flip a coin”

Hand Position Error

Hand Orientation Error

Body part as Object

Haaland et al 2000 Brain 123 2306-2313

Production Component: Ideomotor Apraxia

Action representation

See kinematic Deficits

Body / Gesture Representation?

Abnormal final posture
But normal kinematics

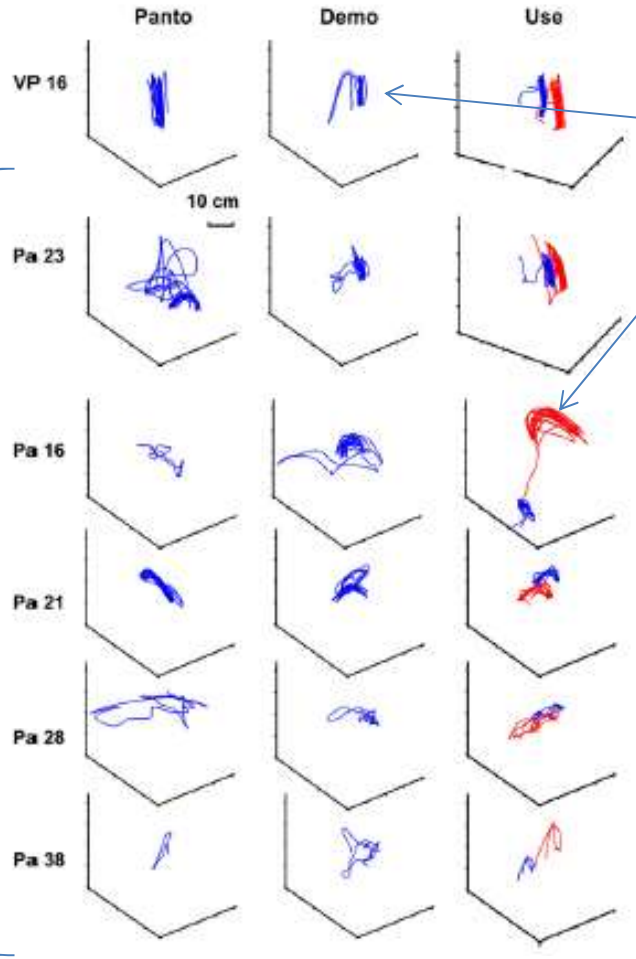
Abnormalities in action recognition and error monitoring

