CHAPTER IV
RESULTS

4.1 Characteristics of participants

The recruitment processes were demonstrated in Figure 4.1. PD patients and healthy non-disabled controls with right handedness (defined by Edinburgh Handedness Inventory) aged between 35 – 80 years were recruited. Researcher invited 83 individuals with PD and 11 healthy non-disabled controls. Among these numbers, 50 PDs and 9 controls agreed to participate. Thirty two individuals with PD were met inclusion and exclusion criteria and then allocated to waiting list. Four of them cannot be matched to others after categorized them into stria for preparing to allocate with stratified randomization by age, more affected side, and severity (Hoehn and Yarh stage) into training groups. Then, twenty eight individuals with PD (19 individuals had more affected on right hand) and 9 non-disabled controls signed consent form which approved by Siriraj Institutional Review Board (SIRB, COA: Si038/2014), Faculty of Medicine, Siriraj Hospital, Mahidol University prior to enrollment. Nineteen participants with PD who had more affected on right hand and all non-disabled controls were assessed in first experiment. Eighteen PD individuals were continuously enrolled into second study and were equally allocated into 3 groups of training. However, two of them participated both experiment in different days (1 month interval) because of the problem in the measurement tool (Motion Monitor tracking system).

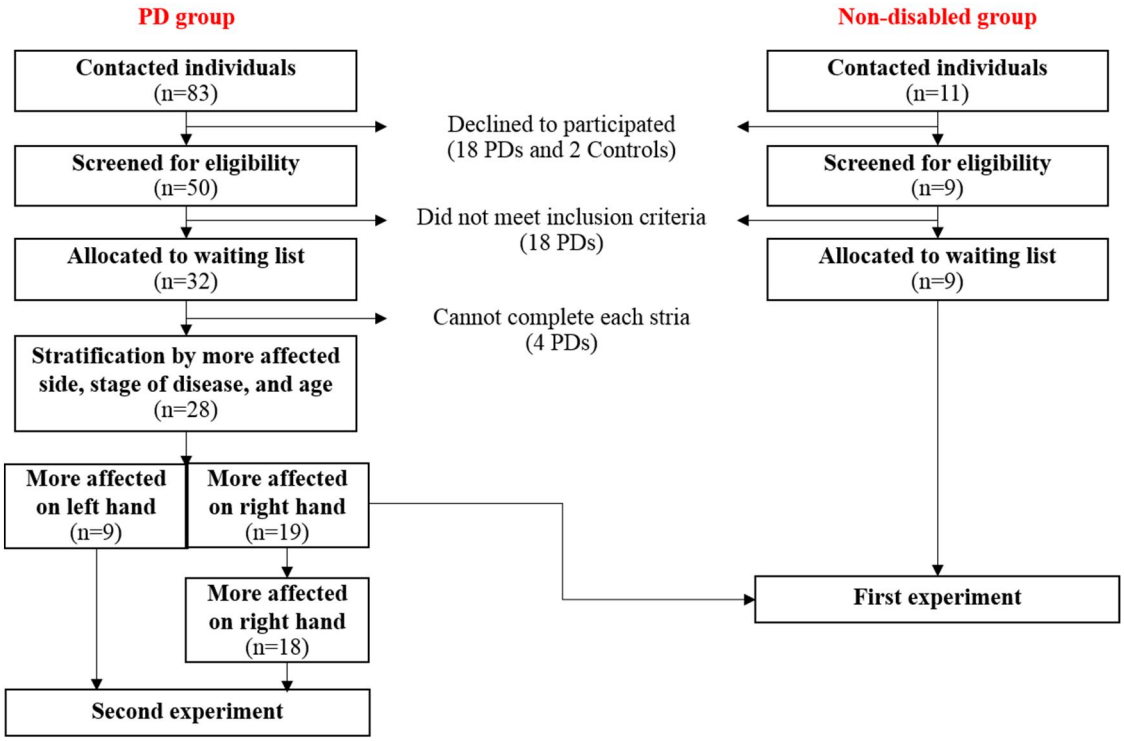

Figure 4.1 The recruitment processes for first and second experiment

4.1.1 First experiment

In first experiment, nineteen Parkinson's disease (PD) patients and nine non-disabled adults who aged between 47 – 77 years were recruited. All characteristics and demographic data were shown in Table 4.1. All of participants in PD group had more affected hand on right side. For upper extremity impairment level as measured by Hoehn and Yarh stage, the number of participants who had stage II and III were 12 and 7, respectively. Unified Parkinson's disease rating scale (UPDRS-Motor section) in hand domain were ranged 2 – 11 scores (full score = 24) in PD group. There were no significant differences in age, Mini Mental State Exam (MMSE) Thai version and Thai hospital anxiety and depression scale (HADS) scores ($p>0.05$) between 2 groups.

Table 4.1 Comparison of age, MMSE scores and anxiety and depression level on HADS in first experiment.

	Group		p-value[a]
	Non-disabled controls (n=9)	PD (n=19)	
	Mean (SD)	Mean (SD)	
Age (years)	62.8 (7.2)	62.5 (6.9)	0.90
MMSE (scores)	27.44 (1.59)	26.68 (2.24)	0.37
HADS anxiety (scores)	5 (3)	5 (3)	0.63
HADS depression (scores)	4 (3)	5 (3)	0.58

a = p-value from one-way analysis of variance

* Significant differenceat p-value <0.05

4.1.2 Second experiment

In second experiment, twenty seven PD patients who participated in this study were divided into three groups; Action observation (AO), Placebo (P), and Control (C) groups by stratified randomization with age, more affected side and impairment level (Hoehn and Yarh stage). All characteristics and demographic data were shown in Table 4.2. They aged between 49 – 80 years. There were 3 participants who had more affected on left hand and 9 participants who had more affected on right hand in each group. For upper extremity impairment level as measured by Hoehn and Yarh stage, the number of participants who had stage II and III were 5 and 4, respectively. There were no significant differences in age, disease duration, UPDRS score, MMSE score and HADS score ($p>0.05$) between 3 groups.

Table 4.2 Comparison of age, disease duration, arm impairment on UPDRS, MMSE scores and anxiety and depression level on HADS in second experiment.

	Group			p-value[b]
	C (n=9)	P (n=9)	AO (n=9)	
	Mean (SD)	Mean (SD)	Mean (SD)	
Age (years)	65.0 (6.8)	64.6 (8.3)	64.2 (8.2)	0.97
Disease duration (years)	5 (3)	7 (6)	6 (4)	0.78
UPDRS (III-UE scores)	6 (2)	6 (2)	6 (2)	0.98
MMSE (scores)	27 (3)	26 (3)	27 (2)	0.51
HADS anxiety (scores)	6 (3)	5 (3)	6 (2)	0.92
HADS depression (scores)	7 (4)	5 (3)	5 (2)	0.40

b = p-value from one-way analysis of variance

* Significant difference at p-value <0.05

4.2 First experiment: effects of Parkinson's disease on reach-to-grasp actions.

Overall, all participants accomplished their reach-grasp actions without unsuccessful trials. The present study, the reach-to-grasp (RTG) actions were assessed in 3 domains: planning as measured by reaction time (RT), transport and grasp kinematics, and Transport-grasp coordination. Table 4.3 represent the mean value and standard deviation of each variable in these domains.

4.2.1 Reaction time measure

The reaction time was measured by the time between LED visual signal onset and movement initiation. PD participants slower responded to signal than non-disabled controls approximately 120 milliseconds (ms). There was significant difference between PD and non-disabled control groups (p-value < 0.001). Partial eta squared revealed a medium effect size for the different between group (ES = 0.342 in Table 4.3).

4.2.2 Kinematics measures

4.2.2.1 Movement time (MT)

Overall performance is represented by MT. The non-disabled adults reached around the barrier for grasping the object which place 30 centimeters in front of them within 500 – 600 ms (536.41 ± 55.13 ms). Whereas, PD participants performed the similar movement with longer MT (938.49 ± 256.75 ms). There was significant difference between PD and non-disabled control groups (p-value < 0.001). Partial eta squared revealed a large effect size for the different between group (ES = 0.449 in Table 4.3).

4.2.2.2 Transport component

Figure 4.2 represents an example of the transport velocity profile plot from a control (S21) and an individual with PD (S43). Velocity trajectory from non-disabled adult was obviously double peaked which the highest peak is the second peak. The lowest velocity between the two peaks represent the velocity during passing and avoiding the barrier. PD participant also produced the multiple peaks trajectory (varied between 1 – 4 peaks), but the minimum velocities between peaks cannot be observed as obviously as those in non-disabled group.

PD participants produced a significantly smaller amplitude of maximum transport velocity (V_{max}) (large effect size in Table 4.3). In addition, they had a prolonged transport component as evidenced by longer absolute time to maximum transport velocity (TV_{max}) (large effect size in Table 4.3) and deceleration time (DT) (approximately 200 ms longer than non-disabled group in each time with medium effect size in Table 4.3). In contrast, the relative TV_{max} and DT, which calculated the percentage of time which using for accelerating and decelerating the arm movement respectively, were not significantly different between PD and non-disabled group (p-value = 0.193 and 0.190, respectively).

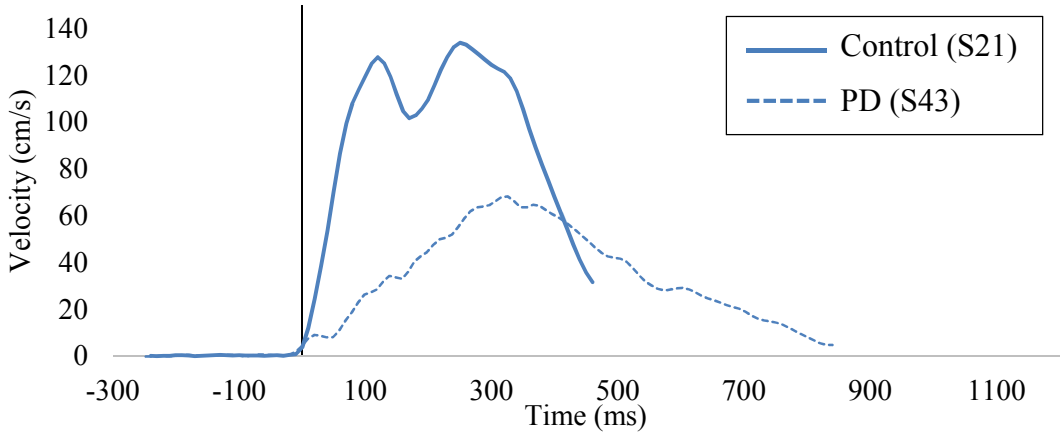

Figure 4.2 Tangential transport velocity profile in PD group and non-disabled controls.

4.2.2.3 Grasp component

Figure 4.3 represents an example of the grasp aperture size plot from a control (S21) and an individual with PD (S43). Similar to velocity trajectory, the grasp aperture performed by non-disabled adult was obviously double peaked which the highest peak is the second peak. The lowest aperture between the two peaks was also found during the time for passing and avoiding the barrier. The pattern of grasp aperture in PD group seem to be similar to pattern in non-disabled group.

Table 4.3 demonstrates that PD participants produced a significantly smaller amplitude of maximum aperture (A_{max}) (small effect size in Table 4.3) and prolonged grasp component as evidenced by longer absolute time to maximum aperture (TA_{max}) and aperture closure time (ACT) (approximately 300 and 100 ms longer than non-disabled group when considering TA_{max} and ACT, respectively). Partial eta squared revealed a large and small effect size for group differences of TA_{max} and ACT, respectively (Table 4.3). In contrast, the relative TA_{max} and ACT, which calculated the percentage of time which using for opening and closing the finger, were not significantly different between PD and non-disabled group (p-value = 0.193 and 0.190, respectively). Aperture closure distance (ACD) was measured the distance between hand and object at the time of occurring A_{max}. It represent the distance that performers start to close their finger to grasp the object. ACD was not significantly different between PD and non-disabled groups (p-value = 0.206).

