

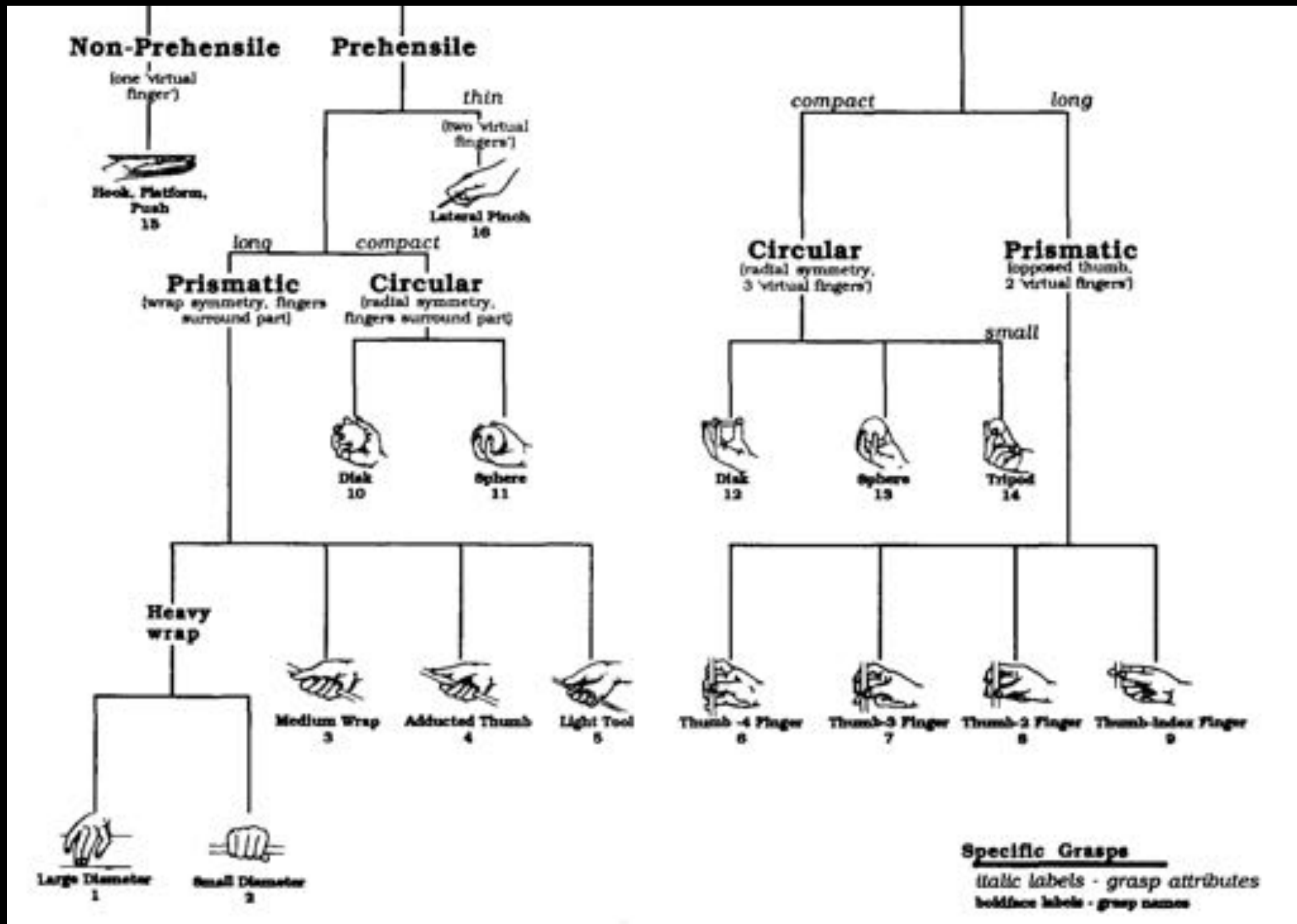
# Taxonomy Follow-up

16-848 Hands: Design and Control for Dexterous Manipulation  
Spring 2020

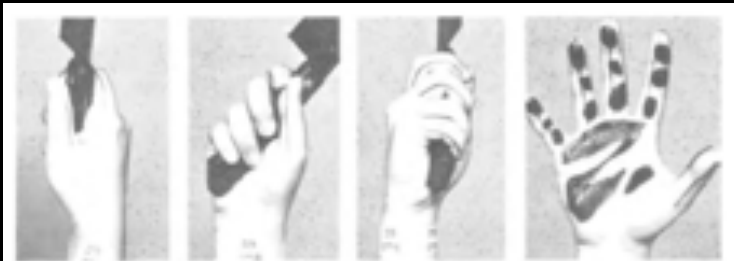
# Taxonomies



# Cutkosky Taxonomy



# Kamakura Taxonomy



a. Power grip - Standard type (PoS)



b. Power grip - Hook type (PoH)



c. Power grip - Index Finger Extension type (PoI)



d. Power grip - Extension type (PoE)



e. Power grip - Distal type (PoD)

Fig.1 Power Grip Category



a. Lateral Grip (Lat)



b. Tripod Grip (Tpd)



c. Tripod Variation 1 (TV1)



d. Tripod Variation 2 (TV2)

Fig.2 Intermediate Grip Category



a. Parallel Mild Flexion Grip (PMF)



b. Surrounding Mild Flexion Grip (SMF)



c. Tip Prehension (Tip)

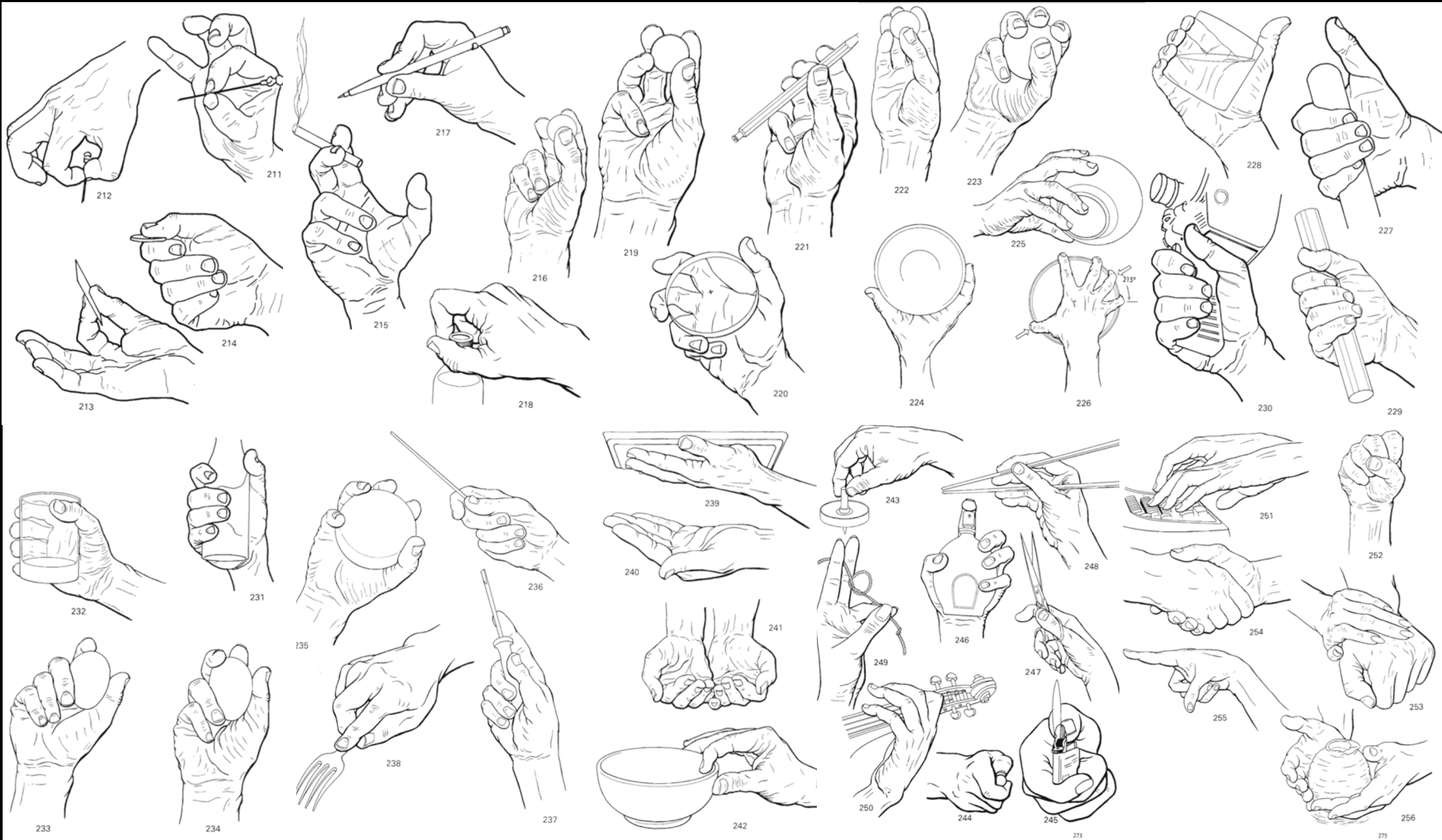


d. Parallel Extension Grip (PE)



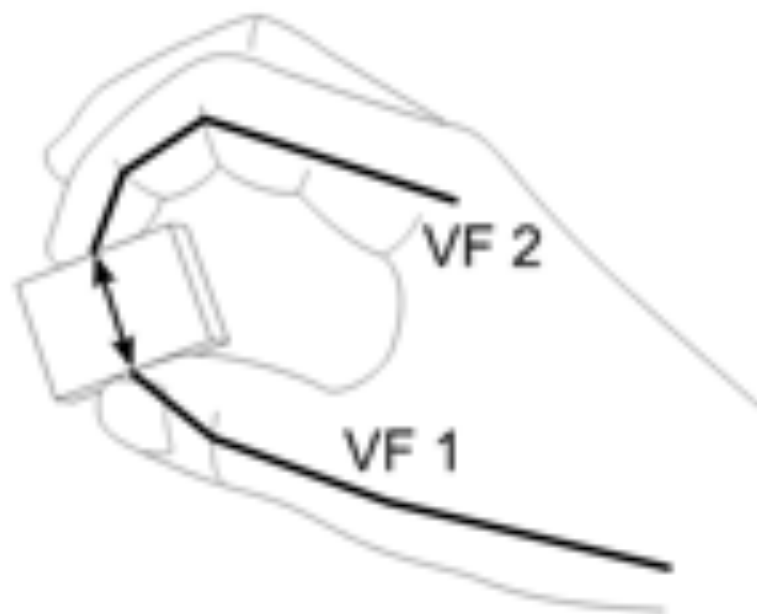
Fig.3 Precision Grip Category

# Kapandji Taxonomy

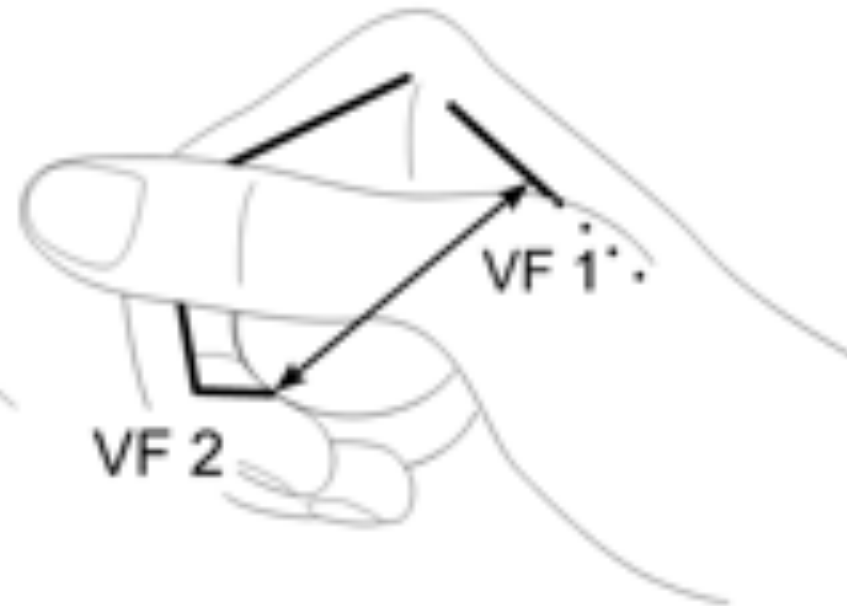


# Iberall's Oppositions and Virtual Fingers

a) Pad Opposition



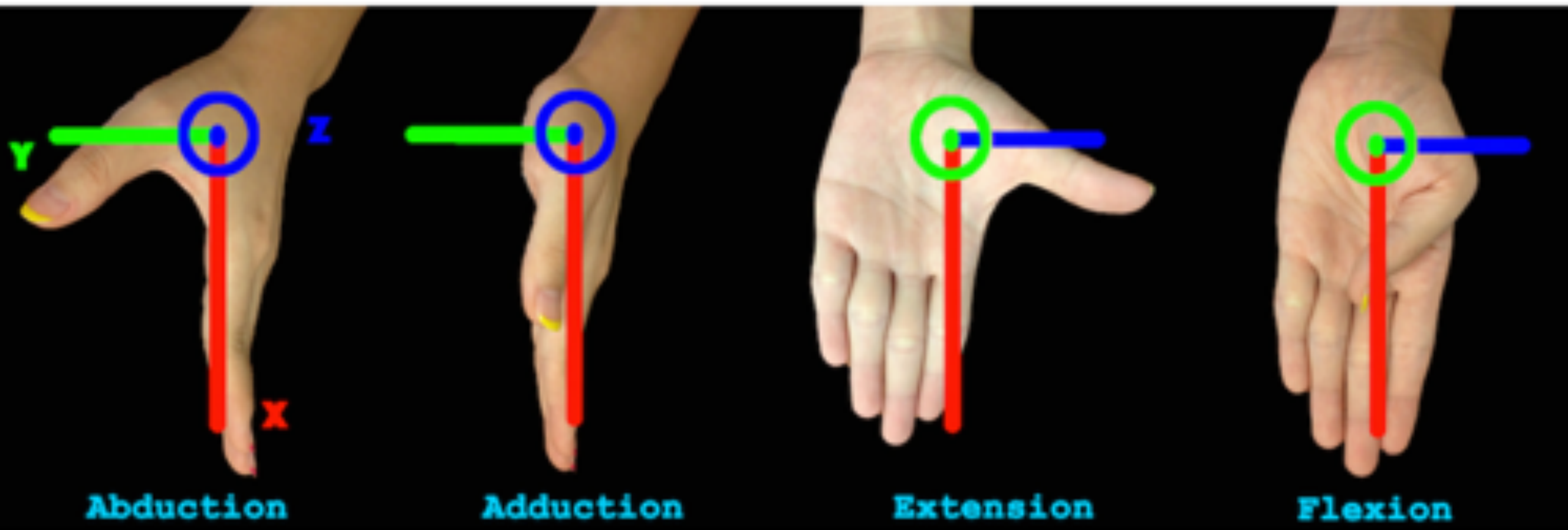
b) Palm Opposition



c) Side Opposition



# Thumb Abduction / Adduction







# Feix et al. Cumulative Taxonomy

































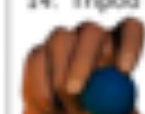
















			Palm VF1: P VF2: 2-5 VF3:	Palm VF1: P VF2: 2-5 VF3:	Palm VF1: P VF2: 2-5 VF3:	Palm VF1: P VF2: 2-5 VF3: 1	Palm VF1: P VF2: 2-5 VF3: (1)	Pal VF1: 1 VF2: 2-5 VF3:	Pal VF1: 1 VF2: 2-4 VF3:	Pal VF1: 1 VF2: 2-3 VF3:	Pal VF1: 1 VF2: 2 VF3:	
Group No.			1	2	3	4	5	6	7	8	9	
Grasp			Large Diameter	Small Diameter	Medium Wrap	Adducted Thumb	Light Tool	Prismatic 4 Finger	Prismatic 3 Finger	Prismatic 2 Finger	Palmar Pinch	Pt
# References			15	8	11	2	2	6	4	3	18	
Group Importance			1.6	0.7	18.8	0.9	4	3.1	3.8	5.1	3.1	
1	Cutkosky 1986	1986	Large Diameter  Large Diameter 1	Small Diameter  Small Diameter 2	Medium Wrap  Medium Wrap 3	Adducted Thumb  Adducted Thumb 4	Light Tool  Light Tool 5	Thumb - 4 Finger  Thumb - 4 Finger 6	Thumb - 3 Finger  Thumb - 3 Finger 7	Thumb - 2 Finger  Thumb - 2 Finger 8	Thumb - Index Finger  Thumb - Index Finger 9	
					Standard Type 				Parallel Mid Flexion Grip 		Tip Prehension 	
2	Kamukura et al. 1980	1980										
3	Kapanis 2006	2006	Cylindrical Palmar Prehension 		Full Palmar Prehension 							
									Intradigital Grip by Pulp Contact 		Subterminal Opposition 	

Fig. 2. Comparison of the grasp listings from 22 taxonomy publications found in literature. Due to the size (22 publications x 47 grasp columns) only an excerpt

# Feix et al. Cumulative Taxonomy

Opp: VF:	Power						Intermediate			Precision				
	Palm		Pad				Side			Pad				Side
	3-5	2-5	2	2-3	2-4	2-5	2	3	3-4	2	2-3	2-4	2-5	3
Thumb Abducted		1: Large Diameter  2: Small Diameter  3: Medium Wrap  10: Power Disk  11: Power Sphere 	31: Ring 	28: Sphere 3 Finger  18: Extension Type  26: Sphere 4-Finger 	19: Distal Type 	23: Adduction Grip 			21: Tripod Variation 	9: Palmar Pinch  24: Tip Pinch  33: Inferior Pincer 	8: Prismatic 2 Finger  14: Tripod 	7: Prismatic 3 Finger  27: Quadpod 	6: Prismatic 4 Finger  12: Precision Disk  13: Precision Sphere 	20: Writing Tripod 
Thumb Adducted	17: Index Finger Extension 	4: Adducted Thumb  5: Light Tool  15: Fixed Hook  30: Palmar 					16: Lateral  29: Stick  32: Ventral 	25: Lateral Tripod 					22: Parallel Extension 	



# Feix et al. taxonomy in use

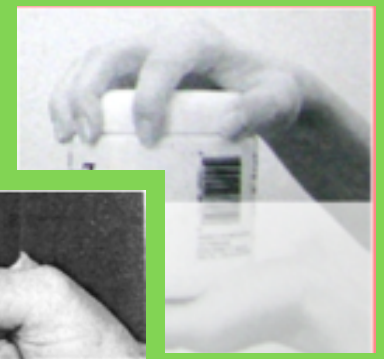


Raphael Deimel and Oliver Brock. A Novel Type of Compliant and Underactuated Robotic Hand for Dexterous Grasping. International Journal of Robotics Research 2015 (in print).

