

### **Selection of ADLs for the application of the DOPA procedure**

A long list of activities of daily living (ADLs) which involve the use of the upper limb(s) has been retrieved from scientific literature and technical documents [1–11], and are reported tout-court (i.e. without any modifications) in Appendix A, grouped in functional Macro-Areas (e.g. Personal Hygiene, Feeding...).

Table I reports the 19 ADLs considered as reference for the application of the DOPA procedure [12, 13] intended to guide the design of a shoulder mechanism for myoelectric upper limb prostheses [14]. This list is a subset of a group of 59 upper limb activities (reported in Appendix B) whose hand Reference Trajectories have been experimentally retrieved with an optoelectronic system for motion analysis [15, 16]. Since not all the activities have the same significance from the functional autonomy point of view (e.g.: opening a window is objectively less important than bringing the hand to the mouth), they have been ranked four different Priority Groups ( $G_0, \dots, G_3$ ), based on a descending order of the tasks' importance:

- $G_0$ : basic and minimal activities of primary importance that any prosthesis subjected to the DOPA algorithms is compelled to perform satisfactorily. The ability to perform these tasks allows the patient to autonomously eat and go to the bathroom. The activities of this Group are intended as performed by the subject also with the aid of supportive devices or special arrangements (e.g. those represented in Figs. B1–B8), and with large compensatory movements of other parts of the body (i.e. the alternative motion strategies typical of the amputees are considered);
- $G_1$ : high relevance activities dealing with feeding and hygiene limited to face and private parts. The alternative motion strategies are considered;
- $G_2$ : activities which allow the subject to autonomously take care of total body hygiene and dressing, and activities which make it possible to do without those special arrangements and devices potentially necessary to perform the motor tasks of the previous groups (e.g. the ability to “Cut food with a knife” makes it possible to do without special cutlery);
- $G_3$ : activities which allow the patient to live a “normal social life”.

For the analytical use of the classification based on the tasks' priority, see [13].

The selection reported in Table I was determined taking into account its intended specific use, i.e. the simulation of the corresponding trajectories performed by upper limb prostheses equipped with different shoulder mechanism models (with one up to three degrees of freedom): the final goal is to evaluate the performance of the different shoulder articulations. In particular, the motor tasks which can be accomplished without the use of the shoulder have not been considered.

Moreover, the analysis of the experimental data was decisive for the determination of the most significant motor tasks. First of all, it should be noted that the Reference Trajectory of a generic task was defined as a set of a limited number of hand poses (Cartesian position and orientation) corresponding to the significant nodes (or “events”) of the whole trajectory (e.g. when the hand reaches for the object to be grasped or sidesteps an obstacle). The trajectory segments which link the mentioned nodes are not considered. More details about the representation of the hand trajectories (and the reasons of this choice) are reported in [15, 16]. The comparison of the hand poses at the significant nodes of the performed trajectories has made it possible to synthesize a limited number of trajectories to be simulated in the application of the DOPA procedure. Indeed, carrying out a given activity might have required the execution of a trajectory (*in terms of the hand pose at the significant nodes, experimentally retrieved*) which “includes” the trajectory corresponding to another activity. For instance “Putting the underpants on” is represented by a Reference Trajectory extremely similar to a part of the Reference Trajectory relative to “Putting the trousers on”; again, “Putting the socks on” and “Putting the shoes on” have similar trajectories, and both can be considered as a subset of the reference trajectory of “Putting the underpants on”. In this

case, only the activity “Putting the trousers on” (the most complete of the mentioned group) is considered in the selection.

