Computerized assessment of ratio of reaction time to movement time for controls and mental retarded patients

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A comparative study of the reaction time and movement time of the horizontal hand movement for controls and others suffering from mental illness have been conducted. Measurements were taken in the time domain and analyzed using a personal computer programmed for this task. Subjects whether controls or patients were asked to draw a line of fixed length, through a prescribed horizontal track using the mouse or light pen. The reaction time and movement time were recorded for each subject, a ratio of movement time to reaction time is proposed as a new parameter for hand movement analysis. Results of tests for controls and patients were compared and proved to be of diagnostic value. Controls mean reaction time was equal to 2.15s and 5.28s for males and females, respectively; while they were equal to 7.32s and 7.33s for male and female patients, respectively. Controls mean movement time was equal to 1.99s and 3.8s for males and females, respectively; while they were equal to 4.41s and 1.53s for male and female patients, respectively. Ratio of movement time to reaction time was equal to 0.93 and 0.72 for male and female controls, respectively; while they were equal to 0.60 and 0.21 for male and female patients respectively. Reaction time was lower for controls compared to that of patients; ratio of movement time to reaction time was higher for controls than for patients of the same gender. The improvement in ratio for male controls to male patients was found to be as high as 1.55: 1, and that for female controls to female patients was found to be as high as 3.42: 1, which proved its dependence on state of health and gender. Low reaction time and high of ratio is an indication of accomplishing a task in a short period of time, an indication of good mental response and sound hand movement, hence good health. Parameters mention above were all increases with increasing age.

اعد نظام محوسب ومبرمج لا يعتمد على المجسات لقياس زمن رد الفعل وزمن حركة اليد البشرية وقورنت النتائج لأشخاص سالمين و آخرين مصابين عقلياً ٠ حيث طلب من مستخدمي هذا النظام رسم خط أفقي بطول معين بواسطة جهاز القلم الضوئي ، تم حساب نسبة زمن رد الفعل إلى زمن الحركة والذي تبين انه ذو قيمة تشخصيه هامة٠ حيث كانت قيمة متوسط زمن رد الفعل للأشخاص السالمين تساوي ٢,١٥ ث و ٥،٢٨ ث للذكور والإناث على التوالي بينما كانت هذه القيم تساوي ٧,٣٢ ث و ٧,٣٣ للذكور والإناث المصابين عقلياً على التوالي ، أما متوسط زمن الحركة فكان يساوي ١,٩٩ ث و٣,٨ ث للذكور والإناث السالمين على التوالي ويساوي ٤,٤١ث و ١,٥٣ث للذكور والإناث المصابين عقلياً على التوالي، أما عن النسبة فكانت تساوي ٠,٩٣ و٠,٧٢ للذكور والإناث السالمين على التوالي ، بينما كانت تساوي ٠,٦٠ و ٠,٢١ للذكور والإناث المصابين وعليه فان النسبة للأشخاص السالمين هي أعلى منها للأشخاص المصابين٠ هذا وقد ازدادت نسبة زمن الحركة إلى زمن رد الفعل للأشخاص السالمين مقارنة مع تلك للأشخاص المصابين من نفس الجنس ، حيث كانت تساوي ١,٥٥ إلى ١ للذكور بينما كانت تساوي ٣,٤٢ إلى ١ للإناث٠

Keywords: Hand kinematics, Hand movement, Reaction time, Mental illness, Hand tremor

1. Introduction

Physical therapists use observation to evaluate the movement deficits of subjects with neurological and muscular impairments. Observation of this kind is used to generate hypothesis regarding impaired muscle activity due to central nervous system damage or mental disturbances, and in effect to form bases for clinical decision about treatment strategies as reported by [1]. Studies of this kind are moderately reliable [2]. Main reasons for using observational assessment are; ease of application, instrumented measurements are not appropriate after a neurological injury and the thought by therapists that they are

skilled for accurately assessing hand movement through observation [3].

A study was conducted by [4] in which the results of an upper-limb positioning task performed by patient was compared to those obtained from control participants. Patients tended to undershoot the target to a greater extent than control participants did, this finding suggests abnormality in the sensory input. [5] found out that reaction times for patients were longer that for controls, which is confirmed in this study. In a previous work conducted by [6] hand movement was investigated for adults and was affected by age and gender. It was notices by [7] that the kinematics of pointing was affected by age. [8] found that hand movement is affected by repetitive use of peripheral devices. Health assessment based on hand movement is considered by [9], which is also supported by the work done by [10].

Hand movement is always accompanied with certain amount of time delay which can be defined as the reaction time of the hand or the subject response to a certain stimulus, this can vary with the speed of the hand movement as reported by [11] and [12].

A computer measurements of latency was reported by [13] found that it was affected by state of health, age and gender, this study however builds on the previous work by taking into consideratio other parameters such as the reaction time, the movement time as well as the ratio of (the movement time divided by the reaction time) which will be referred to hereafter as the (ratio), in an attempt to give a quantitative measure of the effect of state of health age and gender on hand movement, and to check if such parameters can be used as a diagnostic tools for human health.

Further consideration of the ratio reveals that it is dependent on two components (parameters), first is the movement time and second is the reaction time, and not a single parameter, in that it takes into account both of the lag behind (reaction time) and the resulting duration of motion (movement times), which gives a net response hence a large ratio is that of short reaction time and vice versa, it is known that a large reaction time is that caused by mental retardation due to poor attention and poor hand brain coordination and hence mental retardation [5]. This research however, postulates that the above mention parameters are affected by state of health, gender and age of the subject conducting the test. If this assumption is made valid then the above parameters can be considered as an important tool for the assessment of the state of health based on hand kinematics, and for diagnosing certain diseases such as mental illness and hand tremor.