Kinematic Deficits

Pantomime

Demo with Hammer

Use hammer and nail



Normal

Abnormal

Hand marker

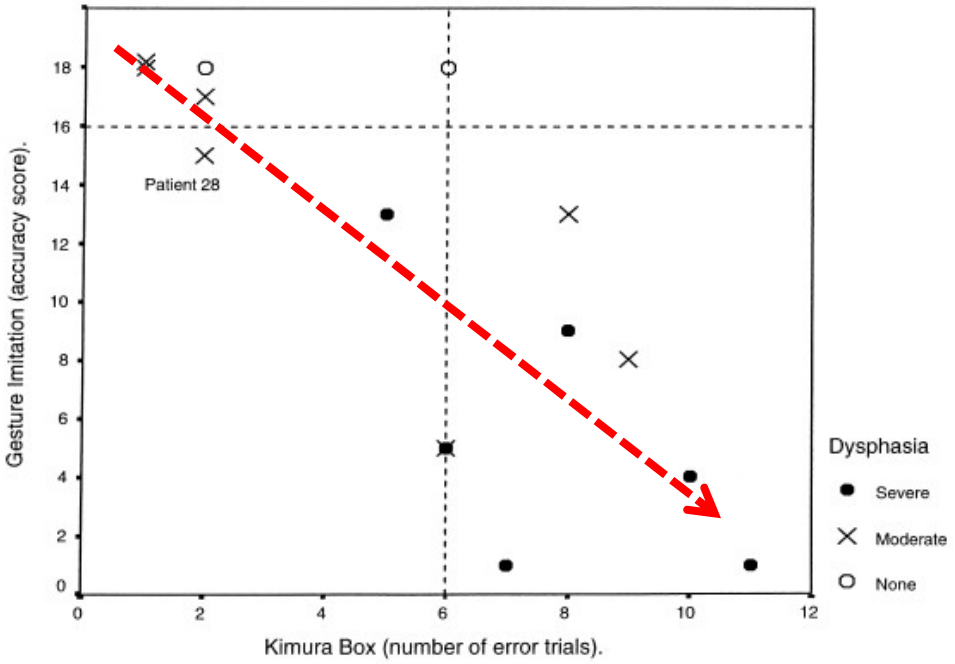
Hammer marker

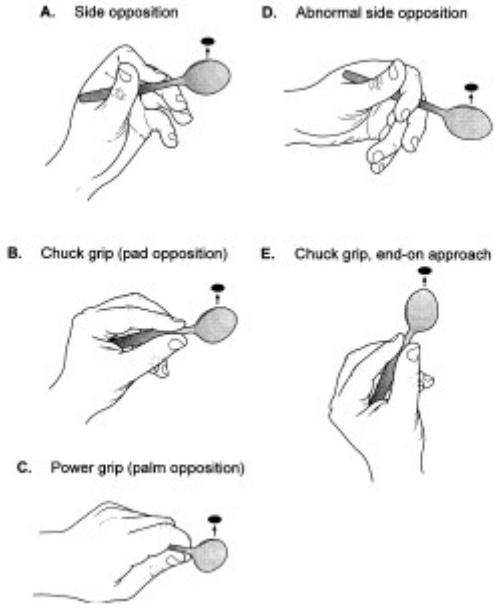
Performed using the non-paretic side

Hermsdorffer et al 2013 Cortex 184

Posture Deficits

Poor hand orientation seen with Kimura Box



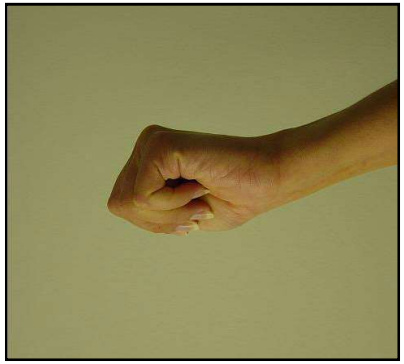


Clumsy posture but more accurate
When object affordances present

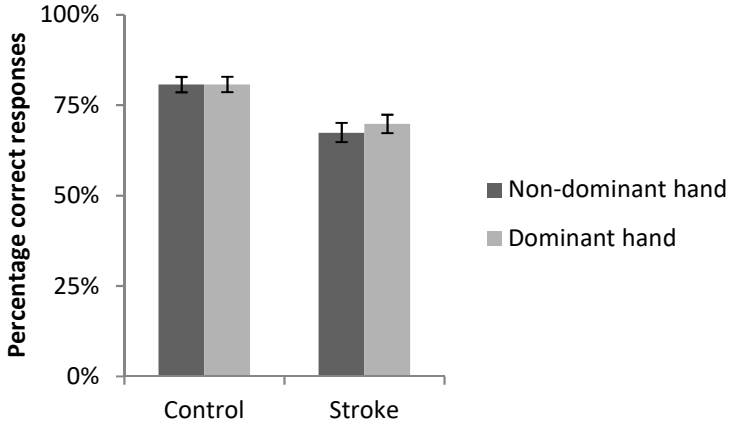
Sunderland and Sluman 2000 Cortex 923

Body Representations

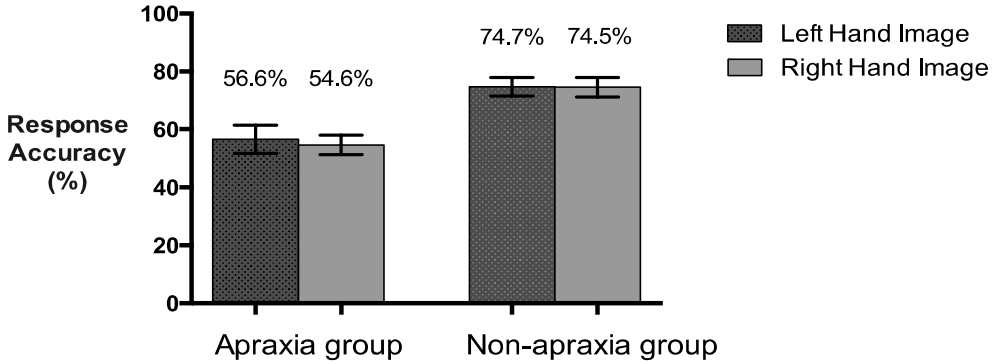
Body Schema



- Lesions centred on Sensori-Motor areas
- Associated with Functional Deficits
- Worse in Apraxics