TABLE I

Tasks	Macro-Area	Priority Group	Notes
Genital hygiene	H	G <sub>0</sub>	
Eating with fork	F	"	(0)
Reaching/placing an object at the hip height	M	"	
Drinking (from a glass)	F	"	
Washing teeth (with electrical toothbrush)	H, F, M	G <sub>1</sub>	(1)
Putting trousers on	D	"	(2)
Eating with spoon	F	"	(3)
Pouring from a bottle	F	"	
Turning on/off a tap	H	G <sub>2</sub>	
Opening/closing a door (using the knob)	M	"	
Cutting food with knife and fork	F	"	
Bringing hand to the opposite-side armpit	H	"	
Bringing hand to the same-side ear	H, M	"	(4)
Fastening/unfastening the trousers zip	D	G <sub>3</sub>	(5)
Fastening/unfastening the jacket zip	D	"	(6, 7)
Opening/closing a window (using the knob)	M	"	
Reaching/placing an object at the head height	M	"	
Bringing hand to the opposite-side ear	H, M	"	(4)
Bringing hand to the top of the head	H, M	"	(4)

Macro-Areas nomenclature:

- H → Personal Hygiene
- F → Feeding
- M → Generic Manipulation
- D → Dressing

Notes:

0. this activity is very important for the posture of upper limb prosthesis when an amputee eats activating only the prono-supination unit (see [12], p. 67). On the contrary, the trajectory of the hand holding the fork can be represented by a part of the trajectory relative to “Washing teeth with an electrical toothbrush”.
1. this activity is extremely significant because it corresponds to “Bringing the hand to the face with different orientations”, which can include many other very important activities. The fundamental hand orientations are three, corresponding to washing the central and the two lateral groups of teeth.
2. this activity is representative for many others that need hand trajectories located on average at a height under the hip.
3. this activity differs from “Eating with fork”, due to the constraint on the orientation of the hand along the path (the spoon should keep its concavity as horizontal as possible when containing food).
4. the palm is inward oriented, toward the subject’s face. These three motor tasks, which together represent the activity of “Combing hair”, are considered separately since each one can represent also other activities (e.g. “Bringing the hand to the same-side ear” is identical to “Using the telephone”, whose priority is greater than the other two motor tasks).
5. important for the particular hand orientation (when executing quasi-straight line trajectories).
6. according to the philosophy that has guided this task selection, the important activity of “Putting shirt on” should be considered. However many reasons have prevented the definition of the corresponding trajectory:
  - a. not only the hand trajectory is significant when dressing a shirt, but also the pose of the arm and the forearm is crucial for the correct execution of the task (and the kinematic analysis algorithm of the DOPA procedure do not manage them);

b. different shirts (long or short sleeves, with or without buttons...) require different motion strategies and it has not been feasible to establish a single representative trajectory;

c. insurmountable problems of markers visibility did not allow the acquisition of experimental trajectories with the optoelectronic system which has been used.

7. important for the particular hand orientation when executing quasi-straight line trajectories in the central sagittal plane.

## References:

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## Appendix A

<b><i>PERSONAL HYGIENE</i></b>
Oral hygiene
Washing (shower, bathtub...)
Shaving
Caring for one's face
Combing hair
Blowing the nose
Washing and drying hair
Putting make up on
Bringing the hand to the opposite armpit
Bringing the hand to the opposite side of the neck
Bringing the hand to the lateral sides of the head

<b><i>DRESSING/UNDRESSING</i></b>
Fastening shoelaces
Putting a long-sleeves shirt on and fastening all the buttons
Putting a jacket on and fastening the zip
Putting the socks on
Holding clothes while fastening/ unfastening the zip
Putting trousers/skirt on and fastening buttons/zip
Putting the shoes on
Tucking shirt into the trousers
Tying the necktie
Fastening the belt
Cleaning the glasses
Putting the watch on
Putting a head covering on
Putting overshoes on
Putting on and fastening a bra
Fastening garters
Fastening suspenders

<b><i>FEEDING</i></b>
Cooking (preparing hot drinks and food)
Placing food into the refrigerator
Turning the cooker on
Cooking on the kitchen range
Cooking on the kitchen range
Baking food
Using the mixer
Opening bags and packages
Cutting food with fork and knife
Cutting bread
Opening the milk can
Broaching a bottle (cap or cork)
Spreading sauce on bread
Opening/closing a jar

