

# 3D motion analyse used in prehension study

## Interactions with obstacle properties.

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**Abstract**—The aim of the present work is to propose an experimental method to analyse the effect of obstacle properties on human prehension. We investigated the impact of intrinsic and extrinsic properties of the obstacle on transport and grasp components in the same protocol. For that, different tools are combined to record the movement and obtain a redundancy of information about the upper limb in complex prehension movement and allow natural gesture. Vicon 3D motion analysis system and a Cyberglove with a Flock of Birds sensor on the wrist are used to capture arm movements. Results show significant effects of unstructured environment on kinematic parameters during reaching and grasping and specify the influence of obstacle characteristics on movement.

**Keywords-component:** human prehension; Vicon; Cyberglove; obstacle avoidance.

### I. INTRODUCTION

Many studies have examined human prehension and have precised movement parameters. Reach-to-grasp action is described as having two components: transport and grasp [1] [2]. The transport component refers to bringing the hand to the target object, while the grasp component refers to the opening and closing of the fingers and thumb around the object that leads to grasping the object. It has been suggested that the intrinsic properties of the object (i.e., size, shape, and texture) affect the pattern of grasp formation, while the extrinsic properties of the task (i.e., distance, location, and orientation) affect the kinematics of the transport component. Several perturbation studies have since shown that when the location of an object is unexpectedly changed during the initial part of the reach, both the transport and aperture kinematic patterns are affected by a perturbation [3] or that the properties of the object to be grasped affect both transport and grasp components [4].

Recent studies have investigated obstacle effect on reaching and grasping components. The presence of an obstacle increased the control demands of the task because it was represented a perceptive and physical obstruction that the Central Nervous System (CNS) had to consider to avoid the collision [5]. Total transport distance in the obstacle conditions was significantly longer than unobstructed reaches. This additional distance produced an increase in movement time [6] and caused a velocity decrease [7] [8] [9]. The kinematic parameters characterizing the transport component were prolonged due to obstacle avoidance. It was established that

movement time proportionally increased with task difficulty [9] [10]. The grasp component was affected by modifications in reaching phase with obstacle presence and reciprocally [11]. Maximal grip aperture appears decreased to reduce collide possibilities between digits and obstacle [7] [8].

These results appear comparable with difficulty because protocols were not equivalent. Obstacles characteristics and objects properties were variable and could influenced responses. Grasp postures were generally imposed in specific object surfaces and ordinary behaviour was not observed (Tabl.1).

The aim of this study was to investigate the impact of intrinsic and extrinsic properties of the obstacle on transport and grasp components in an exclusive protocol. To manipulate obstruction, we proposed an experimental setup with two different obstacle sizes and positions. Contrary with previous observations, we permitted subjects to perform a natural reach and grasp without constraint movement.

TABLE I. PRINCIPAL PREHENSION STUDIES

| Studies                    | Apparatus             | Restrictions   | Principal results   |
|----------------------------|-----------------------|--|---|
| Saling et al. (1998)       | Optotrak, 4 diodes.   | Thumb and index fingers, no top grasping & same type of grasp. | Increase in MT <sup>a</sup> & Vmax <sup>b</sup> . Decrease in Gmax <sup>c</sup> .   |
| Tresilian (1998)           | Optotrak, 7 diodes.   | Grasp on yellow surfaces.                                      | Increase in MT <sup>a</sup> . Decrease in Vmax <sup>b</sup> & Gmax <sup>c</sup> .   |
| Castiello et al. (1999)    | ELITE, 6 markers.     | No speed or type of grasp imposed.                             | Increase in MT <sup>a</sup> & Vmax <sup>b</sup> .                                   |
| Mon Williams et al. (2001) | Optotrak, 4 diodes.   | Grasp on yellow surfaces.                                      | Increase in MT <sup>a</sup> . Decrease in Vmax <sup>b</sup> & Gmax <sup>c</sup> .   |
| Albert et al. (2002)       | Optotrak, 5 diodes.   | No top grasping & same type of grasp for all trials.           | Increase in MT <sup>a</sup> and Vmax <sup>b</sup> . Decrease in Gmax <sup>c</sup> . |
| Biegstraaten et al. (2003) | Optotrak, 2x2 diodes. | Grasp at the marked positions                                  | Increase in MT <sup>a</sup> .   |

a. Movement time, b. Maximal velocity, c. Maximal grip aperture.

## II. EXPERIMENTAL METHOD

### A. Participants

Twenty adult volunteers (12 women and 8 men; mean age: 23.8 +/- 4.11 years) participated in the experiment. All showed right-handed dominance and they were free from known neurological abnormalities.