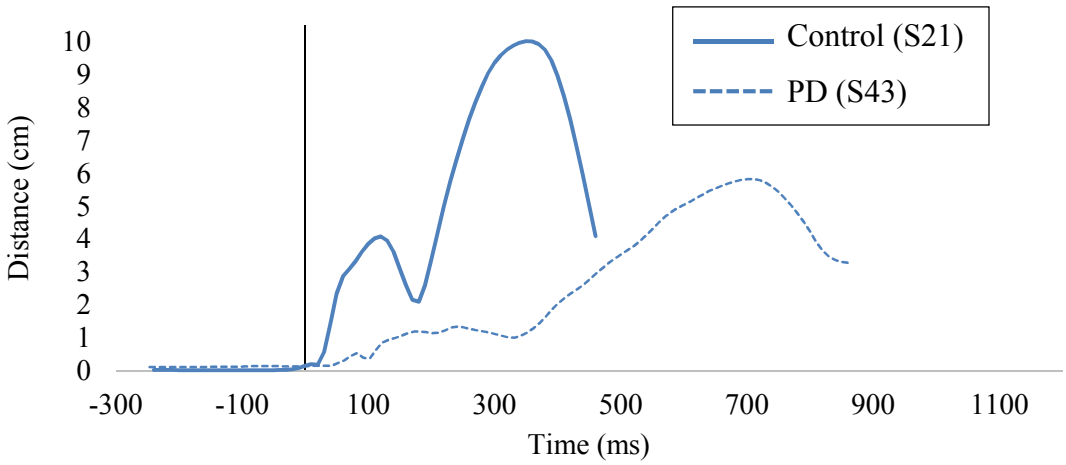

Figure 4.3 Grasp aperture size plots in PD and non-disabled controls groups

4.2.3 Transport-grasp coordination measure

Figure 4.4 represents an example of the transport-grasp coordination plot from a control (S21) and an individual with PD (S43). The coordination plot in PD group shows similar pattern to that in non-disabled group.

Table 4.3 demonstrates that spatial coordination (r_{max}) was not different between PD and non-disabled group (p-value = 0.896). In contrast, temporal coordination, which was represented by associated time lag (T_{max}), in PD group were significantly longer (approximately 150 ms) than it in non-disabled group. Partial eta squared revealed a large effect size for different T_{max} between groups (Table 4.3).

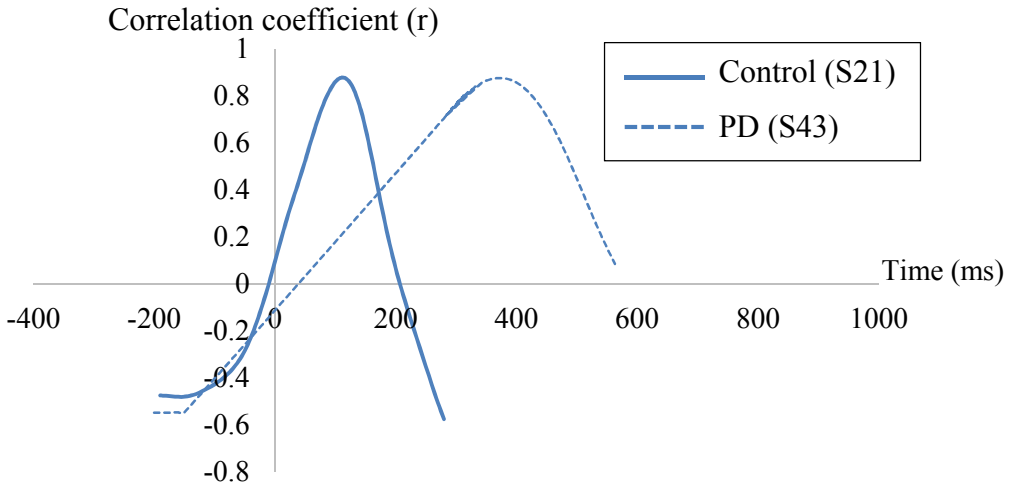

Figure 4.4 Transport-grasp coordination expressed by cross correlation coefficient as a function of time lag in PD and non-disabled controls groups.

Table 4.3 Reach-to-grasp variables from control and PD groups; mean (SD).

Reach-to-grasp variables	Controls (n=9)		PDs (n=19)		p-value[a]	Partial Eta Squared
	mean	(SE)	mean	(SE)		
RT (ms)	146.54	(11.70)	264.45	(21.20)	<0.001**	0.342
Transport component						
- MT (ms)	536.41	(18.38)	938.49	(58.90)	<0.001**	0.449
- V_{max} (cm/s)	111.31	(7.32)	67.81	(2.92)	<0.001**	0.630
- Absolute TV_{max} (ms)	198.78	(19.70)	377.26	(21.47)	<0.001**	0.512
- Relative TV_{max} (%)	36.71	(3.24)	41.18	(1.72)	0.193	0.064
- Absolute DT (ms)	337.63	(19.18)	561.01	(44.64)	<0.001**	0.301
- Relative DT (%)	63.29	(3.24)	58.76	(1.75)	0.190	0.065
Grasp component						
- A_{max} (cm)	7.57	(0.45)	6.11	(0.29)	0.010*	0.231
- Absolute TA_{max} (ms)	394.59	(17.55)	679.81	(40.01)	<0.001**	0.466
- Relative TA_{max} (%)	73.79	(1.67)	73.10	(1.46)	0.779	0.003
- Absolute ACT (ms)	141.83	(9.42)	251.47	(25.23)	<0.001**	0.247
- Relative ACT (%)	26.21	(1.67)	26.84	(1.45)	0.795	0.003
- ACD (cm)	1.71	(0.46)	1.15	(0.20)	0.206	0.061
Transport-grasp coordination						
- r_{max} (r)	0.83	(0.03)	0.83	(0.02)	0.896	0.001
- T_{max} (ms)	143.45	(9.43)	300.50	(22.37)	<0.001**	0.459

a = p-value from one-way analysis of variance

* Significant difference at *p*-value <0.05

** Significant difference at *p*-value <0.01

4.3 Second experiment:

4.3.1 Effects of AO on motor learning of trained-task.

In this study, PD participants were trained with observing model performed 6 tasks of Wolf motor function test (WMFT) and physical training of the same actions. Therefore, the WMFT were tested before, after and 45 minutes after training.

4.3.1.1 Total time of WMFT

Table 4.4 represents the p-value of main effects of time and group, and interaction (time × group) in each variable. There were significant main effect of time (p-value = 0.032) and group (p-value = 0.008), and significant time by group interaction (p-value = 0.005) in total time of WMFT.

Figure 4.5 shows Bonferroni analyses which compared the total time of WMFT between testing times in each group and between groups at each testing time. These multiple comparisons investigated the learning in 3 domains: improvement in acquisition phase, retained capability, and saving capability.

The improvement in acquisition phase was compared the total time between pretest and posttest. The results show that total time of WMFT were significantly decreased after training with AO (p-value < 0.001), P (p-value = 0.002) and C (p-value = 0.001) groups. At posttest, the total time of WMFT in AO group was significant shorter than P group (p-value = 0.047).

The retained capability was determined by comparing the total time between posttest and retention test. The results show that the improvement in total time of WMFT were maintained after training with all training protocols as evidenced by non-significant difference between total time at posttest and total time at retention test. At retention test, the total time of WMFT in AO group was significant shorter than P and C groups (p-value = 0.037 and 0.007, respectively).

The saving capability was determined by comparing the total time between pretest and retention test. The results show that total time of WMFT in all groups were improved at retention test when compared to baseline performance at pretest as evidenced by significant differences between total time at pretest and total time at retention test in AO (p-value < 0.001), P (p-value = 0.001) and C (p-value =

0.009) groups. However, the total time of WMFT in AO group at retention test was significant shorter than P and C groups (p-value = 0.037 and 0.007, respectively). Partial eta squared revealed a medium effect size for the Time × Group interaction and large effect size for saving capability × Group interaction (Table 4.4).

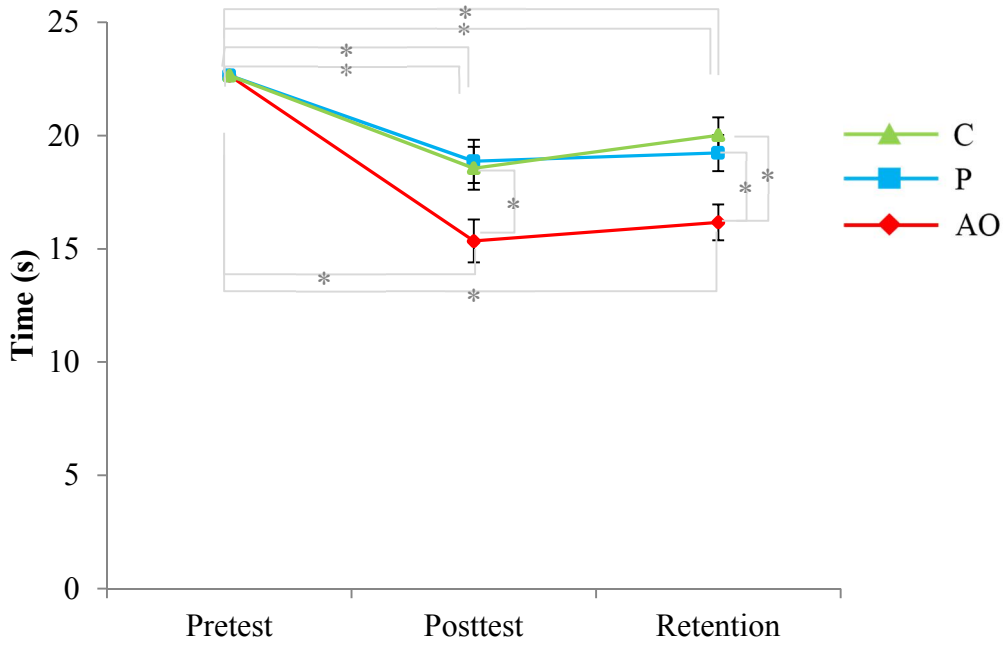

Figure 4.5 Mean total time and standard error (SE) of dexterity domain in Wolf motor function test (WMFT) at each testing time in AO, P and C group. (* denotes significant difference between testing times or groups)

4.3.1.2 Time for each item of WMFT

When considered to time for each item, there were significant main effect of time in all items (Table 4.4). While the significant main effect of group were found only in time for lifting can and turning key (p-value = 0.028 and 0.012, respectively). Additionally, the significant time by group interaction was found only time for turning key (p-value = 0.012). The Bonferroni analyzed each domain of learning in each variable as following paragraph.

1) Time for lifting can

The time for lifting can was significantly reduced after training when compare to pretest in C and AO groups (Figure 4.6). Both groups were able to

maintained their performance at retention test as evidenced by non-significant differences between posttest and retention test (p-value = 0.394 and 1.000 for C and AO groups, respectively). For saving capability, time for lifting can was reduced at retention test when compared to baseline performance at pretest only in AO group as evidenced by significant differences between Time for lifting can at pretest and retention test (p-value = 0.003). While there was no any significant between groups. Partial eta squared revealed a medium effect size for Time × Group and saving capability × group interactions (Table 4.4).

