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# Proprioceptive Sense in the Shoulder Joint of Blind and Blindfolded Sighted Subjects

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Abstract

Proprioceptive sense at the shoulder joint was measured through an arm movement reproduction task. A given joint angle at the shoulder was achieved passively by the subject and the subject was then asked to reproduce the joint angle with the same arm. The joint angles were measured by means of a motion analyzer system (NAC, Model HSV-400). The tasks were conducted in three different conditions for the left and right arms. These conditions were distinguished based on the direction of the arm movement and head position. Six blind (age 23-28, mean 24.6 years) and six blindfolded sighted (age 23-25, mean 23.8 years) persons were selected as subjects. Both blind and blindfolded sighted subjects were able to discriminate any joint angles at the joint shoulder reliably. Based on absolute error, the reproduction accuracy of blind subjects was not significantly different from blindfolded sighted subjects. Absolute error at the target position of 50 deg. was significantly greater than absolute error at the target position of 90 and 120 deg. Furthermore, the reproduction accuracy of the left and right arms were not significantly different. The direction of arm movement and head position had no influence on the accuracy of arm movement reproduction.

**Key words :** blind subject, proprioception, the shoulder joint

## Introduction

Movement is a fundamental dimension of human behavior. Activities in daily life such as walking, running, dancing, and playing are examples of body and limb movements in which motor control is required (Magill, 1980[6]). In order to move effectively, men must be able to monitor their own movements by knowing the relative position of the different parts of the body. These functions are performed by complex sensory receptors called proprioceptors that are located in muscles, tendons, joints, skin, and the labyrinth of the inner ear (Rosenbaum, 1991[8]; Shea, 1993[9]). Perception of position and movements are called proprioception or kinesthesis. For blind people, proprioceptive information plays an essential role in controlling their movements such as body balance, postural attitude, and independent walking (Kratz, 1973[5]).

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Some investigations on proprioceptive sense of sighted subjects have been conducted using a variety of approaches. One approach has been conducted in which a subject points to a given spot in space and was then asked to reproduce that spot in the absence of vision (Cohen, 1958a[2] and Cohen, 1958b[3]). Another approach has been to use a matching paradigm: a given joint angle in the reference limb is achieved and the subject was then asked to match that joint angle with the other limb (e.g. Rodier et. al., 1991[7]; Euzet and Gahery, 1995[4]).

The purpose of the present study was to examine the effect of blindness on proprioceptive ability. Specifically, this study aimed to provide answers to the following questions:

1. Are the blind and blindfolded sighted subjects able to discriminate any joint angles at the shoulder reliably?
2. Are there any differences in the accuracy of arm movement reproduction among the three target positions (50, 90, and 120 deg.)?
3. Is there a difference in the accuracy of arm movement reproduction between the left and right arms of the subjects?
4. Is the accuracy of arm movement reproduction influenced by the direction of arm movements and head position?
5. Is there a difference in the accuracy of arm movement reproduction between the blind and blindfolded sighted subjects?

## Method

### *Subjects*

Six blind and six blindfolded sighted persons participated in this experiment as subjects. The blind subjects ranged in age from 23 to 28 years (mean 24.6 years). The blindfolded sighted subjects ranged in age from 23 to 25 years (mean 23.8 years). All subjects were male and right-handed. The characteristics of the subjects are shown in Table 1. The duration of visual loss indicated in Table 1 shows the time following loss until the time they were measured in connection with the present study.

### *Apparatus and Procedure*

A motion analyzer system (NAC, Model HSV-400) was used to record the subject's arm movements. Three spotlight tape markers were placed on the shoulder joint (Acromion), wrist (Carpus), and waist (Greater trochanter) to help identify the arm movements. The movement of the markers were videotaped and the joint angles were analyzed with a computer. The videotape was displayed on the motion analyzer and could be viewed frame by frame. The Graf-Pen was used in conjunction with the motion analyzer to determine the x and y coordinates of the positions of the markers on the viewing screen and to calculate the joint angles.