Parboiling vegetables with/without knife
Pouring into a glass
Eating with the hands
Eating with a fork
Eating with a spoon
Drinking from a glass or from a cup
Opening a sachet and putting sugar into a cup
Cracking a nut
Opening a can
Drawing a chair from under the table
Using a napkin
Manipulating dishes
Using the oil dispenser
Using the salt dispenser
Drinking from a bottle
Eating an ice-cream cone
Opening an egg
Mixing with a spoon

<b><i>GENERIC MANIPULATION</i></b>
Reaching for and grasping objects (with different shapes and masses) placed on a shelf (at different heights)
Giving someone an object or placing an object on a shelf
Reloading a watch spring
Using the umbrella
Plugging appliances
Using a call box
Ringing a bell
Opening/closing doors/windows with different knobs and handles
Turning the light on/off
Opening/closing tap
Opening/closing drawers
Using radio and tv
Lighting a match on
Lighting a cigarette lighter and smoking
Carrying a case
Driving
Opening the car hood
Using the bottle jack
Replacing a tyre
Using vending machine

<b>TASKS RELATED TO HOME MAINTENANCE, JOB AND SCHOOL ACTIVITIES</b>
Washing dishes and crockery
Drying dishes manually
Cleaning tableware
Using the dishwasher
Using the phone and writing notes simultaneously
Manipulating mail
Grasping coins from a wallet
Picking up coins from a table
Grasping banknotes from a wallet
Housekeeping (cleaning floor, removing dust...)
Ironing
Washing and drying clothes
Using the washing machine
Laundering
Placing clothes on the drying rack
Sewing
Thread a needle
Putting/removing pins on/from sweaters
Using a tray to carry dishes
Writing
Manipulating newspapers/magazines/books
Using pencil and ruler
Manipulating paper sheets
Scissoring a sheet
Sharpening a pencil
Placing/removing cap on/from a pen
Toeing a nail
Using hand tools
Using a computer (keyboard and mouse)
Rubbing out
Refilling a fountain pen with ink
Bending a sheet and placing it into an envelope
Manipulating folders
Using paper clips
Using a machine pistol
Packaging/Opening packages

<b>HOBBIES</b>
Using toys
Using bicycle (holding the handlebar)
Playing instruments
Using playing cards, draughtsman, chess
Using a camera
Using the stereo (manipulating tapes, records and cd)
Hobbies (gardening, painting, ...)

## Appendix B

	TASK	SPECIAL MOTION STRATEGIES
1	Grasping of an object placed at the table edge	
2	Fastening/unfastening the trousers zip	Assistive device: ring placed on the zip hook (Fig. B1)
3	Opening a sachet	Alternative strategy: using mouth to rip a corner
4	Opening a cd box	
5	Opening/closing a window (by turning the handle)	
6	Opening/closing a tap (equipped with a lever) <i>I</i>	
7	Opening/closing a tap (equipped with a knob)	
8	Opening/closing a tap (equipped with a knob) <i>II</i>	Large compensatory movements of the body
9	Grasping banknotes from a wallet	
10	Drinking (from a glass) <i>I</i>	
11	Drinking (from a glass) <i>II</i>	Compensatory movements of the head (downwards) and of the shoulder inner articulation (upwards)
12	Fastening/unfastening the shirt buttons	Assistive device: hook-like tool to insert the buttons. (Fig. B2)
13	Rubbing out	
14	Fastening/unfastening the jacket zip	
15	Cooking on the kitchen range (manipulating pots, pans...)	
16	Taking out a cd from its box	
17	Scissoring a sheet	Assistive device: scissors with a spring for automatic opening (Fig. B3)
18	Hygiene of the rear intimate parts	Assistive device: extension with a sponge (Fig. B4)
19	Hygiene of the front intimate parts	
20	Putting socks on/off	
21	Putting underpants on/off	
22	Putting trousers on/off	
23	Washing the face with a sponge <i>I</i>	
24	Washing the face with a sponge <i>II</i>	Compensatory movements of the head (downwards) and of the shoulder inner articulation (upwards)
25	Washing the upper body (i.e. bringing the hand to different parts of the body, e.g. the opposite armpit)	
26	Using the washing machine	
27	Eating with a spoon <i>I</i>	
28	Eating with a spoon <i>II</i>	Compensatory movements of the head (downwards) and of the shoulder inner articulation (upwards)
29	Eating with a fork <i>I</i>	
30	Eating with a fork <i>II</i>	Compensatory movements of the head (downwards) and of the shoulder inner articulation (upwards)
31	Eating with the hands	
32	Opening/closing a window (by turning the bi-manual handle)	
33	Opening/closing a doorknob	
34	Picking up coins from a table	
35	Combing hair <i>I</i>	
36	Combing hair <i>II</i>	Compensatory movements of the head
37	Reaching for an object at the head height	
38	Reaching for an object at the feet height	Compensatory movements: the subject stooped