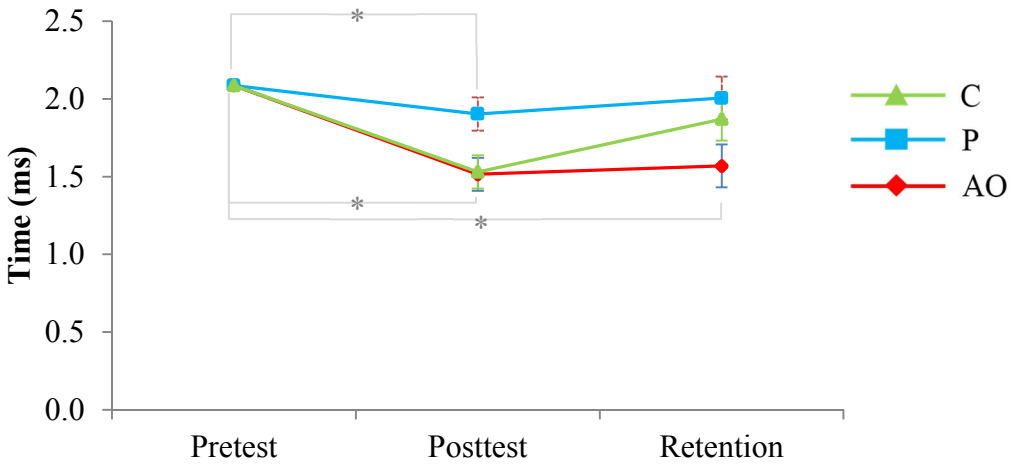

Figure 4.6 Mean time for lifting can and standard error (SE) of Wolf motor function test (WMFT) at each testing time in AO, P and C group.
(* denotes significant difference between testing times or groups)

2) Time for lifting pencil

The time for lifting pencil was significantly reduced after training when compare to pretest in all groups (Figure 4.7). They were able to maintained their performance at retention test as evidenced by non-significant differences between posttest and retention test (p-value = 0.471, 1.000, 0.088 for AO, P and C groups, respectively). For saving capability, times for lifting pencil were reduced at retention test when compared to baseline performance at pretest only in all groups as evidenced by significant differences between Time for lifting pencil at pretest and retention test (Table 4.5). While there was no any significant between groups.

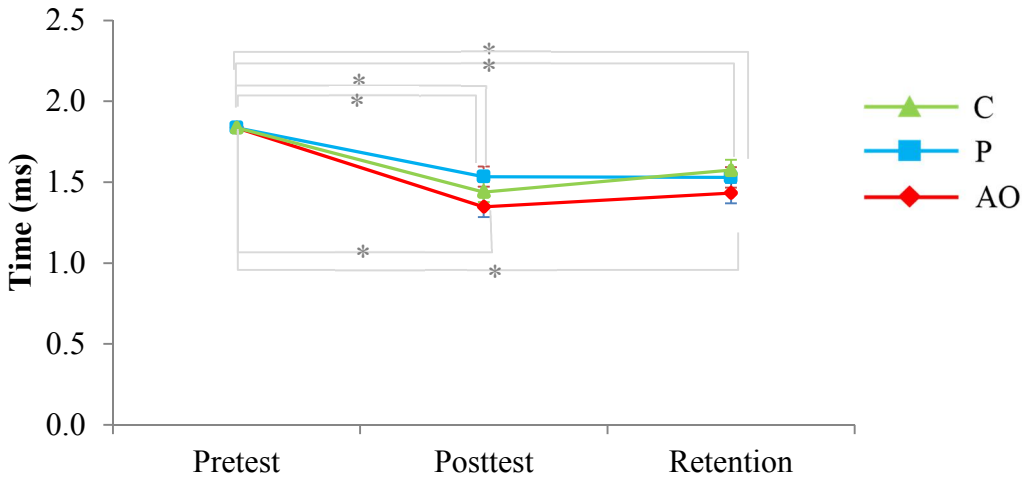

Figure 4.7 Mean time for lifting pencil and standard error (SE) of Wolf motor function test (WMFT) at each testing time in AO, P and C group.
(* denotes significant difference between testing times or groups)

3) Time for lifting paper clip

There was no significant differences between pretest and posttest in all group (Figure 4.8). The significant decreasing of time for lifting paper clip were found at retention test when compare to pretest in all groups (p-value < 0.000 for AO, p-value = 0.005 and 0.009, P and C groups, respectively). While there was no any significant between groups.

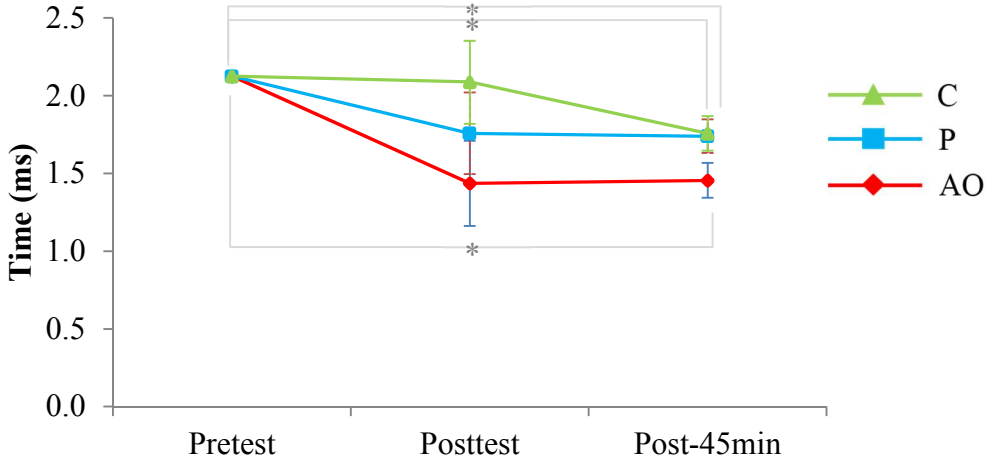

Figure 4.8 Mean time for lifting paper clip and standard error (SE) of Wolf motor function test (WMFT) at each testing time in AO, P and C group.
(* denotes significant difference between testing times or groups)

4) Time for stacking checkers

Similar to the result of time for lifting can, the time for stacking checkers was significantly reduced after training when compare to pretest in C and AO groups (Figure 4.9). Both groups were able to maintained their performance at retention test as evidenced by non-significant differences between posttest and retention test (p-value = 0.761 and 1.000 for C and AO groups, respectively). For saving capability, time for stacking checkers was reduced at retention test when compared to baseline performance at pretest only in AO group as evidenced by significant differences between time for lifting can at pretest and retention test (p-value < 0.001). While there was no any significant between groups.

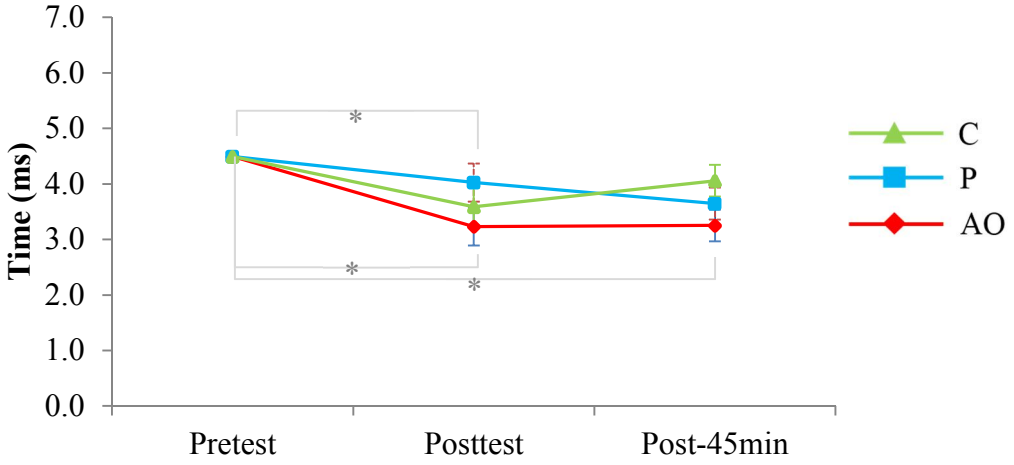

Figure 4.9 Mean time for stacking checkers and standard error (SE) of Wolf motor function test (WMFT) at each testing time in AO, P and C group.
(* denotes significant difference between testing times or groups)

5) Time for flipping cards

The time for flipping cards was significantly reduced after training when compare to pretest in P and AO groups (Figure 4.10). Both groups were able to maintained their performance at retention test as evidenced by non-significant differences between posttest and retention test (p-value = 0.959 and 0.938 for C and AO groups, respectively). For saving capability, time for flipping cards was reduced at retention test when compared to baseline performance at pretest only in AO group as evidenced by significant differences between Time for flipping cards at pretest and retention test (p-value = 0.012), while there was no any significant between groups.

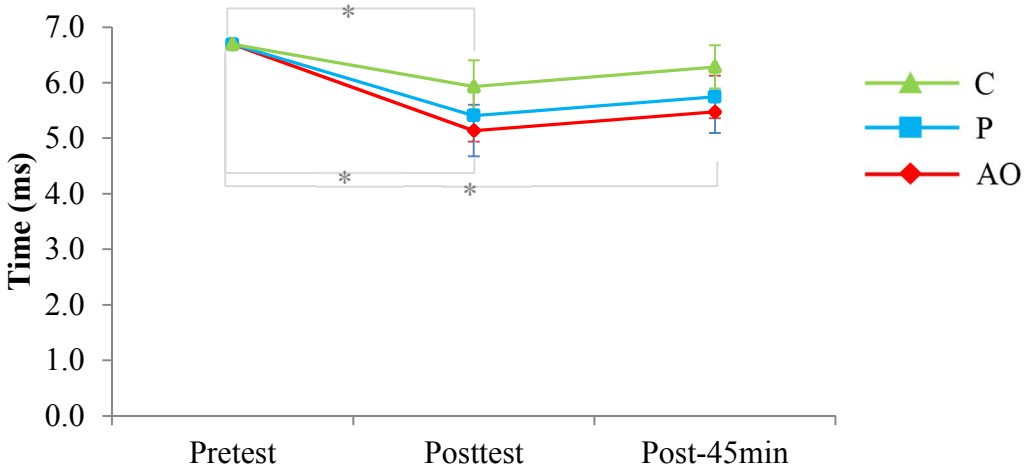

Figure 4.10 Mean time for flipping cards and standard error (SE) of Wolf motor function test (WMFT) at each testing time in AO, P and C group.
(* denotes significant difference between testing times or groups)

6) Time for turning key

The time for turning key was significantly reduced after training with all training groups when compare to pretest (Figure 4.11). They were able to maintain their performance at retention test as evidenced by non-significant differences between posttest and retention test. For saving capability, times for turning key were reduced at retention test when compared to baseline performance at pretest only in all training groups as evidenced by significant differences between Time for flipping cards at pretest and retention test (p-value = 0.012). In addition, there was significant differences between AO and control groups (p-value = 0.036) at posttest and different between AO and other groups (p-value = 0.020 and 0.044 when compare to P and C groups). Partial eta squared revealed a medium effect size for Time × Group and saving capability × group interactions (Table 4.4).