The subject stood in front of the video camera in a comfortable position allowing free movement of arm around the shoulder joint. The experimenter guided the subject's arm to one of the target positions. After five seconds, the subject was instructed to return his arm to the starting position, relaxed hanging by his side. The subject then was required to reproduce the target with the same arm as accurately as possible. Three joint angles of 50 deg., 90 deg., and 120 deg. were arbitrarily chosen as targets. A 5-second time interval took place between the end of a trial and the beginning of the next trial. The subject was not informed of the results after each trial. Brief practice was given to

Table 1 Characteristics of the subjects

| Subjects | Sex | Age (years) | Preferred Hand | Visual Acuity R | Visual Acuity L | Onset of Blindness (years) | Buration of visual loss (years) |
|---|---|---|---|---|---|---|---|
| Blind | | | | | | | |
| Ma | M | 23 | Right | 0 | 0 | birth | 23 |
| Og | M | 24 | Right | 0 | 0 | 5 | 19 |
| Im | M | 28 | Right | LP | LP | 6 | 22 |
| Ta | M | 24 | Right | LP | LP | birth | 24 |
| Fu | M | 26 | Right | 0 | 0 | birth | 26 |
| Fn | M | 23 | Right | LP | 0 | 5 | 18 |
| Blindfolded sighted | | | | | | | |
| Ab | M | 23 | Right | | | | |
| Na | M | 23 | Right | | | | |
| Ro | M | 23 | Right | | | | |
| Na | M | 24 | Right | | | | |
| Nu | M | 25 | Right | | | | |

each subject before performing the experimental tasks to ensure that the subject understood the instructions.

The subject was asked to perform the tasks in the three different conditions (C1, C2, C3). In C1, the subject was required to perform shoulder flexion in the vertical direction with the arm extended to the side of the body and the head rotated around 90 deg. to the side of the required arm. In C2, the subject performed shoulder flexion in the longitudinal direction parallel to the sagittal plane of the body with the head in normal position. In C3, the subject performed shoulder flexion as in C1 without rotating the head (Fig. 1). Each target appeared at each condition. Therefore, there were nine target/condition configurations. Each configuration was replicated three times and presented to each subject in a completely random order.

The head position was the main difference between C1 and C3 and the main difference between C2 and C3 was the direction of arm's movement. Therefore, comparison between C1 and C3 was conducted in an attempt to examine the effect of the head position on the proprioceptive sense. In addition, comparison between C2 and C3 was carried out to evaluate the effect of the direction of arm movement on the proprioceptive sense.

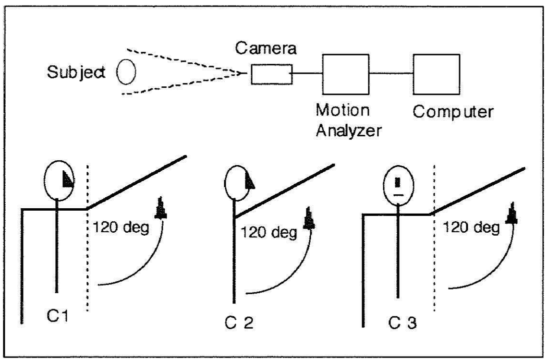


Fig. 1 Experiment set up and illustration of the shoulder joint angle (120 deg) in condition 1 (C1) ; condition 2 (C2) ; and condition 3 (C3)

## Results

*Blind group*

Figure 2 (A, B, C) show the mean reproduced position for each target position in blind subjects under the three conditions (C1, C2, C3). The repeated ANOVA with arm and target position variables were conducted addressing the data obtained from the set of trials in the three conditions. For C1, the ANOVA revealed a significant main effect of the target position ($F(2, 15)=1042.11$, $p< .0001$). The main effect of arm and interaction effect of target position X arm were not significant. For C2, the ANOVA showed a significant main effect of target position ($F(2, 15)=799.62$, $p< .0001$). The main effect of arm and interaction effect of the two variables were not significant. Similarly, for C3, ANOVA showed significant main effect of target position ($F(2, 15)=465.48$, $p< .0001$). Neither the main effect of arm nor its interaction effect with target position was significant. In the three conditions, main effect of target position was significant but not for arm. It suggests that blind subjects were able to discriminate the target positions reliably and the ability did not differ between the left and right arms.

