Powered Orthosis Project Forum

by

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This document contains reports from two meeting that were organized at Applied Science and Engineering Laboratories (ASEL) as part of the powered orthosis project. These meetings were held with families which had at least one child with **S**pinal **M**uscular **A**trophy (SMA) or **D**uchenne's **M**uscular **D**ystrophy (DMD). Table I presents some data about the subjects. These meetings were to explore with the families the tasks that they wished their child could do, but could not do now because of their child's condition. The families were also given a tour of the labs and shown various devices. The event was video taped.

Subject	Age (in yrs)	Disability	Sex
A	14	SMA-II	M
B	8	SMA-II	F
C	13	DMD	M
D	5	SMA-II	M
E	11	DMD	M
F	15	DMD	M
G	14	DMD	M
H	13	DMD	M
J	23	DMD	M
K	18	SMA	M

Table I : Subject details

DMD Duchenne's Muscular Dystrophy

SMA Spinal Muscular Atrophy, Type I Werdnig-Hoffman, Type II Intermediate and Type III Kugelberg Welander

Brain storming for generating functional orthosis specifications was done prior to a tour of the robotics laboratory to avoid biasing the participant's ideas. Later, a tour was given to show the capabilities of current technology and some of the orthosis related work. The tour was given to allow them to re-evaluate some of their ideas from the earlier brain storming session.

The meeting was begun with the question "**What activities would you like an orthosis or brace or machine to help you do, that you cannot do for yourself now"?**. The question was phrased in this manner to minimize any bias towards a particular type of device, while restricting the ideas to the area of orthoses. First, the children were asked to give their ideas. The children continued until they had no more ideas. This ensured that they did not have a bias based on the needs of their parents. Next, the parents were asked to give their ideas. After this, both the parents and the children were allowed to add ideas. The list of tasks that were generated is presented in Appendix I.

Next, the families were given a tour of the robotics laboratory, which focused on some of the orthotic devices that are currently available for the arm and others which are research ideas.

Four families attended the first meeting,

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while five families attended the second meeting.

During the first meeting four workstations were setup for the tour. The four workstations were the Balanced Forearm Orthosis (BFO) and overhead slings, RTX test bed for a powered orthosis with one joint activated, a prototype of an orthosis incorporated with an anti-gravity mechanism and a painting robot.

During the second meeting five workstations were setup for the tour. The five families were shown demos at each workstation. The five workstations were the Balanced Forearm Orthosis (BFO) and overhead slings, RTX test bed for a powered orthosis, force measuring setup, the MANUS robot and a prototype of an orthosis incorporated with an anti-gravity mechanism.

The BFO is a device which provides lower arm support and is mounted on the side of the wheelchair. It is also referred to as a mobile arm support, ball-bearing feeder, or linkage feeder. The BFO consists of various arrangements of sloping metal links and a simple lever at the forearm. It is generally used by shifting the weight of the shoulder or trunk, which in turn will provide hand motion due to the lever support at the forearm. One child was already using a BFO, while two of the other children were very good candidates for being fitted with BFOs. Two of the children were prescribed these devices from the hospital, but had not yet used them. This was an opportunity for them to evaluate the device.

The RTX100 is a six DOF (degrees of freedom) scara configuration robot. During the first meeting there was only one joint activated and a force sensor was attached. There were no elaborate control scheme implemented, it was based on a direct mapping of the user force to robot velocity. The families in the first meeting thought that this was a good idea.

During the second meeting the RTX had a more elaborate setup. It used only five DOF in the orthosis test bed and was equipped with a force sensor and a splint for the lower arm support. The five DOF were mapped to force input in three cartesian directions and moment input about 2 orthogonal axes. Two different control schemes, which related force input (at the force sensor) to movement of the arm, were demonstrated. One of the control schemes which was presented, mapped input force to cartesian velocity. Another control scheme which was presented used force pulses, above threshold values, to activate and deactivate the motion of the orthosis. Further details of the two control scheme are given in Appendix II. Every parent and child tried[1] this device and they felt that it was a good idea. At least two children and one parent felt that the second control scheme was not as good as the first one, since it did not exercise their muscles. They considered the orthosis with this control scheme as a “lazy man’s device”.