Amesz et al 2016 Brain Inj 30(8) 999-1004



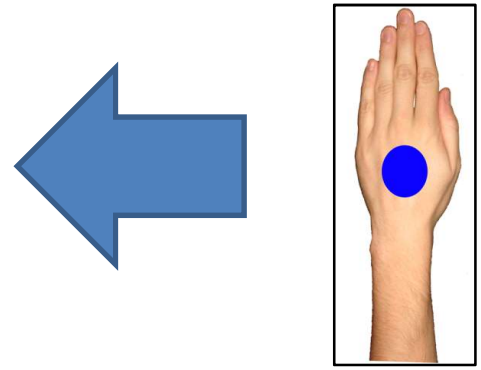
Lane et al (2019) In preparation

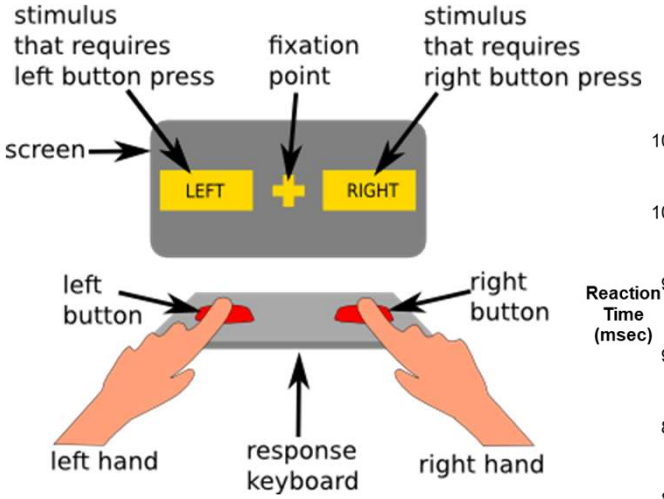
Body Representations

All had defined apraxia

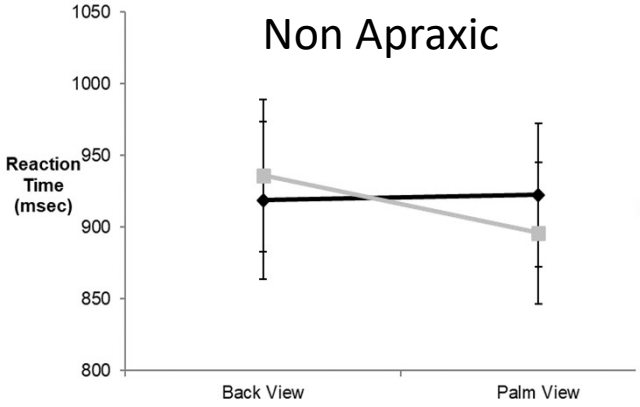
Fronto-parietal Lesions
L>R

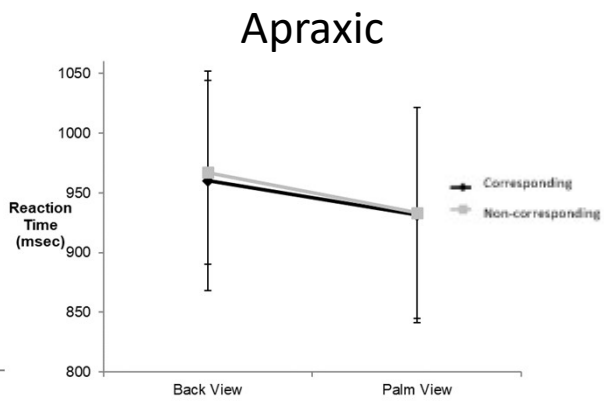
Structural Body Description





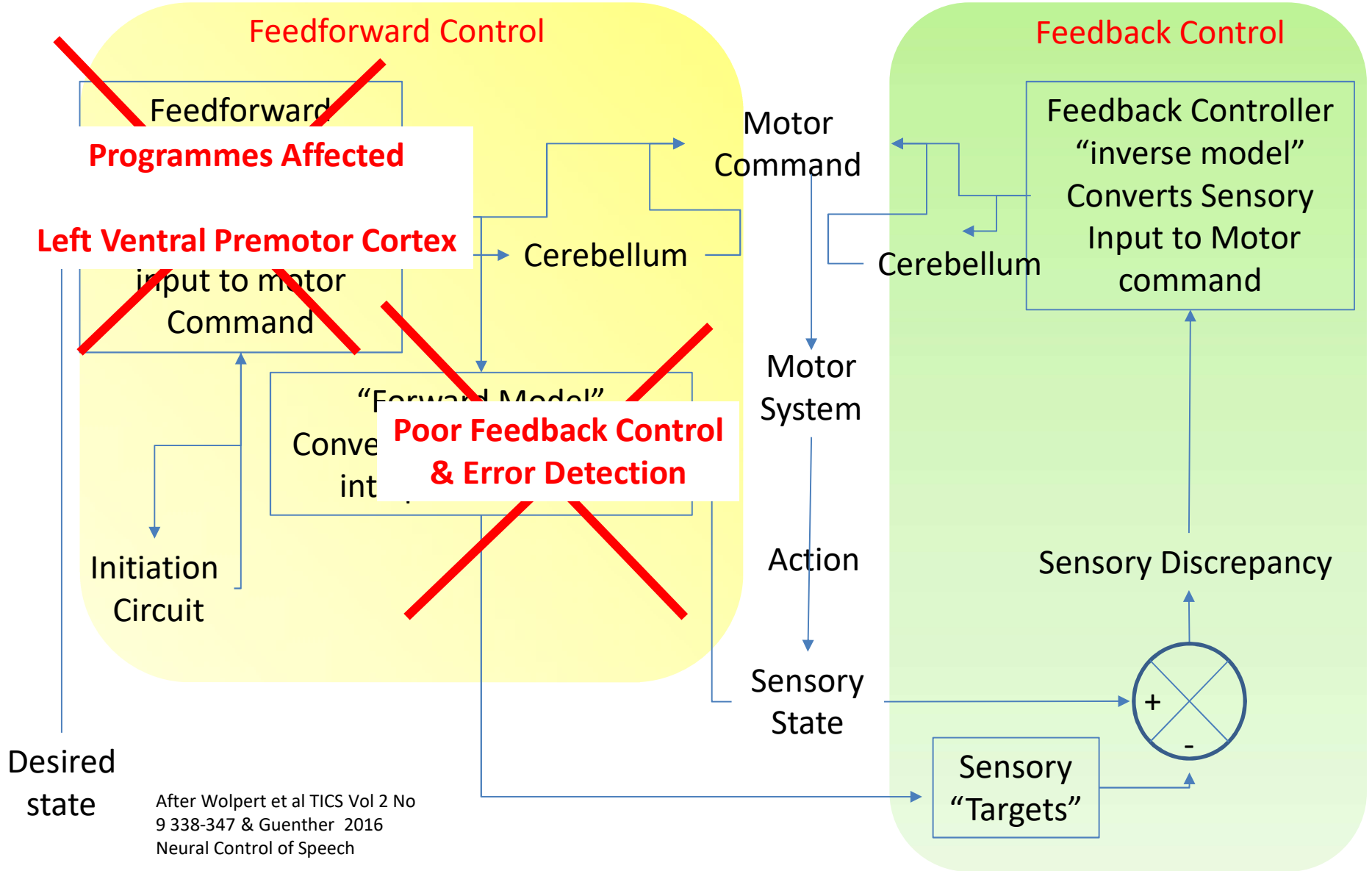
"Implicit Processing of Sidedness"





Lane et al (2019) In preparation

A Model of Motor Control



After Wolpert et al TICS Vol 2 No 9 338-347 & Guenther 2016 Neural Control of Speech

Action Recognition and Error Monitoring

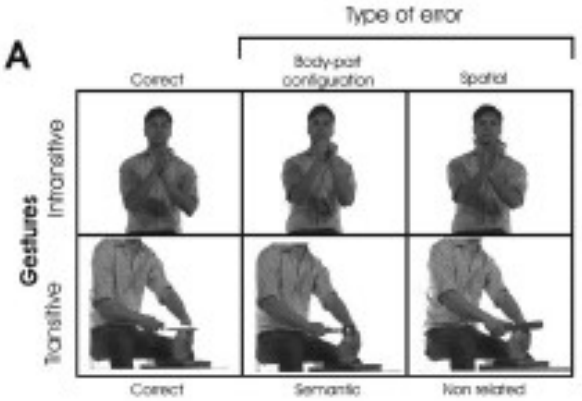
TEST

Transitive

Correct
Vs
Incorrect (semantically related)
Vs
Incorrect (not related)

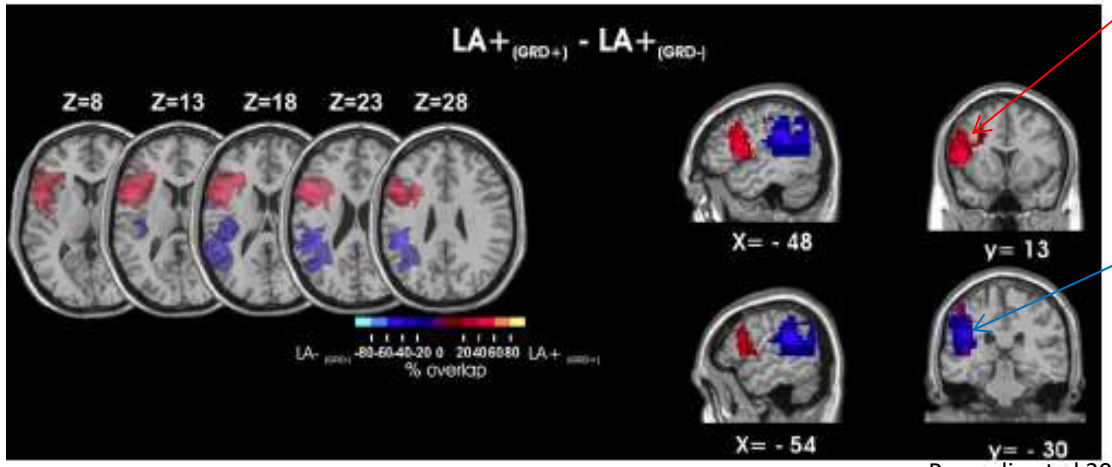
Intransitive

Correct
Vs
incorrect (alter hand/finger orientation)
Vs Incorrect (alter part in space)



Relationship between Apraxia and Ability to recognize actions

Worse Action Recognition in Apraxia



Poor

Good

Pazzaglia et al 2008 J Neuroscience 28 3030

In people with Apraxia

Poor recognition associated with Dorsal premotor / Inferior Frontal Lesions

Better recognition associated with inferior parietal / supramarginal lesions

Representational Vs Dynamic Apraxia

Ideational Apraxia

Choosing the Right Action

Ideational Apraxia: Errors

Sequence errors

- Action Addition
- Action Anticipation
- Step Omission
- Perseveration

Conceptual Errors

- Misuse
    - misappropriation of object
    - Subordinate action misuse
- Mislocation
    - Action wrong
    - Location of action wrong
- Tool Omission
- Pantomiming
- Perplexity
- Toying



