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Hand orientation for grasping depends on the direction of the reaching movement.

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Abstract

The 3D orientation of the hand for grasping was studied while subjects reached for objects placed at several locations on a horizontal bored, with movements starting from three initial hand positions. The hand movements were recorded with electromagnetic sensors giving 3D position and orientation information. The study focused on the azimuth, which is the projection of the hand orientation in a horizontal plain. The hand azimuth for grasping was linearly correlated with the direction of the reaching movement and not with the object direction in head- or shoulder-cantered coordinates. This relationship was valid regardless of the initial hand position. A control experiment with constant movement direction showed a weaker, probably postural, effect of object direction in shoulder- centred coordinates. The suggestion is that hand orientation for grasping is mainly controlled in relation to the reaching movement direction.

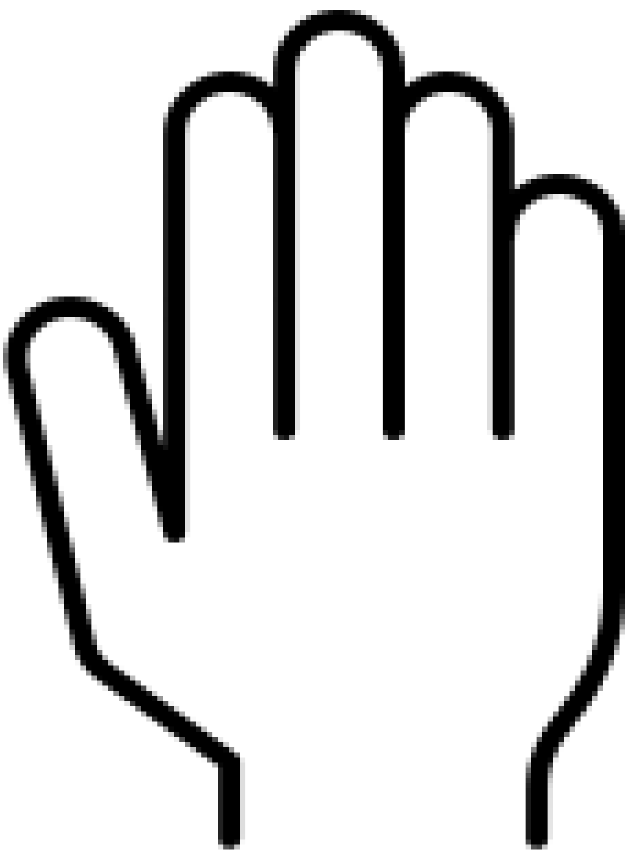

Table of Contents

1. Introduction

The orientation adopted by a grasping hand is known to depend on the shape and orientation of the object [1]. In addition, two recent studies have demonstrated that the orientation of the grip opposition axis also depends on the location of the object, independently of its shape and orientation [2,3]. However, the interpretation of this observation remains unclear despite its importance for understanding the coordination between reaching and grasping. Gazo et al. have proposed that the orientation of the grip opposition axis is related to the direction of the object with reference to the head [4]. However, several studies of pointing and grasping movements have shown that the final configuration of the upper limb is affected by its initial posture.

The present study was performed to assess the relationships between the hand orientation for grasping and the spatial parameters of reaching movements: in particular the initial hand position and the location of the target object. To this end the concentration was on the horizontal projection of natural 3D movements and analysis focused on the hand orientation in the horizontal plane (hand azimuth) during grasping an axially symmetrical vertical object. Variations in the azimuth of the hand fro grasping which is not constrained by the shape of the object were then studied as a function of the initial position of the hand and of the object in a relatively wide but central workspace. The present work extends and generalizes previous findings by demonstrating that changes in hand orientation are predominantly linked to the direction of the movement from the initial to the final hand positions.

2. Materials and Methods

Six right-handed healthy subjects, three men and three women, aged 26ñ47yr (mean 35.5yr) volunteered for this study, which was approved by a regional ethics committee.

2.1 Movement Recording

The 3D motion analysis was performed with Fastrack Polhemus sensors. This system uses an electromagnetic field generated by a transmitter to determine the position and orientation (Euler angles) of two remote sensors (sampling rate 30Hz). The static accuracy of these sensors is 0.08cm RMS for the marker positions and 0.15RMS for the marker orientations. Calibration measurements showed that the system was accurate within 0.7m of the transmitter (40 %). The sensors were attached distally to the dorsum of the hand (middle part of the third metacarpal bone) and proximally at shoulder level on the ipsilateral acromion. This study concentrates on the azimuth of the hand, which is the projection of its longitudinal axis in the horizontal plane (angle about the vertical Z reference axis).