Another workstation was a prototype for a non powered orthosis. This prototype incorporated an anti-gravity mechanism and also had a splint for lower arm support. The lower arm support was provided only for the second meeting. The proto-

1. Some of them pushed the splint by their fingers to activate the device, while others strapped their arms in the splint and used the device. It was felt that some learning time was needed before they could use the system.

type was attached to a chair which mimicked the wheelchair. All the families thought that this was a good idea and would like to use it. They felt that the designers should refine the prototype. They felt that it was a better idea than using a robot as an orthosis[1]. One parent said that they could benefit from the device in its present state.

Pizza was served for lunch. The idea of providing lunch was to observe how the children with SMA and DMD managed to eat. Six of the ten children could eat on their own. One of the six children could eat by himself, if his food was cut into pieces. One child used a BFO to feed himself, but required some peculiar motions to do so. Four of the children used the edge of a table as a support to feed themselves. Three of children were fed by one of their parents, while one of them did not eat.

After lunch, the group got together to refine their ideas based on what they saw on the tour. It was noticed that they did not think of many new ideas. Most of the ideas that were presented in the morning session were very practical and realistic. One comment from a parent was to design devices that exploit the full capabilities of the children. It was specifically mentioned that the designed devices should exploit the muscle forces of the user to the maximum extent.

Once they had run out of ideas, they were shown some of the results from previous surveys. They were asked to rank their top five choices from the ones they developed in the morning and the list from other surveys. The choices of every individual participant is reproduced in Appendix IV. Appendix V contains the tasks survey which was given to the group.

The result of the kid's survey is as follows. The top five tasks of each group appears in italics in the below list. The two numbers in the parenthesis are the number of votes a task got. The first number is the number of votes from the first meeting while the second number is from the second meeting.

- *Reaching and picking things off shelves* (3,5)
- *Keeping from falling forward, straightening oneself, Maintaining Balance* (1,5)
- *Feeding oneself* (1,3)
- *Picking things off the floor* (0,3)
- *Brushing, Combing and Scratching* (3,0)
- *Talking on the phone* (2,1)
- *Two handed operations* (2,0)
- Raising hand in school (0,2)
- Transferring devices to use toilet, shower (0,2)
- Personal Hygiene (0,2)
- Preparing food (1,1)
- Dressing (1,0)
- Playing with Legos (1,0)
- Playing games (Baseball, Hockey) (1,0)
- Operating a manual wheelchair (1,0)
- Throwing a ball (1,0)
- Holding IPBB (respirator) machine (1,0)
- Typing (1,0)
- Opening/Closing door (0,1)

1. The reason why the idea was better was not clear, and was not explicitly asked. It could be due to the fact a non-powered device is preferable, or possibly that the prototype orthosis looked compact.

- Clamping wheelchair (0,1)

The results of the parents/caretakers survey is as follows.

- *Picking up and manipulating objects from floor and shelves* (6,6)
- *Transferring device to use toilet, shower etc*. (2,8)
- *Feeding and preparing food* (6,3)
- *Brushing, Combing and Scratching* (7,0)
- *Reaching beyond close range* (7,0)
- *Straightening oneself. i.e. providing trunk support* (1,4)
- *Typing* (4,0)
- *Providing full range of arm motion* (0,3)
- Playing board games (3,0)
- Two handed tasks (2,1)
- Opening/closing doors (2,1)
- Talking on the phone (2,0)
- Personal hygiene (0,2)
- Holding/placing arm in specific position (0,2)
- Straightening their own legs & ankles (0,2)
- Playing (2,0)
- Placing arm to manipulate wheelchair controls (0,1)
- Exploiting full potential of the children (0,1)
- Wearing clothes, shoes etc. (0,1)
- Turning pages (1,0)
- Throw a ball (1,0)
- Operating a manual wheelchair (1,0)
- Dressing (1,0)