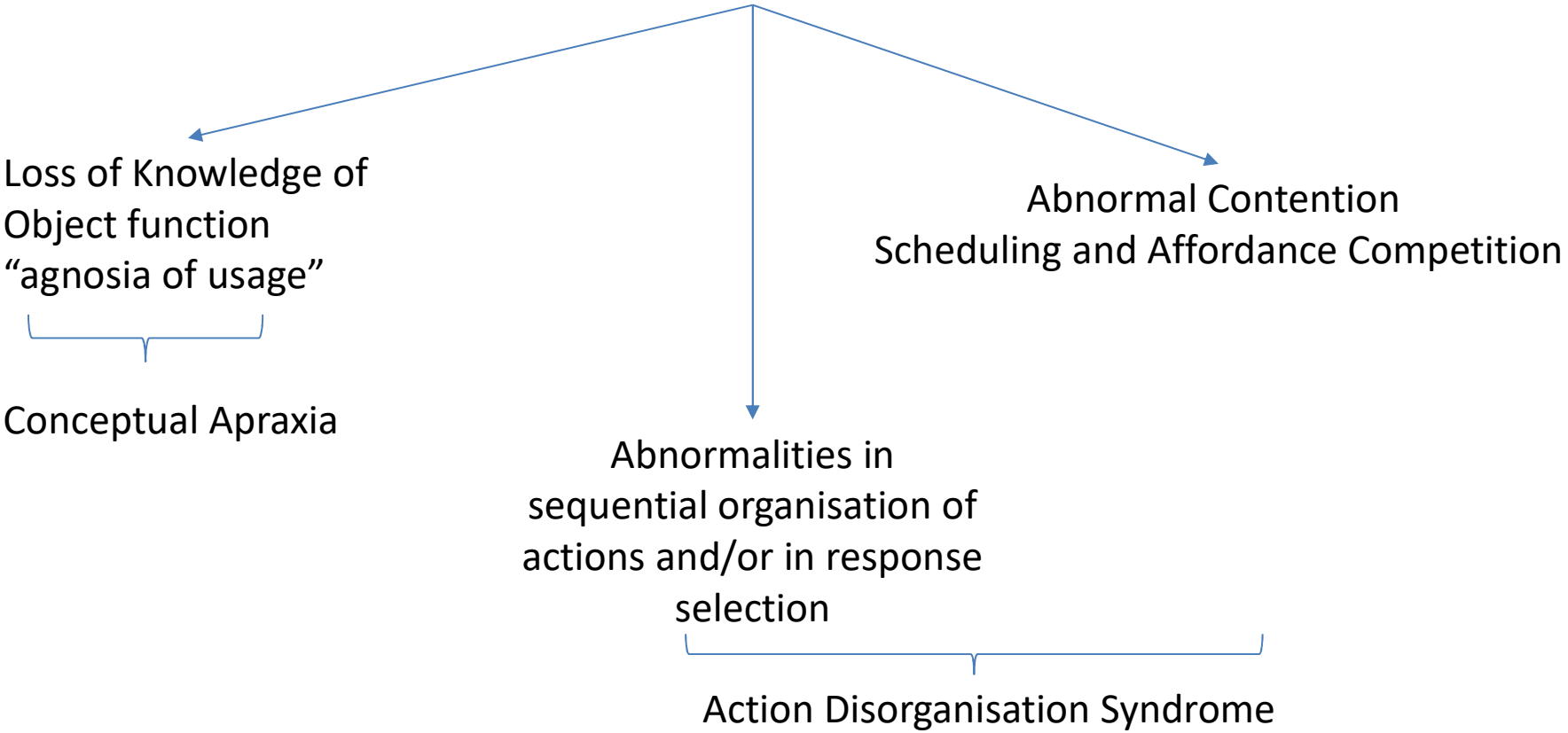


Errors do not correlate with tests of Ideomotor Apraxia

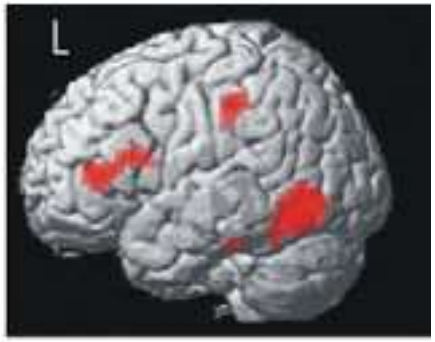
See more errors with complex movements

De Renzi and Lucchelli 1988 Brain 111 1173-1185
Rumiati et al 2001 Cog Neuropsychology 18(7) 617-642

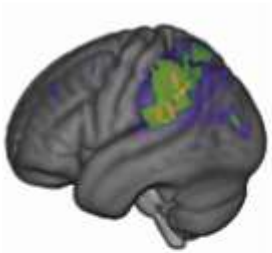
Ideational Apraxia: Theories



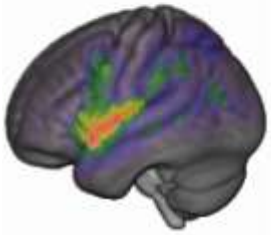
Conceptual Apraxia



Noppeney (2008) J Physiol (Paris) 102 40-49



Tool Use x Tool select ✓



Tool Use ✓Tool select x

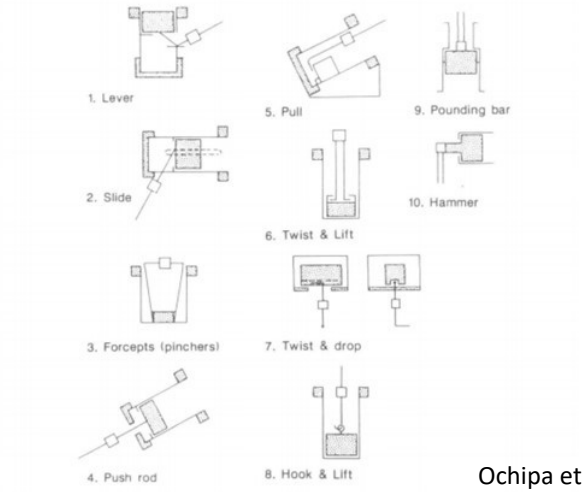
Martin et al Cerebral Cortex 2016 26 3754

Tool Selection

Match tool to action

Tool Puzzles

Complete mechanical tasks with fingers or tool



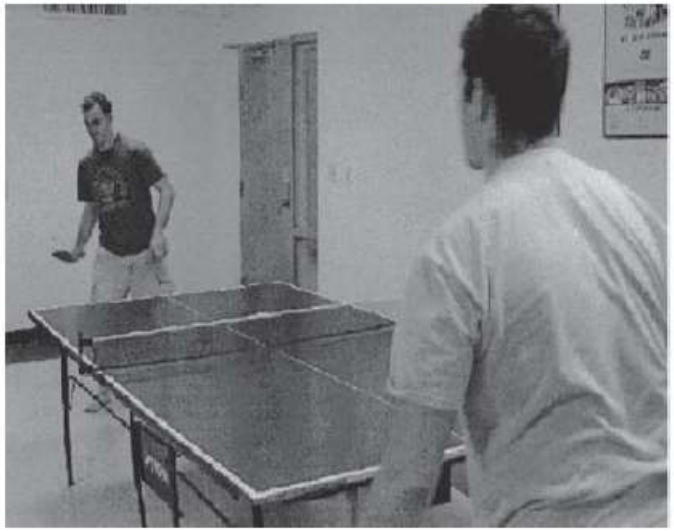
Ochipa et al 1992 Brain 115 1061-1071

Stored Knowledge less accessible

Rely more on Object visuo-spatial cues (affordances)