Absolute error was calculated and used as a general indication of accuracy. Figure 3 shows mean absolute errors across target positions and arms under the three conditions in blind subjects. A repeated ANOVA showed that mean absolute errors of the three conditions were significantly different ($F(2.70)=3.98$, $p< .05$). However, post hoc analysis using Scheffe F-test showed that the errors of C1 and C2 were significant ($p> .05$). However, the errors of C1 and C2 were not significantly different than that of C3 ($p> .05$).

Figure 4 shows mean absolute errors across conditions and arms for each of the three target positions in blind subjects. A repeated ANOVA revealed a significant dif-

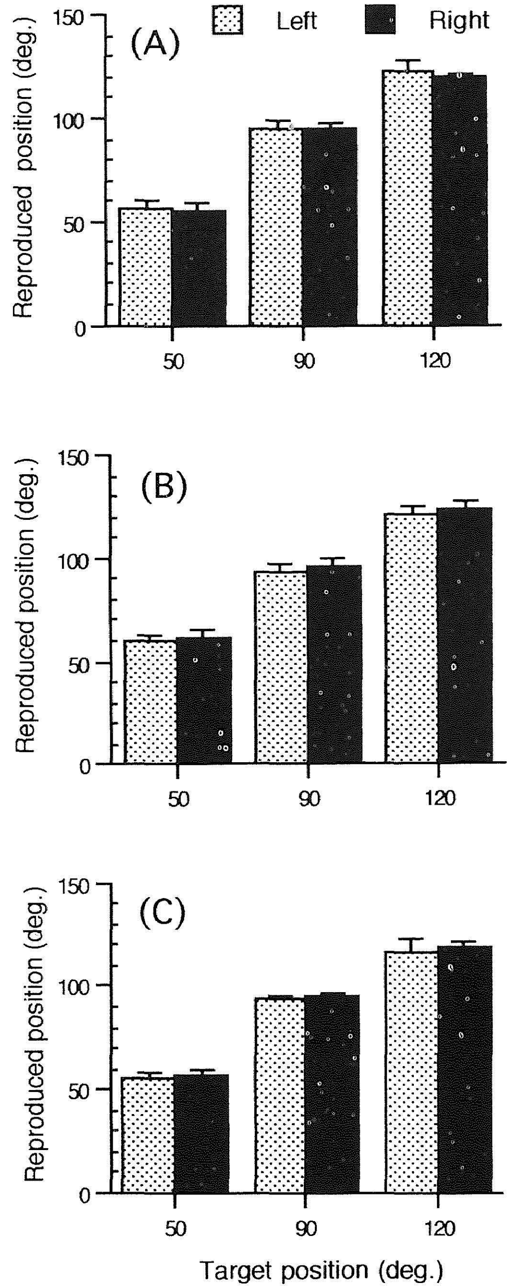


Fig. 2 Mean reproduced position as a function of target position in blind subjects (A) Condition 1 ; (B) Condition 2 ; and (C) Condition 3

ferent between the means ($F(2, 70)=9.54$, $p<.05$). Post hoc analysis using Scheffe F-test showed that absolute error of the target position of 50 deg. was significantly greater than that of 90 deg. and 120 deg. ($p<.05$).

