A Simple and Objective Method for Evaluating Wrist and Hand Movement's Accuracy

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ABSTRACT

Restoration of wrist and hand function after neuro-musculo-skeletal injuries is a problem facing the rehabilitation team. In this study wrist and hand performance was studied using graphical computer interface used in personal computers for two groups of subjects. The two groups included a group of normal subjects, and a group of patients after successful completion of rehabilitation program following lower cervical roots involvement. Subjects tracked targets at one, and two-dimensional motions at various frequencies. The results showed that the patients group performance was significantly inaccurate. The system proved to be simple, accurate, and practical in evaluation of the hand rehabilitation program.

Key words: Hand, Movement, Computer, Tracking, Rehabilitation.

INTRODUCTION

Physical therapists see patients presenting with a variety of cervical spine symptoms. Treatment of the symptoms could be achieved by acknowledging the dysfunction of the cervical, and/or the upper extermity. The individual experience of symptoms involve a variaty of excitatory and inhibitory reflexes occuring at spinal, and supra spinal levels. Dysfunction, in fact, can exist in the absence of any subjective complaints[3,9].

After rehabilitation the individuals go back to work. In the work place, productivity is essential, that means they have to be both accurate and fast. Graphical user interfaces such as Microsoft Windows (Microsoft, Redmond, WA) are now the standard in personal computer[14]. A mouse (pointing device) is used for traget tracking tasks in order to investigate the effectiveness of the subjects in the use of the pointing device, that is, how fast can he move while maintaining accuracy[10,13]. The purpose of this study was to use a commercially available computer interface as an objective method for evaluating wrist and hand movement accuracy; and to investigate the possibility that, some levels of sensori-motor integration dysfunction can still exist after successful completion of a rehabilitation program for lower cervical roots involvement, even in the absence of any subjective complaints.

MATERIALS AND METHODS

Subjects :

Two groups of volunteer subjects participated in the study. The patients group consisted of twenty subjects (8 females and 12 males), aged 29 to 58 years (Mean age, 42.25 years, standard deviation, 8.16 years) with confirmed lower cervical roots involvement following successful completion of a rehabilitation program. The normals group consisted of twenty healthy subjects (9 females and 11 males), aged 25 to 55 years (Mean 37 years, standard deviation, 9.45 years). All subjects gave their written consent to the experiment.

Instrumentation :

An IBM-compatible personal computer, equipped with Microsoft serial mouse and Microsoft Mouse Driver 9.0, was used for this study. A program was written to get a constant sampling at 19 Hz.

Procedure :

The computer mouse sense motion in two spatial dimensions; horizontal (x) and vertical (y). To evaluate the performance a target moving in one, and two dimensions were used.

One-dimension (1-D) tracking :

A vertical line was displayed on the computer monitor, its length was 50 VGA pixels, corresponding to 2.6 cm of mouse displacement. A small target oscilated along the right side of the line sinusoidally. The subject tracked the target with the mouse cursor on the other side of the line. The x (horizontal) component of the mouse motion was disregarded by the program during the 1-D tracking experiments.

Two dimensional (2-D) tracking :

A circle was displayed on the computer monitor, it's diameter was 50 VGA pixels, corresponding to 2.6 cm of mouse displacement. A small target moved around the circle and the subject tracked it with the mouse cursor. The x and y (horizontal and vertical) velocity components of the target were both sinusoidal, and both components were allowed by the program for the mouse cursor signal.

For both 1-D, and 2-D testing a sample cycle was displayed at the start of each test[12]. Subjects were tested at 8 frequencies (0.4 Hz to 4.6 Hz) for the 1-D testing, and 4 frequencies (0.4 Hz to 2.6 Hz) for the 2-D testing. Data were recorded from four cycles at each frequency for each subject at a randomized order.

Data analysis :

During tracking sinusoidal targets human subjects exhibited a transient response lasting between 0.5 sec. to 1 sec., before reaching a steady state[15]. For all testing cycles the intial 1 sec. of the data was not included in the analysis. Student t-test was used to determine significance of differences between the two groups, differences were considered significant at $P < .05$.

Accuracy Index (AI) was calculated as follow:

$$e = t - o$$

where t is target motion (input), o is the cursor location (output), and e is the error vector. The root-mean-square (RMS) values of the error vector e and the target signal t are ϵ and a, respectively[4,7]. The over all accuracy of the subject is represented by:

$$AI = 1 - \frac{\epsilon_1}{a_1}$$

RESULTS

Table 1, and Figure 1, show the AI results for the 1-D experiment. The normal's group performance was more accurate than that of the patient's group at all frequencies and was significantly accurate $P < .05$ at 1.7 Hz, and 2.0 Hz.

The normal's group AI was significantly greater than zero $p < .05$ at frequencies up through 1.7 Hz. The patients groups AI was significantly greater than zero $p < .05$ at 0.4 Hz, and 1.0 Hz.