# Cumulative Taxonomy: My Summary



1. Power grasps using the Palmar Gutter



2. Power grasps using Other Parts of the Palm



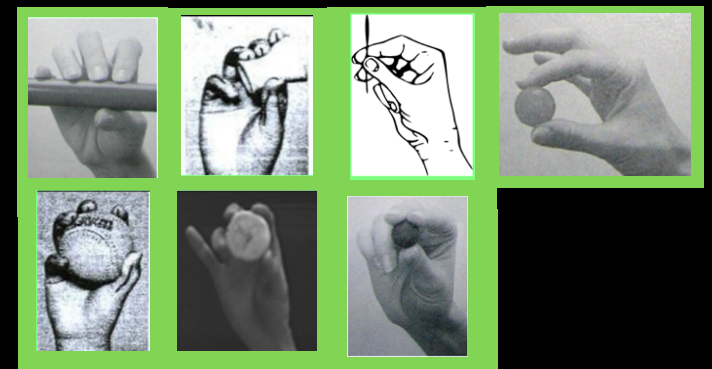
3. Power grasps with Lateral Stabilization

4. Precision grasps with Lateral Stabilization



5. Power grasps with Pad Opposition

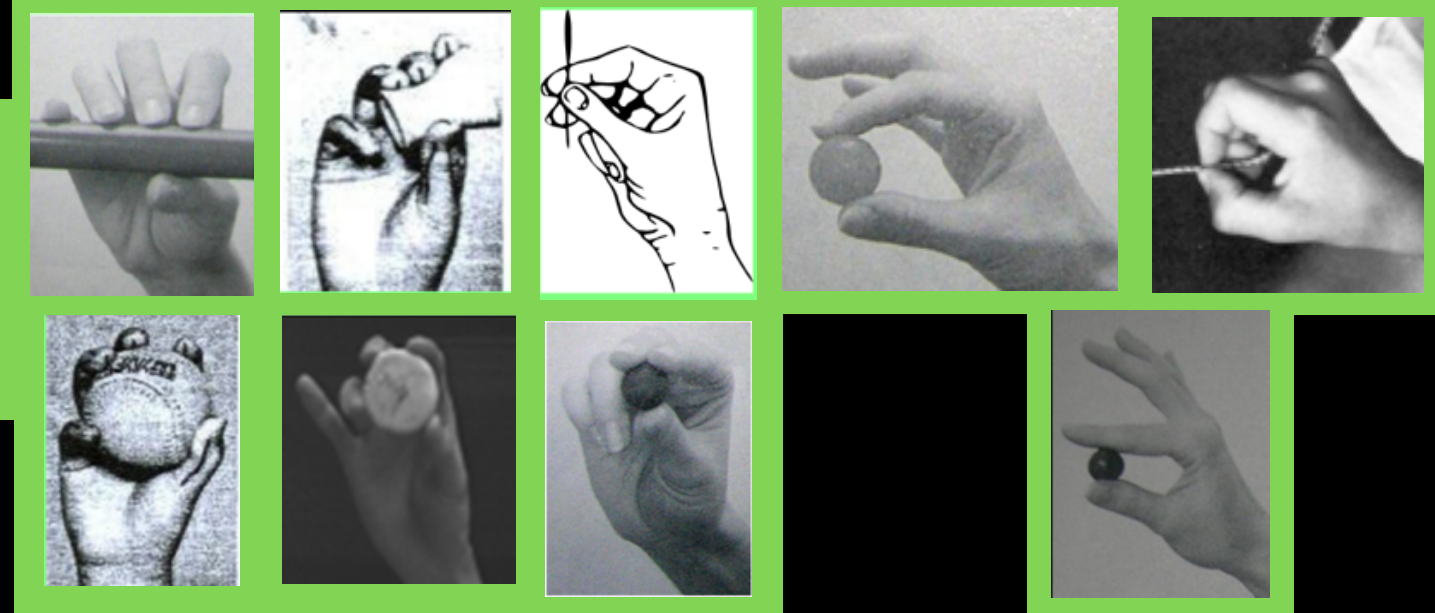
4. Precision Grasps with Pad Opposition





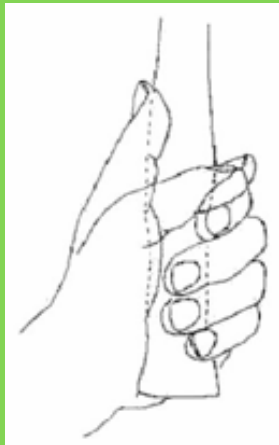
The image contains four panels illustrating different types of grips:

- Power Grip:** A line drawing of a hand with the thumb wrapped around the fingers, showing a strong, enveloping grip.
- Precision Grip:** A line drawing of a hand holding a small object between the tips of the thumb and index finger.
- Force Grip:** A photograph of a hand holding a small, round object (like a ball) with the palm and fingers, showing a strong, enveloping grip.
- Precision Grip:** A photograph of a hand holding a key between the tips of the thumb and index finger.



Feix et al. Cumulative  
Taxonomy — is this sufficient?

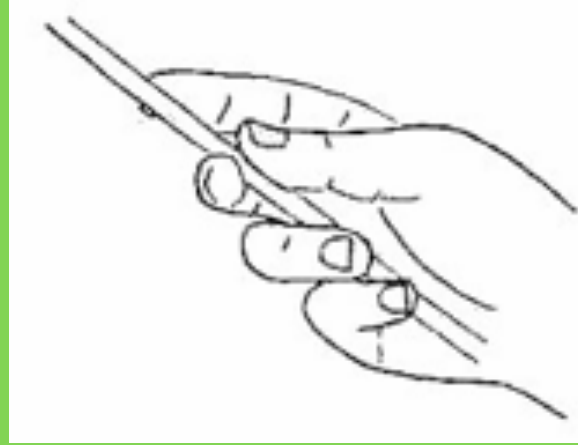
# Taxonomy from a Surgeon



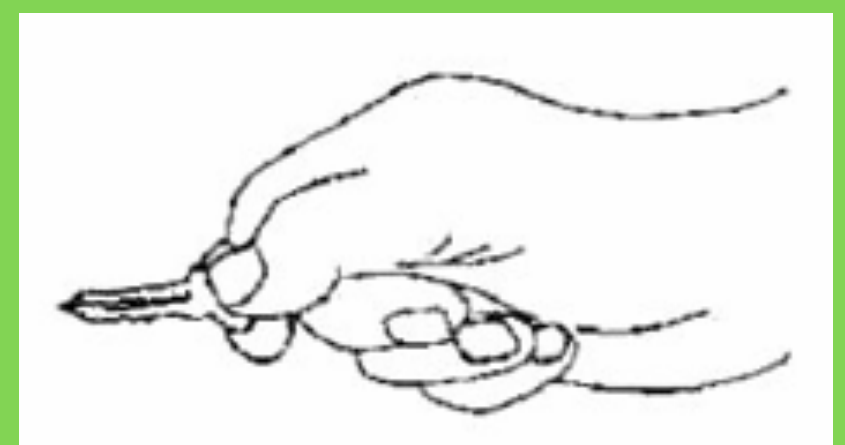
**Power**



**External Precision**



**Internal Precision**



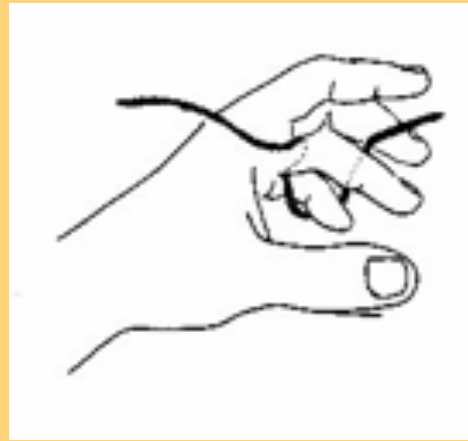
**Pinch**



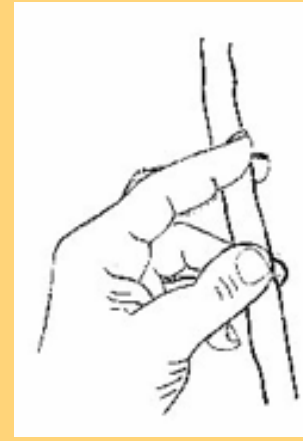
**Power  
Variation**



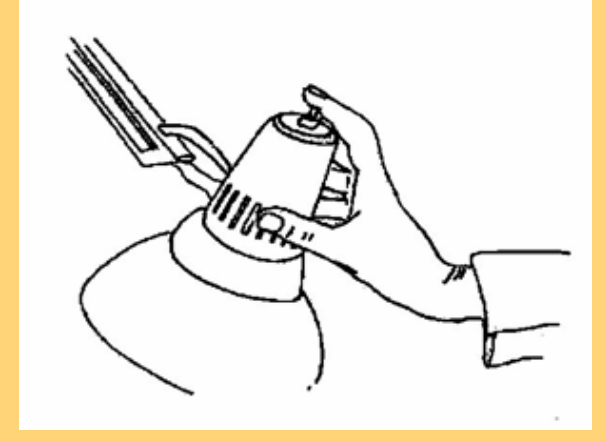
**Ulnar Storage**



**Suture Storage**

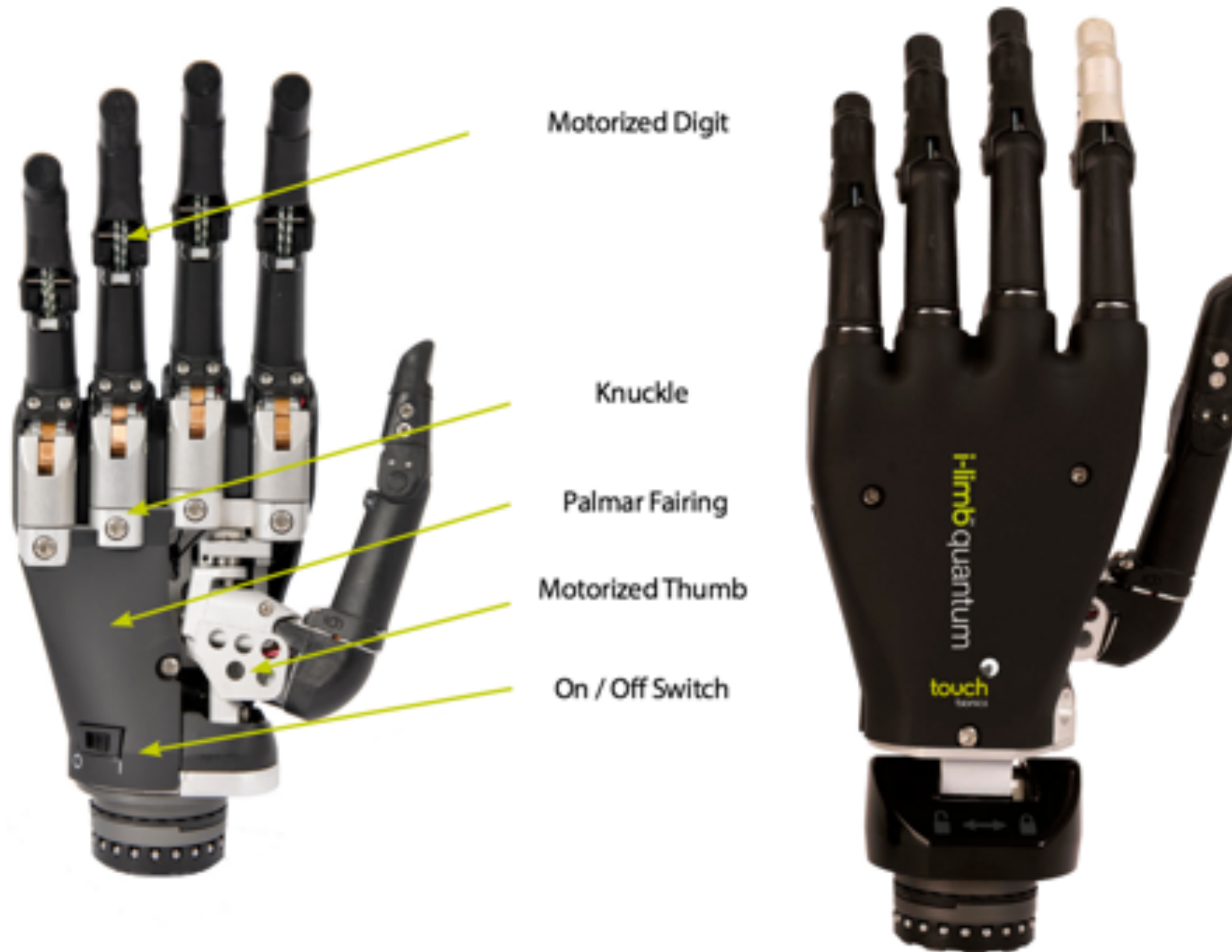


**Stretching**



**Trigger**

# I-Limb Taxonomy



<https://www.youtube.com/watch?v=doWAAtRT00T0>



# I-Limb Taxonomy: 1 of 2

## Precision Pinch Grip Options

### Standard Precision Pinch Opened

middle, ring and little finger remain fully opened and switch off. Index finger and thumb provide grip.



### Standard Precision Pinch Closed

middle, ring and little finger automatically close and switch off. Index finger and thumb provide grip.



### Thumb Precision Pinch Opened

middle, ring and little finger remain fully opened and switch off. Thumb automatically moves to a partially closed position. Index finger will move to provide grip against a fixed thumb.



### Thumb Precision Pinch Closed

middle, ring and little finger automatically close and switch off. Thumb automatically moves to a partially closed position. Index finger will move to provide grip against a fixed thumb.



## Tripod Grip Options

### Standard 3 Jaw Chuck (Tripod) Opened

ring and little finger remain fully opened and switch off. Thumb, index and middle fingers move to provide grip.



### Standard 3 Jaw Chuck (Tripod) Closed

ring and little finger move to terminal close. Thumb, index and middle fingers move to provide grip.



### Thumb 3 Jaw Chuck (Tripod) Opened

ring and little finger remain fully opened and switch off. Thumb automatically moves to a partially closed position. Index and middle fingers move to provide grip against a fixed thumb.



