Electromyographic Switch Navigation of Power Wheelchairs

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Abstract

This paper describes the use of an Electromyographic (EMG) switch for control of a power wheelchair. The EMG switch employs surface electrodes to sense muscle activity. The electrode signal is connected to a microprocessor based signal processor which converts the signal activity into a single switch closure. The switch closure is used to drive a scanning wheelchair control module. Drive profiles for a specific controller are described. The advantages and disadvantages of the EMG switch are discussed.

Introduction

Independently navigating a power wheelchair can become a tremendous challenge for persons with progressive neuromuscular disorders. While muscle weakness and limited range of motion presents the initial challenge, this is exacerbated by diminishing abilities that can make dynamic proportional control systems inaccessible. For persons with advanced conditions that have reached this point, single-switch scanning is commonly considered to be the "option of last resort." This is such a commonly held view in the field of rehabilitation technology that few rehabilitation technologists even consider it as a viable option. EMG activity is used extensively for prosthetic control and recently for computer control (1), but its use for power wheelchair control has not found wide acceptance. This case study demonstrates that EMG control of a switch based scanner control system offers a viable means for persons with severely limited motor movement to independently control a power wheelchair. While it by no means can replace the dynamic, fluid control of proportional systems, it does offer many advantages over traditional latched control methods.

Methods

The switch based scanner control system used in this case study is available through PG Drives Technology's Omni+ Specialty Controls Module. The Single Switch Scanner option provides cycling menus that offer control of navigation, seat actuators, and system options. Menu choices are selected by engaging a single Mode/Stop switch connected to the Omni+ Module via a 3.5mm jack socket. In this study, the Tinkertron Model RRSS EMG switch available through Emerge Medical was used as the single switch, and a 3.5mm cable provided the interface between the modules. The Model RRSS EMG switch is designed to sense EMG signals and convert the signals into a switch closure output (2). The device is completely self contained and operates on internal batteries which helps reject transient signals from the large currents associated with the motors in the power wheelchair.

A critical link in the system is the identification of the most effective and most comfortable placement of the electrodes. Persons are somewhat hesitant at the thought of going around with wires attached to them, but if several muscle options are available to choose from a discrete and comfortable placement of the EMG and reference electrodes can be found. For example, the EMG electrode can be placed on an active muscle on either shoulder using a sticker interface to attach to the skin. The reference wire snaps onto an adhesive electrode that can remain on the skin. The reference electrode should be placed away from the muscle(s) being used to engage the EMG electrode. In our case study, the adhesive electrode was changed every week while the EMG sticker interface was changed daily. No skin breakdown or irritation was observed.

The Omni+ Module has the ability to customize drive profiles. Any one of 5 profiles can be programmed to offer variations in speed, acceleration, deceleration, turning speeds, and latched vs. momentary control. With these profiles pre-programmed, a single-switch scanning user has the needed flexibility to navigate in all possible environments and conditions. Table 1 shows the 5-profile system that was used in this study.

Table 1 goes here

There are three basic types of profiles used: *Cruise*, *Crawl*, and *Proximity*. Cruise is the main profile and is used for traveling between rooms indoors or traveling distances outdoors. This profile offers *stepped latched* control when moving forward. This means that choosing forward latches the wheelchair into forward motion. Repeated switch activations on the forward menu choice will increase forward speed. When the wheelchair is stationary, left, right, and reverse operate in *momentary* control. This means that the wheelchair will move in the chosen direction as long as the switch is engaged. Upon relaxing the muscle located near the EMG electrode, the switch will release and the wheelchair comes to a halt. Latched control and momentary control both have their place and switching between profiles allows the single-switch scanning user to have the best of both worlds.

Cruise has a secondary profile that offers latched control for both forward and backward. This is necessary when needing to navigate the wheelchair in reverse for more than a short distance. The Proximity profile offers momentary control in all directions. Short muscle twitches can allow the single-switch scanning user to inch by inch navigate into proximity of a desk or table. This profile also has dampened speed, more abrupt deceleration, and a little more bite in turning power. The third type of profile is the Crawl profile. This profile has significantly dampened speed to allow the user to navigate with extreme precision. In our case study, this profile was designed for the user to navigate onto a wheelchair lift for loading into a van. Switching to this profile gave the user the navigational precision to position the wheelchair safely on the platform and navigate through the narrow space in the van. There are two versions of this profile offering either momentary or latched control.