Sequence Errors in Apraxia

Sequential Action-Praxis Test



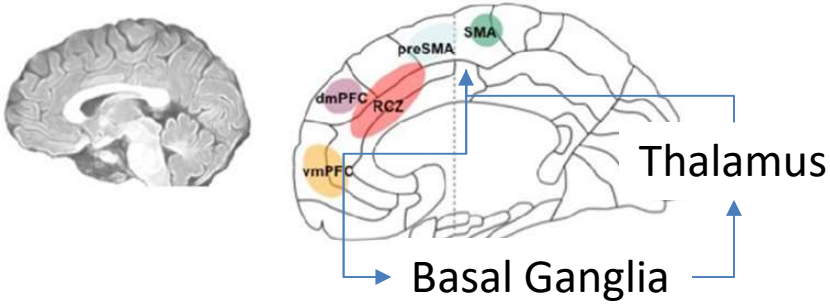
Sequential Word-Sentence Test

Deficits Seen inaction-praxis test Parkinson's Disease

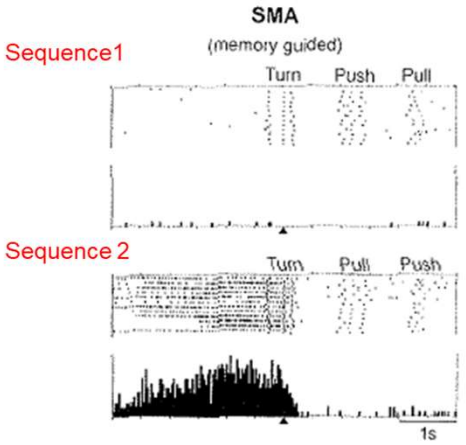
Qureshi et al 2011 Cog Behavioural Neurol 24 122-127

Sequencing Actions and Movements

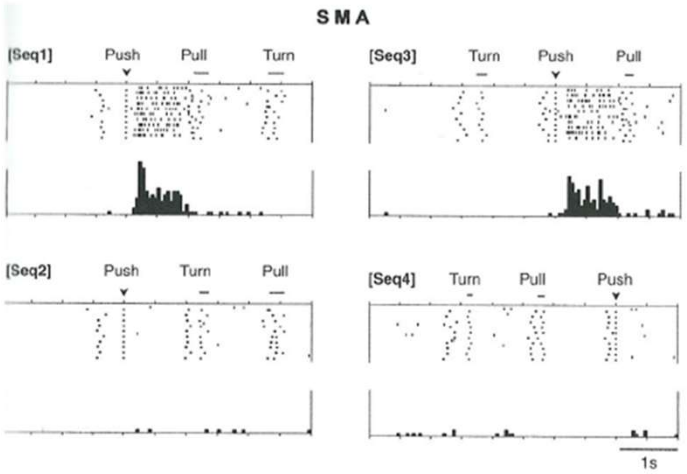
Supplementary Motor Area



Specify Sequence → Specify the transition between elements



SMA neurone active prior to a
Specific memory guided sequence

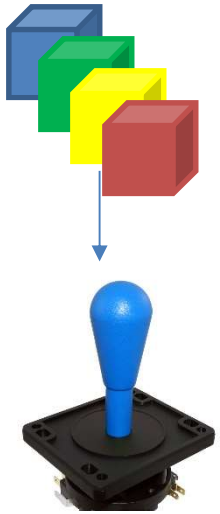


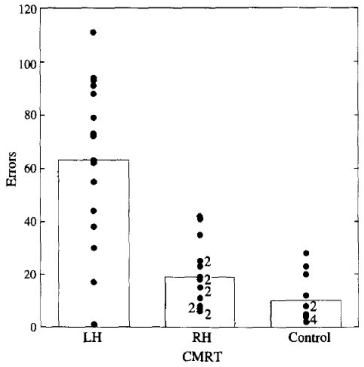
SMA neurone active in the period
Between two specific movements

Tanji.j (1996) In Vision and Movement :
Mechanisms in the cerebral cortex

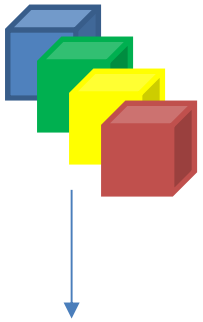
Sequencing and response selection in Apraxia

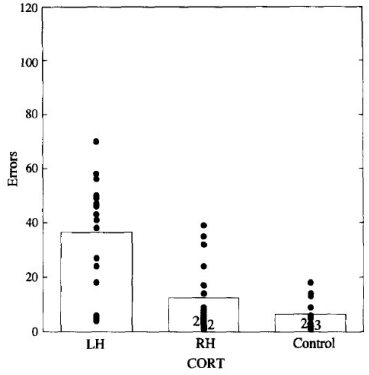
Match cube colour to movement



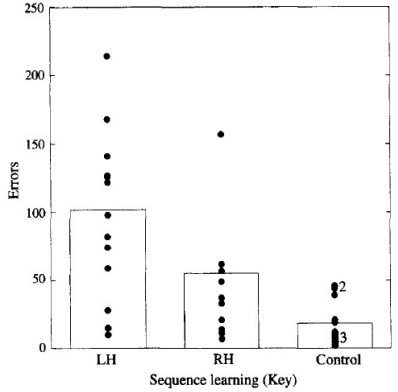


Match cube colour to pattern





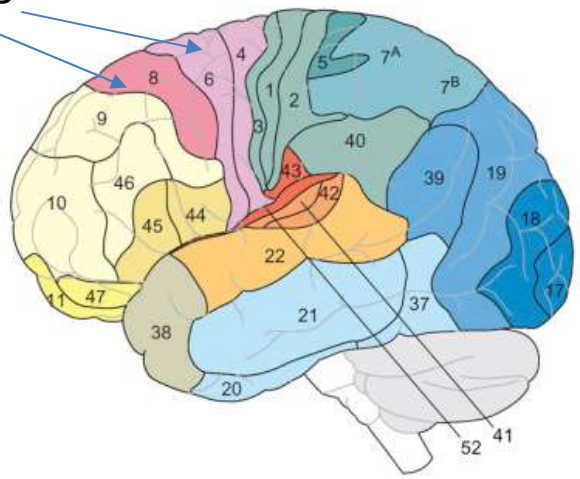
Learn a sequence through trial and error



Rushworth et al 1998 Neuropsychologia v36 11-24

Response selection

Premotor
Area 6 and 8



Lateral
Premotor

Parietal

Thalamus

Basal Ganglia

Contention Scheduling and Affordance Competition

Objects can “afford” actions = “graspability”

Functional Affordance: Different tools have different abilities to achieve a Goal