### Thumb 3 Jaw Chuck (Tripod) Closed

ring and little finger move to terminal close. Thumb automatically moves to a partially closed position. Index and middle fingers move to provide grip against a fixed thumb.



# I-Limb Taxonomy: 2 of 2

## Thumb Park Continuous

all four fingers remain open and switch off, only the thumb will move.



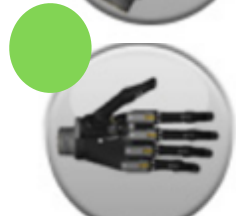
## Grasp

hand forms a shape appropriate for grasping an object. Fingers flex rapidly when any user signal is applied



## Cylindrical

hand forms a shape appropriate for grasping a cylinder



## Lateral Grip

all four fingers fully close and switch off. only thumb will move.



## Thumb Park Quick

all four fingers remain open and switch off, for 1.5 seconds the thumb will close and then automatically return to an open position.



## Rotate Thumb

thumb and all four fingers fully open and switch off. Only thumb will rotate



## One Finger Trigger

hand forms a shape appropriate for using a spray bottle with the index finger active



## Trigger Two Finger

hand forms a shape appropriate for using a spray bottle with the index and middle finger active



## Thumb Trigger

hand forms shape appropriate for using an aerosol spray can with thumb active



## Mouse

hand forms shape appropriate for using a computer mouse



## Handshake

hand forms a shape appropriate for shaking another persons hand



## Index Point

thumb, little, ring and middle fingers close and switch off. Only the index finger will move.



## Open Palm

hand forms a shape appropriate with holding plate or saucer



## Custom Grip

all fingers automatically move to a user defined position. The user can choose to keep certain digits active and switch others off.



## Custom Gesture

all fingers automatically move to a user defined fully opened or fully closed position and switch off.







## Don Doff

hand forms the proper shape for donning and doffing a cover





Standard Precision Pinch Opened		Middle, ring and little fingers remain fully opened and switch off. Both index finger and thumb will move to provide grip.	Allows for a wider opening than thumb precision. Aids with visualization or for pinching objects where the non-active digits may get in the way.	<ol style="list-style-type: none"> <li>1. Returning cards or money to wallet</li> <li>2. Picking up napkins</li> <li>3. Folding laundry</li> </ol>
Thumb Precision Pinch Opened		Middle, ring and little fingers remain fully opened and switch off. Thumb automatically moves to a partially closed position. Only index finger will move to provide grip against the fixed thumb.	Accuracy is improved when picking up an object by allowing you to place the thumb against the object to be pinched. Only the index finger moves to grasp the object. Ideal for repetitive tasks.	<ol style="list-style-type: none"> <li>1. Pick up pencil or slim, long objects</li> <li>2. Thread needle</li> <li>3. Sort/Pick up medications</li> </ol>
Lateral Grip		All four fingers fully close and switch off. Only thumb will move.	Holding onto plate, papers, CD or other flat objects. Improved stability with use of the side of the index finger.	<ol style="list-style-type: none"> <li>1. Hold plate while serving food</li> <li>2. Hold clipboard</li> <li>3. Get card from ATM</li> <li>5. Open ziplock bag</li> <li>6. Tie Shoe Laces</li> </ol>
Thumb Park Continuous		All four fingers remain fully open and switch off. Only the thumb will move.	For longer dressing period that will require more than the 1.5 seconds of thumb park quick or grasping light weight flat objects. Can also use stalling out digits to complete, putting pressure against index to little and closing thumb in to hand.	<ol style="list-style-type: none"> <li>1. Put on jacket</li> <li>2. Grasp flat objects, such as a book or a tablet computer or clipboard</li> <li>3. Allows readjustment of the object opening letters or sorting paperwork.</li> </ol>

# One Object, One Task, 17 Subjects



**Lateral**



**Precision Disk**



**Palmar Pinch**



**Parallel Extension  
Variation?**



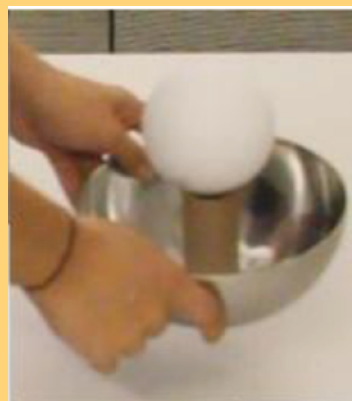
**Ventral  
Variation?**



**Palmar Pinch  
Variation?**



**Palmar Pinch  
Variation?**



**Bimanual  
Lateral**



**Bimanual Parallel  
Extension?**



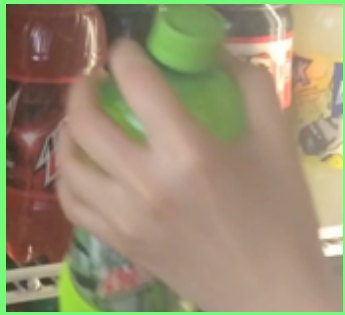
**Bimanual  
Cupping**



**Bimanual  
Ring**



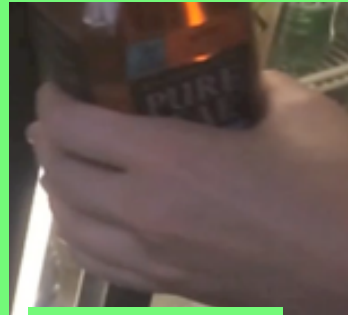
# 3 Minutes of Shopping, One Subject



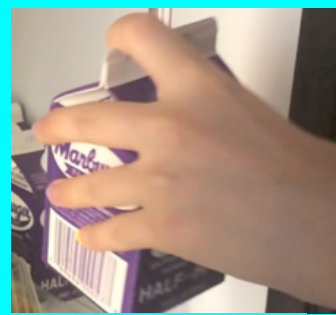
Power Sphere 3



Small Diameter Heavy Wrap 1



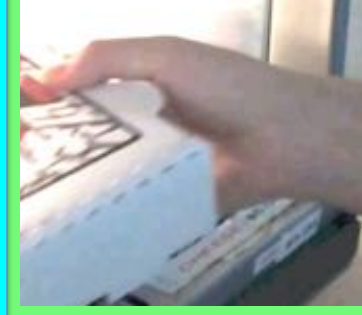
Large Diameter Heavy Wrap 8



Large Diameter Heavy Wrap / Index Top 3



Power Parallel with Index Side 2



Power Parallel 1



Power Grip Distal Type 1



Multi-Item 3



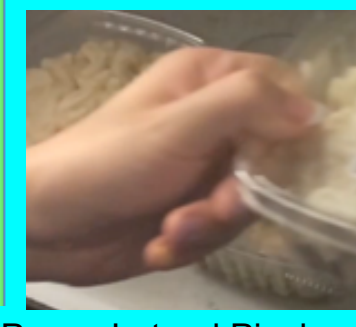
Power Medium Wrap 1



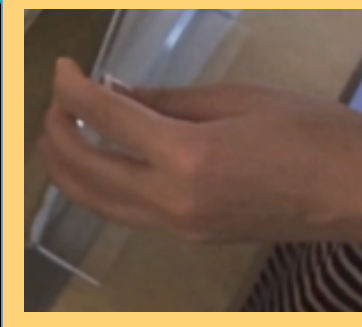
Power Grip Extension Type 3



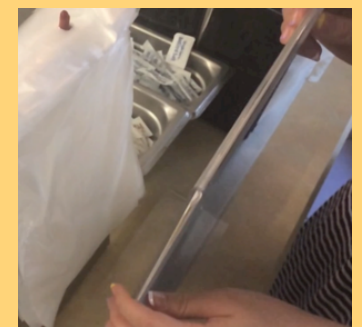
Power Lateral Pinch 3



Power Lateral Pinch Torque Supported 2



Power Non-Prehensile 1



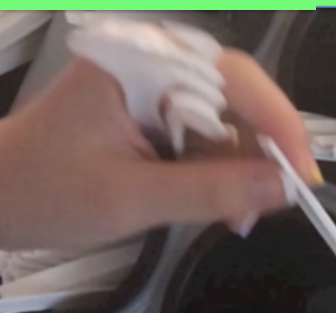
Two-Hand 1



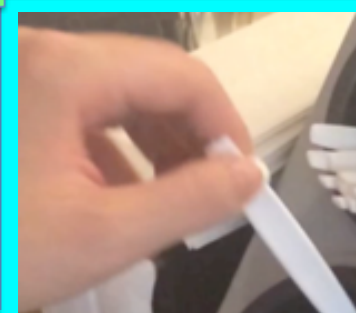
Thumb Proximal Phalanges Pinch 4



Ulnar 7



Ulnar Plus Pinch 3



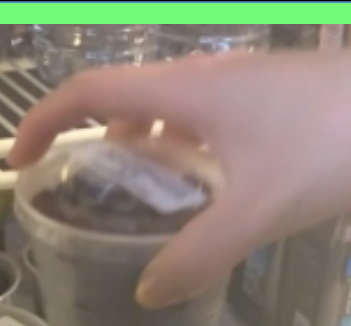
Thumb Index Pad Pinch 8



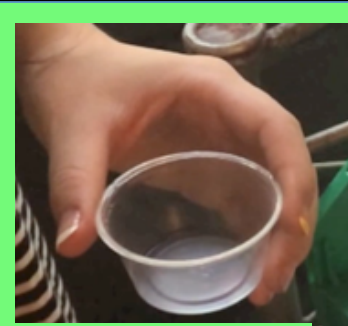
Power Lateral Pinch, Middle 3



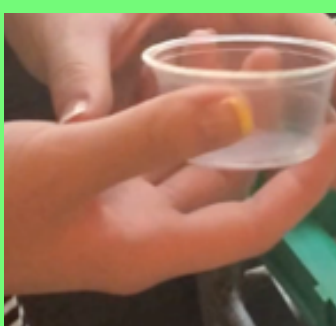
Precision Sphere 1



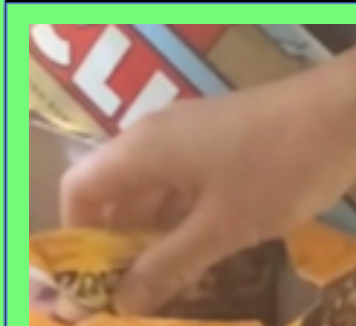
Precision Disk 4



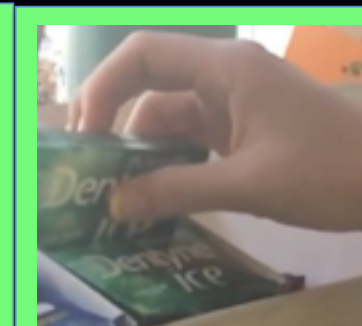
Precision Thumb 2-Finger 1



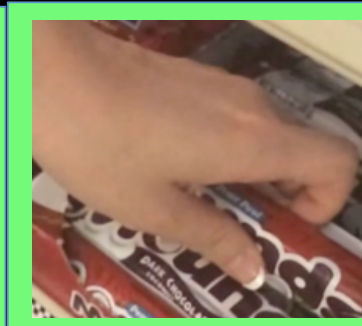
Precision Tripod 2



Precision Thumb 4-Finger 4



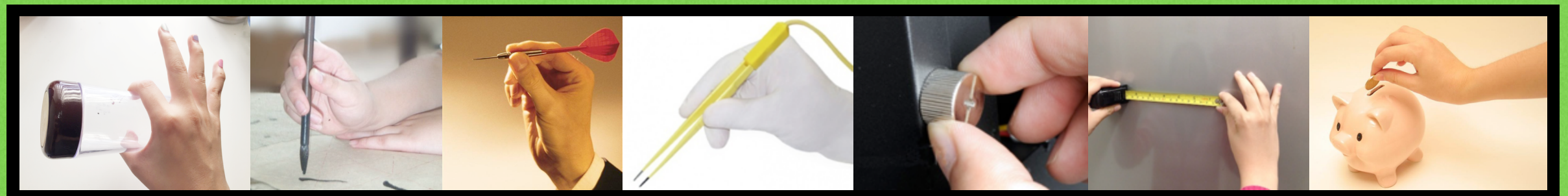
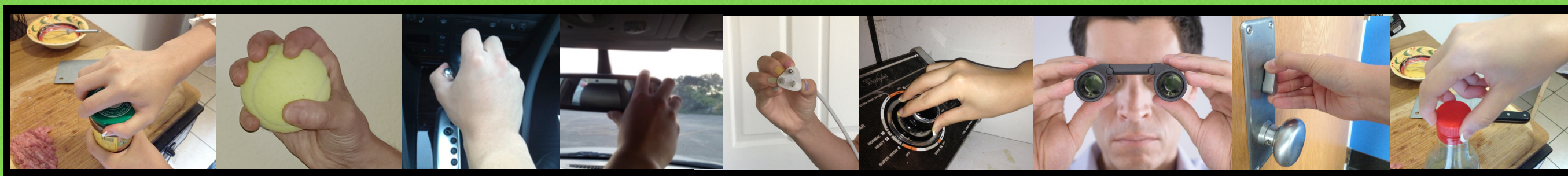
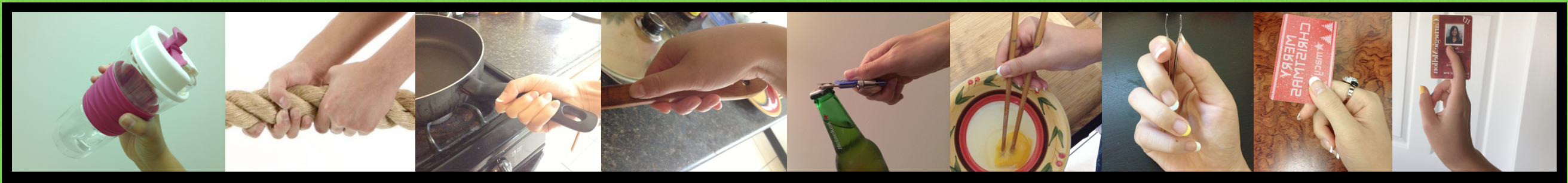
Precision Thumb 3-Finger 3