As far as the collection of data was concerned the use of electrical transducers was avoided due to the presence of noise [14]. Cinematography is also avoided due to the time latency induced between shots, which are known to reduce the accuracy of the test. In contrast a light pen and a mouse are used as given by [15], which suffices for this type of work. The light pen output depends totally on the agent moving it, which is the hand in this case. Visual Basic 6 as given by [16] is used to capture, measure, and analyse the data together with Microsoft office Excel for statistical analysis and presentation of the results.

2. Method

2.1. Participants

Four participant groups took part in the experiment. The first group comprised 49 Male controls aged 14 to 67 years. The second group comprised 27 Female controls aged 5 to 35 years. None of the participants reported any skeletomuscular hand or neurological problems [17]. The third group comprised 67 Male patients aged 10 to 55 years. The fourth group comprised 39 Female patients aged 6 to 42 years. Participants in all groups were required to have normal vision and to be able to move the hand freely in both flexion and extension.

2.2. Equipment

A personal computer, a table 72 cm high and a light pen or a mouse are used for conducting the test. The light pen provided a measure of displacement in response to the lateral hand movement, and is connected to

the personal computer for the analysis of the signal and the presentation of the results. The table provided the horizontal datum at which the hand rests while performing the test, and keeps the arm at constant height, which eliminates the presence of possible vertical deviation that might degrade the results. The set up used by [18] for the measurements of hand latency is used again in this study, with a slight modification made to the software prepared, to count for the calculations of the newly proposed parameters such as the reaction time, the movement time and the ratio (movement time to reaction time). The duration measured for each of these parameters was based on system timer set to count in ms via the software prepared.

2.3. Procedure

Participants were seated in front of the personal computer screen with their hand holding the light pen relaxed on the table, with clear emphases on its freedom to perform flexion-extension movement of the wrist joint. A stimulus is used to start the test, which is a line segment of 10cm long that appears on the screen in front of the participant for a period of 3s, and then disappears, which signal the start of the test and enables the timer. The participant is asked to responds to the stimulus by moving the hand holding the light pen horizontally to match that of the line segment just disappeared, in effect a line is traced on the screen which resembles the hand movement, the test end when the participants releases the light pen. Participants were given enough time to familiarize themselves with set up and the test procedure and if wanted to repeat the process many time until they become sure of performing it correctly. This in effect reduces measurement errors [19] and [20]. The direction of movement was from right to left, each test is repeated twice or three times and the average values are taken for improved accuracy. The hand movement, which is a reflection of the light pen motion, produces a positional signal, which in turn is transformed into a digital signal suitable for the computer to work on.

2.4. Analysis

The computer records timings for the above parameters, in the form of an array for further analysis. Reaction time is the period elapsed from the disappearance of the sample line segment off the computer screen (*Td*) to the moment of the onset of hand movement i.e. start of trace (*Ts*) on the computer screen as shown in eq. (1),

$$\text{Reaction Time } (s) = Ts - Td. \quad (1)$$

Movement time is the period elapsed from the onset of hand movement, i.e. start of trace (*Ts*), to the time the light pen is released i.e. end of trace (*Te*) as shown in eq. (2),

$$\text{Movement Time } (s) = Te - Ts. \quad (2)$$

The total Time is the time elapsed from the disappearance of the sample line segment off the screen (signaling the start of test), to the time the hand stops moving i.e. end of trace and hence end of test), and is therefore equal to the sum of Reaction Time and Movement Time as shown in eq. (3),

$$\text{Total Time } (s) = (Ts\text{-}Td) + (Te\text{-}Ts). \quad (3)$$

$$= Te\text{-}Td. \quad (4)$$

The last parameter to be calculated is the ratio between the movement time and the reaction time, which is dimensionless as shown in eq. (5).

$$\text{Movement Time/Reaction Time} = (Te\text{-}Ts)/(Ts\text{-}Td). \quad (5)$$

Test session lasted approximately 10 minutes including the trial period. Above parameters were calculated for every participant using the above formulas, and the results of each group were plotted as a function of state of health, gender and age, in order to check for the validity of the assumption made earlier in the introduction of the possibility of the dependence of each of the parameters (reaction time, movement time and their ratio) on state of health, age and gender.

3. Results and discussion

The mean values of the tests parameters for the participants are given in figs. 1 through 8.

Mean Reaction time was equal to 2.15 s (SD = 1.96 s). Mean movement time was equal to 1.99 s (SD = 1.36 s). It can be seen from the figure that reaction time values are close to the movement time values, they differ by only 8% from each other, both values are small except for control aged 76 years whose reaction time was 12 s, which was due to old age, the same was noticed for controls aged 34,42 and 52 years. In general both reaction time and movement time seem to increase with age to different degrees. Correlation factor of reaction time with age was 0.48 while that for movement time with age was 0.09, which ascertain the dependence of these two parameters on age.