### B. Apparatus

Subjects were seated in a chair facing a semicircular table and equipped by a data glove Cyberglove (Virtual Technologies, Palo Alto, CA) on the right hand. It was composed by 22 piezoelectronic sensors who measured angular displacements in continuous for each hand articulation. Wrist displacements were considered with an electromagnetic sensor (The Flock of Birds, Ascension Technology Corp., Burlington, Vermont, USA). Movements were recorded using a Vicon 3D motion analysis system (Oxford Metrics Inc.). Six infrared cameras were positioned around the workspace. Nineteen reflective markers were attached to the head, the chest, the right upper limb (Fig.1) and the right hand (Fig.2). The sampling rate for the Cyberglove was 60 Hz and for the Vicon, it was 120 Hz. The recording period was 6 s. The object to be grasped was a polystyrene sphere (diameter 3.5; 5.5 and 7.5 cm) located 50 cm in medial (P2), or lateral (P1 and P3) axis to the starting point (P0). Two obstacles (OB1: 15x15x4.5 and OB2: 20x20x6 cm) were successively used to manipulate the hand path of the reach and/or the grasp. These obstacles were placed at 20 or 40 cm (O1 and O2) from the starting position of the hand. Each subject performed 2 blocks of 15 trials (3 objects x 2 obstacles x 2 positions + 3 controls) in a randomised order to remove order effect. Control conditions consisted in prehension movement without obstacle for each size object.

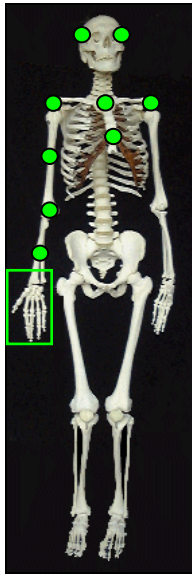


Figure 1. Marker positions.

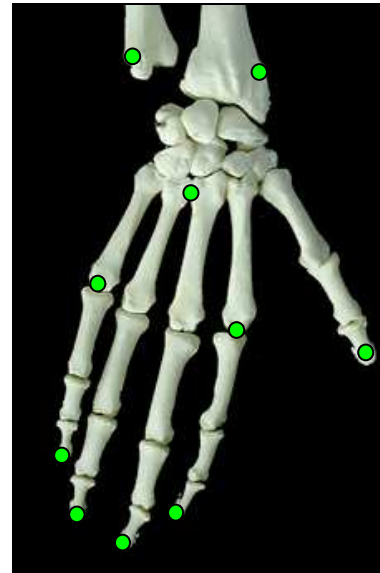


Figure 2. Marker positions on the right hand.

### C. Procedure

Participants were instructed to reach for, grasp, and lift the spherical object after start signal "Go" and to place it at the marked position (P0) on the table without touching eventual obstacle. The reaching movement had to be the more natural as possible and no restrictions were indicated for grasping object. There were three obstacle conditions: *control* (no obstacle), *OB1* obstacle (h=15 cm), and *OB2* obstacle (h=20 cm) and two obstacle positions *O1* (d=20 cm) and *O2* (40cm). For the near-obstacle condition, the obstacle was placed 20 cm directly in front of the hand starting position. In the far obstacle condition, the obstacle was placed 40 cm directly in front of the hand starting position. When the obstacle was present, participants were required to reach over or around the obstacle and grasp the target. The three-dimensional position of each marker was displayed on the monitor. Trial blocks were randomised for each participant.

### D. Data analyse

The transport component was based on the position of the marker on the wrist and compared with the Flock of Bird data. The transport was analysed by numerical derivatives of the *x*-, *y*-, and *z*-coordinates of wrist markers. The grasp aperture was defined as the distance between the thumb and index finger markers. Movement time (MT) was determined by calculating the time difference between transport onset and object grasp. Amplitude kinematic variables were used to assess the effects of obstacle location on the transport and grasp components. Single means for each participant for each condition were calculated and entered into a repeated-measures analysis of variance (ANOVA) in Statistica program. The alpha level was set at  $p < 0.05$ . Two planned orthogonal contrasts were used to determine which conditions were different from one another. A case I contrast was used to determine the effects of an obstacle condition (OB1 versus OB2 or O1 versus O2), while a case II contrast was used to determine the effects the presence of an obstacle [control condition versus (OB1 + OB2) or (O1 + O2)].

### III. RESULTS

#### A. Movement time (MT)

ANOVA analyses reveal an effect to object size on MT ( $F=6.18$ ;  $p=0.002$ ). MT appears significantly longer for B2 & B3 than B1 (2.75 s. +/- 0.63 vs 2.53 s. +/- 0.65;  $p<0.01$ ). MT increases for obstacle compared to control conditions (2.82 s. +/- 0.4 vs 2.62 s. +/- 0.6;  $p<0.01$ ). We found an effect to obstacle size on MT ( $F=11.57$ ;  $p<0.01$ ) and an effect to the obstacle position on MT ( $F=10.13$ ;  $p<0.01$ ). MT increases proportionally with size and distance obstacle augmentation.