Goal ⟷ Tool- Object

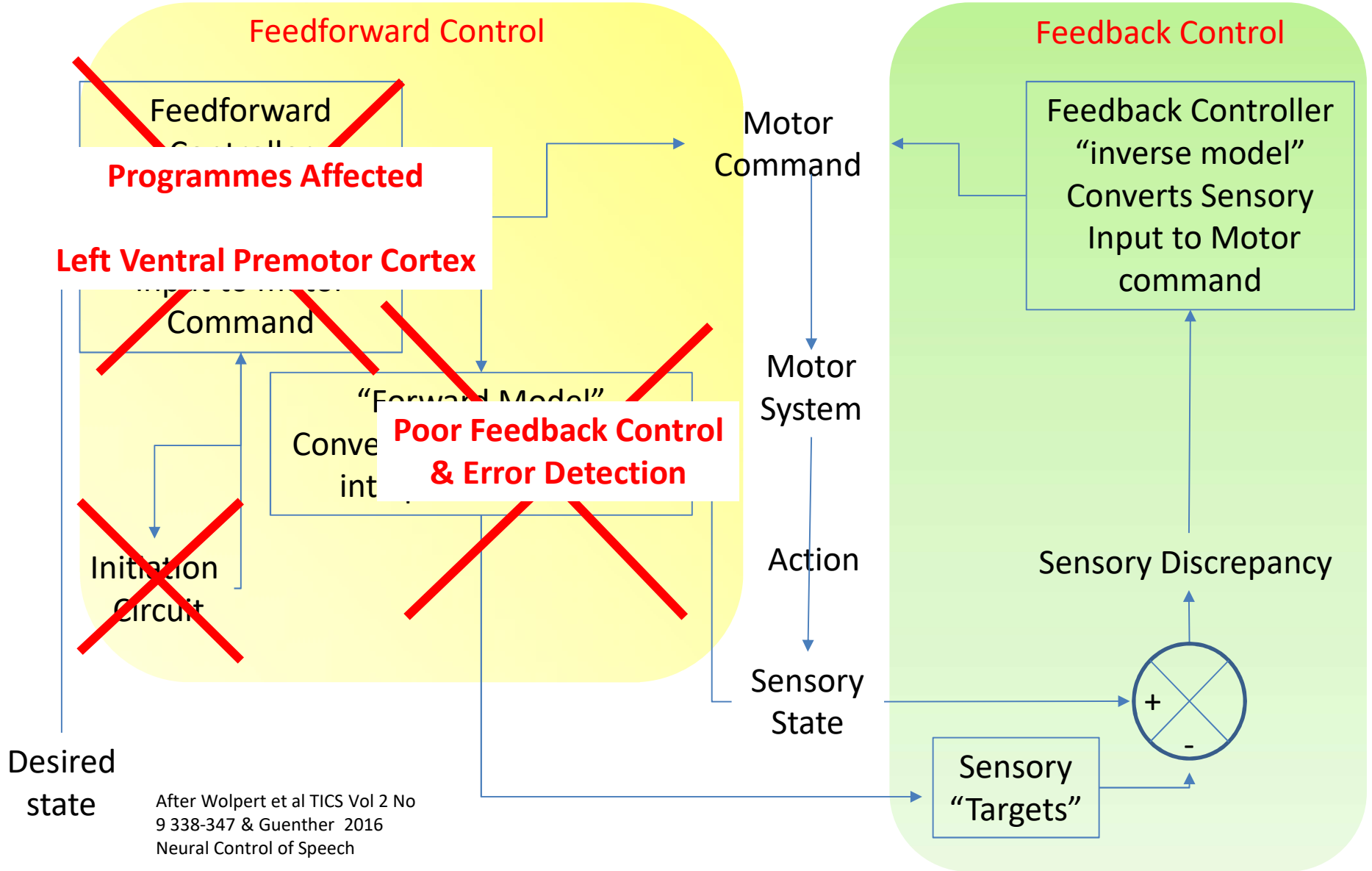
Affordances may aid people with apraxia
= better with tools than pantomime / imitate

Affordance Competition may occur when there are multiple affordances

Pick wrong object / action for a task

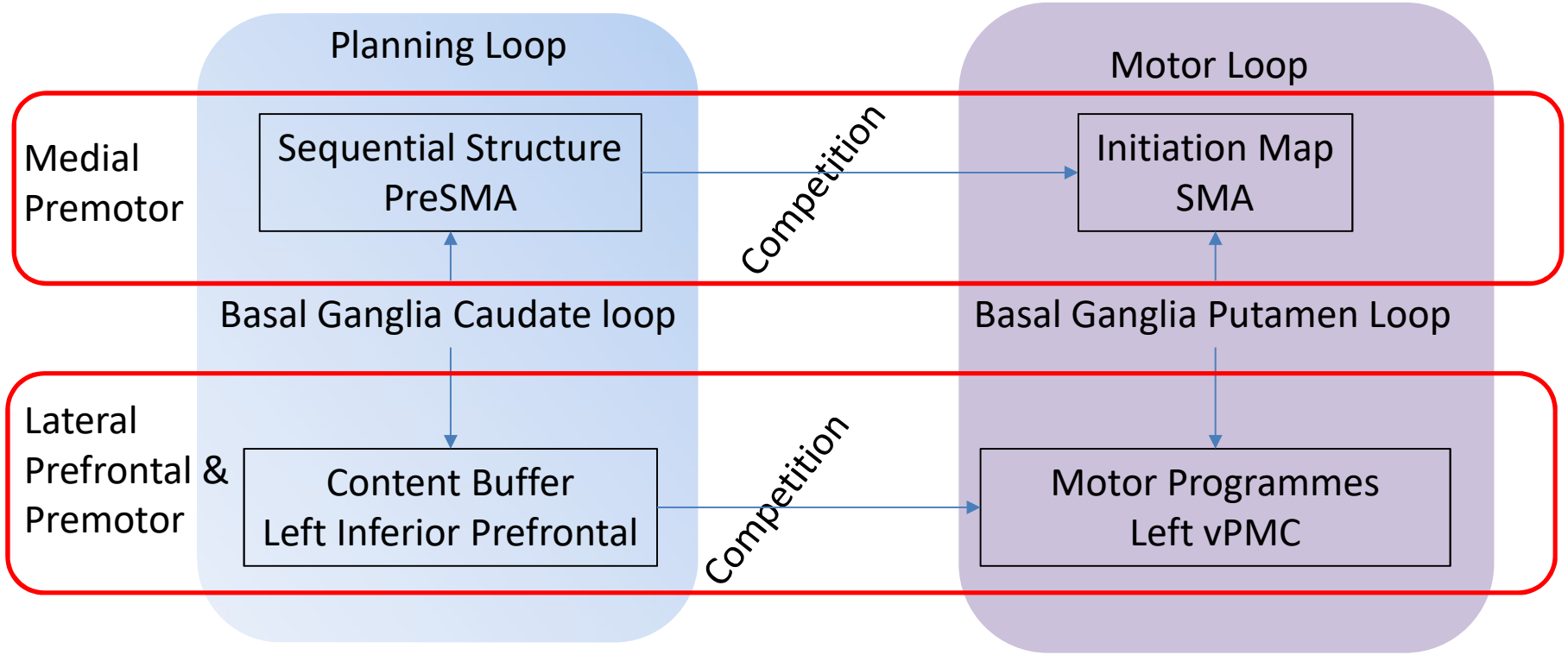
Rounis and Humphreys 2015 Front in Human Neurosci v9 article 429