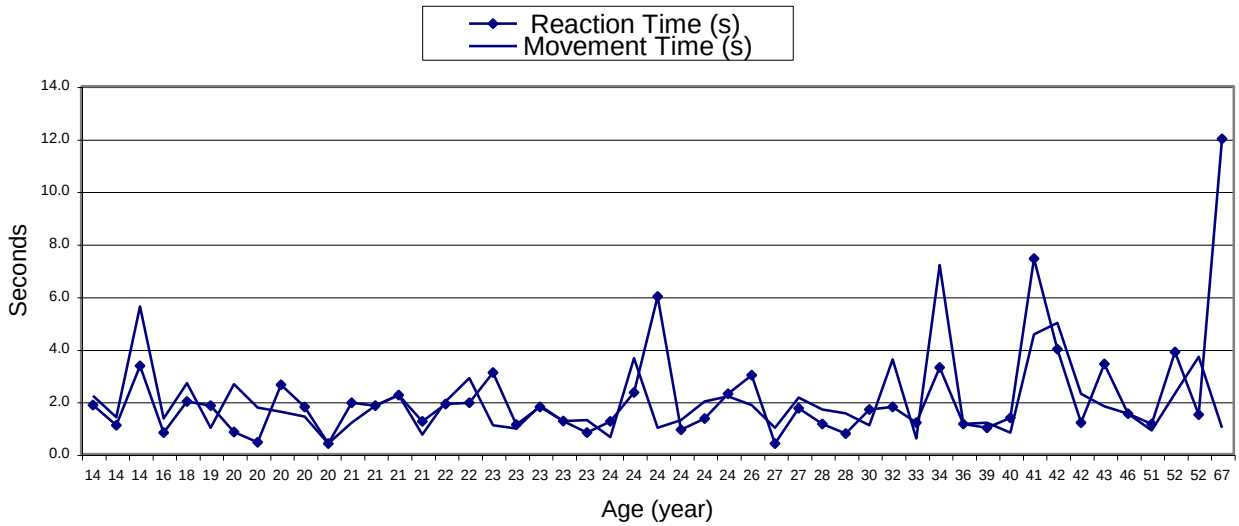

Fig. 1. Male controls (reaction time and movement time) as a function of age.

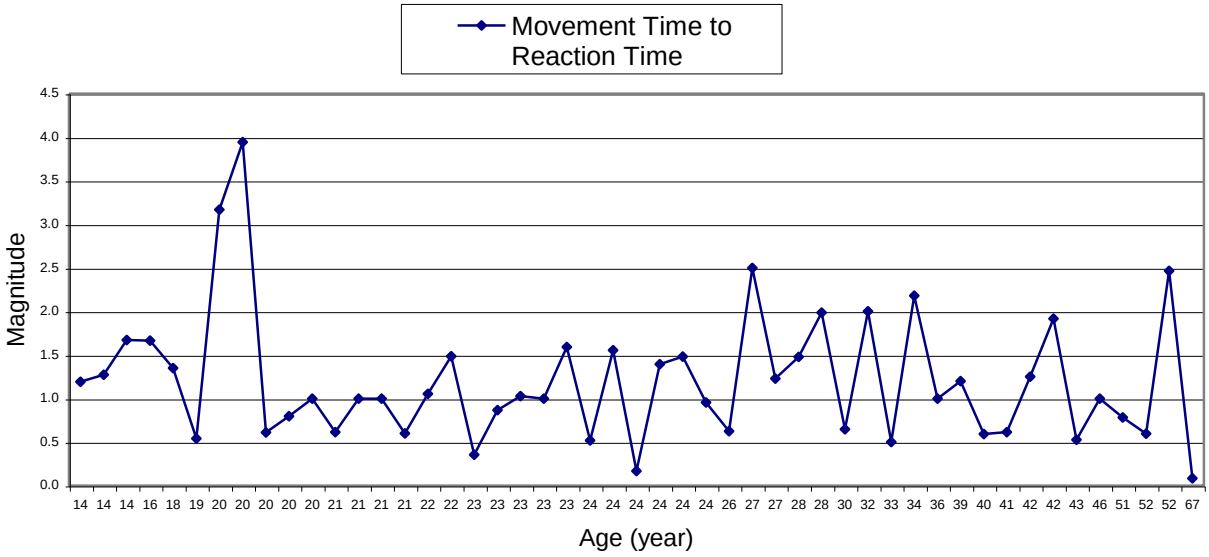

Fig. 2. Male controls (movement time to reaction time) as a function of age.

Mean value of movement to reaction time was equal to 0.93 (SD = 0.69). This figure shows that the magnitude of the Ratio of (movement time to reaction time) fluctuating

in the range 0.1 to 3.9. Eliminating the two extreme values of 3.2 and 3.9 makes the mean value close to mid rang of the data. Ratio is less than 1, which indicates that the reaction time is greater than the movement time of the hand trajectory. It might be said that if the line traced by the participant is stretched then the movement time would be increased to exceed that of the reaction time elapsed, and hence the ratio will be greater than 1, this is actually possible but, as the line to be traced should be of fixed length and all participants are asked to reproduce it without modification to its length then the results are considered as standardized and values obtained are assumed true for this test under this condition. Correlation factor of the Ratio with age was equal to 0.17, which indicates slight dependency.

Mean Reaction time was equal to 5.28 s (SD = 3.67 s). Mean movement time was equal to 3.8 s (SD = 5.7 s). It can be seen from the figure that reaction time values are close to the movement time values apart from that noticed for certain cases such as participants aged 5, 21, 25 and 35 years. Control aged 35 years had a sharp increase of movement time. Both reaction time and movement time seem to increase with age to different degrees. Correlation factor of reaction time with age was 0.12 while that for movement time with age was 0.28, which ascertain the dependence of these two parameters on age. From Figs. 1 and 3 shown above it was noticed that the mean values of the reaction time for female controls is more double that for male controls, while the movement time for female controls was slightly less than double that for male controls.

