INTRODUCTION
Reaching to grasp is a frequently performed activity of daily living. To perform the task, control of hands and coordination of visual and environmental messages are used in concert to perceive and interact with specified objects and events. Quantification of reaching patterns is clinically important for rehabilitation practice and research of patients with stroke [1]. Reaching performance could vary over different visual and space obstructions in the workspace. Thus, the objective of the present study was to determine the association between obstacle positions (height and distance) and reaching quality in patients post-stroke.

METHODS
Ten highly functioning patients following hemiplegic stroke (Brunnstrom Stage VI) participated with informed written consent as approved by the IRB. They were seated and asked to use both hands separately to reach, cross obstacles of different heights and distances, and then grasp an object placed on the desk. The distance from each subject’s trunk to the obstacle were 0%, 50%, 65%, and 80% of the length of the upper extremity and the height of obstacle was 0%, 10%, 20% and 30% of the length of the upper arm.

Upper limb movement was measured using a motion capture system (Vicon, Oxford Metrics, U.K.). The reaction time (RT) was determined as the interval between the moving cue and the hand starting to move while the movement time (MT) was defined as the interval between the hand starting to move and the hand touching the object. Aperture excursion (AE, differences between the maximum aperture angle and the angle at grasping), peak speed of the wrist (PSW), time to peak speed of the wrist (TPSW) and the number of acceleration peaks (NA) were also calculated. The mid-clearance (Mid-C) was the vertical distances between the middle finger marker and the obstacle when the middle finger was directly above the obstacle. Angular motions of the elbow and wrist were calculated and their values when the middle finger was above the obstacle were extracted, namely the crossing angles of the elbow (ECA) and wrist (WCA).

The 9 variables of the reaching tasks were separated into two factors by a factor analysis. A 2 by 4 by 4, 3-way analysis of variance with between-hand (side), between obstacle-height, and between obstacle-distance conditions was performed (α=0.05).

RESULTS AND DISCUSSION
The 9 variables were separated into two factors (Table 1). Factor-1 corresponded to most temporal variables, being positively correlated with RT, MT, TPSW and NA. On the other hand, Factor-2 corresponded to most spatial variables, being positively correlated with AE, mid-C, ECA and WCA. No significant differences between sides were found for both Factor-1 and Factor-2 (p=0.16 & p=0.87), suggesting a symmetrical strategy between affected and unaffected sides in the highly functioning patients post-stroke.

There were significant differences between obstacle-height conditions in both factor-1 and factor-2 (p=0.04, p=0.002), indicating that both Factor-1 and Factor-2 were affected by obstacle height. However, significant differences between obstacle-distance conditions were found in Factor-2 but not in Factor-1 (p<0.0001, p=0.57). This indicates that only Factor-2 was affected by obstacle distance.

CONCLUSIONS
The highly functioning patients following hemiplegic stroke showed a symmetrical strategy between affected and unaffected hands. Temporal variables were affected by obstacle height but not obstacle distance whereas spatial variables were affected by both obstacle height and distance. The analysis of reaching-to-grasp movement different visual and space obstructions in the workspace appeared to be useful for a better understanding of the control of the upper extremities in performing movements. The reaching-to-grasp movement with obstacles of different heights and distance may be a potential training and evaluation tool for patients with neurological pathologies.

REFERENCES

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*RT: reaction time; MT: movement time; TPSW: time to peak speed of the wrist; PSW: peak speed of the wrist; NA: number of acceleration peaks; Mid-C: mid-clearance; ECA: crossing angle of elbow; WCA: crossing angle of wrist