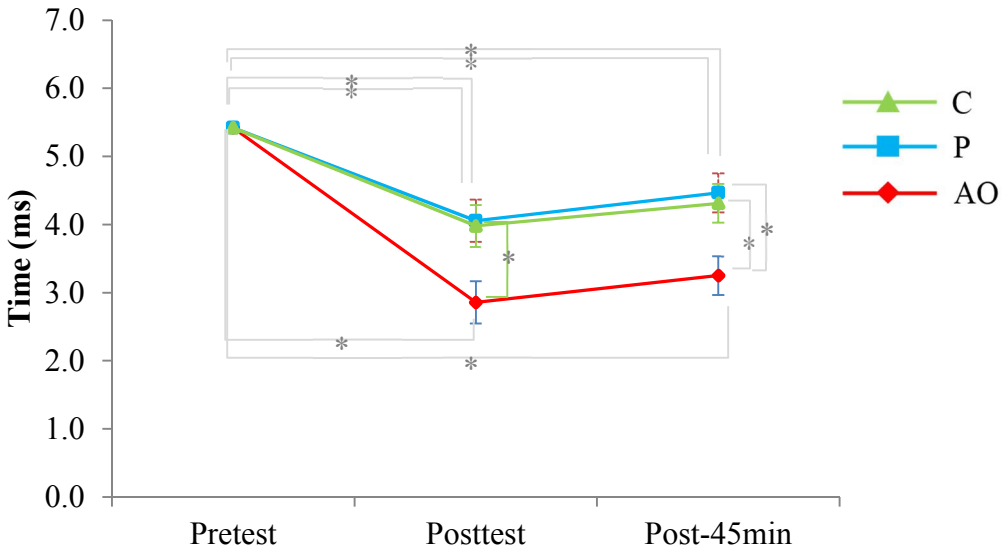

Figure 4.11 Mean time for turning key and standard error (SE) of Wolf motor function test (WMFT) at each testing time in AO, P and C group.
(* denotes significant difference between testing times or groups)

4.3.2 Effects of AO on motor learning of untrained-task.

Although PD participants in this study were physically trained 6 hand actions of WMFT, they were additionally tested RTG performances by RTG under barrier avoidance condition. It was used for investigating the transferred capability from trained task to another untrained task. This test was able to measure the planning by RT, RTG kinematics and transport-grasp coordination. The effects of each training protocol present on following sections.

4.3.2.1 Reaction time (RT) measure

Although training with AO could improve the planning as measured by decreasing RT at posttest and retention test (Figure 4.12), there were not significant main effect of time, main effect of group and interaction (time × group) (p-value = 0.162, 0.068, and 0.080 respectively).

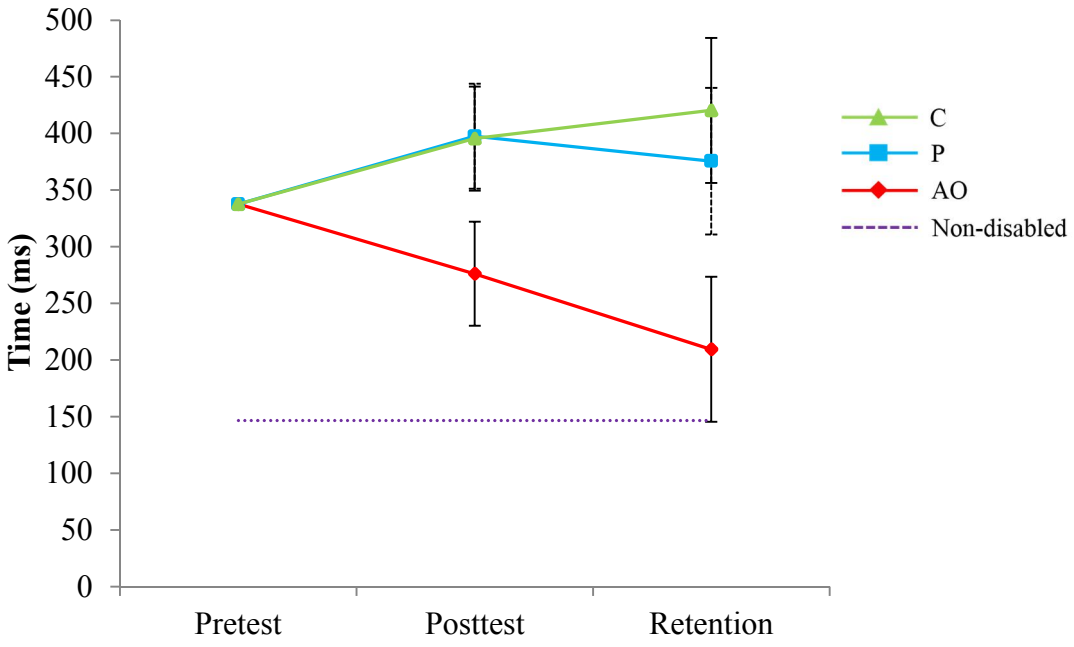

Figure 4.12 Mean reaction time and standard error (SE) at each testing time in AO, P and C group

4.3.2.2 Kinematics measures

1) Movement time (MT)

For overall performance measured by MT, there was a significant main effect of time (p-value < 0.001), whereas, no significant main effect of group (p-value = 0.192) and no significant time by group interaction (p-value = 0.069). Figure 4.13 shows Bonferroni analyses which compared the MT between testing times in each group and between groups at each testing time. These multiple comparisons investigated the learning in 3 domains: improvement in acquisition phase, retained capability, and saving capability.

In acquisition phase, multiple comparisons show significant decreasing in MT after training with all protocols at posttest when compare to pretest (p-value < 0.001 for AO and P group, and p-value = 0.001 for C group).

The retained capability was compared the MT between posttest and retention test. The improvement in MT were maintained after training with all training protocols as evidenced by non-significant difference between MT at posttest and retention test.

The saving capability was compared the MT between pretest and retention test. The results show that MT was improved only in AO group (p-value < 0.001) at retention test when compared to baseline performance at pretest. However, there were significant differences between groups at each testing time. Partial eta squared revealed a medium effect size for Time × Group and saving capability × group interactions (Table 4.4). The improvement could not be reached the normal level (compare to purple dash line which was the data from the first experiment).

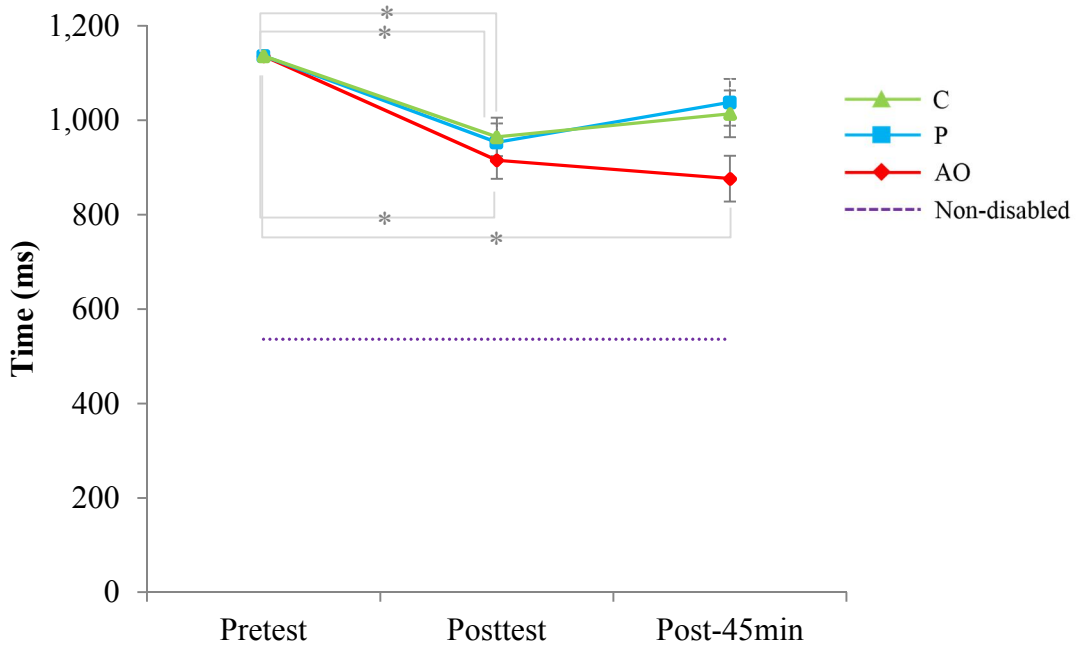

Figure 4.13 Mean movement time and standard error (SE) at each testing time in AO, P and C group

(* denotes significant difference between testing times or groups).

2) Kinematics in transport component

The kinematics in transport component compose of maximum velocity V_{max}, absolute and relative TV_{max}, and absolute and relative DT

For V_{max}, there was a significant main effect of time (p-value = 0.048), whereas, no significant main effect of group (p-value = 0.513) and no significant time by group interaction (p-value = 0.434). Figure 4.14 shows Bonferroni analyses which compared the V_{max} between testing times in each group and between groups at

each testing time. In acquisition phase, multiple comparisons show significant increasing in V_{max} after training with AO (p-value = 0.031) and C (p-value = 0.043) group at posttest when compare to pretest. The improvement in V_{max} of AO and C groups were maintained for 45 minutes as evidenced by non-significant difference between V_{max} at posttest and retention test. Considering, saving capability the results show that V_{max} was improved only in AO group (p-value = 0.021) at retention test when compared to baseline performance at pretest. However, there were significant differences between groups at each testing time.

Similar to V_{max}, there was a significant main effect of time (p-value < 0.001), whereas, no significant main effect of group (p-value = 0.240) and no significant time by group interaction (p-value = 0.336) in absolute TV_{max}. Figure 4.15 shows Bonferroni analyses which compared the absolute TV_{max} between testing times in each group and between groups at each testing time. In acquisition phase, multiple comparisons show significant decreasing in TV_{max} after training with AO (p-value = 0.009) and P (p-value = 0.036) group at posttest when compare to pretest. The improvement in TV_{max} of AO and P groups were maintained for 45 minutes as evidenced by non-significant difference between TV_{max} at posttest and retention test. Considering, saving capability the results show that TV_{max} was significant shorter only in AO group (p-value = 0.001) at retention test when compared to baseline performance at pretest. However, there were significant differences between groups at each testing time.

For absolute DT, there were a significant main effect of time (p-value = 0.011) and significant time by group interaction (p-value = 0.049), whereas no significant main effect of group (p-value = 0.172). Figure 4.17 shows Bonferroni analyses which compared the absolute DT between testing times in each group and between groups at each testing time. In acquisition phase, multiple comparisons show significant decreasing in DT after training with all protocols (p-value < 0.001 for AO and C group, p-value = 0.002 for P group) at posttest when compare to pretest. The improvement in DT of all groups were maintained for 45 minutes as evidenced by non-significant difference between DT at posttest and retention test. Considering, saving capability the results show that DT was significant shorter only in AO group (p-value = 0.001) at retention test when compared to baseline performance at pretest. Importantly, there was significantly shorter DT in AO when compared to P group at retention test.

Partial eta squared revealed a medium effect size for Time × Group and saving capability × group interactions (Table 4.4). However, these improvement could not be regained the normal level.

For all relative values including relative TV_{max} and DT, there were not any significant main or interactive effect (Table 4.4). Figure 4.16 and 4.18 are demonstrated consistent findings as in first experiment (Table 4.3) that relative TV_{max} and DT were not impaired in PD (compare to purple dash lines).