2.2 Task and Experimental Set-up

The task was to grasp a cardboard cone (10g weight, 5cm diameter and 17cm tall, giving an area of 111.3cm2) using the most natural hand configuration. The subject sat in front of a horizontal wooden board with three initial hand positions (P1ñP3) and seven object locations. The origin of the reference frame was fixed in the middle of the board back edge. The board was placed about 15cm from the subject’s abdomen so what his/her right shoulder was located 30cm behind the reference frame (Y=-30cm).

The subject was instructed to look forward so that the head was situated in the midline of the board (at X=0). The right hand was placed comfortably in one of the three initial positions,

palm down, its longitudinal axis along the Y reference direction. The seven object locations were comprised within a 20X20cm work space (400cm2) in front of the subject. This is between Y=12cm and Y=36 cm (200 %) from the reference frame. Subjects were told to reach and grasp the cone when asked to do so, and to place it on the board in front of the abdomen at a constant final location (situated at X=0, Y=0).
Movement distances and directions for each trial were calculated for the initial hand and object positions. In a control experiment, the subjects had to reach and grasp object placed in the same seven locations from seven different initial hand positions. These positions were chosen so that the direction of the movements was constant (160o) and in the midrange of the movements (a1) calculated from the first experiment. The movement distance was 15cm.

3. Results

The amplitude of the velocity peak during reaching was used to characterize hand kinematics. The peak velocity of the hand varied with the object location (F(6,105)=18.6, P=0.0001) and the initial hand position (ANOVA: F(2,105)=7.3, P=0.001); it was 0.60+/-0.03ms-1 (mean+/-sem) for P1; 0.64+/-0.02ms-1 for P2 and 0.69+/-0.03ms-1 for P3. An analysis of covariance showed that these differences were due to a linear relationship between object distance and the hand peak velocity (ANCOVA: F(1,120)=240.4, P=0.0001) regardless of the initial hand position (F(2,120)=0.83, P=0.44). The peak velocity of the hand did not vary significantly (3 %) with either the direction of the reaching movement or the object direction head- or shoulder-centred coordinates.
The present experimental set-up did not include a direct measure of finger posture or aperture during grasping. The assessment of finger configuration can be approached in two ways: the distance between the hand and the object (grasp length); and the angle between the hand axis and the direction of the object (grasp angle g). ANOVA showed that neither grasp length (9.4cm+/-0.1, mean+/-S.E.M.) nor grasp angle (30.78+/-0.8) depended on object location or initial hand position (F(6,105)51.5 ns; F(2,105)=1.1ns and F(6,105)=1.7ns; F(2,105)=2ns respectively).

4. Discussion

Our study explores variation in hand posture for grasping as a function of the initial relative positions of hand and object. We have concentrated on variations of hand orientation in the horizontal plane (azimuth) which is not constrained when grasping a vertical, axially symmetrical object. Therefore, our experimental design gets round the influence of object shape and utilization on the hand orientation for grasping.
One question we have to answer is whether the hand azimuth for grasping is primarily controlled by the central nervous system, or whether the regularities we observed result from the control of several selected degrees of freedom. In particular, it has been proposed that reaching is controlled in a shoulder-centred frame of reference as a function of the upper arm azimuth, elevation and elbow extension [2]. Our results and particularly the relationship between hand azimuth for grasping and movement direction cannot be easily explained by a selective control of arm azimuth and elbow extension. This should be further confirmed by a computation of the upper-limb inter-joint angles, particularly shoulder horizontal abduction and elbow extension [1]. By opposition, the effect of the workspace

area observed in the control experiment when movement direction is constant, could well depend on some intrinsic shoulder angle.

5. Conclusions

The results show that the hand orientation (azimuth) is primarily determined by the movement direction (vector joining the initial hand position to the target). This rule may be responsible for the correlation between the hand orientation, target location and initial hand position observed in this and in other studies. This implies that hand orientation during reaching to grasp an object is produced in an external rather than in a body-centred (i.e. head- or shoulder-centred) frame of reference. Our observations are consistent with the hypothesis that goal directed movement involves the transition between an initial and a reference equilibrium upper limb configuration [3].

We suggest that the hand azimuth for grasping is a combination of two factors. The first and predominant one depends on movement direction. The other one, related to the target direction with reference to the shoulder, is more likely related to the choice of a comfortable posture rather than to movement control per se since it was also observed on the initial hand azimuth before movement. Exploration of a wider workspace would be necessary to examine the combined effect of the posture of the limb and movement direction. Indeed, when the object has to be grasped near the border of the limb workspace, more orientation. We expect that when grasping objects near the border of the workspace or when starting from extreme the influence of object direction with respect to the shoulder will be greater (and conversely that of movement direction smaller) than for grasping objects located, as in the present study, in the central part of the workspace.

6. References

NUM.	REFERENCE
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