Precision Thumb Index Finger 1

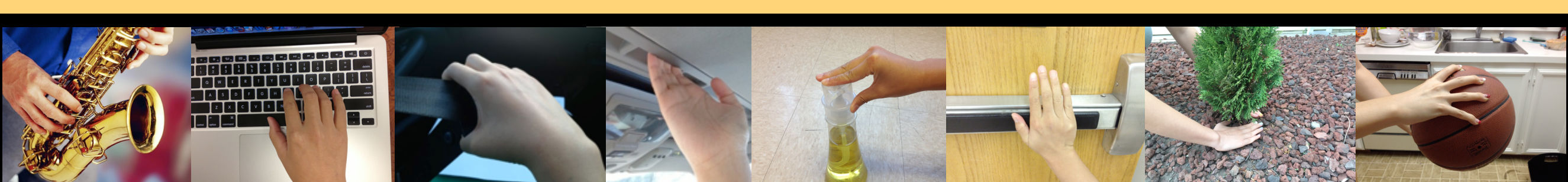


# 1 Day, Two Subjects, Grasps from Feix et al.





# 1 Day, Two Subjects, "Grasps" NOT in Feix et al.

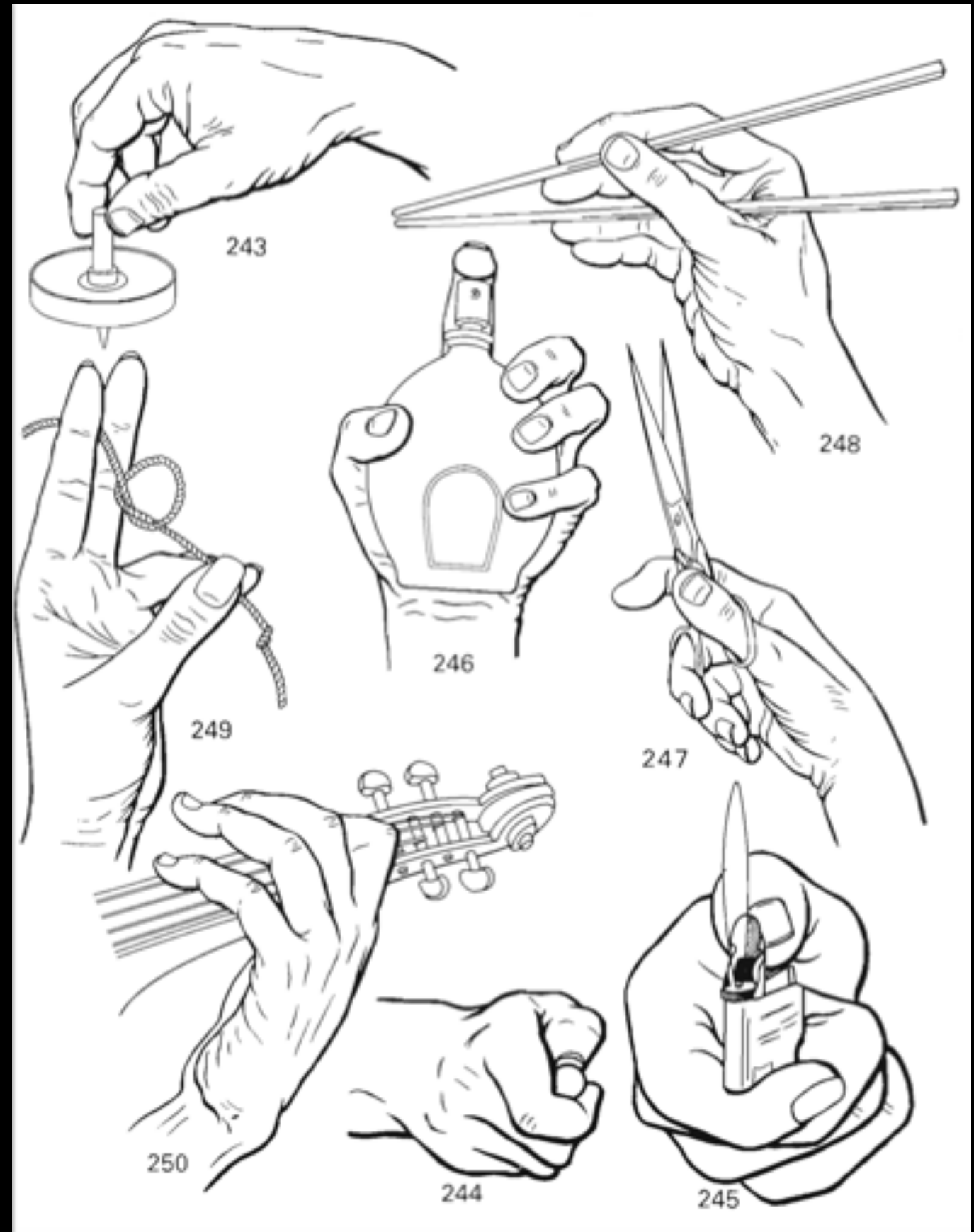
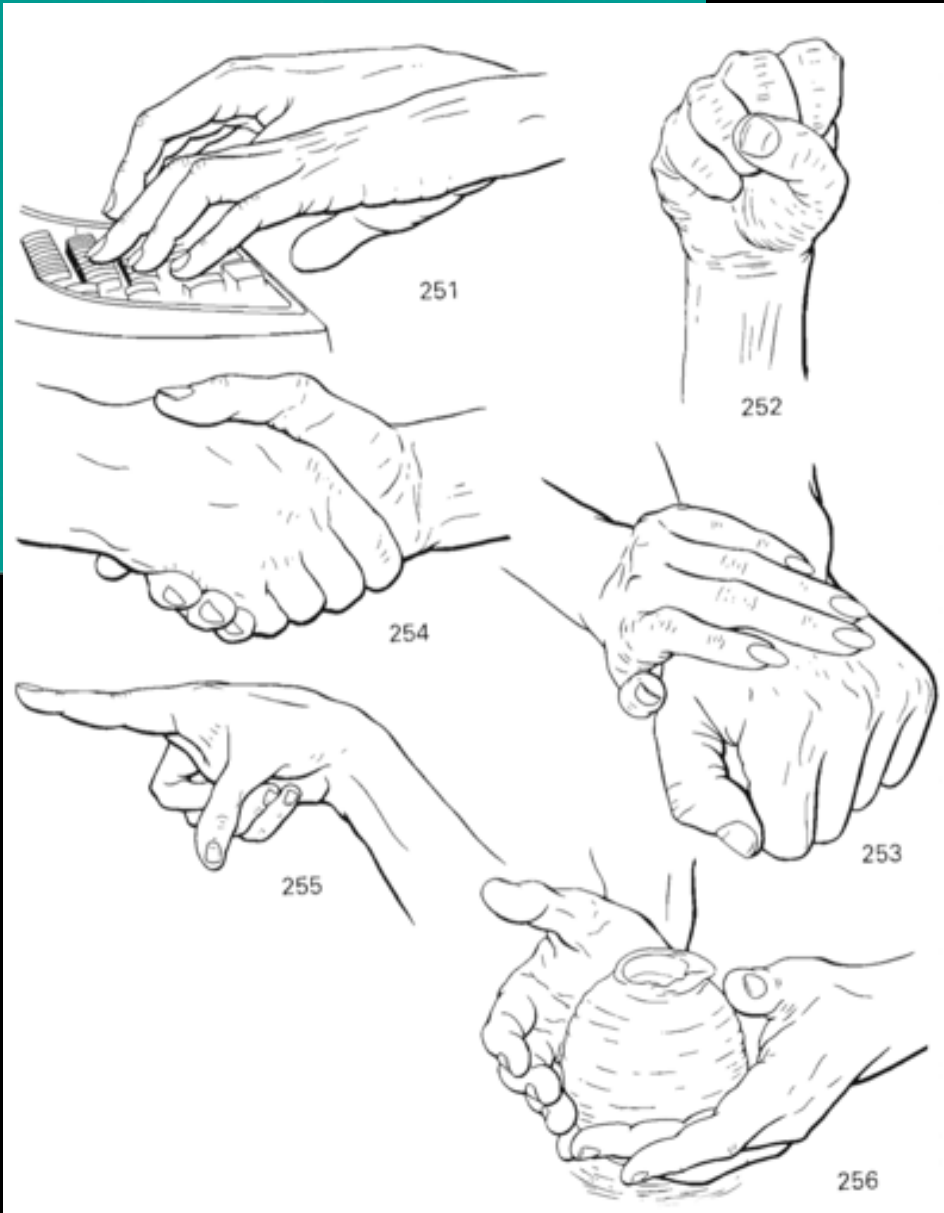




# Grasps in Action: Two Pages from Kapandji

Churchill Livingstone





## The Physiology of the Joints I.A. Kapandji







Hand shape is not enough

# Motion, Force, and Stiffness

## Lateral (Pinch) Grasp

Example		
Force Type	Pull	Pull
Motion Dir	-x (hand)	xz plane (hand)
Force Dir	-	-
Flow	Bound Motion/ Bound Force	Half Bound Motion/ Bound Force
Annotation	Put on gloves(along the arm)	Drag toilet paper
Example		
Force Type	Twist	Twist
Motion Dir	around y axis (hand)	around x axis (hand)
Force Dir	-	-
Flow	Bound Motion	Bound Motion
Annotation	Twist the key to start up the car	Twist the knob in car

Example		
Force Type	Hold	Rub/Stroke
Motion Dir	xy plane (hand)	xy plane (hand)
Force Dir	-	inwards (hand)
Flow	Free Motion/ Half Bound Force	Half Bound Motion/ Bound Force
Annotation	Give card to someone	Wipe classes
Example		
Force Type	Hold	Hold
Motion Dir	z (global)/ -z (global)/ around x axis (hand)	around x axis (hand)
Force Dir	-	-
Flow	Free Motion/ Bound Force	Half Bound Motion/ Bound Force
Annotation	Eat with scoop	Pour washing powder

J. Liu, F. Feng, Y. Nakamura, and N. S. Pollard, 2014. A Taxonomy of Everyday Grasps in Action, IEEE International Conference on Humanoid Robots (Humanoids 2014), Madrid, Spain, November 2014.

<http://www.cs.cmu.edu/~jiali1/database.html>

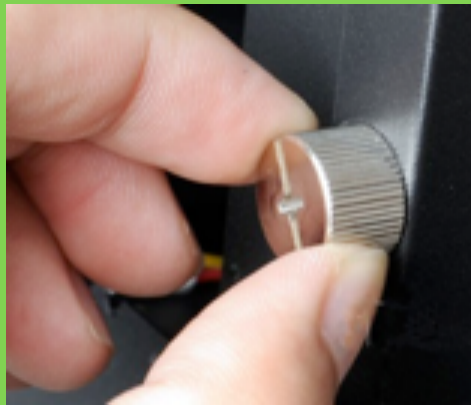


# People prefer expressing forces as verbs

## 20 Verbs for 173 Observed Grasps

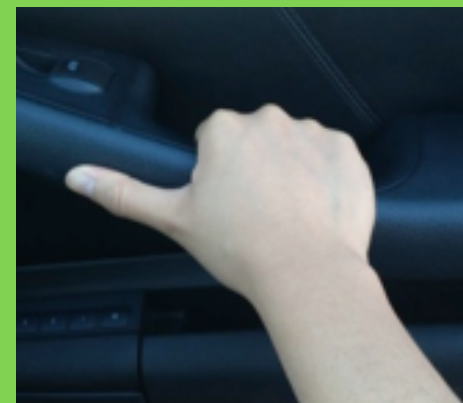
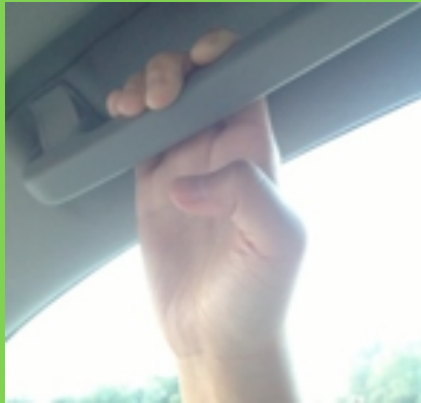
Force Type	Definition	Frequency
Break off	Remove a part of an object	3
Extend	Apply outward forces from within the object	3
Grab	Hold or secure without opposing gravity	32
Hold	Grasp object in a way that resists gravity	41
Lever	Pivot one end of an object around a fixed end	4
Lift	Apply upward force greater than gravity	7
Place	Put something in a specified position	1
Press	Exert force in a direction away from the shoulder	31
Pull	Exert force in a direction towards the shoulder	18
Punch	Press or push with a short, quick movement	1
Put in	Insert one object into another	4
Roll	Cause rotation without prehension	3
Rub/Stroke	Move back and forth while pressing	9
Scratch	Rub with something sharp or rough (with the hand directly or a tool)	2
Squeeze	Apply compressive force around object greater than needed to hold object	4
Take out	Remove one object from another	2
Throw	Propel an object through the air	3
Turn	Flip or rifle through pages	1
Twist	Cause rotation with prehension	13
Swing	Move with a smooth, curving motion like hand waving or arm swinging	6

# Twist

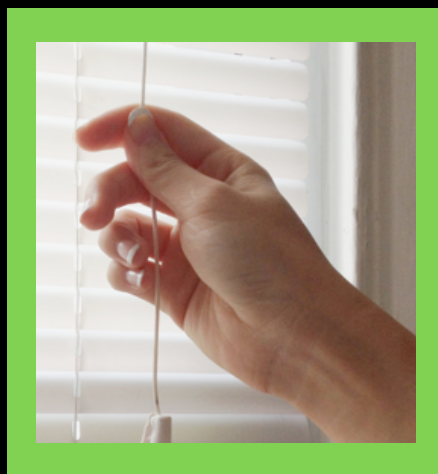
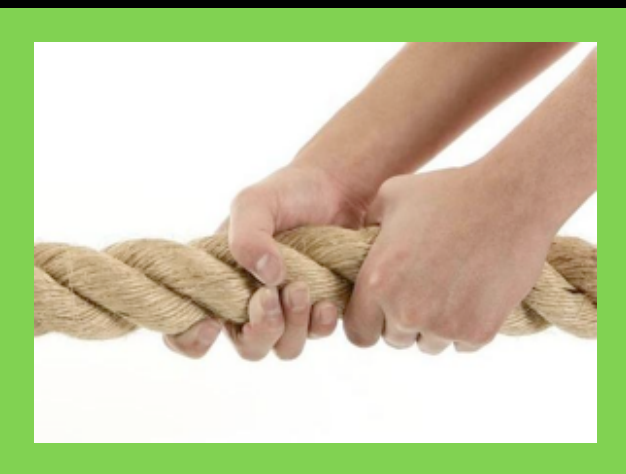
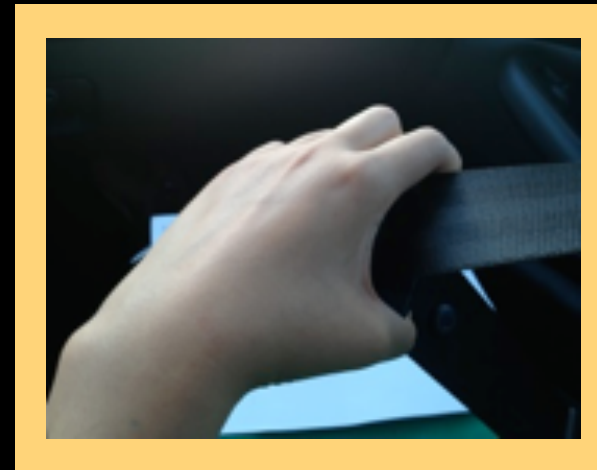
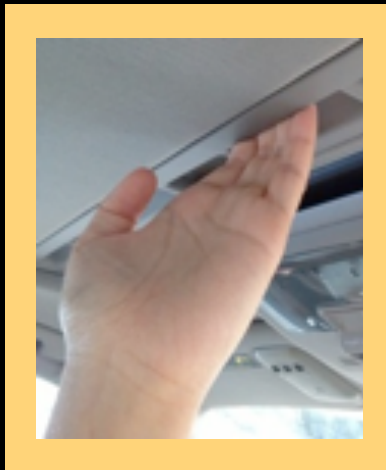