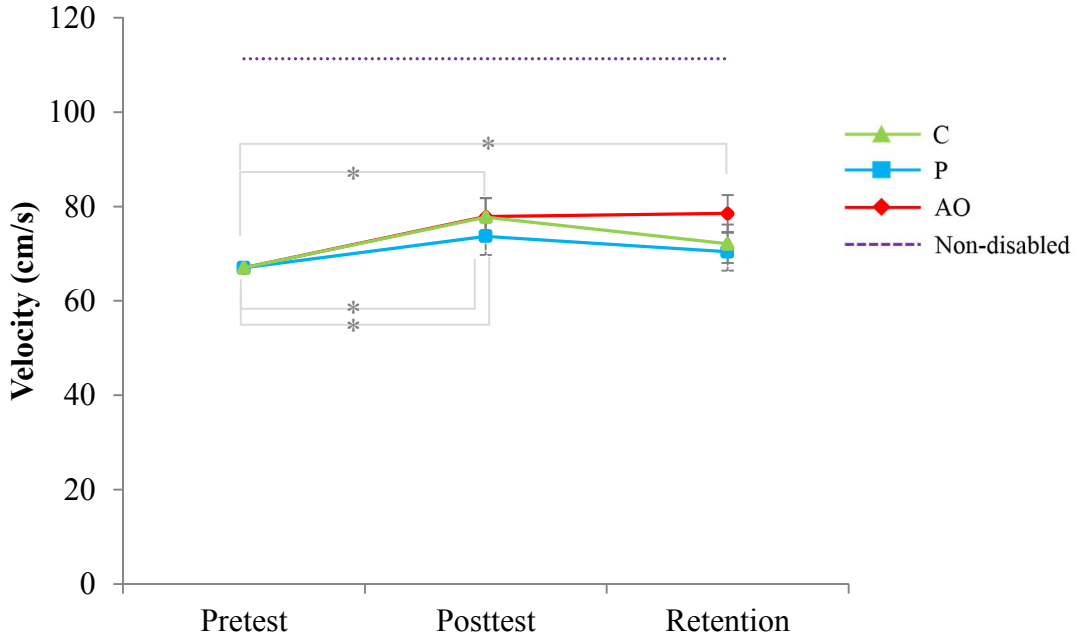

Figure 4.14 Mean maximum velocity and standard error (SE) at each testing time in AO, P and C group

(* denotes significant difference between testing times or groups).

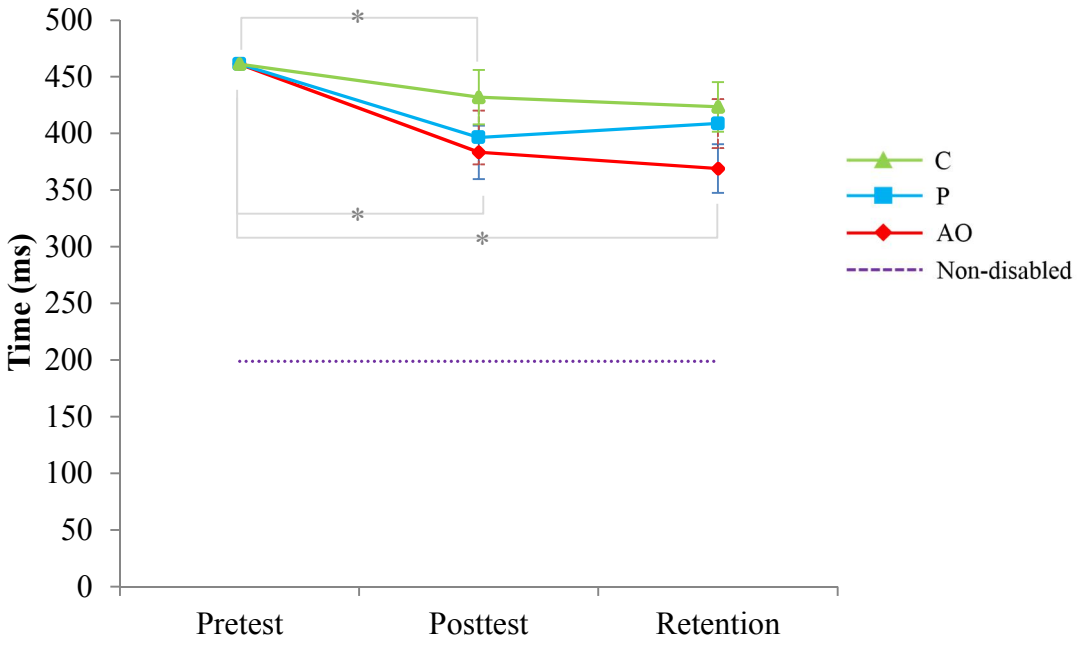

Figure 4.15 Mean absolute time to maximum velocity and standard error (SE) at each testing time in AO, P and C group
(* denotes significant difference between testing times or groups).

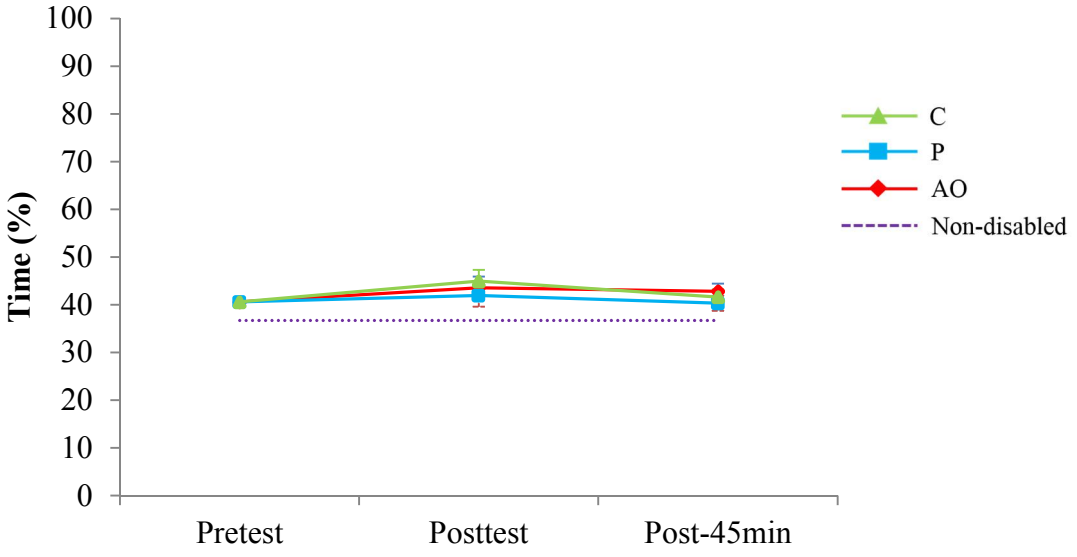

Figure 4.16 Mean relative time to maximum velocity and standard error (SE) at each testing time in AO, P and C group

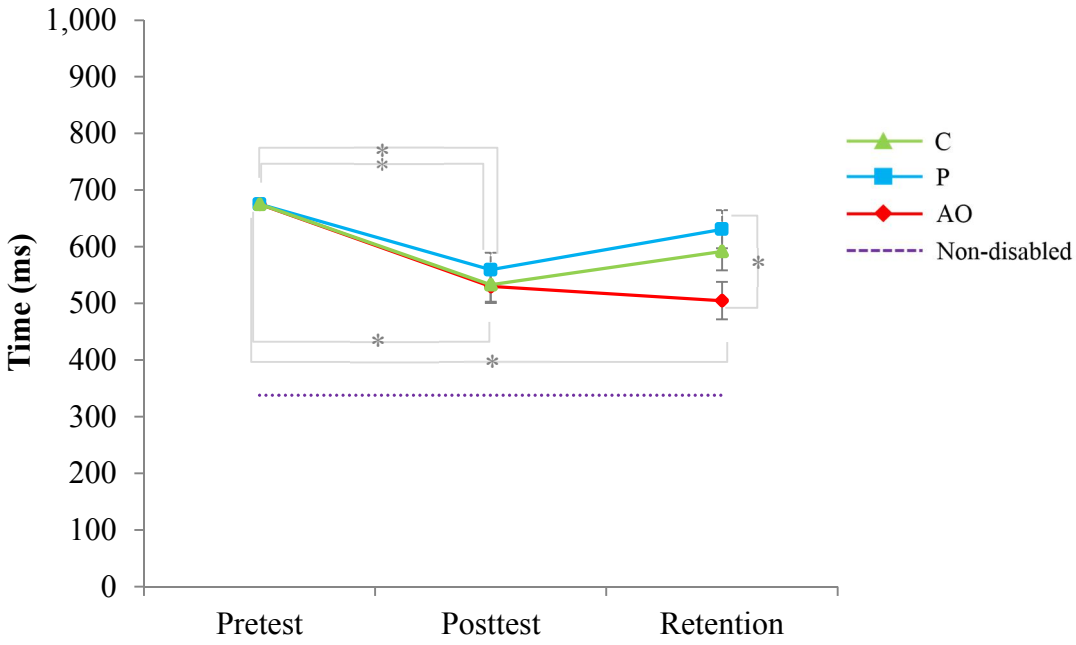

Figure 4.17 Mean absolute deceleration time and standard error (SE) at each testing time in AO, P and C group
(* denotes significant difference between testing times or groups).

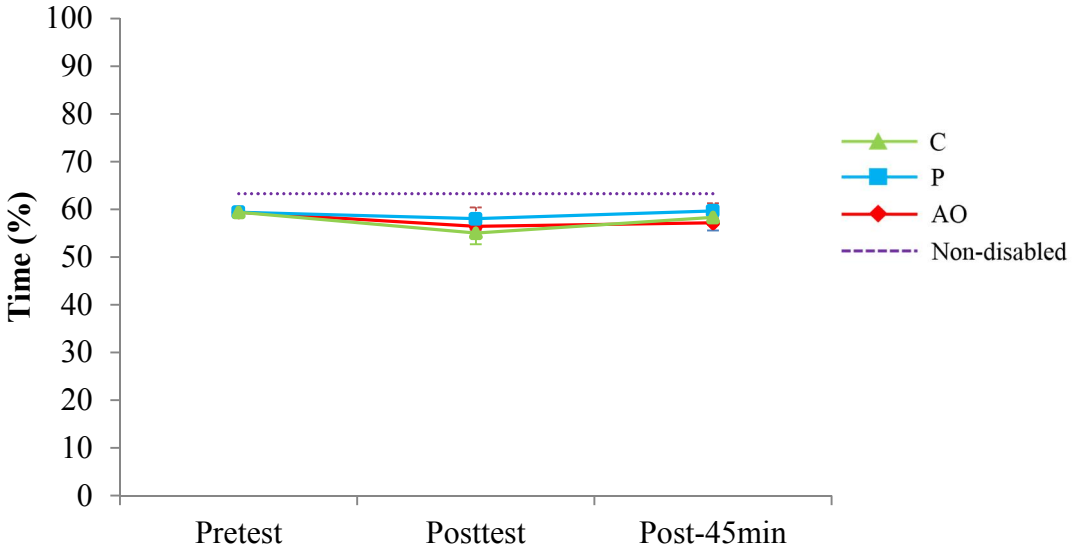

Figure 4.18 Mean relative deceleration time and standard error (SE) at each testing time in AO, P and C group

3) Kinematics in grasp component

The kinematics in grasp component compose of A_{max}, absolute and relative TA_{max}, and absolute and relative ACT and Aperture closure distance (ACD).