39	Reaching for an object at the hip height	
40	Placing an object into the shopping cart	
41	Using a dispenser to place soap over a sponge	
42	Writing (holding a pencil properly and approaching it to a sheet)	
43	Flipping trough the book pages	
44	Placing the toothpaste over the toothbrush <i>I</i>	
45	Placing the toothpaste over the toothbrush <i>II</i>	Assistive device: dispenser with a big button for the toothpaste. (Fig. B5)
46	Spreading sauce on bread	
47	Broaching a bottle cup	
48	Placing clothes on the drying rack	
49	Ironing	
50	Cutting food with fork and knife	
51	Using a keyboard	
52	Using a bench scales	
53	Using saltcellar <i>I</i>	
54	Using saltcellar <i>II</i>	Large compensatory movements of the body
55	Washing teeth with an electrical toothbrush	
56	Using a mobile phone	
57	Using a desk telephone <i>I</i>	
58	Using a desk telephone <i>II</i>	Alternative strategy: using only one hand
59	Pouring from a bottle	

*I* : “natural” trajectory for a sane subject.

*II* : trajectory performed adopting the special motion strategies typical for prosthesis wearers.



**Figure B1: ring for the zip**



**Figure B2: device for fastening buttons**



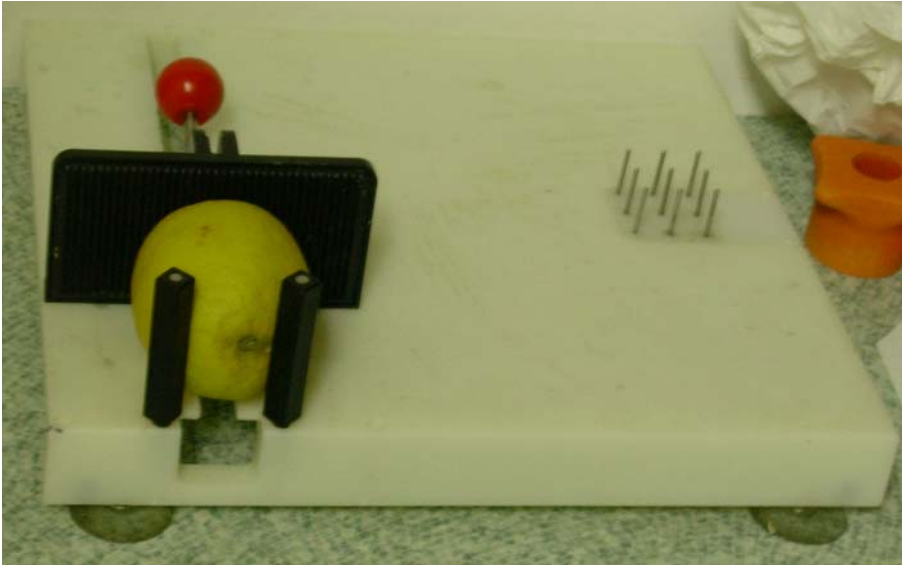
**Figure B3: scissors with automatic opening**



**Figure B4: tool extensions**



**Figure B5: toothpaste/soap dispensers**



**B6: tools for holding food to be cut**



**B7: grasping tool with extension**



**B7: tool for tip-grasp (precision manipulation)**