Key to the success of single-switch scanning navigation is the availability of a "cutoff" switch accessible to the user. Having the cutoff switch available allows the user to drive more naturally and aggressively in latched mode without fear of losing control. Without an easily accessible cutoff, the user is forced to exercise extreme anticipation which limits speed and ease of navigation. In this study a Microlight switch was used with the right thumb although a secondary EMG switch could easily be used at another muscle site if desired.

Results

Because of the nature of EMG switch input, all seating and positioning considerations can focus on stability and comfort. Typically, priority must be given to allowing necessary movement to control the driving mechanism. For persons using joystick variations, arm support and position must be constrained to the area where an adequate range of motion can be maintained. Using seat actuators for shifting weight or changing positions can frequently cause the user to be unable to return to a driving position. This is similarly true for persons using head array systems. Often a personal care attendant must help the user to regain access to the control mechanism. Another example would be someone using a puff-n-sip system that must depend upon someone else to place or remove the mechanism from their face. These obstacles are eliminated when using the EMG switch.

In our case study, the user was able to have his wheelchair seating completely customized for stability and comfort. With the EMG switch and single-switch scanning, the user could (for the first time) use all seating actuators for changing positions while also being able to independently return to a driving position. For example, he could park in a living room and recline the backrest and elevate the footrests into a completely horizontal position. He could then independently lower the footrests and elevate the backrest and navigate the wheelchair into the next room. While the seating customization is designed for stability, any shearing or shifting from using the seat actuators and/or driving over rough terrain do not pose threats to the user's ability to control navigation. EMG switches which stick onto the surface of the skin stay in place no matter what position changes the person makes. Keeping the scanner display in view is the only navigational requirement.

Long exposure to temperatures below 70 degrees Fahrenheit significantly reduces muscle movement prohibiting independent control of most wheelchair navigation systems by persons with neuromuscular diseases. Such circumstances often require some intervention like a hairdryer to provide quick, yet temporary, warmth to restore movement. This proved to no longer be an issue with the EMG switch. In our case study, the user tolerated colder temperatures for extended periods of time without noticing any reduction in ability to engage the EMG switch.

There is a modest learning curve in using the EMG switch efficiently and effectively. The user must learn not to over exert muscle flexing. Very faint muscle action can engage the switch, sometimes resulting in "false triggers" when first getting accustomed to the mechanism. As the user gains experience navigating with the EMG switch, muscle flexing naturally becomes more disciplined. In our case study, the user quickly learned that slight but steady activations with varying durations between activation and release could result in smooth 90 degree turns "on-the-fly." Even though the wheelchair requires frequent veering corrections while moving in a latched forward mode, such corrections require insignificant muscular effort sparing the user from fatigue. This is in sharp contrast to the fatigue issues associated with other wheelchair navigation systems for persons with neuromuscular diseases.

Conclusion

This work indicates an EMG switch is an effective alternative to other single switch methods including sip and puff and head pointing. The device has been used continuously for 3 months and is now the preferred switch method for the user.

References

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Table 1

Alternative Text Description of Table 1: Table shows the parameter settings for each of 5 profiles of the Omni + Module used during this investigation. Also included are the EMG switch parameter settings. The Click Duration was set to 200ms. Click duration is the time that the switch closure remains closed after the EMG signal increases above the threshold setting. The Click Holdoff was also set to 200ms. Click Holdoff is the amount of time between activations before another switch closure can occur. Click Holdoff prevent double clicks as the EMG signal drops below the threshold for activation.

	Profile #1	Profile #2	Profile #3	Profile #4	Profile #5
Functional Title	***Cruise***	***Proximity***	***Cruise***	***Crawl***	***Crawl***
Latched/Momentary	*Latched F*	*Momentary*	*Latched F/R*	*Momentary*	*Latched F/R*
Acceleration	10	10	10	10	10
Deceleration	20	60	20	60	20
Forward Speed Max.	90	40	90	25	25
Forward Speed Min.	38	10	38	25	25
Reverse Speed Max.	50	40	50	25	25
Reverse Speed Min.	25	10	25	25	25
Turning Acceleration	20	20	20	20	20
Turning Deceleration	20	60	20	60	20
Turning Speed Max.	20	30	20	30	20
Turning Speed Min.	5	10	5	10	5
EMG SWITCH SETTINGS					
Click Duration	**200**	**ms**	**Switch Closure Activation Time**		
Click Holdoff	**200**	**ms**	**Minimum Time Between Clicks**		
Beep Enable/Disabled	**Disabled**				