# Pull



# Pull





<b>Adjust</b>	Delicately changing the position of an item in other hand (usually an item held in <u>loose-grip</u> during this), using <u>pinch-grip</u> , <u>knuckle-push</u> , or movements of a single finger or the lips. <b>M/R.</b>	<b>Pick</b>	<u>Pinch-grip</u> on clearly defined object which is pulled against force of natural attachment, usually to procure the item.	<b>Slide-adjust</b>	Re-locate a firm grip on a different portion of an item by sliding the hand, while supported with mouth, other hand, or both. <b>M/R.</b>	<b>Tuck-fold</b>	Base of leaf-bunch held by one hand, while the other hand uses digits 1, 4 and 5 to tuck in leaf-blades at the sides, before digits 2 and 3 fold over the top leaves. By definition, the hand holding the bunch is swapped over. <b>R.</b>
<b>Bite-off</b>	Use teeth to cut off portion of naturally attached or hand-supported object, either with single bite or repeated biting. <b>[M]</b>	<b>Pick-at</b>	Single digit used to damage or loosen item, e.g. to allow <u>peel</u> to begin. <b>[R].</b>	<b>Snap-apart</b>	Bend object to break it– although not necessarily to fully detach it– supported by both hands on either side of the break. <b>B.</b>	<b>Twist-apart</b>	Object (usually leaves) held in both hands, then twisting of each hand versus the other is used to tear the object. <b>R.</b>
<b>Brush-off</b>	Using the side of a digit or digits (e.g. 1 and 2 held in “C” shape) to gently brush along stem, midrib or bundle held in hand in order to dislodge debris. <b>R.</b>	<b>Pick-off</b>	<u>Pinch-grip</u> or <u>lip-grip</u> on small item which is pulled off an object held in other hand. <b>M/R.</b>	<b>Snap-off</b>	Holding a naturally attached object in one hand and bending; thus applying force to detach item. <b>M.</b>	<b>Twist-fold</b>	A special case of <u>leaf-fold</u> where the leaf-blades are twisted before being folded over. <b>R.</b>
<b>Combine</b>	Carrying out separate functions with fingers 1:2 and 3–5 at same time (in various functions), e.g. <u>pinch-grip</u> with 1:2 to <u>pick</u> while <u>loose-grip</u> of 3–5 in order to accumulate already picked items.	<b>Pick-out</b>	<u>Pinch-grip</u> or <u>lip-grip</u> on small item which is taken out from among a mass of items, requiring discrimination of one item from among many (such as in cleaning a food handful). <b>M/R.</b>	<b>Snip-case</b>	Use incisor teeth to clip off outer casing (an action like that of pincers) in order to discard the casing and expose edible pith. Used typically for removing <i>Peucedanum linderi</i> casing, only occasionally for thistle. <b>M.</b>	<b>Twist-in</b>	Handful twisted as it is fed into mouth, in the case of leaves having the effect of keeping the bundle compact. <b>M.</b>
<b>Crossed hands</b>	Both hands held flat and palm up, crossed at right angles to support greater force e.g. during <u>scrape-off</u> . <b>B.</b>	<b>Pick-up</b>	<u>Pinch-grip</u> on object to lift from flat surface.	<b>Spaghetti-feed</b>	With stem held in mouth without use of the hands, lips used to feed in rest of its length – similar to eating spaghetti.	<b>Twist-off</b>	Holding a naturally attached object in one hand and twisting, thus applying force to detach object.
<b>Dig</b>	<i>Using fingers held flat as blade or curved, to excavate in soft earth or litter (often to get access to roots). Used typically for getting root epithelium, e.g. of Senecio johnstonii or Lobelia wollostoni.</i>	<b>Pinch-grip</b>	Firm precision grip, varying in whether tip-to-tip (1:2 or 1:other) or tip-to-side (1:2 normally); usually either for support or procurement, as if holding in pliers.	<b>Squeeze-grip (power)</b>	<i>Potentially strong, closed power grip of one hand on cylindrical object with thumb along the object as support. Used routinely in processing Peucedanum linderi.</i>	<b>Two-hand (A)</b>	(Asymmetrical) one hand (the “major” hand) uses some sort of strong, closed-hand grip as support while the other (“minor”) hand also supports, but with <u>pinch-grip</u> (or sometimes <u>pencil-grip</u> ) to allow processing by mouth (minor hand often alternates between supporting role and strip, peel, etc while grip of other hand remains). <b>R.</b>
<b>Flat hand</b>	Hand held flat and palm up to support plant material e.g. during <u>scrape-off</u> .	<b>Power-grip</b>	Potentially strong, closed-hand grip (varying as to whether whole-hand or 1+ fingers only; see Marzke and Wullstein 1995); includes using both hands with thumbs pointing same way,) on cylindrical object (often stem) for support or for procurement, or on a bundle while accumulating items.	<b>Squeeze-up</b>	<i>Gather together a bundle of items so that they are finally held in some sort of power grip in one hand (often loose-grip becoming power-grip), using closure of first one hand for compression of loose bundle, then the other, alternately. Used typically by immature animals, especially with Laportea alatipes leaves.</i> <b>R.</b>	<b>Two-hand (S)</b>	(Symmetrical) strong, closed-hand grip of both hands on cylindrical object, with thumbs pointing towards each other, to allow processing by mouth. <b>B.</b>
<b>Hook</b>	Whole hand or only certain fingers or both hands, held rather rigidly in open curve, to pull attached object (often used to heave down mass of vegetation).	<b>Pull-apart</b>	Holding an object in the two hands, the hands then pulling apart in a movement at a tangent to body, thus applying force to object to pull it apart. <b>B.</b>	<b>Stem-fold</b>	Holding with one hand, used to apply force to central part of long object that is supported at its ends by the other hand and either natural attachment or friction, having the effect of folding it to a manageable size. <b>R.</b>	<b>Two-handed-bend</b>	<i>Loosening and re-grasping by the hand holding a long item, while item is folded into a bundle with the other hand, either once or many times, to form a concertina shape as in zig-zag. Used typically for dealing with Galium ruwenzoriense stems.</i> <b>R.</b>
<b>Knock-off</b>	The knuckle of one or more digits, used with a flick of the wrist, to knock off an item (e.g. flower head) from bundle held in hand. <b>R.</b>	<b>Pull-off</b>	Holding a naturally attached object with one hand and pulling, thus applying force to detach item; effect as <u>yank</u> .	<b>Strip-down</b>	Half-open grip (often constricted at 5:palm, but not always) around leafy stem or midrib of leaf, slid down stem to detach leaves or side-shoots, sometimes supported by other hand (thus removing unwanted items during stem processing). <b>[R].</b>	<b>Two-hand cup</b>	<i>Object held between palms of both hands and supported by cupping of hands around it. Occasionally used with large pieces of stem, e.g. Senecio johnstonii.</i> <b>B.</b>
<b>Knuckle-push</b>	Fist held as in knuckle-walking to apply force to object supported by other hand. <b>R.</b>	<b>Reach</b>	Various sorts of grip, with one or both hands or fingers or <u>pinch-grip</u> , on attached object which is pulled to bring into range. <b>[B]</b>	<b>Strip-out</b>	The exposed section of stem or midrib of large leaf is held in one hand and then pulled, often to the mouth, thus stripping the case away and exposing lower section of object. <b>R.</b>	<b>Wrap</b>	One hand grips the base of a bunch of leaves and the other comes in at a tangent to one side then slowly contracts the fingers systematically wrapping leaf over leaf. By definition, the hand holding the bunch is swapped over. <b>R.</b>
<b>Knuckles</b>	Knuckles held against object, allowing other hand to procure an item. <b>R.</b>	<b>Retain-nucleus</b>	Using the remains of the last handful eaten (bitten off from these remains with a shear-bite) as a basis for starting to accumulate the next (implies <u>combine</u> ).	<b>Strip-up [-rev]</b>	Half-open grip (often constricted at 1:2, but not always) around leafy stem or midrib of leaf, slid up stem with thumb uppermost to detach bunch of leaves, against force of substrate or other hand’s supporting grip (thus accumulating leaves, the bunch protruding between 1:2). Occasionally hand reversed so that thumb away from direction of motion (-rev). <b>[R].</b>	<b>Yank</b>	Grip with one hand (or teeth) used to apply force on object which is pulled against natural attachment (often to detach the object), or to part of object supported by other hand or mouth (often to detach the part).
<b>Invert</b>	Knuckles held against object, allowing other hand to procure an item. <b>R.</b>	<b>Roll</b>	<i>While holding a loose or untidy bundle, roll against flat support (e.g. of chin or hard palate) to produce roll shape. Used typically for tidying up Galium ruwenzoriense bundles.</i>	<b>Swap-hand</b>	Transfer object or handful from one hand to the other. <b>R.</b>	<b>Zig-zag</b>	Repeated loosening and re-grasping, by the hand holding a plant strand, with a rocking motion of this hand, to enfold the strand into a concertina shape. (Thus combine two grips in same hand.) Has the effect of allowing it to fit into neat bundle using gravity or the strand’s natural attachment to bend the strand, or (if specified) bent against an object. Used typically with <i>Galium ruwenzoriense</i> stems, only occasionally with thistle. <b>R.</b>
<b>Leaf-fold</b>	A special case of <u>adjust</u> , using finger or lips to pull out leaf-blades from the grip of other hand, then folded over (sometimes using thumb as fulcrum) and gripped again. Used typically for <i>Laportea alatipes</i> leaves, only occasionally with thistle. <b>M/R.</b>	<b>Rotate</b>	Turn or twist a long object held in strong, closed-hand grip to bring into range or into more convenient position within other hand to allow processing. <b>R</b>	<b>Tooth-pick</b>	<u>Pinch-grip</u> or single digit (usually 2) used to remove debris from mouth, either after mouthful has been swallowed and debris lodged between teeth, or from mouthful of food containing unwanted item. <b>M.</b>		
<b>Lever-apart</b>	Object (usually leaves) held in both hands using strong, closed-hand grip, then leverage of rocking the hands or knuckles against each other, used to tear the object. <b>B.</b>	<b>Rotate-adjust</b>	Rotate item by adjusting position in hand, whilst item is supported with mouth or other hand. <b>M/R.</b>	<b>Tooth-pull</b>	Pull with object held in teeth, against bracing of limbs. Typically used to pull up underground shoots of <i>Arundinaria alpina</i> , only occasionally used with thistle. <b>M.</b>		
<b>Lift-up</b>	<u>Power-grip</u> on object to lift from flat surface.	<b>Rotate-push</b>	Turn or twist long object held in strong, closed-hand grip and pushed to break, whilst supported by other hand or by substrate. <b>[R].</b>	<b>Tooth-strip</b>	Partial closure of incisors around root or stem, pulling against support of hand(s), an action like that of wire-strippers. Typically used for stripping off root epithelium e.g. of <i>Senecio johnstonii</i> or <i>Lobelia wollostoni</i> . <b>M.</b>		
<b>Lip-grip</b>	Delicate grip with centre of lips, e.g. when removing debris from bundle.	<b>Sausage-feed</b>	Repeated loosening of the grip and re-grasping lower down an approximately sausage-shaped food bundle, in order to feed it into the mouth as a whole, without the bundle coming apart.	<b>Tooth-twist</b>	<i>Holding object in mouth and hand with strong, closed-hand grip (sometimes with other hand duplicating action of upper hand), using a twisting of hand and head to tear the object. Typically used for getting Arundinaria alpina shoots from the ground.</i> <b>M.</b>		
<b>Loose-grip</b>	Loose, part-open whole hand grip, usually applied to detached objects to allow delicate processing with hand or mouth (e.g. <u>pick-out</u> to clean, or <u>leaf-fold</u> ) or to accumulate leaves or stems.	<b>Scissor apart</b>	Break object by holding it in both hands and moving the hands apart at right angles to axis of object, creating a scissoring motion. <b>B</b>	<b>Teeth-grip</b>	Grip with teeth to allow processing with hands, usually to detach from, or adjust bundle. <b>M.</b>		
<b>Manipulate</b>	Rearranging the position or shape of item(s) held in one hand, simply using the fingers and without using other hand.	<b>Scissor-grip</b>	Part-open or open grip, object is held between the sides of adjacent digits, usually on stem.				
<b>Mouth-grip</b>	Grip using mouth (not usually possible to be sure whether or not <u>teeth-grip</u> ), to allow processing with hands, usually to detach from, or <u>adjust</u> bundle.	<b>Scrape-off</b>	Incisor teeth scrape soft layer off harder backing while object supported with <u>flat hand</u> or <u>crossed hands</u> , movement up or down. <b>M [and B].</b>				
<b>Mouth-peel</b>	Use of lips or teeth to pull off covering while other hand supports the item. <b>M.</b>	<b>Shear-bite</b>	Shearing bites used to detach a slice of a large, compact handful of items, either singly to finish eating a handful (when remains discarded unless <u>retain-nucleus</u> ) or repeated in order to eat the entire handful. <b>M.</b>				
<b>Peel [-back]</b>	One hand (usually with precision grip, e.g. <u>pinch-grip</u> ) used to pull off covering, while other hand supports. Often done with a twisting-back action (-back). <b>R.</b>	<b>Slice-off</b>	Slicing action, with finger(s), or half-open grip, or simply closed fist, to detach unwanted items, against force of substrate or support of other hand e.g. to clean leaves off thistle stem. <b>[R].</b>				
<b>Pencil-grip</b>	Closed-hand grip of one hand on cylindrical object (usually stem) but with object caught between pair of fingers and resting on thumb (2:3 or 3:4 or 4:5), usually for support. Presumed to be an accidental variant of <u>power-grip</u> .						

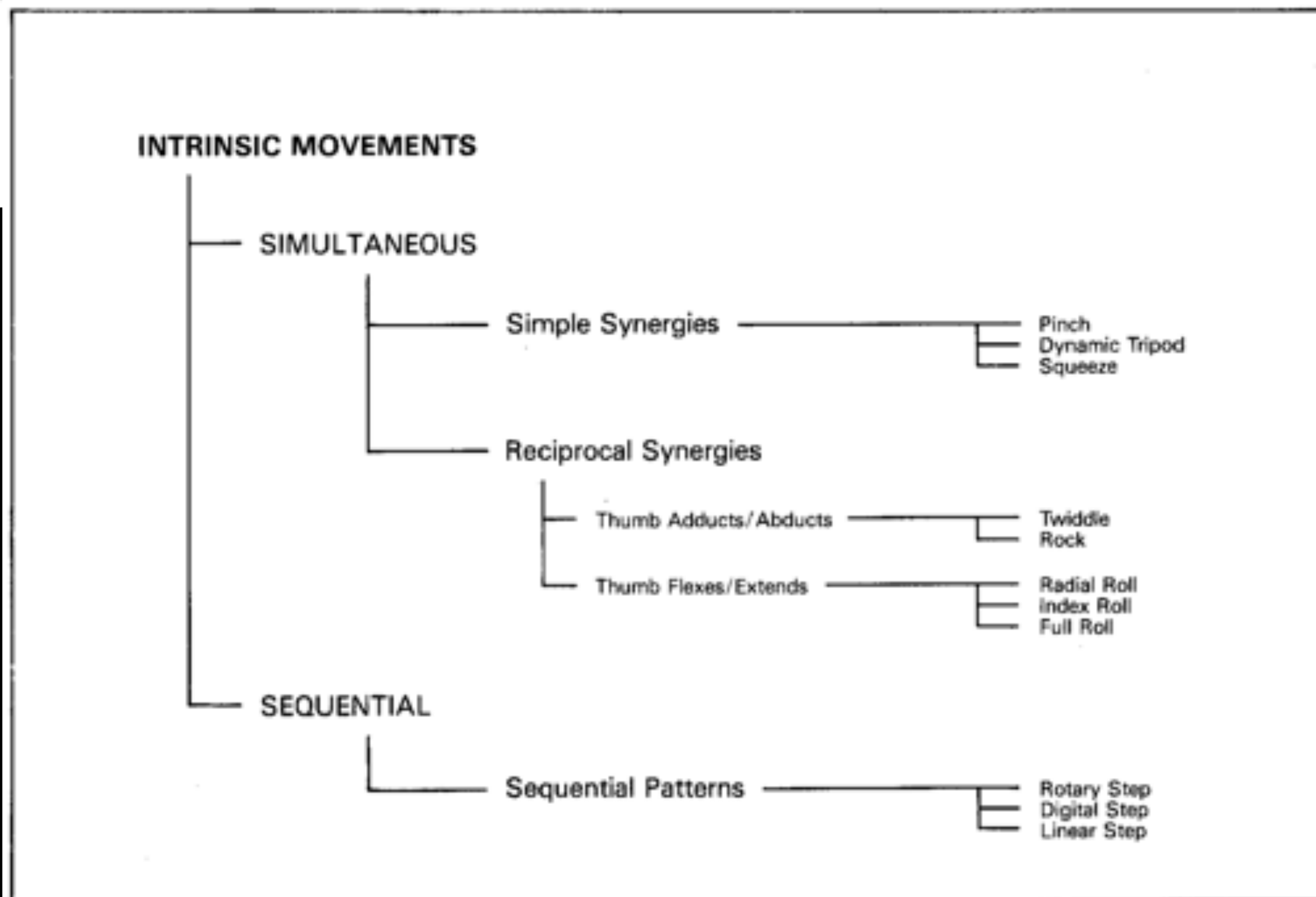
Byrne, Richard W., and Jennifer M. Byrne. "Manual dexterity in the gorilla: bimanual and digit role differentiation in a natural task." Animal Cognition 4, no. 3-4 (2001): 347-361.