Mean value of movement to reaction time was equal to 0.72 (SD = 1.55). This figure shows that the mean values of the Ratio were fluctuating in the range 0.1 to 4.4. Mean ratio was less than 1, which indicated that the reaction time is greater than the movement time of the hand trajectory. Correlation factor of Ratio of (movement time to reaction time) with age was 0.19, which indicates slight dependency. From Figs. 2 and 4 shown above it is noticed that the mean ratio for female controls was 77% of that for male controls.

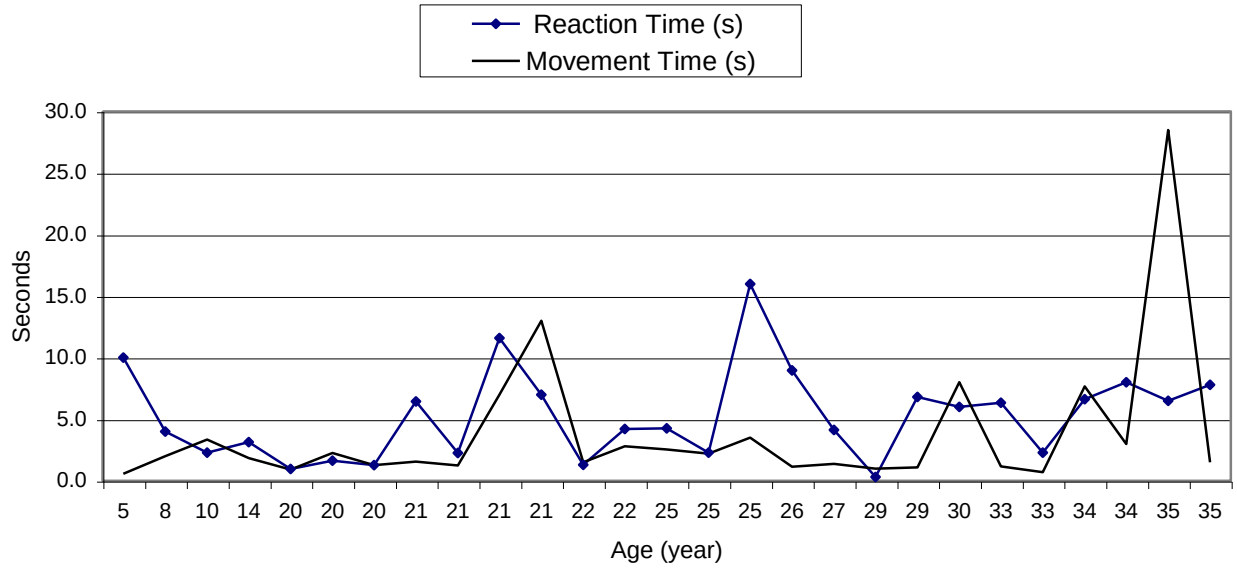

Fig. 3. Female controls (reaction time and movement time) as a function of age.

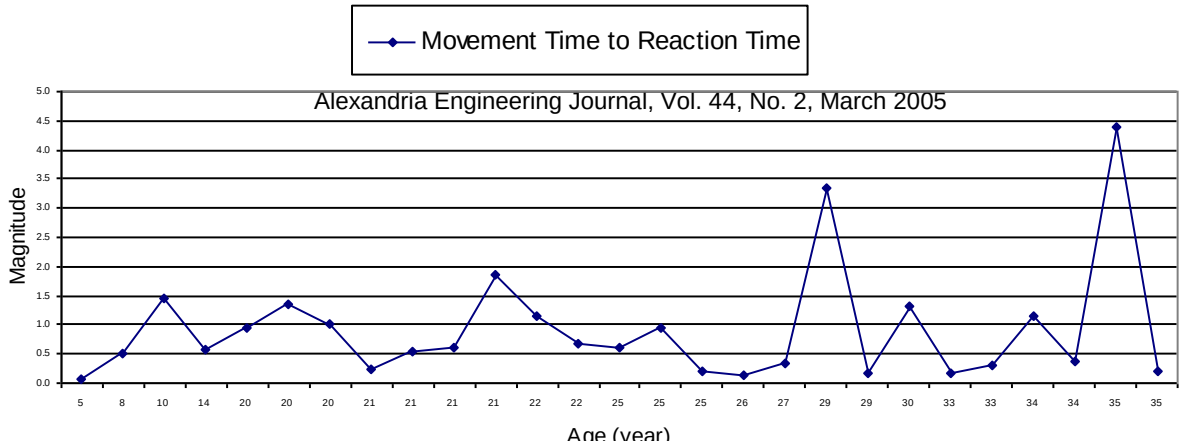

Fig. 4. Female controls (movement time to reaction time) as a function of age.

Mean Reaction time was equal to 7.32 s (SD = 4.48 s). Mean movement time was equal to 4.41 s (SD = 4.15 s). The mean reaction time was far higher than that for the movement time, which indicates that the participant is delaying the action of moving the hand; this is the result of mental retardation. In a previous study conducted by [15] it was reported that quick movement of the hand can lead to deviation in the upward or the downward direction, which are considered as error in the movement, such deviation are also features of disability. Both reaction time and movement did not seem to vary with increasing age. Correlation factor of reaction time with age was equal to 0.03 while that for movement time with age was equal to 0.06, which ascertain the independence of these two parameters on age.

Mean value of movement to reaction time was equal to 0.6 (SD = 0.86). This figure shows that the magnitude of the Ratio is fluctuating in the range 0.1 to 5.8, which is more than that measured for other groups. Mean ratio was less than 1, which indicated that the reaction time is greater than the movement time of the hand trajectory and hence poor tracking. Correlation factor of Ratio with age was 0.16, which indicates slight dependency. From figs. 2 and 6 shown above it is noticed that the mean ratio for male controls was 55% better than that for male patients.