It was interesting to note that the children thought of ideas which were a real need for them, not whimsical or fancy ones. Another observation was that the children thought of needs for their present use only, while some of the parents thought of long term ideas too. It was also interesting to note that the parents and their child had a few common ideas as being among the top five things to do. This can be seen from the results presented in Appendix IV. The children in this second group were heavier than in the first group and hence the task of transferring them became a more important issue for the parents/caretakers. Two children made a remark that they would love a third arm, in addition to assisting their two arms. Some of the parents also suggested that the project staff spend at least one day with the child in their own environment. This would enable the staff to observe tasks which are done routinely and unconciously by the children and their parents, but they are not able to recall that activity as a desired function of an orthotic device.

Appendix I

The following were the list of tasks that the participants wanted an orthosis or brace or machine to help them do which they cannot do now. The list is presented in no particular order.

TASKS CHILDERN DEVELOPED

- Picking stuff off shelf, floor etc.

  These include picking books, things fallen on the floor, picking goods in grocery stores, etc.
- Straightening legs, ankle
- Moving arm from lap to control
- Playing baseball
- Opening and closing doors
- Switching lights on/off

- Keeping feet from bending inward (heel on foot plate)
- Reaching and picking up telephone
- Raising hand at school
- Designing devices that encourage arm power etc.
- Adjusting devices as disability progresses
- Shifting body on wheelchair
- Placing items in the microwave
- Combing hair, scratching nose & neck, brushing teeth
- Driving a powered wheel chair, manual wheelchair
- Typing at a computer
- Two handed operations
- Moving things around
- Holding hand in place
- Playing board games, cards, musical instruments, pool, dart throwing, throwing ball, etc.
- Writing

TASKS PARENTS DEVELOPED

- Eating help - hold cups, plates etc.
- Preparing food, fixing their own snack
- Moving arm to wheelchair control
- Providing full range of arm motion
- Positioning arm in space
- Combing hair, applying cologne, shaving
- Buttoning dress
- Helping with toileting
- Device to lift disabled person, while able person can change clothes etc.
- Device to lift person to ease transfer
- Device to clamp wheelchair in vans
- Supporting trunk
- Putting shoes on, and pulling on pants
- Getting stuff off the floor
- Allowing for independent transfer - (Like a sliding seat; something that lifts over wheelchair parts)
- Holding arm at keyboard, holding pencil or pen at paper for writing
- Opening and closing doors
- Switching on lights
- Being more independent
- Reaching in general
- Raising hand in class
- Shaking hands
- Playing Lego, stacking blocks
- Grabbing things beyond arms reach
- Two handed operations
- Holding respirator by themselves
- Picking up their own head
- Holding an open book, turning pages
- Use scissors
- Throwing ball
- Playing board games, cards, pool etc. Playing games in general
- Raking leaves
- Operating environmental control systems
- Opening/closing of pen
- Opening school bags

Appendix II

A powered orthosis prototype was demonstrated to children with either DMD or SMA and their parents/caretakers. The prototype consisted of an RTX100 robot with a force sensor fixed to a bracket which in turn is fixed to the end of the robot's wrist unit (where the gripper is usually located). A splint is fixed to the top of the force sensor. The splint is used to secure the person's arm to the end of the robot. Two different control schemes, which related force input of the user (at the sensor) to movement of the arm, were demonstrated. The shoulder, elbow, yaw, zed (zee), and roll axis were active; the pitch axis was not used.

One of the control schemes which was presented, mapped input force to cartesian velocity. More specifically, translational velocities were proportional to forces, and angular velocities were proportional to torques. For example, if the force sensor detected a force vector of 5**i** + 3**j** + 4**k**, the velocity would have been 10**i** + 6**j** + 8**k**, if the proportionality constant was set to two. (**i**,**j** and **k** are unit vectors. A similar example would apply to torques and angular velocities). No force input resulted in no motion.

