COGNITIVE LOAD IN LEARNING TO USE A MULTI-FUNCTION HAND

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ABSTRACT

Despite the promising functions of a multi-function hand, it is challenging to learn to use a hand that has up to 36 grip patterns. If it requires too much cognitive load to learn to operate a prosthetic hand, the user may eventually stop using it. Measurement of cognitive load while learning to use a bionic hand will help the therapist to adjust the training pace and help the user to achieve success.

An innovative, non-obtrusive method for measuring cognitive load is by tracking eye gaze. Gaze measures provide pupil diameters that indicate subjective task difficulty and mental effort. Three subjects wore a pair of Tobii eye-tracking glasses during control training and performed eight activities. Eye-tracking data were imported in Tobii Pro Lab software for extracting pupil diameter during the activities. Pupil diameter (normal range: 2-4mm during normal light) was used to indicate the amount of cognitive load.

Pupil diameters were below 4mm in 9 out of 23 training activities. Pupil diameters were above 4mm in all three subjects when they used precision pinch to perform the activities “stack 4 1-inch wooden blocks” and “pick up small objects”. Subject 3 had pupil diameters over 4mm in all training activities. Pupil diameters were largest when the subjects were adjusting the grip and when they had difficulties in initiating the grip.

It seems appropriate to introduce no more than four grips during the first control training session. Further study is required to determine if pupil diameters will decrease over time when adequate prosthetic training is given.

BACKGROUND

In recent years, prosthetic technology has advanced significantly and many new hands with increased dexterity and functionality have been introduced to the commercial market. Clinicians want to offer the most useful device for their clients, however, it is challenging to learn how to operate a hand that has up to 36 grips. The cognitive load required to learn to use these hands and switch between the multiple grip patterns is unknown.

During training, most occupational therapists introduce features of these hands gradually so as not to overwhelm the client. As the client masters the basic grips, additional grips may be added. It is assumed that if the cognitive load is too high, the user may stop using the multi-function hand or may not take full advantage of its advanced features. Measurement of cognitive load while learning to use a bionic hand will help the therapist to adjust the training pace and help the user to achieve success. An innovative, non-obtrusive method for measuring cognitive load is by tracking eye gaze. Gaze measures provide pupil diameters that indicate subjective task difficulty and mental effort. [1]

Previous studies have demonstrated that there is a connection between the need for visual feedback and learning to operate a myoelectric prosthesis [2], but few have looked at cognitive load in the learning/training process. Therapists have no objective data to help determine if a person is experiencing excessive cognitive load or when they are ready to progress to learning more advanced functions of the hand.

AIM

The aim of this project was to analyze cognitive load at various time intervals during the learning process in using a multi-function hand.

METHOD

After receiving ethics board approval and informed consent, three prosthetic users were assessed while learning to use multi-function hands. In cases where they had experience using a myoelectric hand, they were assessed using that hand as well. They went through basic skills training of learning to open and close the hand, and switch between two to three basic grips and use them to pick up and manipulate various objects. All three users had prior experience in using myoelectric control. Table 1 shows demographic information.

Table 1: Subject demographics

	Subject 1	Subject 2	Subject 3
Age	68	47	33
Level of amputation	transradial	transradial	transhumeral
Time since amputation	12 years	6 years	10 years
Previous prosthetic hand(s)	MC Pro-Control, Bebionic	iLimb Ultra (2 years of no use)	iLimb Ultra (3 years of no use)
Control of previous hand	Two site	One site	Two site (weak muscles)
Prosthetic hand assessed	iLimb Quantum	iLimb Ultra	iLimb Quantum
Control used	Two-site	Two-site	Coapt pattern recognition

Subjects wore Tobii Pro2 eye-tracking glasses before beginning initial training with the prosthetic hand. When the subject was comfortable with the use of the hand, a SHAP assessment was completed in a seated position with the table set to the appropriate height to allow the elbow to rest at 90 degrees on the table surface.

The glasses data were imported in the Tobii Pro Lab version 1.130. The data was first inspected to remove unexpected pupil changes due to sudden head movements. Then the recordings were extracted according to the activities being performed. Measurements of pupil diameter for each activity were extracted from the time when the therapist just finished her instruction and before the subjects initiated the grip until the activity was completed and the hand returned to its resting position. The normal range of pupil diameter was set at 2-4mm (during normal light) to indicate an acceptable amount of cognitive load. [3]

RESULTS

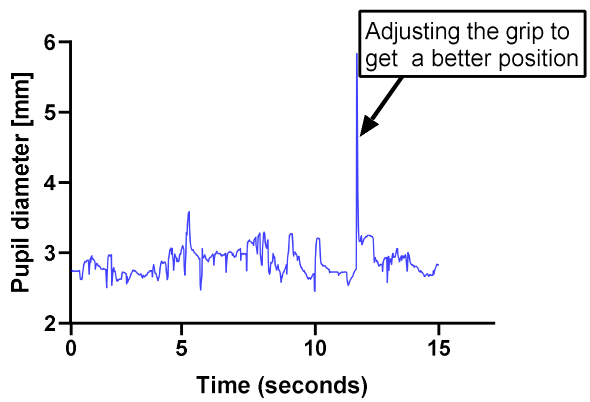
Larger pupil diameters were found in all three subjects when they used precision pinch to perform the activities ”stack 4 1-inch wooden blocks” and “pick up small objects” (Table 2). Subject 3 had pupil diameters over 4mm in all the activities. From Fig.1, it shows that pupil diameters were largest when the subjects were adjusting the grip and when they had difficulties in initiating the grip.