Mean Reaction time was equal to 7.33 s (SD = 3.23 s) and was the highest of all groups. Mean movement time was equal to 1.53 s (SD = 1.14s) and was lowest least of all groups. Hand traces performed were badly affected with vertical deviations. The reaction time is far higher than the movement time, which indicates that the participant is delaying the action of moving the hand; this is a sign of mental retardation [21]. Both reaction time and movement increased with increasing age. Correlation factor of reaction time with age was equal to 0.12 while that for movement time with age was equal to 0.05. It was found that mean reaction time was 75% slower than that measured for male controls.

Mean value of Ratio was equal to 0.21 (SD = 0.35). This figure shows that the magnitude of the Ratio is fluctuating in the range 0.1 to 2.65, if the extreme value of 2.65 is eliminated then the range is reduced to 0.1 to 0.8, and hence the mean value become closer to mid range of the data. Results were consistent with those reported by [22], who suggested that the central nervous system is responsible for the operation of an internal model in planning movement of hand. This value of Ratio is the least to be measured amongst all groups. Ratio was dependent on age as the correlation factor was equal to 0.23. From figs. 2, 4, 6 and 8 it can be said that female patients had the poorest performance, since their reaction time was slow and their movement time was fast which resulted in this value of low ratio.

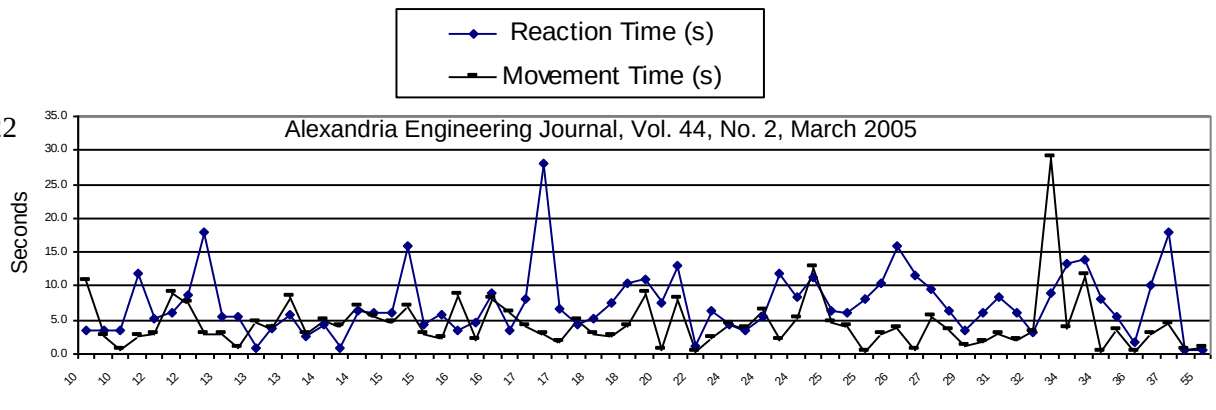

Fig. 5. Male patients (reaction time and movement time) as a function of age.

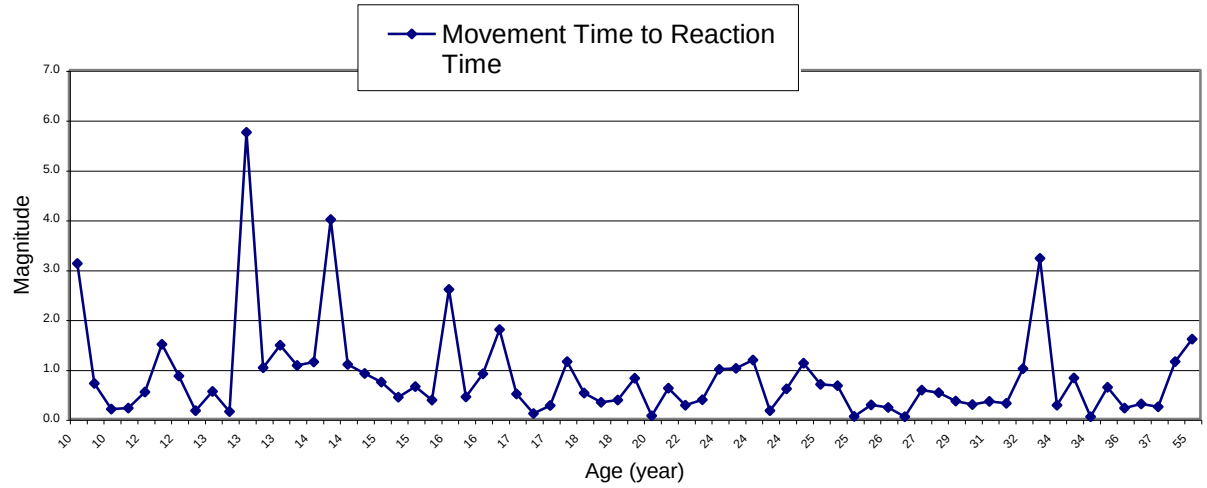

Fig. 6. Male patients (movement time to reaction time) as a function of age.