Intrinsic hand motions

# A CLASSIFICATION OF MANIPULATIVE HAND MOVEMENTS

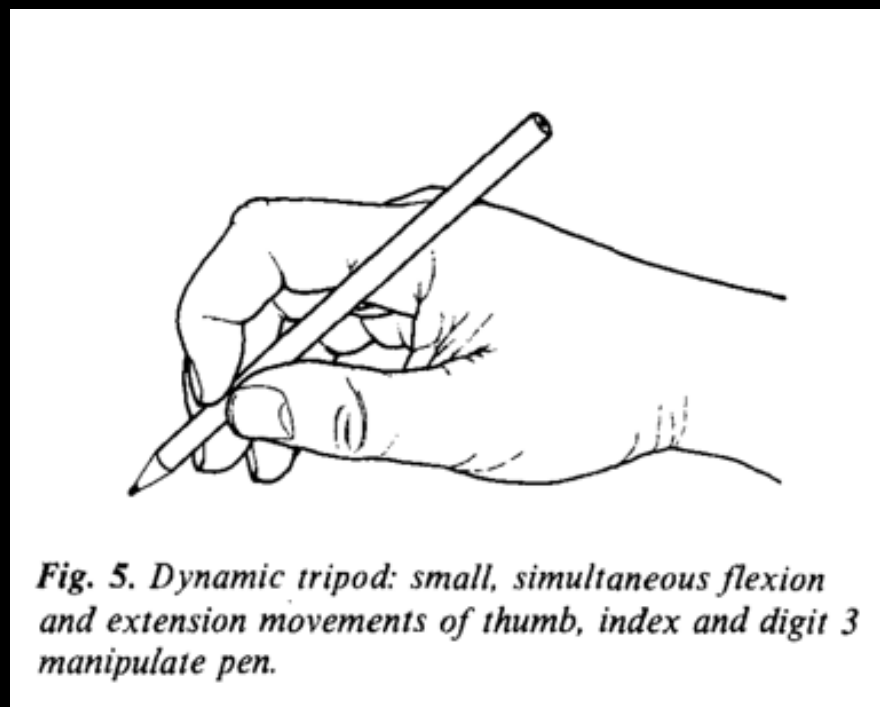
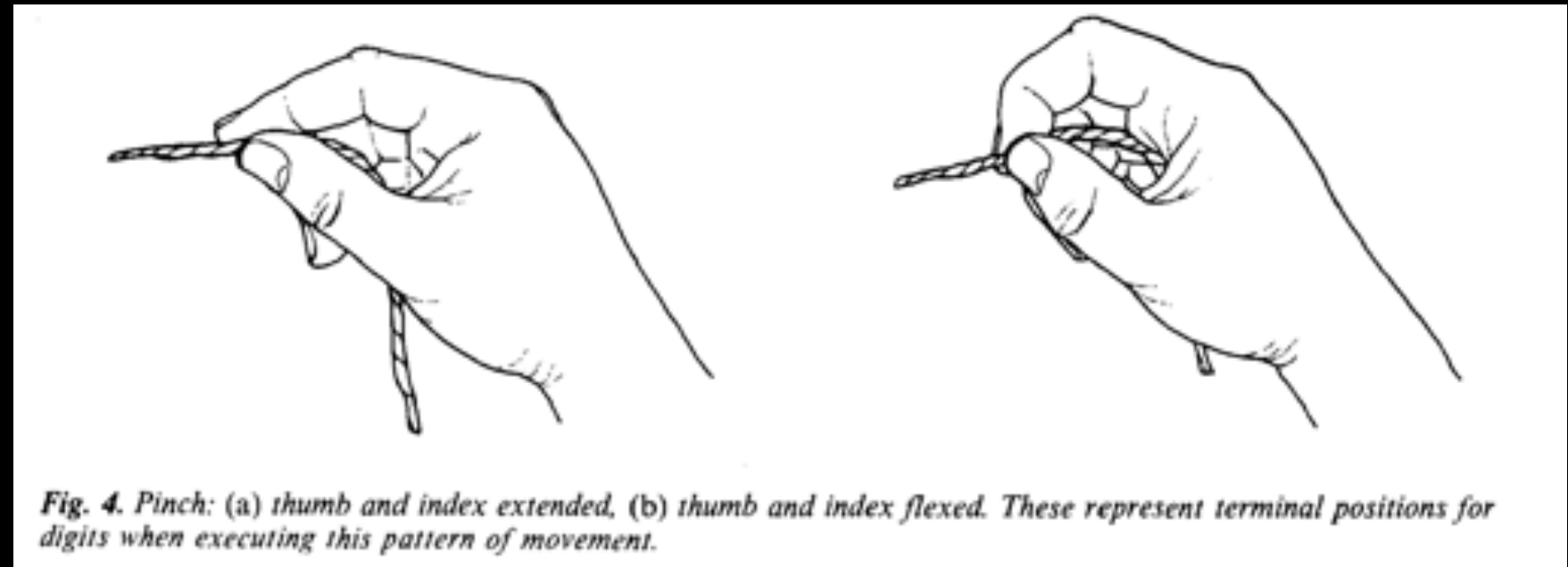
*J. M. Elliott*  
*K. J. Connolly*



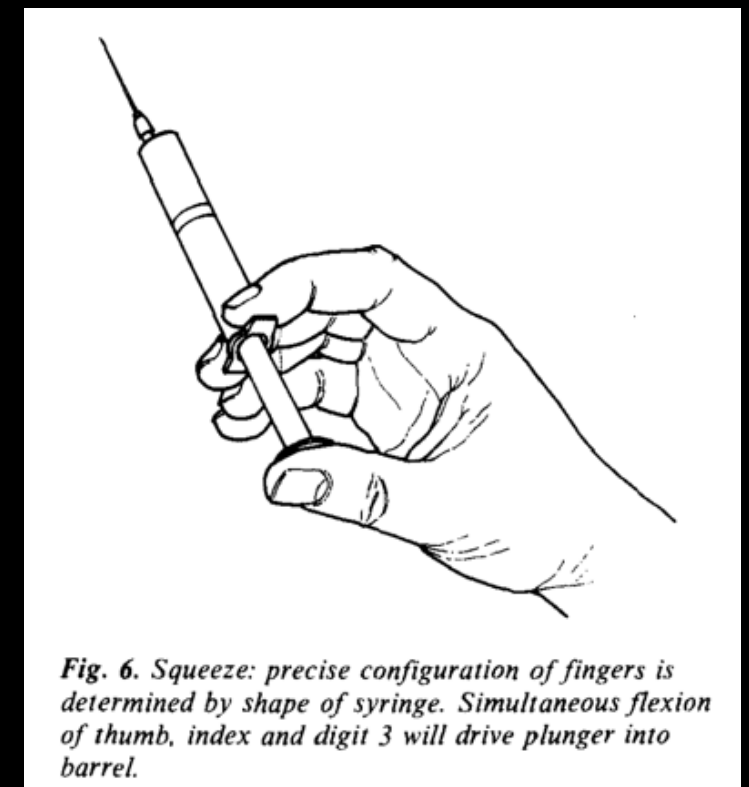
*Fig. 1. Classification of intrinsic hand movements.*

# Simple Synergies

Pinch



Dynamic Tripod

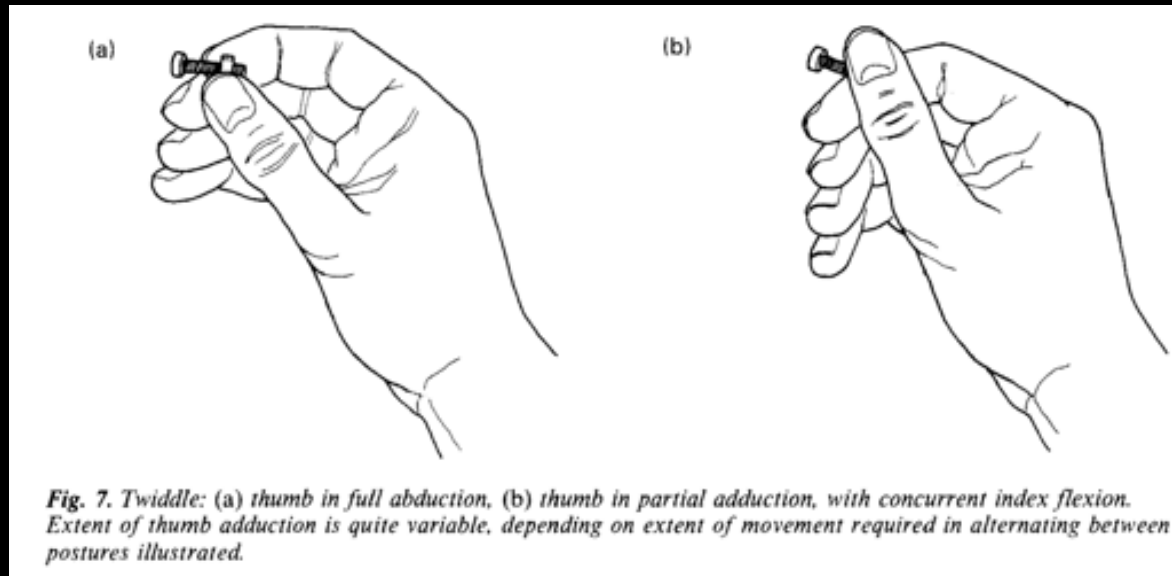


Squeeze



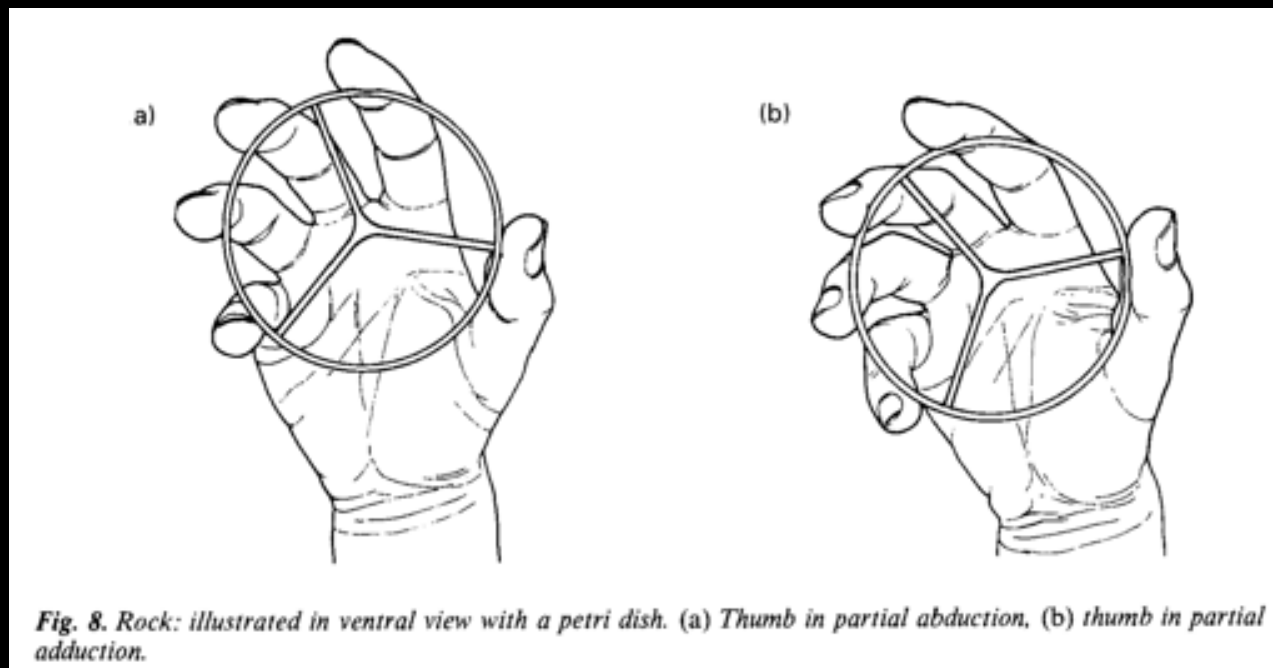
# Reciprocal Synergies

## Thumb Abducts/Adducts

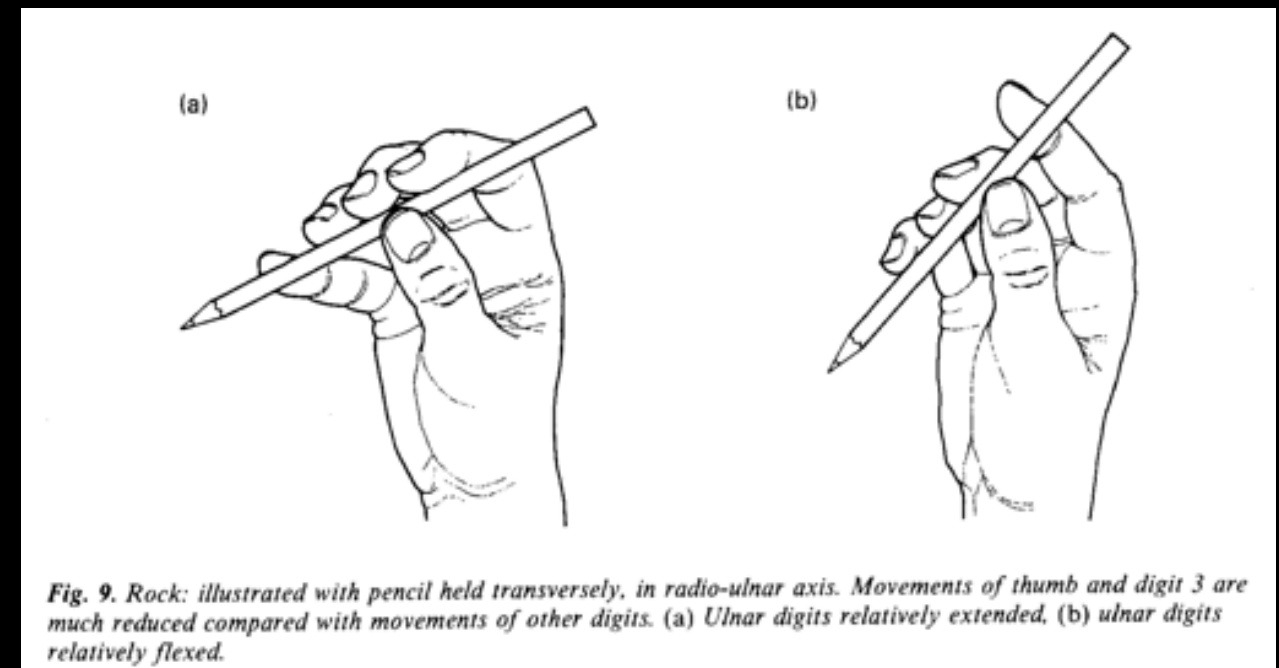


Twiddle

Rock



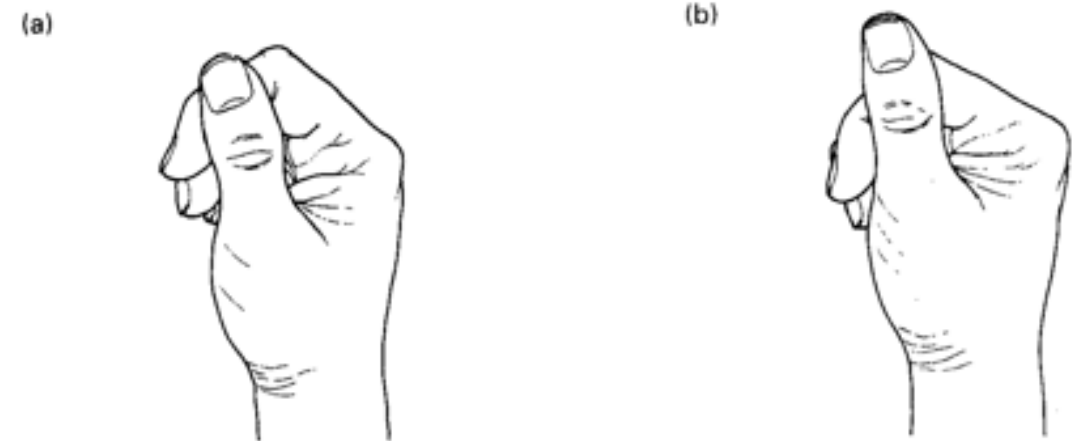
Rock



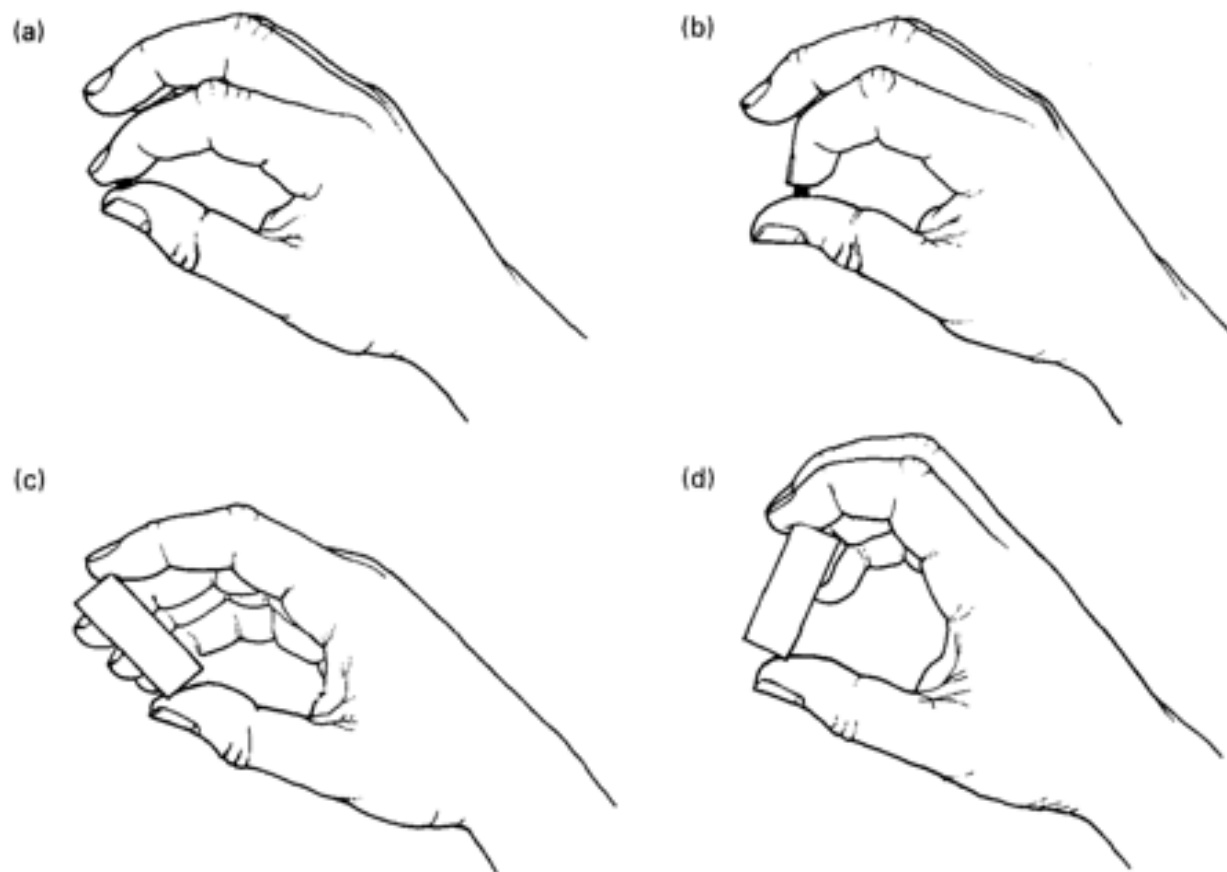
# Reciprocal Synergies

## Thumb Flexes/Extends

### Radial Roll



*Fig. 10. Radial Roll. In this example the thumb is adducted throughout; in other instances it may be partially abducted, consequently operating radial index more distally. (a) Index less flexed, (b) index more flexed.*