A Model of Motor Control



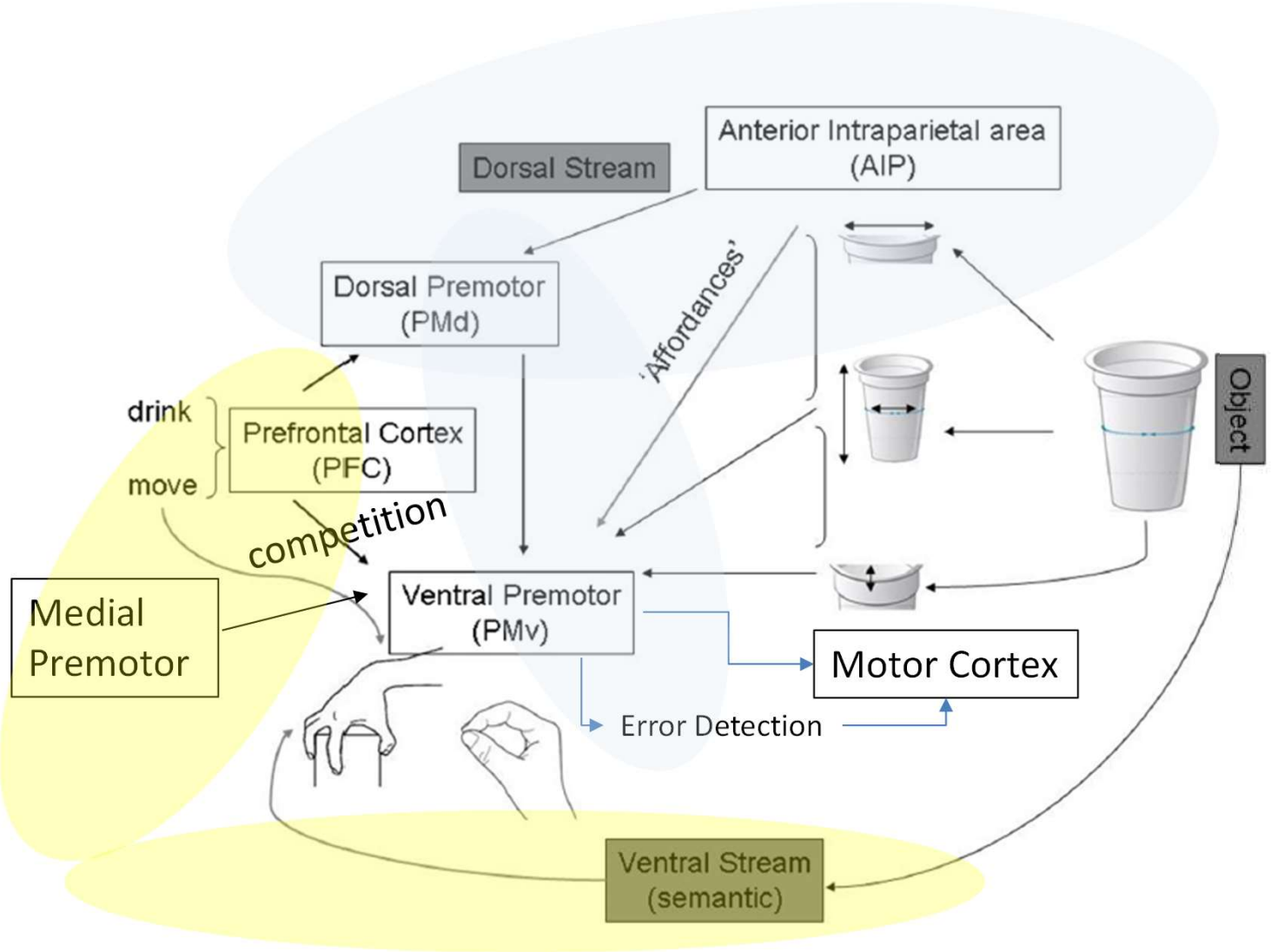
After Wolpert et al TICS Vol 2 No 9 338-347 & Guenther 2016 Neural Control of Speech

A Model of Motor Control



After Guenther 2016 Neural Control of Speech

Adaption of the GODIVA model


Dorsal Stream
Anterior Intraparietal area (AIP)
Dorsal Premotor (PMd)
'Affordances'
drink
move
Prefrontal Cortex (PFC)
competition
Medial Premotor
Ventral Premotor (PMv)
Motor Cortex
Error Detection
Object
Ventral Stream (semantic)

Rehabilitation and Recovery of Apraxia

Retraining Pantomime and Imitation

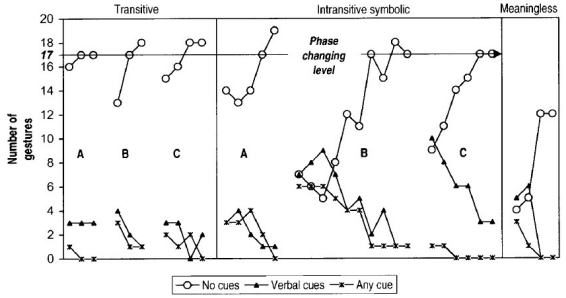
Train

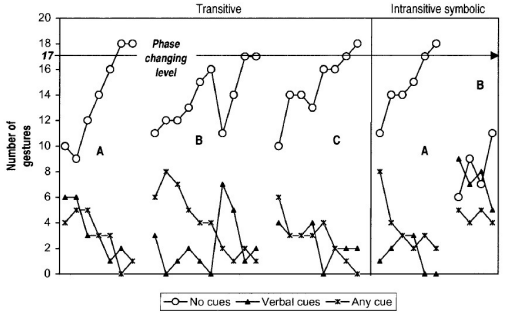
35 sessions 50 mins each x3/week

Transtitive-symbolic
A Show object and use it (affordances)
B Show picture using an object--- produce gesture
C Show picture of an object --- produce gesture

Intransitive-symbolic
A Context-gesture --- reproduce
B Context --- gesture
C New context --- gesture

Intransitive non-symbolic
Imitate static and dynamic
Non symbolic intransitive gestures involving distal and proximal components





Improvements with

Apraxia Tests
- Using objects
- Copy intransitive gestures
- Recognizing gestures

Caregiver ADL questionnaire

Smania et al 2006 and 2000

Task Related Training in Apraxia

12 weeks
3-5 x / week
Focus of relevant functions

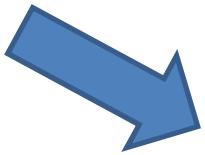
Assess activity in terms of errors in initiation, execution and control

Hierarchical Progression

Instructions
Verbal
Correct environment
Alert patient
Use gestures
Demonstrate task
Show pictures of activity
Write down instructions
Use of objects in correct sequence
Adjust task