For A_{max}, there were not any significant main or interactive effect (Table 4.4). Figure 4.18 shows Bonferroni analyses which compared the A_{max} between testing times in each group and between groups at each testing time. In acquisition phase, the A_{max} was significantly increased after training with control group at posttest when compare to pretest (p-value = 0.030). The improvement in A_{max} of C group were maintained for 45 minutes as evidenced by non-significant difference between A_{max} at posttest and retention test. Considering, saving capability the results show that A_{max} was not improved by any training at retention test when compared to baseline performance at pretest. There was not significant differences between groups at each testing time.

In contrast, there was a significant main effect of time (p-value < 0.001), whereas, no significant main effect of group (p-value = 0.090) and no significant time by group interaction (p-value = 0.076) in absolute TA_{max}. Figure 4.19 shows Bonferroni analyses which compared the absolute TV_{max} between testing times in each group and between groups at each testing time. In acquisition phase, multiple comparisons show significant decreasing in TA_{max} after training with all protocols at posttest when compare to pretest (p-value < 0.001 for AO, p-value = 0.010 and 0.006 for P and C groups, respectively). The improvement in TA_{max} were maintained for 45 minutes as evidenced by non-significant difference between TA_{max} at posttest and retention test in all groups. Considering, saving capability the results show that TA_{max} was significant shorter only in AO group (p-value < 0.001) at retention test when compared to baseline performance at pretest. Partial eta squared revealed a medium effect size for Time × Group interaction (Table 4.4). However, there were significant differences between groups at each testing time.

For absolute ACT, there were no any significant main effect or interactive effect (Table 4.4). Figure 4.21 shows Bonferroni analyses which compared the absolute ACT between testing times in each group and between groups at each testing time. In acquisition phase, there were no significant difference in ACT after training with all protocols at posttest when compare to pretest (p-value = 0.535, 0.060,

0.229 for AO, P, and C group, respectively). The ACT of all groups were consistent for 45 minutes after trainings as evidenced by non-significant difference between ACT at posttest and retention test. Considering, saving capability the results show that ACT was significant shorter only in AO group (p-value = 0.018) at retention test when compared to baseline performance at pretest. There was no significant difference between groups. However, these improvements in absolute TA_{max} and ACT could not be regained the normal level (purple dash line in Figure 4.19 and 4.21).

Considering the ACD, there was a significant main effect of time (p-value < 0.001), whereas, no significant main effect of group (p-value = 0.572) and no significant time by group interaction (p-value = 0.297). Figure 4.23 represents no significant differences between testing times and groups when investigated by Bonferroni.

For all relative values including relative TA_{max} and ACT, there were not any significant main or interactive effect (Table 4.4). Figure 4.20 and 4.22 are demonstrated consistent findings as in first experiment (Table 4.3) that relative TV_{max} and DT were not impaired in PD (compare to purple dash lines).

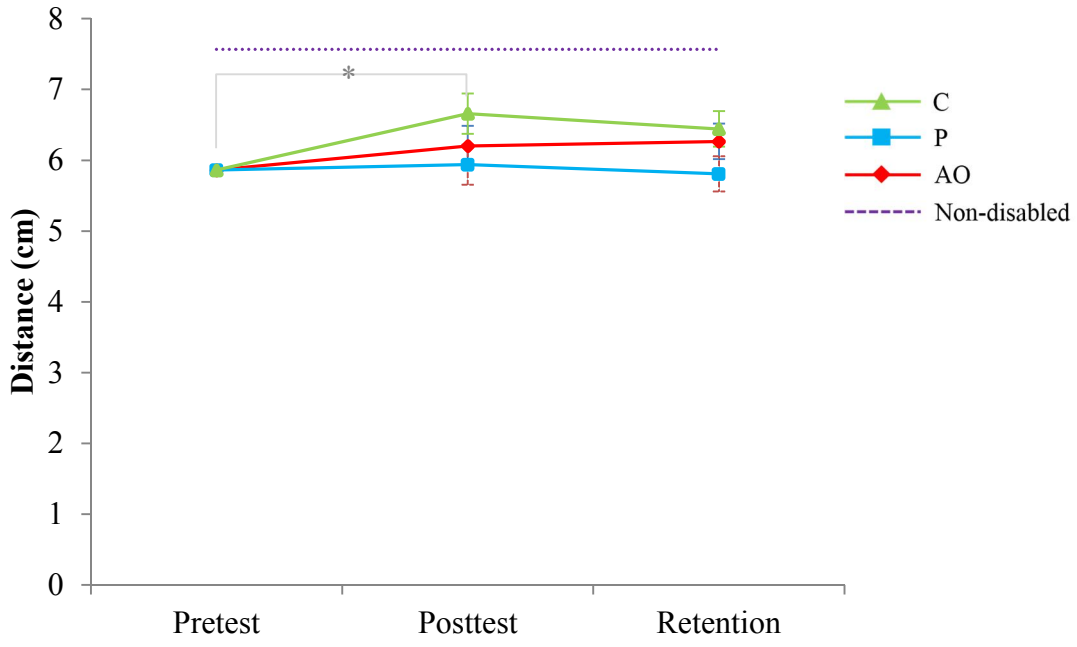

Figure 4.19 Mean maximum aperture and standard error (SE) at each testing time in AO, P and C group

(* denotes significant difference between testing times or groups).

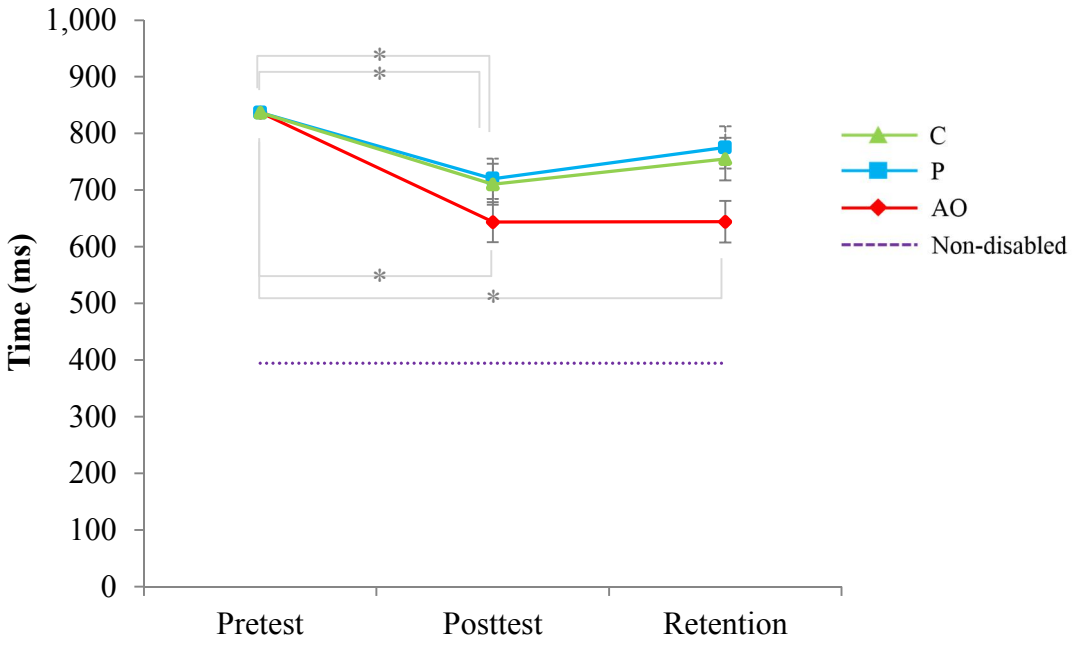

Figure 4.20 Mean absolute time to maximum aperture and standard error (SE) at each testing time in AO, P and C group
(* denotes significant difference between testing times or groups).

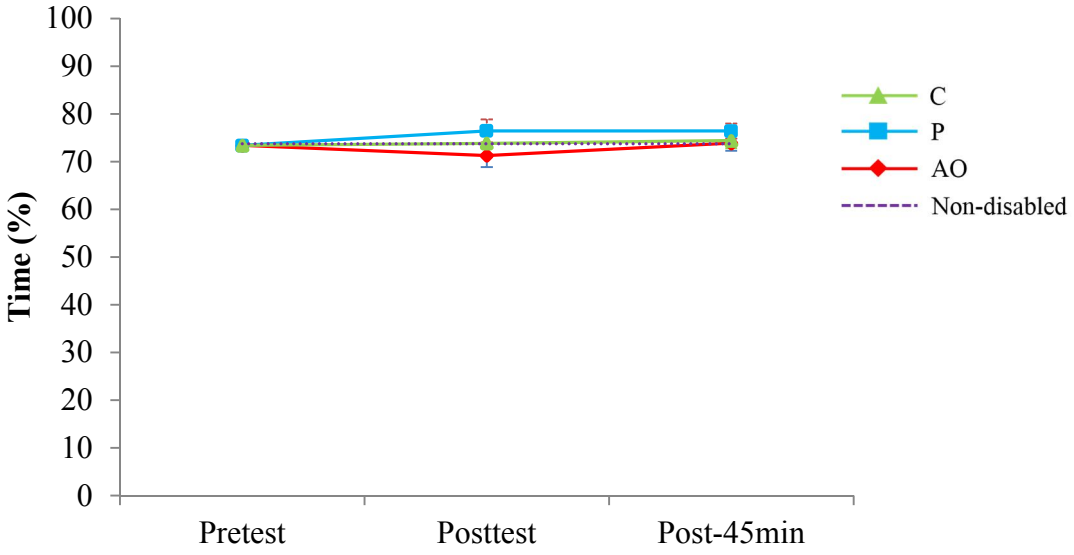

Figure 4.21 Mean relative time to maximum aperture and standard error (SE) at each testing time in AO, P and C group

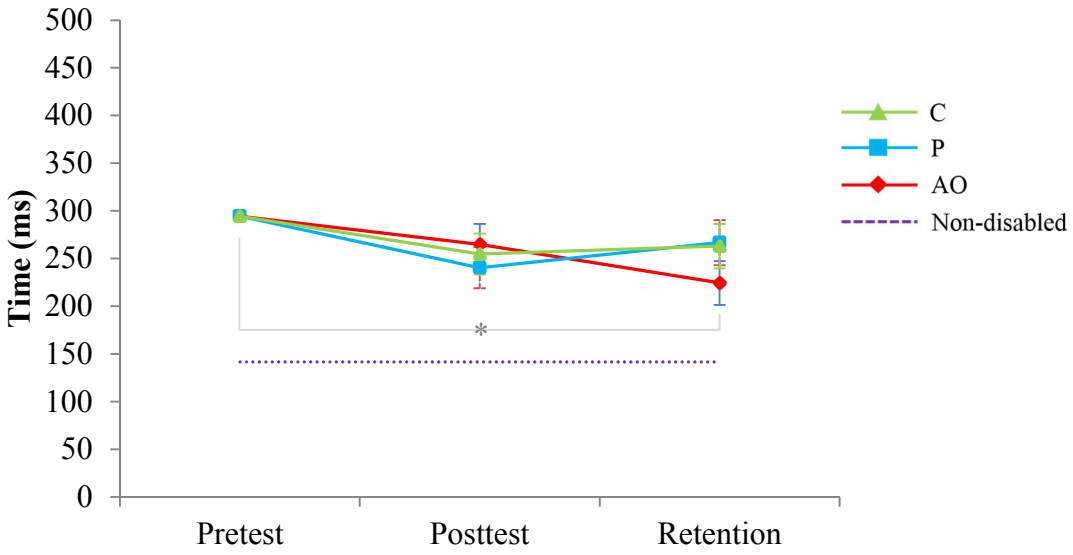

Figure 4.22 Mean absolute aperture closure time and standard error (SE) at each testing time in AO, P and C group
(* denotes significant difference between testing times or groups).