Table (1): The accuracy index (AI) for the 1-D experiment:

Frequency Hz	Accuracy Index	
	Normals	Patients
0.4	0.68	0.60
1.0	0.52	0.32
1.7	0.42*	-0.18
2.0	0.03*	-0.48
2.7	-0.08	-0.41
3.0	-0.09	-0.18
3.7	-0.20	-0.40
4.6	-0.12	-0.40

* significant

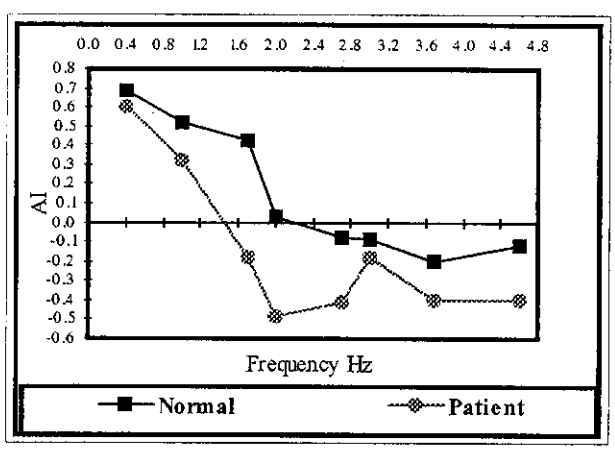

Fig. (1): Accuracy index of both groups, 1-D performance.

Table 2 and figure 2 show the AI results for the 2-D experiment. The normal's group performed significantly better $p < .05$ than the patients group at 0.4 Hz, and 1.7 Hz. The normals group AI was significantly greater than zero $p < .05$ at 0.4 Hz, and 0.8 Hz while the patients group was not significantly positive at any point.

Table (2): The accuracy index for the 2-D experiment:

Frequency Hz	Accuracy Index	
	Normals	Patients
0.4	0.64*	0.05
0.8	0.50	0.03
1.7	0.15*	-0.36
2.6	-0.28	-0.48

* significant

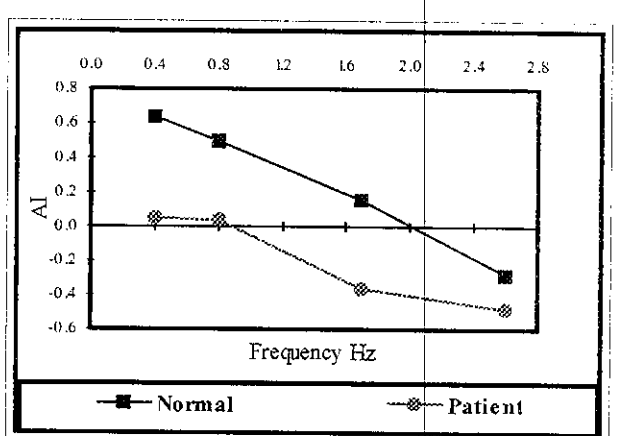

Fig. (2): Accuracy index of both groups, 2-D performance.

The AI greater than zero was considered the lower limit of the band width where the subject can perform the task with an acceptable degree of accuracy.

DISCUSSION

The study investigated the wrist and hand movement's both accuracy, and speed in executing fast, targeted movements. The possible control strategies used in fast movements to unpredicatable changing-targets were studied by many investigators [2,5,6,8]. These studies have not completely clarified this issue. The study presented here has addressed the subject under new methodology to study the peripheral control of fast hand movements, and to qualitatively compare movements produced by normal subjects and patients with lower cervical roots involvements after successful completion of rehabilitation programs. Two-dimensional tracking was used in addition to one-dimensional tracking to allow for time interval analysis at a more complex level[11].

The data obtained showed that 1.7 Hz is the maximum bandwidth for tracking targets using a computer mouse.

The bandwidth could be increased with longer training[12] to a maximum of 2.0 Hz (upper limits of normals group). The patients group results showed a decreased bandwidth than the normals which in turn indicated motor disorder which may limit the subject's performance and they might have difficulty working with the wrist and hand. The motor disability could be due to changes in brain response[16], or to distal sensori-motor dysfunction[1].

The system has been proven objective, practical, accurate, and valuable in evaluation of hand and wrist movements. There are different levels of sensori-motor integration dysfunction existing in patients with lower cervical roots involvements after successful rehabilitation even in the absence of subjective complaints.

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الملخص العربي

طريقة بسيطة وموضوعية لتقييم دقة حركة المعصم واليد

يهدف هذا البحث لدراسة إمكانية استخدام فأرة الكمبيوتر كوسيلة بينية بين حركة اليد ورسومات الكمبيوتر فى تقييم حركة المعصم واليد بعد اصابة جذور الأعصاب السفلى فى منطقة الرقبة . اشترك فى الدراسة مجموعتين من الأشخاص المتطوعين ، الأولى تكونت من عشرون من الأشخاص الطبيعيين تتراوح أعمارهم بين ٢٥ ، ٥٥ عاما ، منهم احدى عشر من الذكور وتسعة من الاناث وهى المجموعة الضابطة ، وتكونت المجموعة الثانية من عشرون من المرضى بعد أن أتموا بنجاح برنامج التأهيل الخاص بعلاج اصابات الجذور فى أسفل الرقبة ، وتتراوح أعمارهم بين ٢٩ ، ٥٨ عاما ، منهم أثنى عشر من الذكور وثمانية من الاناث . أدى كل منهم اختبارات تتبع لاشكال أحادية وثنائية الأبعاد باستخدام فأرة الكمبيوتر . تم قياس نطاق الذبذبات التى أدى فيها عملية التتبع ودرجة الدقة باستخدام مقياس لدرجة الدقة .

أشارت نتائج البحث إلى وجود فروق معنوية بين أداء المجموعتين وأن أداء مجموعة المرضى المفترض شفائهم كان أسوء من أداء المجموعة الضابطة بشكل واضح . كما أثبتت هذه الطريقة أنها طريقة موضوعية ، عملية ، دقيقة وذات قيمة فى تقويم أداء مفصل المعصم واليد . لذا ينصح باستخدامها فى حالات اصابة الجهاز العصبى – العضلى – الهيكلى التى تؤثر على أداء الطرفين العلويين .