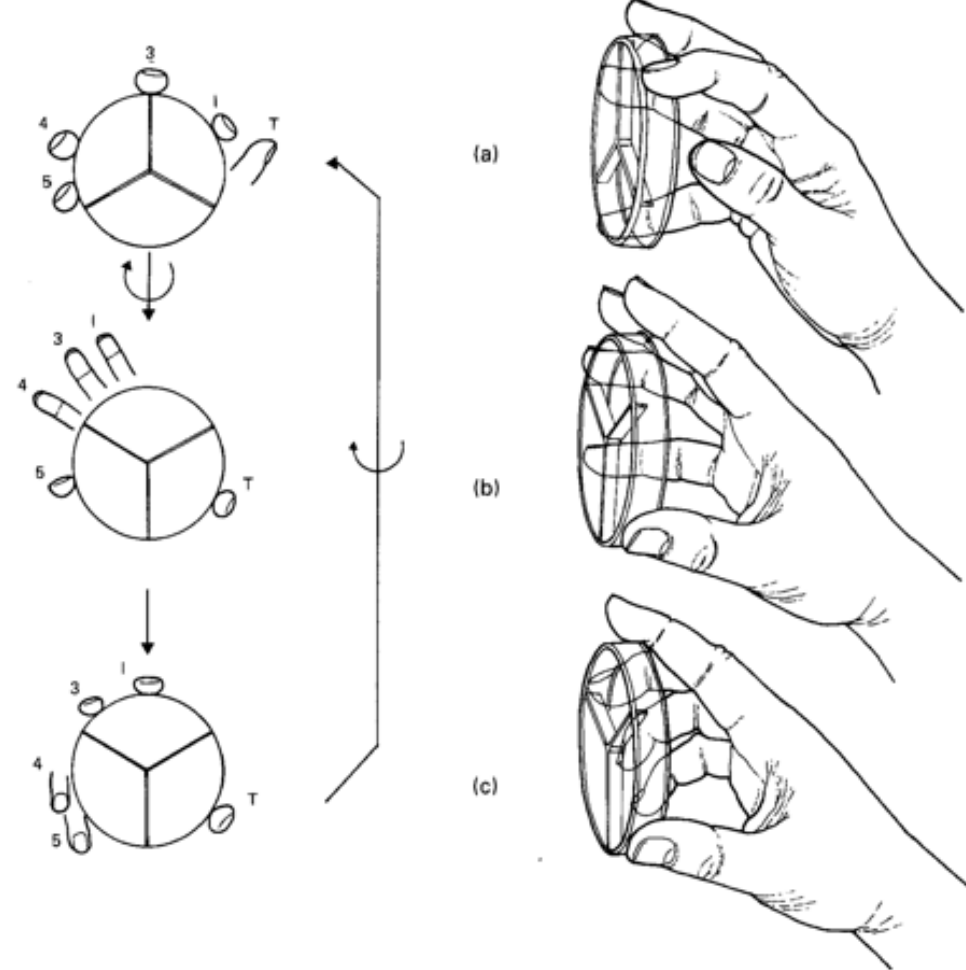
*Fig. 11. Index Roll (a,b), showing slight reciprocal flexion of thumb and extension of index (a), and the reverse (b). Full roll (c,d), as for index roll, but with involvement of additional digits. The object rocks about the radio-ulnar axis as result of movement between positions illustrated.*

### Index Roll

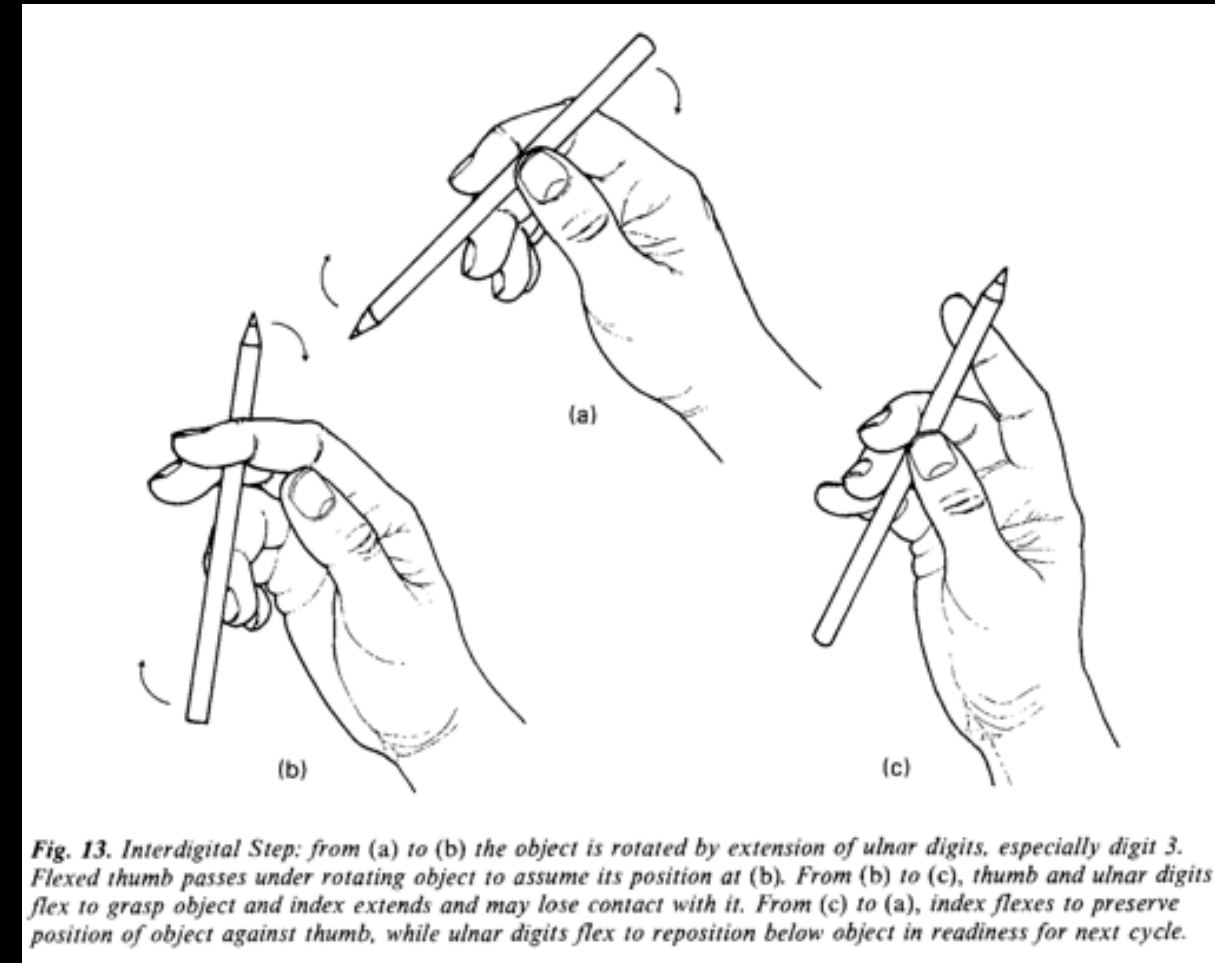
### Full Roll

# Sequential Patterns

## Rotary Step



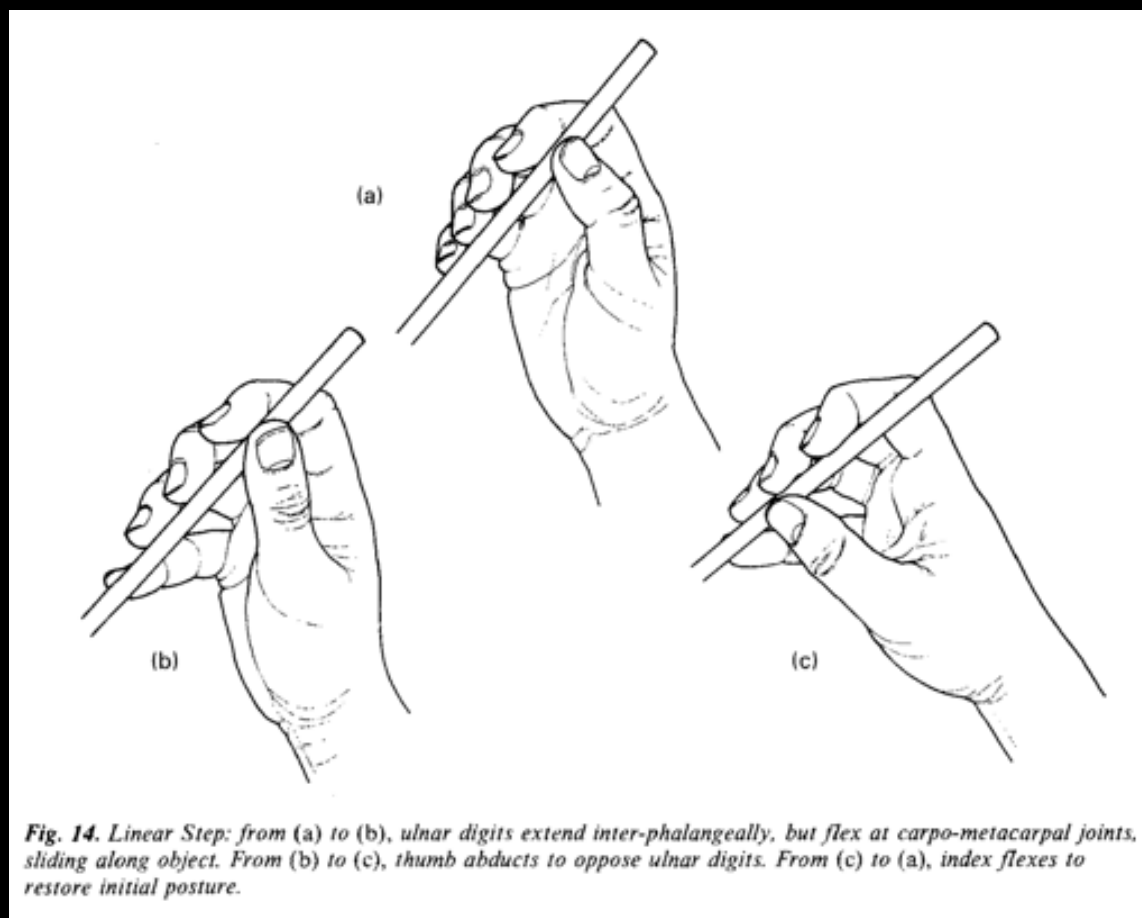
**Fig. 12. Rotary Step.** A schematic representation of positions in which the digits are placed (left), and successive postures of the hand (right). Sequence (a-b-c-a) shows successive phases in clockwise rotation totalling approximately  $120^\circ$  of object rotation. This occurs between transitions a-b and c-a, as indicated by the rotary arrows.



**Fig. 13. Interdigital Step:** from (a) to (b) the object is rotated by extension of ulnar digits, especially digit 3. Flexed thumb passes under rotating object to assume its position at (b). From (b) to (c), thumb and ulnar digits flex to grasp object and index extends and may lose contact with it. From (c) to (a), index flexes to preserve position of object against thumb, while ulnar digits flex to reposition below object in readiness for next cycle.

## Digital Step

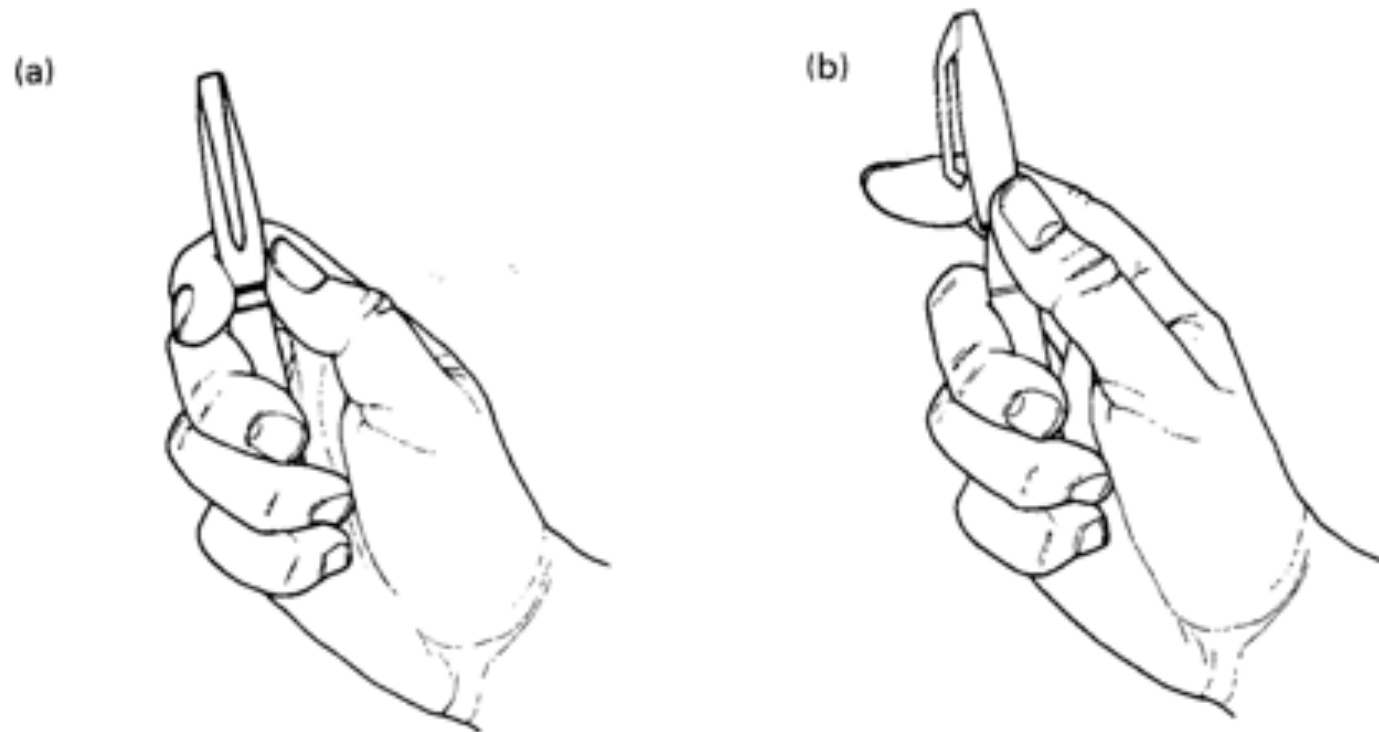
## Linear Step



**Fig. 14. Linear Step:** from (a) to (b), ulnar digits extend inter-phalangeally, but flex at carpo-metacarpal joints, sliding along object. From (b) to (c), thumb abducts to oppose ulnar digits. From (c) to (a), index flexes to restore initial posture.