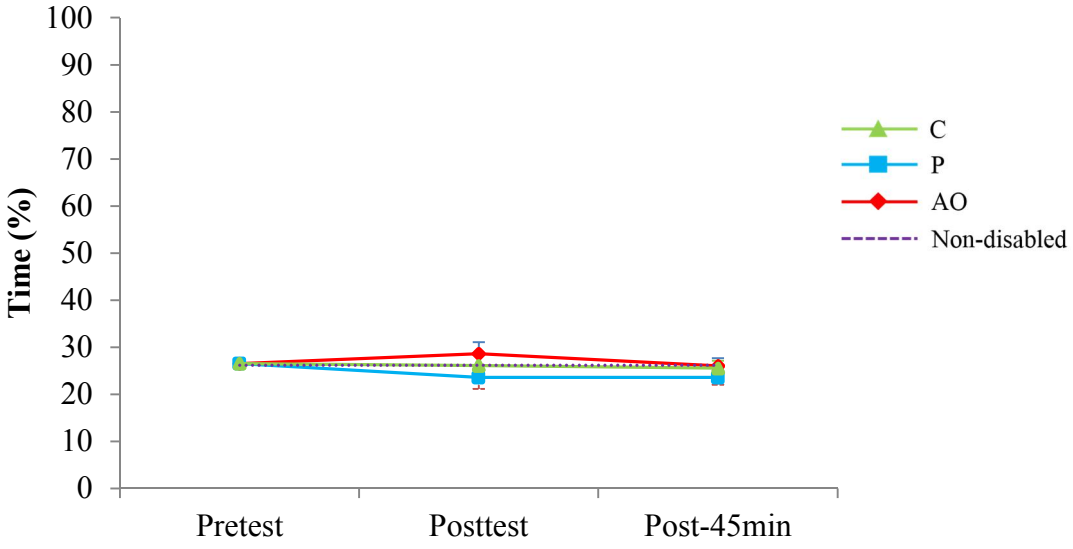

Figure 4.23 Mean relative aperture closure time and standard error (SE) at each testing time in AO, P and C group

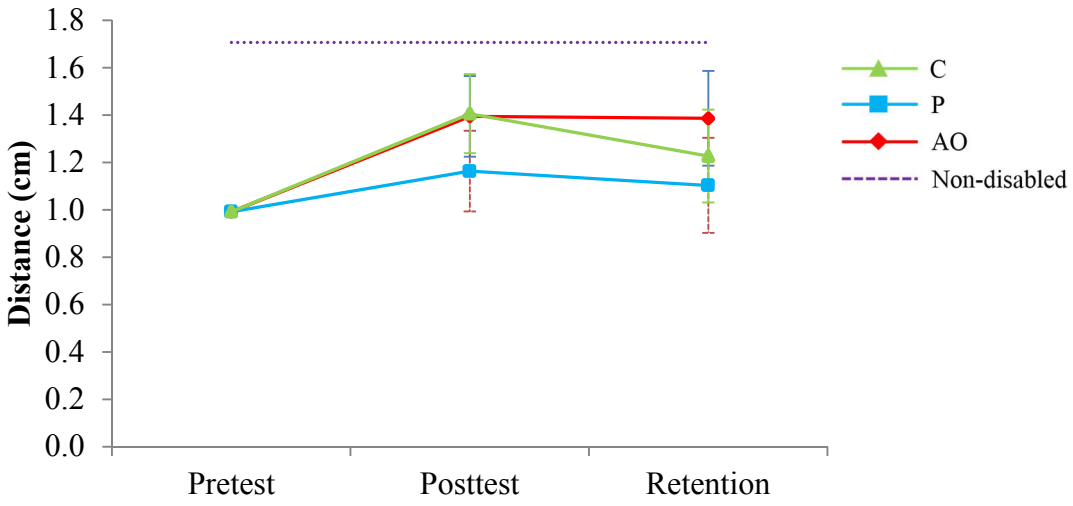

Figure 4.24 Mean aperture closure distance and standard error (SE) at each testing time in AO, P and C group

4.3.2.3 Transport-grasp coordination measures

The transport-grasp coordination was measured in 2 domains: 1) spatial domain which represented by r_{max} and 2) temporal domain which represented by T_{max}.

For r_{max}, there were significant main effect of time and time by group interaction, whereas no significant main effect of group (Table 4.4). Figure 4.24 represents no significant differences between testing times and groups when investigated by Bonferroni. Moreover, Figure 4.24 also demonstrated consistent findings as in first experiment (Table 4.3) that r_{max} was not impaired in PD (compare to purple dash lines).

In contrast to r_{max}, there were significant main effect of group and time by group interaction, whereas no significant main effect of time in T_{max} (Table 4.4). Bonferroni analyses (Figure 4.25) represent significant decreasing in T_{max} in acquisition phase only after training by AO (p-value < 0.001). And this improvement in AO group was maintained in retention test as evidenced by no significant difference between posttest and retention test (p-value = 1.000). For saving capability, the significant decreasing of T_{max} from pretest to retention test was found only in AO group (p-value < 0.001). In retention test, the T_{max} in AO group was significantly shorter than P (p-value = 0.009) and C groups (p-value = 0.027). Partial eta squared revealed a

medium effect size for Time × Group and large effect size for saving capability × group interactions (Table 4.4). However, the improvement in Tmax could not be reached the normal level (compare to purple dash line).

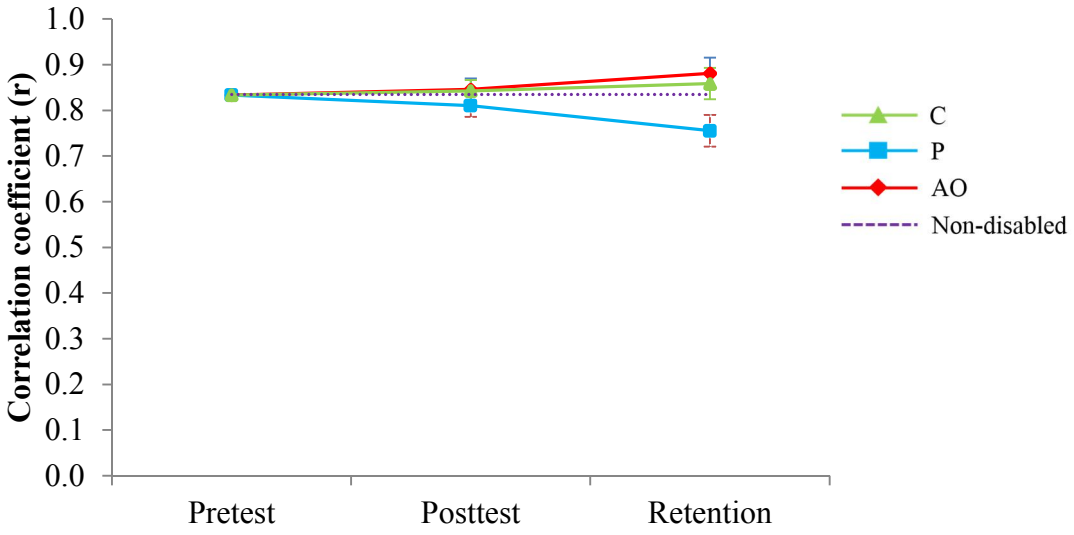

Figure 4.25 Mean maximal correlation coefficient and standard error (SE) at each testing time in AO, P and C group

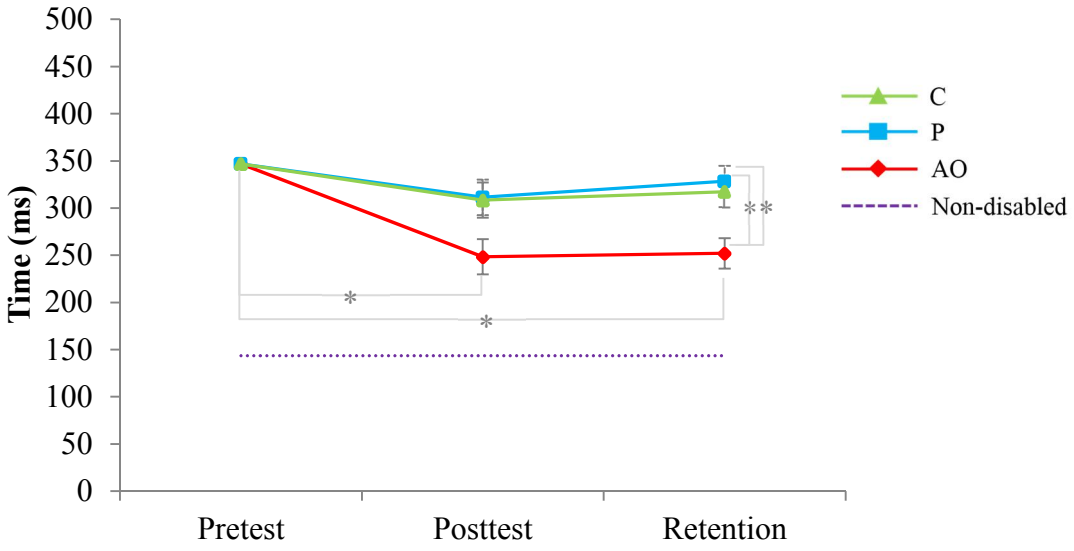

Figure 4.26 Mean associated time lag and standard error (SE) at each testing time in AO, P and C group

(* denotes significant difference between testing times or groups)

Table 4.4 The main effects of time and group, and interaction (time × group) and effect size for time by group interaction in each variable.

Reach-to-grasp variables		p-value[C]			Partial Eta Squared for	
		Time effect	Group effect	Interactive effect	time × group	Saving capability × group
WMFT	Total time	0.032*	0.008*	0.005*	0.268	0.365
	Lifting can	0.005*	0.028*	0.060	0.175	0.186
	Lifting pencil	<0.001**	0.184	0.173	0.127	0.102
	Lifting paper clip	0.005*	0.206	0.307	0.098	0.159
	Stacking checkers	0.028*	0.167	0.260	0.107	0.148
	Flipping cards	0.042*	0.373	0.590	0.056	0.088
	Turning key	0.034*	0.012*	0.012*	0.269	0.316
RT		0.162	0.068	0.080	0.175	0.208
Transport component	MT	<0.001**	0.192	0.069	0.181	0.218
	V_{max}	0.048*	0.513	0.434	0.076	0.096
	Absolute TV_{max}	<0.001**	0.240	0.336	0.092	0.129
	Relative TV_{max}	0.179	0.612	0.762	0.039	0.052
	Absolute DT	0.011*	0.172	0.049*	0.184	0.246
	Relative DT	0.341	0.612	0.762	0.039	0.052
Grasp component	A_{max}	<0.001**	0.240	0.336	0.102	0.131
	Absolute TA_{max}	<0.001**	0.090	0.076	0.176	0.108
	Relative TA_{max}	0.064	0.356	0.437	0.075	0.060
	Absolute ACT	0.634	0.880	0.253	0.108	0.082
	Relative ACT	0.139	0.372	0.453	0.072	0.057
	ACD	<0.001**	0.572	0.729	0.042	0.040
Coordination	r_{max}	0.048*	0.092	0.041*	0.191	0.243
	T_{max}	0.114	0.009*	0.010*	0.245	0.362

c = p-value from a mixed repeated-measure analysis of covariance

* Significant difference at p-value <0.05

** Significant difference at p-value <0.01

Table 4.5 The mean and standard value in each variable of trained-task at pretest, posttest and retention.