Table 2: Pupil diameters during training

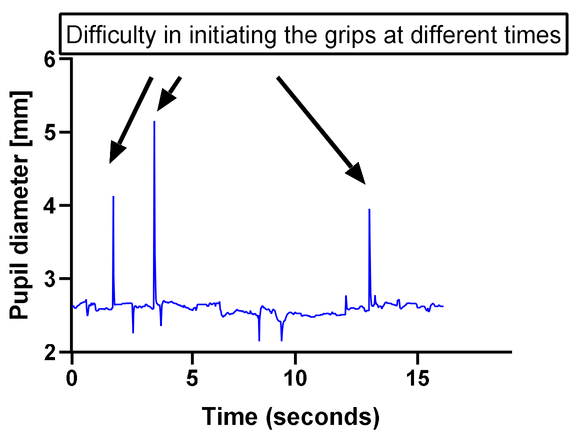
	Pupil dilation (in mm)		
	Subject 1	**Subject 2**	**Subject 3**
Pre-activity baseline (no stimuli)	R:2.52-3.21 (M=2.96, SD=0.13)	R:2.05-2.67 (M=2.45, SD=0.09)	R:2.68-3.86 (M=3.75, SD=0.15)
Activity			
Pick up ball Grip: spherical (whole hand)	R:2.42-3.63 (M=2.89, SD=0.11)	R:2.34-2.99 (M=2.56, SD=0.09)	R:3.01-**5.88** (M=4.06, SD=0.44)
Pick up drinking glass Grip: whole hand	R:2.22-3.48 (M=2.99, SD=0.20)	R:2.07-**5.17** (M=2.58, SD=0.12	R:2.36-**4.99** (M=3.88, SD=0.36)

Stack 4 1-inch wooden blocks Grip: precision pinch	R:2.39-**5.87** (M=2.95, SD=0.14)	R:2.07-**5.15** (M=2.6, SD=0.12)	R:2.61-**4.90** (M=4.20, SD=0.27)
Pick up small objects (paperclip, nail, plastic button) Grip: precision pinch	R:2.44-4.29 (M=3.00, SD=0.14)	R:1.86-**4.74** (M=2.52, SD=0.11)	R:3.05-**5.27** (M=4.32, SD=0.38)
Open plastic storage bag Grip: precision pinch	R:2.44-3.37 (M=2.86, SD=0.18)	Not performed	R:3.31-**4.37** (M=4.02, SD=0.17)
Hold playing cards Grip: lateral/key	R:2.33-3.42 (M=2.88, SD=0.17)	R:188-3.02 (M=2.48, SD=0.09)	R:2.54-**4.67** (M=3.61, SD=0.43)
Hold knife to cut playdough Grip: Lateral and between fingers	R:2.26-3.55 (M=2.90, SD=0.15)	R=2.02-2.85 (M=2.48, SD=0.13)	R:2.82-**5.83** (M=3.6, SD=0.36)
Hold fork to hold playdough Grip: lateral/key	R:2.46-**5.83** (M=2.88, SD=0.24)	R:2.02-3.07 (M=2.37, SD=0.16)	R:2.53-**4.59** (M=3.12, SD=0.30)

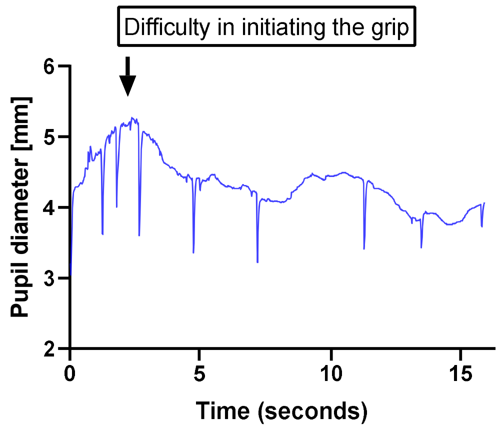
R: range, M= mean, SD =standard deviation, numbers in bold=over 4mm



Subject 1: Hold fork while cutting playdough (lateral grip)



Subject 2: Stack 4 1-inch wooden blocks (precision pinch)



Subject 3: Pick up small objects (precision pinch)

Fig.1: Changes in Pupil Diameter over time

DISCUSSION AND CONCLUSION

Based on the pupil diameters from the four grips analysed here, it seems appropriate to introduce not more than four grips during the first control training. It is unknown whether pupil diameters will decrease over time when adequate prosthetic training is given. As we can see from the results, it is cognitively demanding to learn to use a multi-function hand, especially during initiating a new grip. Further research with more prosthesis users over time and other multi-function hands is needed to confirm the study findings.

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