# Not Classified

## Palmar Slide



*Fig. 15. Palmar Slide: the movement, illustrated in change from (a) to (b), involves extension of thumb and radial deviation of index, with some extension.*

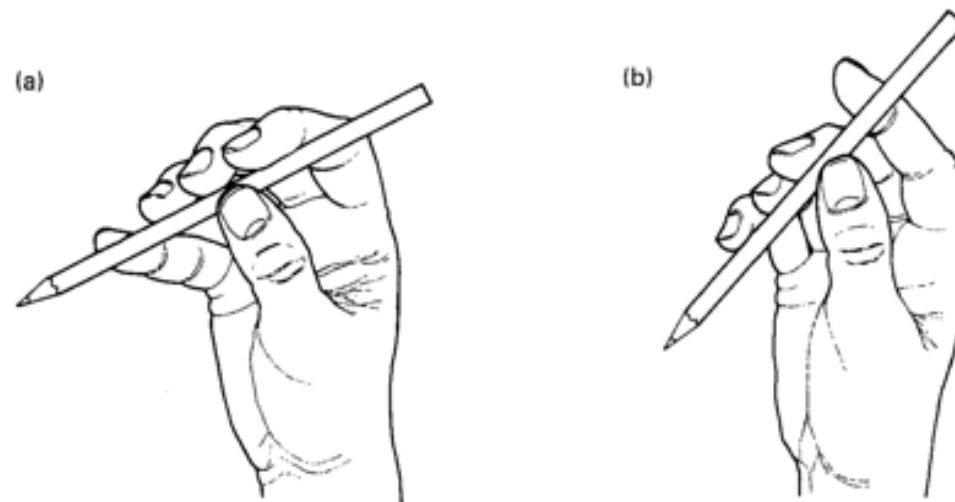


# Transitions



**6. Prismatic  
4-finger**

Rock



*Fig. 9. Rock: illustrated with pencil held transversely, in radio-ulnar axis. Movements of thumb and digit 3 are much reduced compared with movements of other digits. (a) Ulnar digits relatively extended, (b) ulnar digits relatively flexed.*



**29. Stick**



**6. Prismatic  
4-finger**



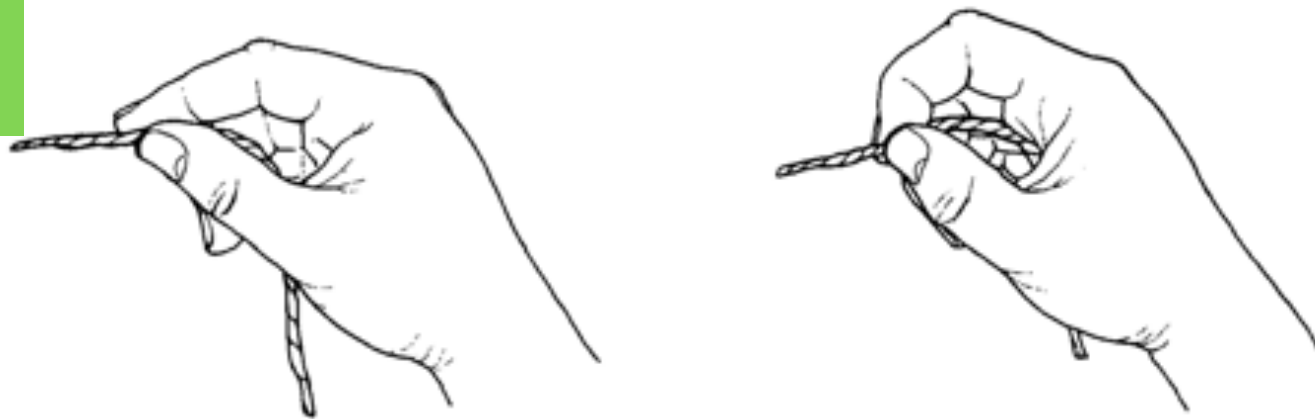
**32. Ventral**

# Transitions



**9. Palmar**

Pinch



*Fig. 4. Pinch: (a) thumb and index extended, (b) thumb and index flexed. These represent terminal positions for digits when executing this pattern of movement.*



**24. Tip Pinch**

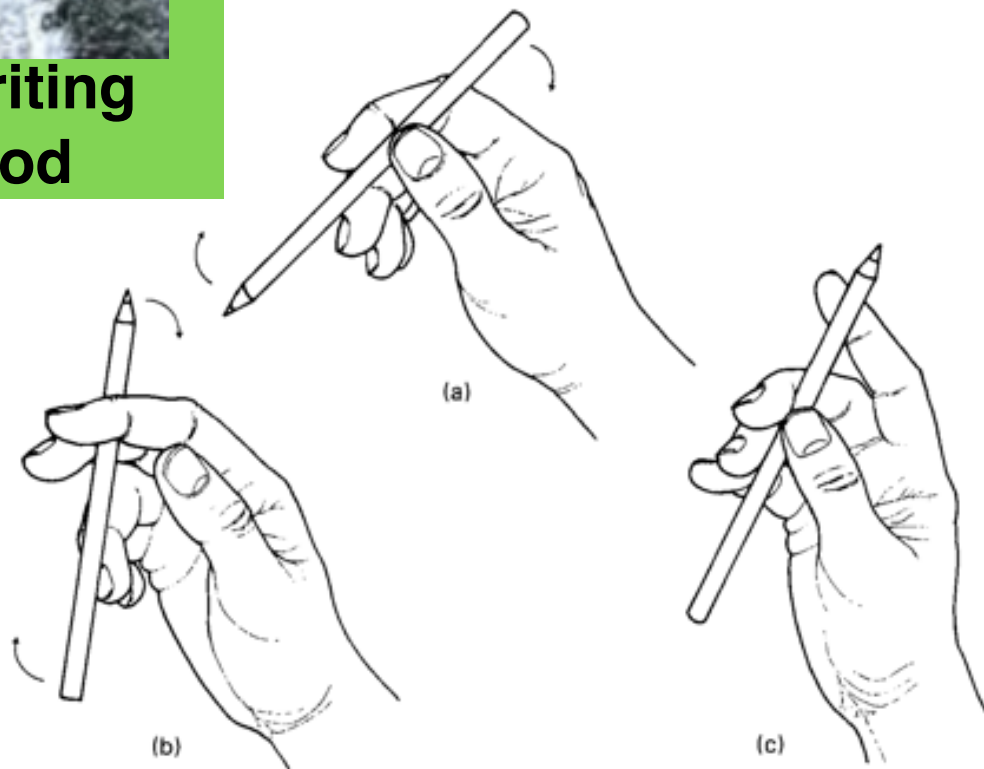
# Transitions



**20. Writing  
Tripod**



**23. Adduction  
Grip**



*Fig. 13. Interdigital Step: from (a) to (b) the object is rotated by extension of ulnar digits, especially digit 3. Flexed thumb passes under rotating object to assume its position at (b). From (b) to (c), thumb and ulnar digits flex to grasp object and index extends and may lose contact with it. From (c) to (a), index flexes to preserve position of object against thumb, while ulnar digits flex to reposition below object in readiness for next cycle.*

Digital Step



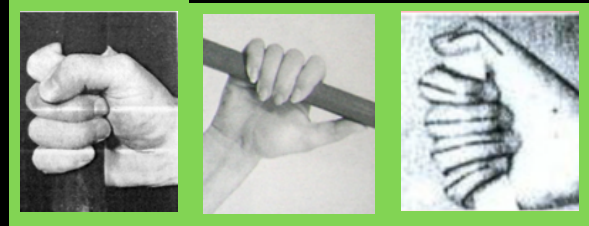
**32. Ventral**



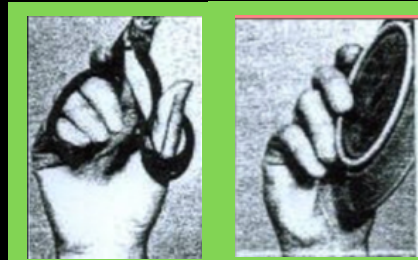
**6. Prismatic  
4-finger**



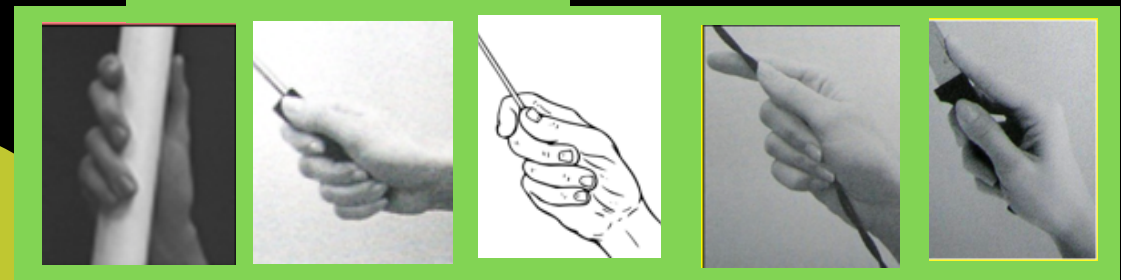
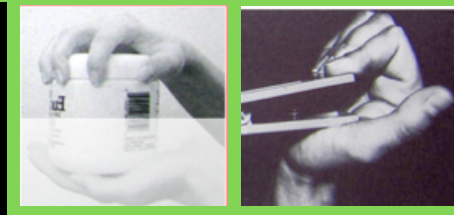
## Power Palm



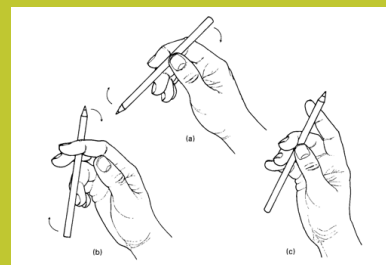
## Palmar Gutter



## Power Pad



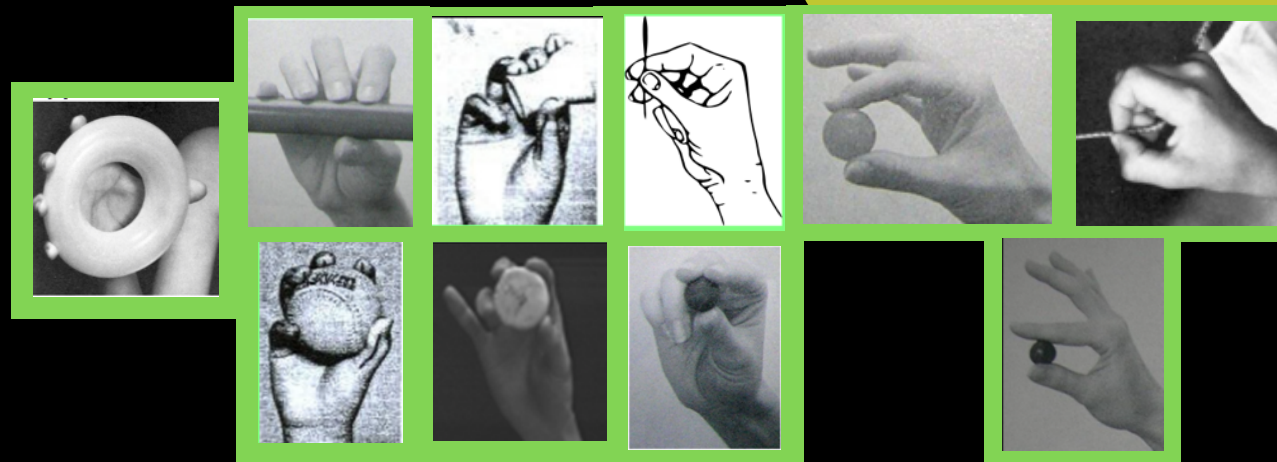
## Transitions



## Power Lateral



## Precision Pad



## Precision Lateral



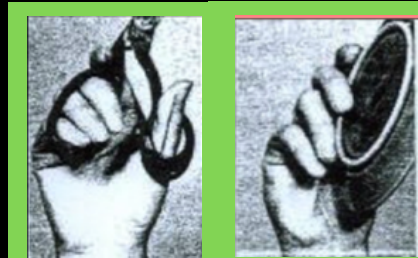
# Grasp Network



Power Palm



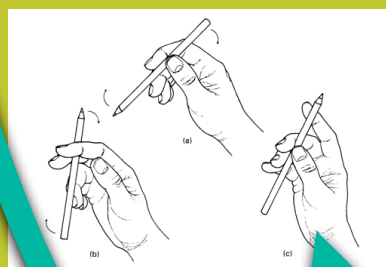
Palmar Gutter



Power Pad



Transitions



Power Lateral



Precision Pad

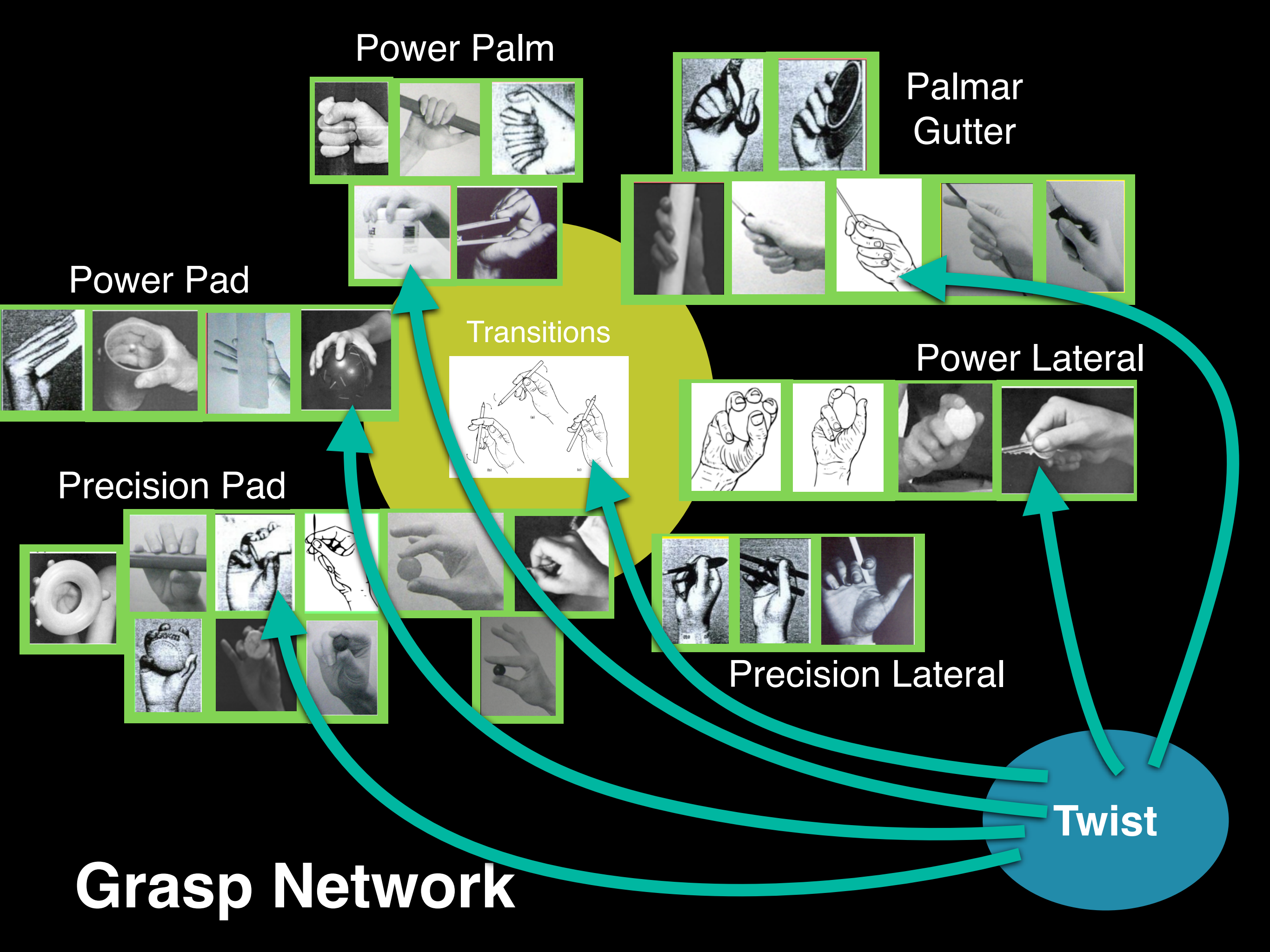


Precision Lateral



Grasp Network

Twist



# Our data collection effort





# Grasps from the 3min shopping video plus Elliott and Connelly



Finger and thumb tip triangles in  
back of the hand frame