Assist
Verbal
Gestures
Pictures
Physical assistance
Take over task

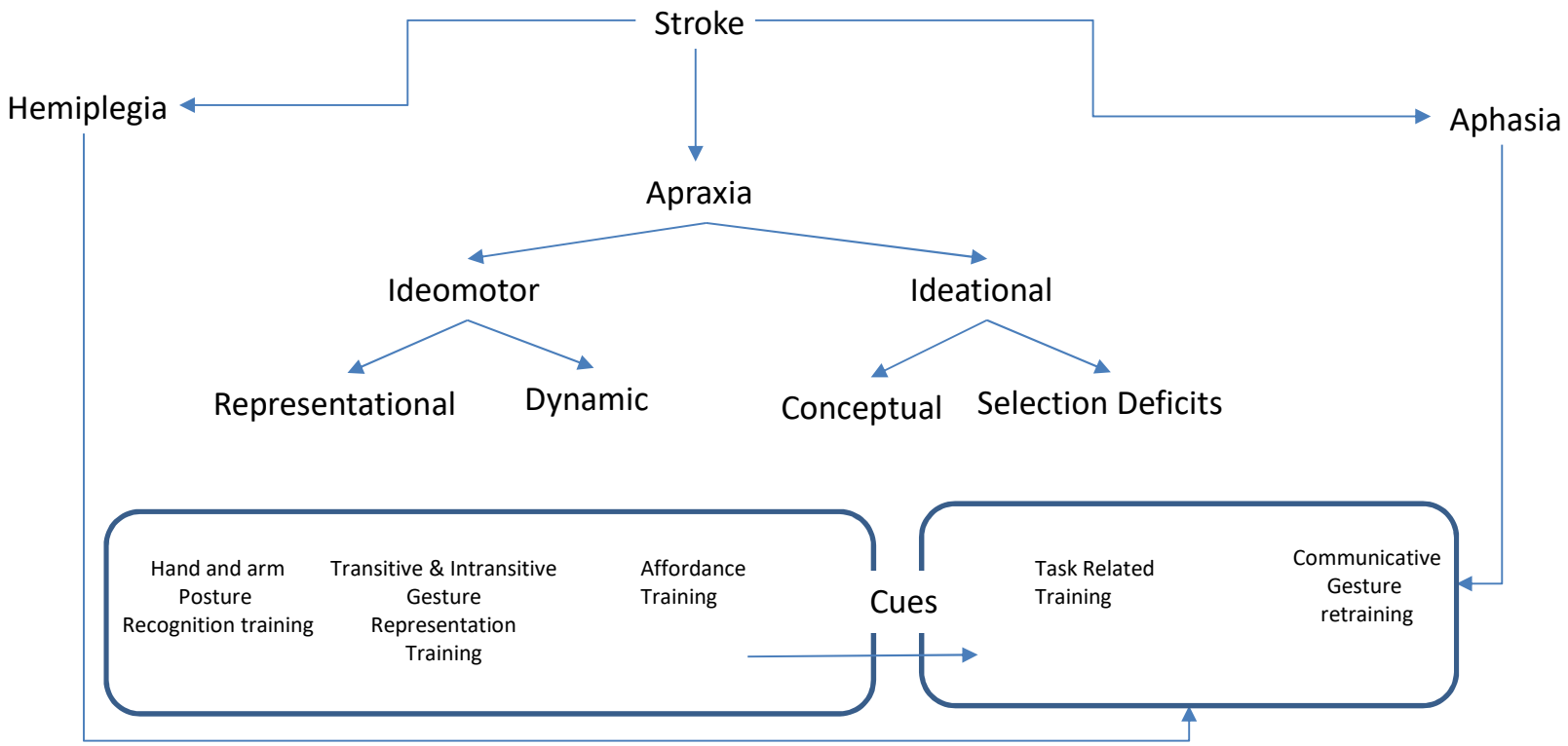
Feedback
None
Verbal
Visual (mirror)
Physical



N=33 No Control
Improvements in ADL and Apraxia Tests

Van Heugten et al 1998 Clin Rehabil 12 294-303

Towards a theory driven treatment algorithm for Apraxia

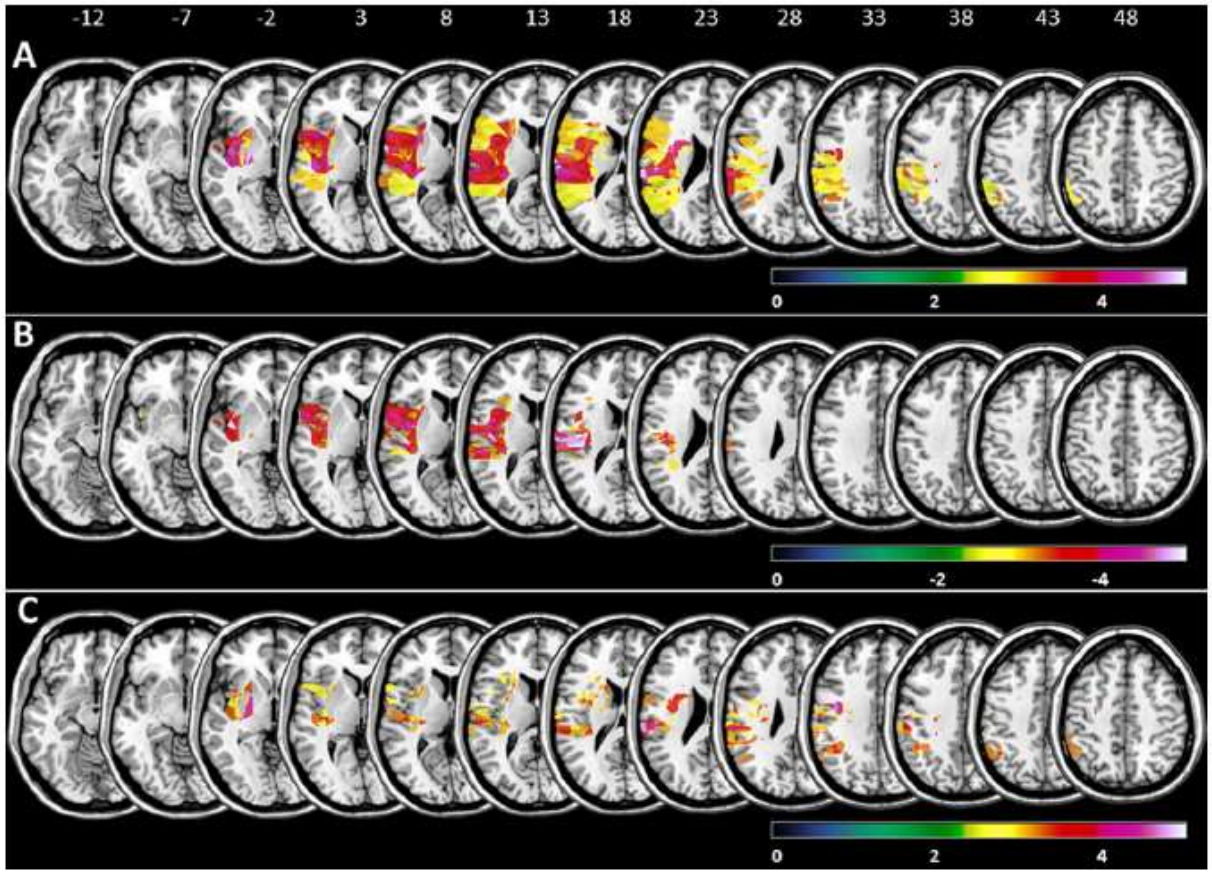


Changes in representation over time?

Lesions associated with initial apraxia

Lesions associated with recovery of apraxia

Lesions associated with persistent apraxia



- Left insula associated with remission.
- Inferior parietal Lobe and superior longitudinal fasciculus associated with persistent deficits

Kusch et al 2018 Restorative Neurology and Neuroscience 36(669-678)

Conclusion

- Fronto-parietal Circuits interact with Subcortical areas particularly the Basal Ganglia to control reaching, grasping and tool use

- Many dissociations can occur in apraxia

- Impairment based and task based training may lead to improvement in Apraxia

- Action Representation/Recognition Systems may be capable
of adaptation post lesion