*Blindfolded sighted group*

Figure 5 (A, B, C) show the mean reproduced positions for each target position in blindfolded sighted subjects under the three conditions. For C1, the repeated ANOVA with arm and target position variables revealed that the main effect of target position was significant ($F(2, 15)=860.93$, $p<.0001$). The main effect of arm and interaction effect of target position X arm were not significant. For C2, the ANOVA showed that the main effect of target position was significant ($F(2, 15)=809.34$, $p<.0001$) and yet the main effect of arm and interaction effect of the two variables were not significant. Similarly, for C3, the main effect of the target position was significant ($F(2, 10)=509.57$, $p<.0001$) and the main effect of arm and interaction effect between the two variables were not significant. Similar to the results of the blind subjects, these results showed that blindfolded sighted subjects were also able to discriminate the target positions reliably and the ability was not different between their left and right arms.

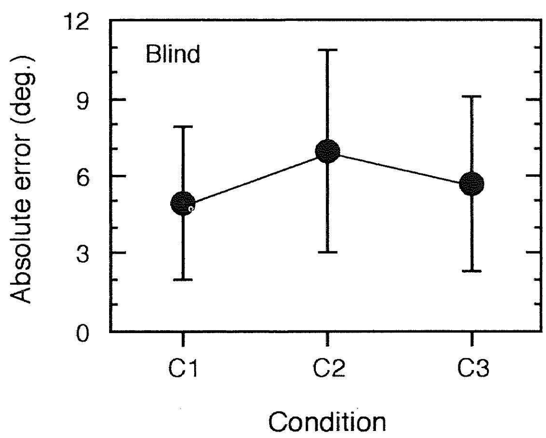


Fig. 3 Mean absolute error as a function of condition in blind subjects

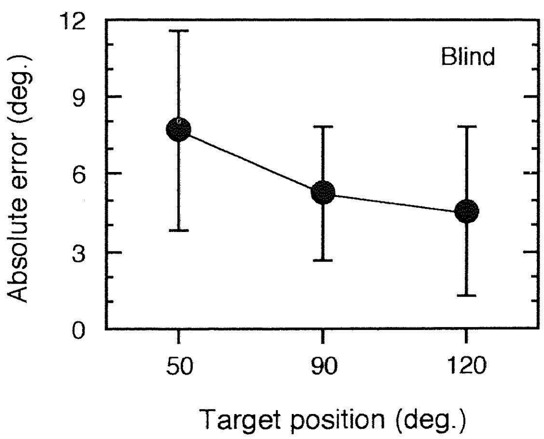


Fig. 4 Mean absolute error as a function of target position in blind subjects

Figure 6 shows mean absolute errors across target positions and arms under the three conditions in blindfolded sighted subjects. A repeated ANOVA showed that mean absolute errors of the three conditions were not significantly different each other ($F(2, 70)=2.87$ $p>.05$).

Figure 7 shows mean absolute errors across conditions and arms for each of the three target positions in blindfolded sighted subjects. A repeated ANOVA demonstrated that mean absolute errors of the three target positions were significantly different ($F(2, 70)=21.60$, $p<.05$). In addition, post hoc analysis using Scheffe F-test indicated that mean absolute error of the target position of 50 deg. was significantly greater than that of 90 deg. and 120 deg. ($p<.05$).

*Blind vs. Blindfolded sighted groups*

An unpaired t-test was conducted to compare the mean absolute errors of the two groups for each of the three targets and the three conditions. The results showed that there were no significant differences between blind and blindfolded sighted subjects in absolute error for all target position and conditions (df=10, p> .01).