Another control scheme which was presented used force pulses, above threshold values, to activate and deactivate the motion of the orthosis. In this scenario, the orthosis would move at a linear velocity proportional to the magnitude of the force impulse and in the direction of the impulse. The orthosis would continue to move, until the appropriate stopping force impulse occurred. The stopping force impulse was defined as that force which exceed a threshold value and was non-colinear with the present orthosis velocity. So, this scheme resulted in a start and stop type of motion. The orthosis needed to stop before a new velocity could be commanded.

Two subjects liked the first scheme, while they said that the second scheme was not very comfortable to them. One parent felt that the first control scheme used the child's potential all the time, while the second scheme was a lazy man's device.

Appendix III

Table II presents the results of the force data collected from the children. The child was asked to apply a force to a static joystick in different directions. The directions chosen were anterior/posterior, superior/inferior and lateral/medial. This data was collected to give a ballpark figure for the force capabilities of these children. The subjects seemed to apply a force which

Subject	Max	Min	Max	Min	Max	Min	Max force	θ_x	θ_y	θ_z
	(med)	(lat)	(post)	(ant)	(sup)	(inf)	magnitude	in degrees	in degrees	in degrees
E	34.5	-12.7	36.7	-60.9	55.8	-6.8	85.99	68.29	131.65	49.52
F	xx	xx	24.0	-20.8	17.1	-13.5	24.31	98.68	8.93	87.90
G	13.2	-7.8	27.2	-18.7	6.3	-11.8	28.4	74.77	16.13	84.83
H	49.6	-17.0	25.5	-71.1	32.9	-20.6	92.28	58.06	140.36	69.10
J	0.6	-1.6	5.1	-1.6	0.3	-2.4	5.63	93.40	24.76	114.49
K	29.2	-17.7	31.0	-30.5	27.8	-11.8	50.37	54.97	127.22	56.50

Table II : Summary of Force data collected using the Flexbar

probably ranged from comfortable to maximum. Subject F's results may not be very accurate since he managed to work the mounting loose when he applied a force. The results were graphically displayed during the experiment to give the children some visual feedback. The units of forces are Newtons, and the angles are with respect to the reference frame of the force sensor.

Appendix IV

Each subject has been given a alphabetic code (A,B,C...) here to withhold their identity. The caretakers of each child have been identified by the same alphabetic code, followed by a number. For example subject A has care takers A1,A2, etc.

TASKS RATING OF VARIOUS CHILDERN

SUBJECT A (SMA TYPE II, 14 YEARS)

- Two handed operations
- Cutting food
- Pushing (propelling) a manual wheelchair
- Picking things off shelves
- Throwing a ball

SUBJECT B (SMA TYPE II, 8 YEARS)

- Holding respirator
- Brushing teeth
- Reaching for books
- Getting herself up (when she falls)
- Dressing herself

SUBJECT C (DMD, 13 YEARS)

- Talking on the phone
- Brushing, combing, scratching
- Playing with Lego
- Sports - Baseball, Hockey
- Cook food for family

SUBJECT D (SMA TYPE II, 5 YEARS)

- Hold telephone
- Two handed tasks
- Comb hair/ scratch nose
- Type
- Reach up and down

SUBJECT E (DMD, 11 YEARS)

- Picking up something on the floor.
- Raising hand

SUBJECT F (DMD, 15 YEARS)

- Picking up objects.
- Transferring for toileting and shower.
- Personal hygiene.
- Eating/ drinking.
- Picking up oneself.

SUBJECT G(DMD, 14 YEARS)

- Picking up things off the floor.
- Attaching phone to chair.
- Preparing food.
- Opening and closing doors.
- Reaching things off shelves in stores.

SUBJECT H (DMD,13 YEARS)

- Raising hand in school.
- Straightening legs.
- Picking up things on the ground.
- Reaching things that are high, on shelf, etc.
- Restraining from falling forward. (Maintain trunk balance).

SUBJECT J (DMD, 23 YEARS)

- Moving arm to wheelchair control and back.
- Feeding oneself.
- Picking up things from the floor and shelves.
- Better lifting devices for using the toilet.

- Easier way to clamping wheelchair to van.

Subject K(SMA, 18 years)

- Eating / Drinking.
- Personal hygiene.
- Preparing food / Cooking.
- Reaching / Picking up objects.
- Straightening oneself from bent position.