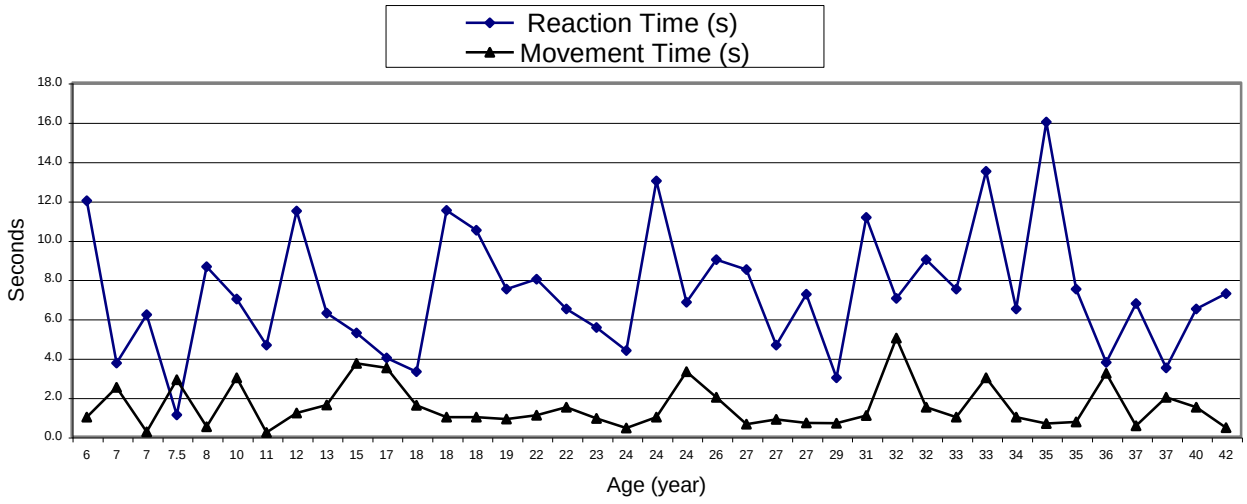

Fig. 7. Female patients (reaction time and movement time) as a function of age.

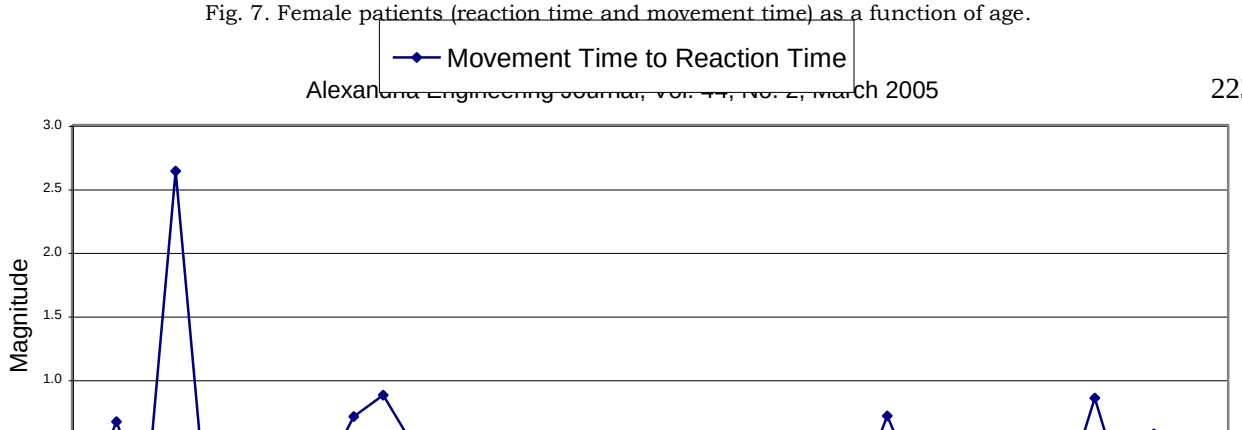

Fig. 8. Female patients (movement time to reaction time) as a function of age.

This figure shows that male controls reaction time was 30% of that for male patients, while movement time was 45% of that for male patients and ratio of movement to reaction time was 155% of that for male patients.

The reduced value of reaction time for controls proved that they can respond with a high degree of alertness, concentration and (vision and hand coordination), compared to male patients whose reaction time was slow which suggests lack of concentration and poor vision hand coordination, as reported by [23].

The high magnitude of the ratio for controls compared to that for patients is of great importance because, first it proved that it is dependent on state of health, and second because of its dependence on both of the reaction time and the movement time, and not on one of them separately, so that if one is affected by any of the previously mentioned factors (health, age or gender) then the other is also affected and hence the net value is mathematically more sensible since it takes the mean.

This figure shows that female controls reaction time was 72% of that for female patients, while movement time was 240% of that for female patients and ratio of movement to reaction time was 340% of that for female patients. The lower reaction time of controls compared to patients agreed with previous findings, but movement time was shorter for patients, this is due to cerebellar diseases, and inaccuracy of the ballistic movement as being reported by [21]. The high magnitude of the ratio for controls compared to that for patients proved its dependency on state of health.

This figure compares the mean values of the different parameters considered in the study.

Certain point can be seen from the results shown such as: Male controls have the lowest reaction time, followed by female controls, and then came male patient and finally female patients. Similar behaviour was noticed with movement time is investigated, except that the value of the female patients were lower than that for all other groups for no obvious reason up to our knowledge, even though their ratios were still consistent with those of other groups, that is male controls had the highest values then came female controls, then male patients and finally came female patients.

Reaction time, movement time and ratio were all increased with increasing age of the participants, as proved by the correlation factors shown below in table 1.

Ratios of movement time to reaction time were higher for males than those for females, therefore it can be said that ratio is dependent on gender.