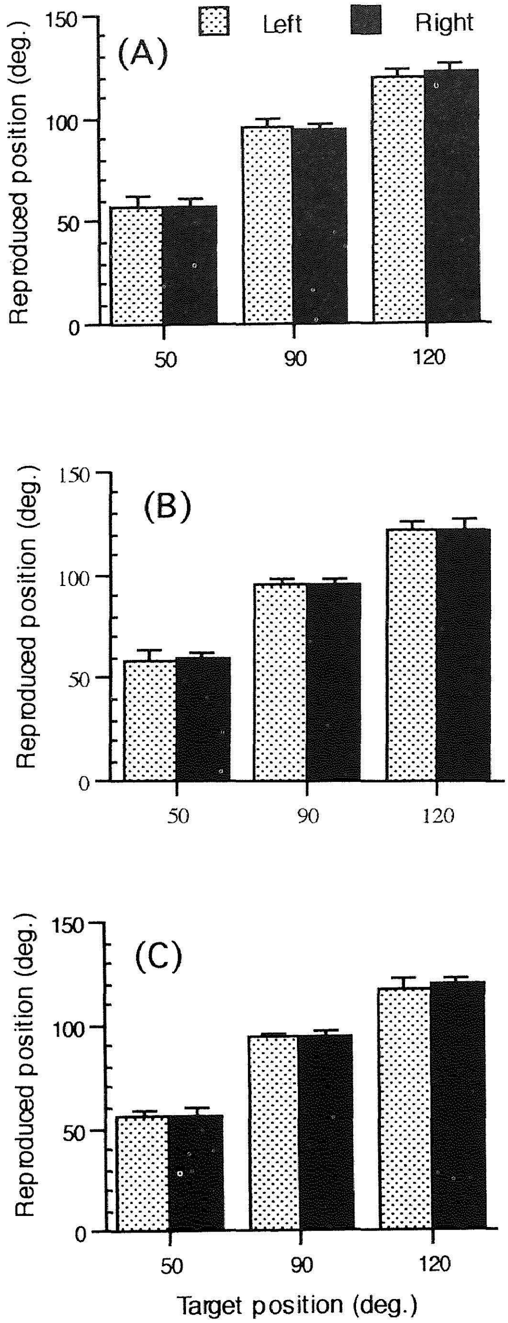


Fig. 5 Mean reproduced position as a function of target position in blindfolded sighted subjects
(A) Condition 1 ; (B) Condition 2 ; and (C) Condition 3

## Discussion

This study examined proprioceptive sensitivity of blind and blindfolded sighted subjects. The proprioceptive sensitivity was measured through an arm movement reproduction task in which a given joint angle at the shoulder was achieved passively by the subjects and the subjects were then asked to reproduce the joint angle with the same arm.

The results indicated that the performance of the blind subjects was similar to the perfor-

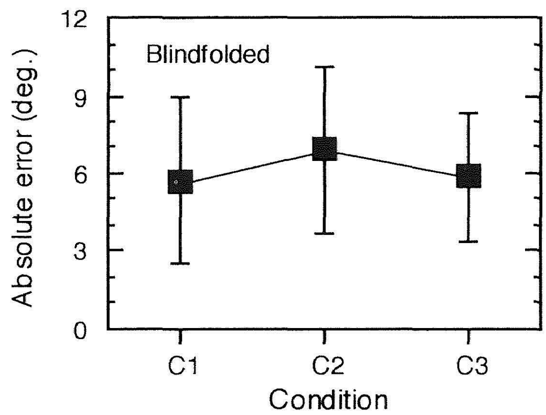


Fig. 6 Mean absolute error as a function of condition in blindfolded sighted subjects

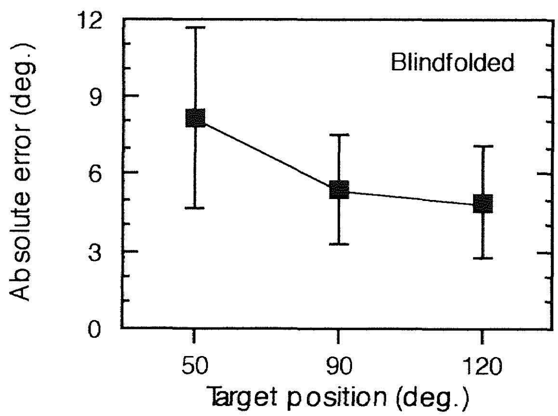


Fig. 7 Mean absolute error as a function of target position in blindfolded sighted subjects

mance of the blindfolded sighted subjects. Both blind and blindfolded sighted subjects were able to discriminate any joint angles reliably. Based on absolute error, accuracy of the performance was not different between the blind and blindfolded sighted subjects. No difference existed in the performance between the blind and blindfolded sighted subjects, perhaps because both of the subjects were not familiar with the task. Alternatively, we suggest that blind persons are able to use proprioceptive information to control their limb movement such as the arm movement reproduction. In other word it suggests that blindness has no effect on the proprioceptive ability.