TASKS RATING OF VARIOUS PARENTS / CARETAKERS

Caretaker A1

- Personal Care - washing face, brushing teeth etc., toileting
- Preparing food
- Reaching and picking up things
- Opening door etc.
- Playing board games, ball etc.

Caretaker A2

- Provide strength to transfer. (Toileting, movement in chair)
- Increase range of motion
- Personal Hygiene
- Opening doors, windows
- Reaching and picking things up

Caretaker B1

- Eating
- Dressing
- Reaching
- Playing
- Picking up heavy objects

Caretaker B2

- Independence
- Picking up items both light and heavy
- Personal Hygiene
- Lift off chair
- Typing on computer

Caretaker C1

- Feeding self
- Get to things out of reach
- Playing board games
- Typing on computer
- Playing with LEGO

Caretaker C2

- Feeding himself
- Getting things that are out of reach. (Lego's)
- Holding the phone
- Reaching his face to scratch, adjusting glasses, blowing his nose
- Typing on computer

Caretaker C3

- Picking up things
- Picking things off the shelf
- Scratch himself where he cannot reach

Caretaker D1

- Eating / Drinking
- Reaching / Picking objects
- Holding arm in given position - painting, playing, building blocks
- Turning pages
- Pushing wheelchair by hand

Caretaker D2

- Brushing Teeth / hair
- Eating
- Two handed tasks
- Throw ball
- Reach beyond close range. "Open window of activity"

Caretaker E1 / F1

- Getting up from bed to chair and back from chair to bed.
- Straightening legs.
- Shifting body.
- Device to wear clothing and shoes.

- Keeping feet from turning in foot rest.

CARETAKER E2 / F2

- Providing full range of arm motion.
- Picking things off floor.
- Supporting trunk.
- Toileting help.
- Being able to lift person for easier transfer.

CARETAKER E3 / F3

- Picking up objects up off floor.
- Lifting torso after falling over.
- Holding arm in given position.
- Reaching high objects.
- Personal hygiene.

CARETAKER G1

- Picking self up when bent over.
- Picking things up off floor.
- Transferring from chair to bed, toilet, tub etc.
- Keeping legs and ankle straight.
- Feeding, doing hair, brushing teeth etc.

CARETAKER G2

- Easier transferring of position to toilet, tub, bed etc.
- Providing full range of arm motion.
- Supporting trunk.
- Two handed operations. (computer, keyboard etc.)
- Eating help.

CARETAKER H1

- Transferring ability.
- Moving arm with permanent fixtures.
- Getting up from prone position.

CARETAKER J1

- Eating help.
- Moving arm to wheelchair controls and return- also turning wheelchair on and off.
- Helping to use the toilet - better lifting devices.
- Holding arms to assist in using computer keyboard or writing with a pen.
- Opening and closing doors.

CARETAKER K

- Able to be self-sustaining i.e. cook, serve himself and eat unassisted by others.
- Transferring safely on himself.
- Turning on lights, TV, radio, picking up telephone.
- Being able to pickup objects.
- Design devices that encourage full potential.

Appendix V

The following is the list that the participants were given.

The following is from a survey conducted by Carolyn Anglin[1] and Stephen Prior[2].

The above two authors conducted surveys to determine the set of tasks of potential users of orthosis and robots. These are the combined results of the surveys.

- Reaching / Picking up objects
- Personal Hygiene

  Brushing teeth, washing face, combing hair applying makeup, shaving, scratching and blowing nose
- Eating/Drinking
- Holding arm in given position

  Keyboard operation, TV remote, Telephone, Painting
- Preparing Food/Cooking

  Cutting, Mixing food, adding ingredients, Closing vessel, Opening vessel, Putting/removing vessel on stove

- Toileting
- Turning Pages
- Dressing

References

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[2]. Stephen D. Prior, *An electric wheelchair mounted robotic arm - a survey of potential users.* Journal of Medical Engineering & Technology, Vol 14,n.4, pp.143-154,July/August 1990.