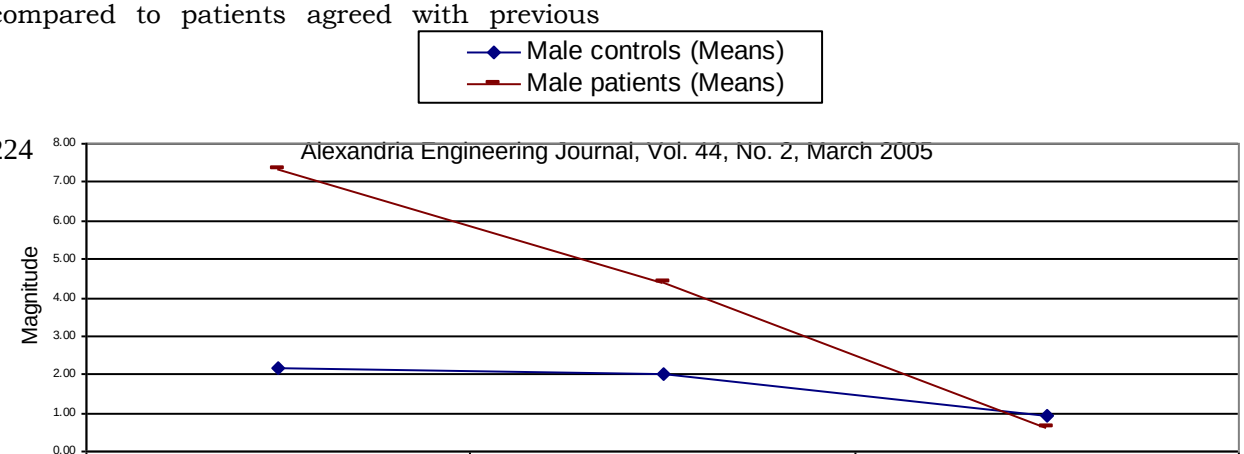

Fig. 9. Mean values of (reaction time, movement time and movement time / reaction time) as a function of state of health.

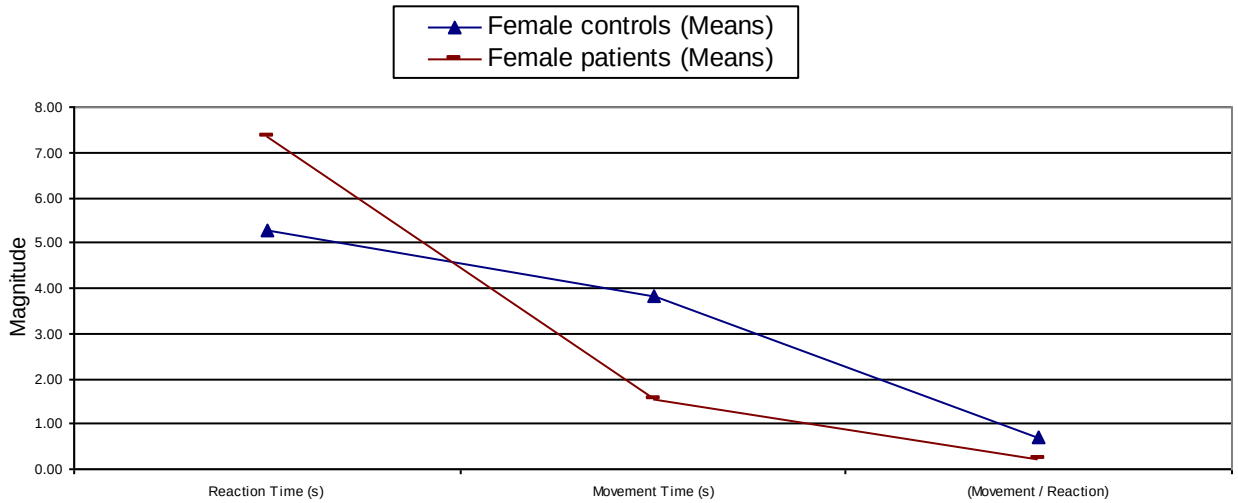

Fig.10. Mean values of (reaction time, movement time and movement time / reaction time) as a function of state of health.

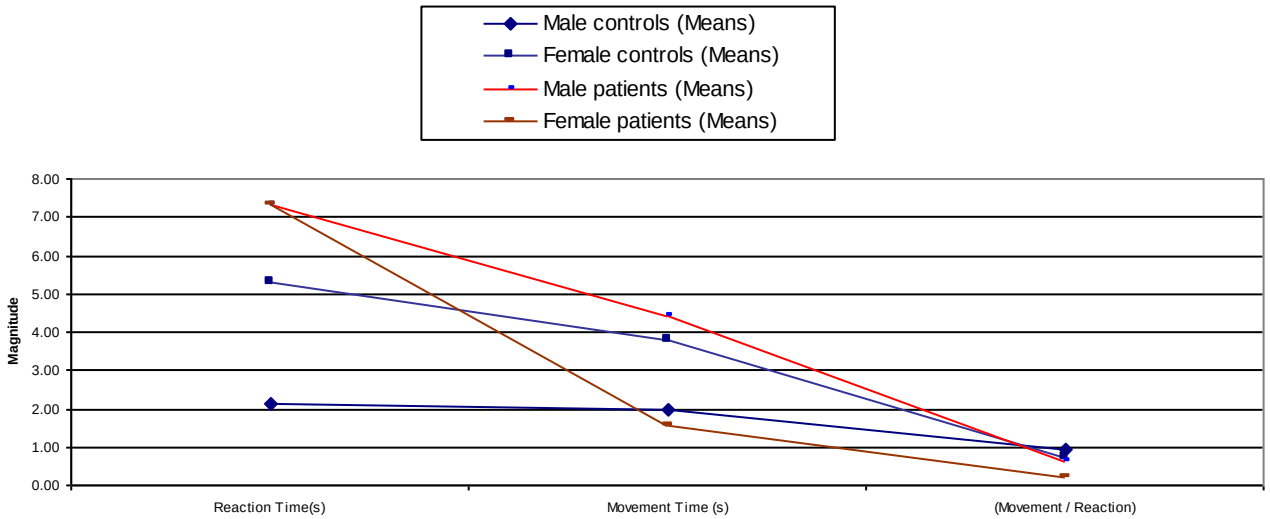

Fig. 11. Mean values of (reaction time, movement time and movement time/ reaction time) as a function of state of health.