Variable	Testing Time	Group					
		C (n=9)		P (n=9)		AO (n=9)	
		mean	(SE)	mean	(SE)	mean	(SE)
Total WMFT (s)	Pretest	23.35	(2.60)	21.14	(1.56)	23.46	(2.77)
	Posttest	18.96	(2.27)	17.98	(1.14)	15.82	(1.33)
	Retention	20.51	(2.34)	18.16	(1.51)	16.74	(1.55)
Lifting can (s)	Pretest	2.16	(0.18)	2.02	(0.19)	2.08	(0.25)
	Posttest	1.56	(0.09)	1.87	(0.19)	1.51	(0.10)
	Retention	1.90	(0.15)	1.97	(0.21)	1.57	(0.13)
Lifting pencil (s)	Pretest	1.91	(0.20)	1.82	(0.18)	1.78	(0.18)
	Posttest	1.47	(0.11)	1.53	(0.13)	1.32	(0.08)
	Retention	1.62	(0.14)	1.52	(0.14)	1.40	(0.10)
Lifting paper clip (s)	Pretest	1.80	(0.14)	2.05	(0.16)	2.53	(0.42)
	Posttest	2.01	(0.43)	1.74	(0.12)	1.53	(0.09)
	Retention	1.68	(0.14)	1.72	(0.10)	1.55	(0.13)
Stack checker (s)	Pretest	4.67	(0.64)	4.15	(0.21)	4.66	(0.69)
	Posttest	3.66	(0.44)	3.88	(0.44)	3.31	(0.35)
	Retention	4.15	(0.56)	3.46	(0.31)	3.34	(0.31)
Flipping card (s)	Pretest	7.41	(0.66)	6.19	(0.58)	6.47	(0.63)
	Posttest	6.28	(0.65)	5.16	(0.50)	5.03	(0.46)
	Retention	6.86	(0.73)	5.35	(0.52)	5.30	(0.58)
Turning key (s)	Pretest	5.40	(1.27)	4.91	(0.61)	5.95	(1.03)
	Posttest	3.97	(0.86)	3.80	(0.37)	3.12	(0.38)
	Retention	4.30	(1.01)	4.14	(0.45)	3.59	(0.49)

Table 4.6 The mean and standard value in each variable of untrained-task at pretest, posttest and retention.

Variable	Testing Time	Group						Non-disabled value
		C (n=9)		P (n=9)		AO (n=9)		
		mean	(SE)	mean	(SE)	mean	(SE)	
RT (ms)	Pretest	374.97	(116.63)	270.68	(25.16)	366.93	(82.62)	146.54
	Posttest	434.28	(146.51)	328.28	(68.24)	306.57	(49.38)	
	Retention	466.92	(204.27)	292.40	(41.80)	245.99	(28.87)	
MT (ms)	Pretest	1344.27	(327.22)	951.47	(33.90)	1113.25	(167.72)	536.41
	Posttest	1089.29	(189.07)	842.68	(53.05)	901.90	(121.64)	
	Retention	1146.58	(210.35)	920.11	(75.14)	861.67	(111.49)	
V_{max} (cm/s)	Pretest	59.38	(3.53)	73.12	(5.24)	68.54	(6.26)	111.31
	Posttest	70.96	(5.79)	79.11	(5.59)	79.21	(6.38)	
	Retention	66.52	(5.38)	74.87	(5.26)	79.65	(5.39)	
Absolute TV_{max} (ms)	Pretest	573.72	(159.02)	385.54	(17.37)	424.46	(65.25)	198.78
	Posttest	494.04	(93.26)	354.78	(21.73)	363.02	(38.58)	
	Retention	489.25	(97.11)	364.46	(24.14)	347.42	(38.91)	
Relative TV_{max} (%)	Pretest	41.98	(2.56)	41.09	(2.38)	38.67	(1.86)	36.71
	Posttest	46.05	(3.85)	42.34	(1.25)	42.04	(3.00)	
	Retention	42.65	(2.00)	40.69	(2.00)	41.46	(2.70)	
Absolute DT (ms)	Pretest	770.56	(172.70)	565.93	(39.00)	688.79	(106.37)	337.63
	Posttest	595.25	(107.89)	487.90	(34.99)	538.88	(88.44)	
	Retention	657.33	(117.82)	555.65	(58.90)	514.25	(77.22)	
Relative DT (%)	Pretest	58.02	(2.56)	58.91	(2.38)	61.33	(1.86)	63.29
	Posttest	53.95	(3.85)	57.66	(1.25)	57.96	(3.00)	
	Retention	57.35	(2.00)	59.31	(2.00)	58.54	(2.70)	
A_{max} (cm)	Pretest	5.56	(0.46)	5.89	(0.61)	6.14	(0.43)	7.57
	Posttest	6.29	(0.62)	5.97	(0.80)	6.54	(0.55)	
	Retention	6.15	(0.52)	5.83	(0.56)	6.53	(0.54)	
Absolute TA_{max}	Pretest	1009.49	(258.83)	695.43	(24.77)	805.45	(134.37)	394.59
	Posttest	803.53	(138.76)	643.70	(43.12)	626.63	(86.18)	

Variable	Testing Time	Group						Non-disabled value
		C (n=9)		P (n=9)		AO (n=9)		
		mean	(SE)	mean	(SE)	mean	(SE)	
(ms)	Retention	851.16	(147.38)	696.32	(50.37)	626.52	(79.13)	
Relative	Pretest	74.52	(1.98)	73.80	(2.62)	71.96	(1.77)	73.79
TA_{max}	Posttest	74.67	(2.44)	76.76	(2.37)	70.23	(3.57)	
(%)	Retention	75.03	(1.66)	76.65	(2.50)	73.09	(1.52)	
Absolute	Pretest	334.78	(72.61)	240.82	(29.11)	307.80	(44.52)	141.83
ACT	Posttest	285.76	(57.46)	198.98	(25.93)	275.27	(46.28)	
(ms)	Retention	295.42	(66.06)	223.79	(34.16)	235.15	(34.42)	
Relative	Pretest	25.48	(1.98)	26.08	(2.59)	28.04	(1.77)	26.21
ACT	Posttest	25.33	(2.44)	23.24	(2.37)	29.77	(3.57)	
(%)	Retention	24.97	(1.66)	23.35	(2.50)	26.91	(1.52)	
	Pretest	1.00	(0.16)	0.78	(0.17)	1.20	(0.26)	1.71
ACD	Posttest	1.41	(0.21)	1.07	(0.15)	1.49	(0.19)	
(cm)	Retention	1.23	(0.21)	0.97	(0.16)	1.51	(0.29)	
	Pretest	0.82	(0.04)	0.86	(0.02)	0.82	(0.04)	0.83
r_{max}	Posttest	0.83	(0.03)	0.83	(0.03)	0.84	(0.03)	
(r)	Retention	0.85	(0.02)	0.77	(0.06)	0.87	(0.02)	
	Pretest	366.58	(51.44)	320.11	(25.35)	353.90	(60.22)	143.45
T_{max}	Posttest	324.37	(54.64)	289.69	(30.11)	254.05	(40.38)	
(ms)	Retention	331.39	(44.99)	309.36	(25.36)	257.10	(40.06)	

4.3.3 Underlying mechanisms of AO on motor learning of RTG actions.

The questionnaire composes of 8 questions regarding the advantages of training condition such as the action understanding, enhancing memory, error detection, error correction, motivation, directing attention, increasing of self-confidence, excitement of training, and willing to receive alternative treatments beyond medications.

Table 4.7 demonstrates that 56% of participants in AO group strongly agreed that AO have advantages in all domains (except excitement of training).

However, there were no significant difference in agreement levels between 3 groups except detecting and preventing the errors. However, most participants (78%) thought their training could enhance action understanding and memory. The difference between groups was nearly to reach significant level (p-value = 0.053 for action understanding and 0.065 for enhancing memory).

Considering to question regarding preventing the errors, there was significant difference between agreements from 3 groups. The participants in AO expressed that they took advantage of AO training in preventing the errors when they physically trained all tasks (89% for strongly agree and 11% for agree level).

There was significant difference between agreements from 3 groups when were asked regarding the willing to receive alternative treatments. Beside from medications, more than half of participants in AO group strongly agreed that they required the alternative treatments, then they participated in this study.

Most of participants (67%) in AO group strongly agreed that AO could help them to detect the error from training (p-value = 0.004).

In contrast to aforementioned findings, lesser number of participants (<33%) strongly agreed that their trained protocols were exciting. In C group who rested for 6 minutes alternating with physical training, forty four percent of them feeling neither agree nor disagree that the training was exciting.

Table 4.7 The number and percentage of patients who chose level of agreement in questionnaire regarding the advantage of training**.**

		Group						
		C (n=9)		P (n=9)		AO (n=9)		
		Count	%	Count	%	Count	%	p-value[d]
Understanding the strategies to improve your RTG speed and performance.	Strongly agree	4	44%	2	22%	7	78%	0.053
	Agree	5	56%	6	67%	2	22%	
	Neutral	0	0%	1	11%	0	0%	
	Disagree	0	0%	0	0%	0	0%	
	Strongly disagree	0	0%	0	0%	0	0%	
Remembering how to train more accurate.	Strongly agree	2	22%	2	22%	6	67%	0.065
	Agree	6	67%	5	56%	3	33%	
	Neutral	1	11%	1	11%	0	0%	
	Disagree	0	0%	0	0%	0	0%	
	Strongly disagree	0	0%	1	11%	0	0%	
Knowing an error or caution from practicing easier.	Strongly agree	3	33%	0	0%	6	67%	0.004*
	Agree	5	56%	5	56%	3	33%	
	Neutral	1	11%	3	33%	0	0%	
	Disagree	0	0%	0	0%	0	0%	
	Strongly disagree	0	0%	1	11%	0	0%	
Being careful or preventing errors from practicing easier.	Strongly agree	3	33%	1	11%	8	89%	0.005*
	Agree	4	44%	5	56%	1	11%	
	Neutral	1	11%	3	33%	0	0%	
	Disagree	1	11%	0	0%	0	0%	
	Strongly disagree	0	0%	0	0%	0	0%	
The training increases your motivation to want to practice more.	Strongly agree	3	33%	3	33%	7	78%	0.070
	Agree	4	44%	3	33%	2	22%	
	Neutral	2	22%	3	33%	0	0%	
	Disagree	0	0%	0	0%	0	0%	
	Strongly disagree	0	0%	0	0%	0	0%	

		Group						
		C (n=9)		P (n=9)		AO (n=9)		
		Count	%	Count	%	Count	%	p-value[d]
Concentration on training activities during training.	Strongly agree	2	22%	2	22%	6	67%	0.078
	Agree	7	78%	6	67%	3	33%	
	Neutral	0	0%	0	0%	0	0%	
	Disagree	0	0%	0	0%	0	0%	
	Strongly disagree	0	0%	1	11%	0	0%	
Increasing your confidence in the use of hands and arms on a daily living.	Strongly agree	3	33%	3	33%	7	78%	0.085
	Agree	5	56%	4	44%	2	22%	
	Neutral	0	0%	2	22%	0	0%	
	Disagree	1	11%	0	0%	0	0%	
	Strongly disagree	0	0%	0	0%	0	0%	
This training is exciting.	Strongly agree	2	22%	0	0%	3	33%	0.077
	Agree	3	33%	6	67%	6	67%	
	Neutral	4	44%	2	22%	0	0%	
	Disagree	0	0%	1	11%	0	0%	
	Strongly disagree	0	0%	0	0%	0	0%	

d = p-value from a Kruskal Wallis Test

* Significant difference at *p*-value <0.05