All the subjects of this experiment were right-handed. However, it was found that accuracy of the performance between the left and right arms were not significantly different. This finding is in agreement with previous studies that analyzed the laterality of the upper and lower limbs. For example, Bairstow and Laszlow (1981[1]) did not find the subject's laterality of upper limbs to be a significant factor in proprioceptive perception. Euzet and Gahery (1995[4]) also reported that laterality of lower limbs was not a significant factor for accuracy of joint position.

The difference between C1 and C3 may be due to the direction of the head. In C1, the head rotated around 90 deg. to the side of the required arm, while in C3, the head was in the normal position. C2 differs from C3 in relation to the direction of arm movement. In C2, the arm extended to the side of the body, while in C3, the arm extended parallel to the sagittal plane of the body (see Fig. 1). For blindfolded sighted subjects, absolute errors of the three conditions were not significantly different. In the blind subjects, on the other hand, the errors of the three conditions were significantly different. However, post hoc test using Scheffe F-test indicated that the error of C1 was significantly smaller than that of C2, and the error of C3 did not differ from those of C1 and C2. This result indicates that the head position did not influence accuracy of the task when the direction of arm movement was the same. In addition, accuracy of the task was not affected by the direction of arm movement when the head was in the normal position.

For both blind and blindfolded sighted groups, absolute error of the target position of 50 deg. was significantly greater than those of 90 and 120 deg. and there was no difference between the errors of the target positions of 90 and 120 deg. It indicates that the subjects were less accurate in performing the task at the target position of 50 deg. At the target position of 120 deg., perhaps the subjects used the head as reference to sense the arm position. However, at the target position of 50 deg. or 90 deg. relatively far from the head, it seems that the subjects prefer to use the gravitational torque as cues to sense the arm position. At the target position of 90 deg., the arm extended perpendicularly to the body in which the gravitational torque acting at the shoulder joint is heavier. Therefore, in this position, it may be possible that the subjects can detect the gravitational torque easily. At the target position of 50 deg., on the other hand, it seems that the gravitational torque acting at the shoulder joint is difficult to detect because the gravitational torque acting at the shoulder joint was lighter. Accordingly, the subjects were less accurate in sensing the arm position at the joint angle of 50 deg. This result suggests that spatial variables such as gravitational torque and spatial vertical and horizontal axes are important for limb orientation performance.

In the arm movement reproduction task of this experiment, can be considered that proprioception was the main channel of information by which the arm position was perceived. Proprioception involves sense of position, sense of movement, and sense of force (Zimmermann, 1989[14]), and impression of the joint's position seems to reflect arm orientation and joint angle. However, it seems that using only sensory information derived from joint angle as cue to perceive arm position was less accurate. Soechting (1982[10]) asked subjects to point the right arm at a target then reproduce the target with the left arm. The results showed that the error was significantly greater for matching joint angle than for matching limb orientation. Similar experiments by Worringham et al. (1987[18]) also demonstrated that subjects were less accurate at perceiving joint angle than perceiving forearm inclination. Turvey and Carello (1995[11]) assumed that spatial variables are more important than joint angles for limb orientation. For the limb orientation, the spatial variables were defined relative to an absolute frame of reference anchored either in the body or in the environment such as gravitational or spatial vertical and horizontal axes. This is relevant to the result of the study by Worringham and Stelmach (1985[12]) that supported a view of proprioception as a system in which afferent signals related to the gravitational torque acting at the joint lead to the perception of limb orientation rather than joint angle.

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