Table 1 A comparison of the correlation factors for reaction time with age, movement time with age and (movement time /

reaction time) with age, as a function of state of health and gender.

Group	Correlation factor of Reaction time with age	Correlation factor of movement time with age	Correlation factor of ratio with age
Male controls	0.48	0.09	0.17
Male patients	0.03	0.06	0.16
Female controls	0.12	0.28	0.19
Female patients	0.12	0.05	0.23

Some of these parameters have not been investigated before this study such as the ratio of movement time to reaction time, therefore; it might be appropriate to refer to the closest possible related studies such as the work done on latency of hand movement. [24] considered latency as a function of age and state of health and reported its dependency on both of them, it can be said that the results are consistent with the results of that work. Results are also consistent with those reported by [22] where the central nervous system was found to plan movement of hand. The model therefore is dependent on a combination of sensory and predictive processes, and measurements based on those may be impaired by poor state of health, gender and old age. Mentally retarded subjects and elderly subjects maintained low values of ratios, which are the result of poor hand mind coordination and other factors mentioned in the study.

4. Conclusions

Male controls have the lowest reaction time, followed by female controls, and then came patient males and finally patient females. Similar behaviour is noticed when movement time was investigated, except that the value of the female patients were lower than that for all other groups for no obvious reason up to our knowledge, even though their ratios were still consistent with those of other groups, that is male controls had the highest values then came female controls, then male patients and finally came female patients. Reaction time, movement time and ratio were all increased with increasing age of the participants, as proved by the correlation factors calculated. Ratios of movement time to reaction time were higher for males than those for females, therefore it can be said that ratio is dependent on gender. Results proved that mental retardation worsen hand movement, and hence the low values obtained for ratios. The three parameters investigated proved to be useful for the diagnoses of the state of health. Outcome of this work fulfilled the postulate made earlier in the introduction that hand movement is affected by state of health, gender and age of the participant. System prepared for this work (Personal computer, Software, Light pen and mouse) was sufficient for the intended purpose, in addition to its fast response, ease of use and data manipulation and presentation.

Acknowledgement

We would like to thank the Administrative boards and staff of the Prince Al-Hassan Centre for the Early Diagnosis of Handicaps and Karak Centre for Welfare and Rehabilitation, for their assistance in providing my study with the necessary volunteers.

Appendix

```
Option Base 0,
Private Sub Form_MouseDown(Button As Integer, Shift As Integer, X As Single, Y As Single),
Timer1.Enabled = True :ti(z) = Label6.Caption
End Sub,
Private Sub Form_MouseMove(Button As Integer, Shift As Integer, X As Single, Y As Single),
If Button = 2 Then :tiD(tp) = Label6.Caption,
End If,
nu = nu + 1:Tmlat = (tiD(1) - tistart),
Text2.Text = Tmlat / 100:Text2.Enabled = False,
End Sub,
Private Sub Form_Mouseup(Button As Integer, Shift As Integer, X As Single, Y As Single),
ti(z) = Label6.Caption:tiD(tp) = Label6.Caption,
Timer1.Enabled = False:Tme(z) = (ti(z) - ti(z)) / 100,
MOtTi = Tme(z):z = z + 1:movti = 0,
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```
For pn = 0 To tp:movti = tiD(pn) - tiD(1),
Next:movti2 = movti / 100,
Print movti2:End Sub,
Private Sub mnuAnalysis_Click(),
For pn = 0 To tp:tiV(pn) = (tiD(pn + 1) - tiD(pn)),
tiV(pn) = FormatNumber(tiV(pn), 4) / 100,
If tiV(pn) = 0 Then:tiV(pn) = tiV(pn) + 0.001,
tiV(pn + 1) = tiV(pn) + 0.002:End If,
Combo1.AddItem tiV(pn):Next,
Visible = False:Call Cls:End Sub,
Private Sub mnuTime_Click(),
For pn = 0 To tp,
tiV(pn) = (tiD(pn + 1) - tiD(pn)),
tiV(pn) = FormatNumber(tiV(pn), 4) / 100,
If tiV(pn) = 0 Then,
tiV(pn) = tiV(pn) + 0.01,
tiV(pn + 1) = tiV(pn) + 0.02,
End If,
Next:End Sub:Private Sub mnuTime(),
On Error GoTo divideByZeroHandler,
Call Cls;Print " Motion is represented in:  "; tt; " Points",
Print " Latency in seconds is:  "; Tmlatency / 100,
Print " Time of motion in Seconds is:  ";
For co1 = 0 To z – 1: Tme(co1) = FormatNumber(Tme(co1), 3),
Print Tme(co1):Next,
Print movtim2:motionT = movtim2 + Tmlatency / 100, and
Exit Sub,
divideByZeroHandler:
Label1.Caption = "Attempted divide by zero"
Exit Sub:inputhandler:
Label1.Caption = "Attempted divide by zero"
End Sub
```

References

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