#### B. Transport component

1) *Maximal vertical height (Hmax)*: Hmax significantly increase between obstacle and control conditions (19.54 cm +/- 9.26 vs 10.19 cm +/- 3.31;  $p<0.01$ ) but we found no differences between each object sizes. It's observed an obstacle size effect ( $F=29.48$ ;  $p<0.01$ ) and an obstacle position effect ( $F=29.56$ ;  $p<0.01$ ) on Hmax. Hmax appears significantly superior for OB1 & OB2 conditions than control conditions and for O1 & O2 than control conditions.

2) *Peak velocity (Vmax)*: Vmax significantly increase between obstacle and control conditions (202.69 cm/s +/- 51.43 vs 157.44 cm/s +/- 33.53;  $p<0.01$ ). We observe no size object effect on Vmax. It's reveal an obstacle size effect ( $F=22.38$ ;  $p<0.01$ ) and an obstacle position effect ( $F=21.44$ ;  $p<0.01$ ) on Vmax. Vmax significantly increase for OB1 & OB2 conditions than control conditions and for O1 & O2 conditions than control conditions (Fig.3).

#### C. Grasping component

Statistical analyses show a significant effect to object size ( $F=22.56$ ;  $p<0.001$ ) on maximal grip aperture (Gmax). Maximal grip aperture are significantly superior to B2 and B3 versus B1 conditions (115.81 +/- 14.33 vs 102.96 +/- 20.22). In contrast, there appears no effect to size or position obstacle on Gmax.

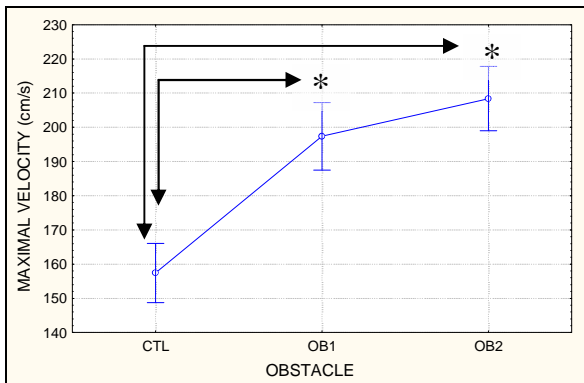


Figure 3. Maximal velocity variations (cm/s) compared to control condition, OB1 obstacle (h=15 cm) and OB2 obstacle (h=20cm). \* $p<0.01$ .

### IV. DISCUSSION

The objective of this study was to specify obstacle properties on reach and grasp characteristics with different size and position conditions. In this experiment, transport path was altered by requiring participants to reach over an obstacle prior to grasping an object. The placement of different obstacle sizes, either early or late in the reach path allowed us to determine the effects of altering wrist path at different points of the reaching action.

Kinematic parameters of reaching appear affected by obstacle presence but varied in different conditions. In accordance with previously published data, a reliable effect of obstacle presence was found on movement parameters. Our results confirm the prediction concerning obstacle effects and specify movement adaptations with obstacle properties.

Movement time (MT) was particularly dependent to workspace environment. We observed a significant obstacle presence effect on MT. We found a proportionally increasing in MT with size and position obstacle conditions, likely others studies [9] [10]. MT appears significantly longer between OB1 and OB2 sizes and between O1 and O2 positions. Maximal vertical height (Hmax) and peak velocity (Vmax) appear affected by obstacle presence. We observe a significant increase in Hmax and Vmax between control and obstacle conditions. However, these parameters are not influenced by two different size or position obstacle conditions. Hmax and Vmax are attached to control or obstacle conditions while they are not modified by intrinsic or extrinsic obstacle variations.

Contrary, we observe no obstacle effect on maximal grip aperture (Gmax). Indeed, Gmax appears only dependent with object size. Gmax significantly increase to B2 and B3 conditions compared to B1. These observations are opposed to literature [7] [8]. Authors found a Gmax decrease with obstacle presence to reduce collide possibilities between digits and obstacle. These opposed results could be explained by the different obstacle positions. The obstacle influence was changed if the obstacle positions are around the object to be grasp [7] [8] [9] [10] or like in this case, in the wrist path [6] [11]. These critical remarks show the importance to intrinsic and extrinsic obstacle characteristics on movement adaptations.

### CONCLUSION

The goal of this study was to learn obstacle impacts on prehension. Results from this study suggest that altering transport path produces no systematic changes in the formation of the grasp component. Grasp appear more dependant to obstacle than object properties. Although transport and grasp are linked, the CNS seems to use spatial information regarding obstacle characteristics as a method to specify the transport adaptations to produce successful prehensile actions without collide obstacle whereas the grasp adjustments depend to object properties.

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