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Sensitivity to differences in the extent of neck retraction and rotation movements made with and without vision

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시각 차단 유무에 따른 경부 후인과 회전의 운동 감각 비교

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< 요 약 >

목적 : 본 연구는 경부의 후인과 회전 운동 범위에 있어 운동 감각 역치의 차이를 비교하기 위해 수행되었다.

방법 : 본 연구의 대상자는 19명(10명 남자, 9명 여자 나이 19~30세 평균 23.2, 표준편차 3.3)이 참가하였다. 이 연구에서 운동 감각 역치는 편안히 앉은 자세에서 시각 차단시와 시각 허용시에, constant stimuli의 방법을 사용하여 반복 측정되었으며, 움직임을 수행 하는 과정에서 정지 상태를 유도하여 그 정지동작에서 두 동작의 차이를 평가하였다.

결과 : 본 연구의 결과 후인 운동 감각이 오른쪽 또는 왼쪽 회전 운동 감각 보다 더 민감하게 나타났다.

결론 : 중간 범위의 두 움직임간의 차이를 비교할 때 시각차단 유무는 각 운동 감각에 영향을 미치지 않았다.

중심단어 : visual information, proprioceptor, movement control

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I. Introduction

To maintain task validity in laboratory research on the control of limb movements, proprioception has been studied by the method of selectively rather than completely obscuring vision, so that general vision is available for maintaining balance, but no visual information is available about the point of contact between the limb and its target (Smyth and Marriott, 1982; Waddington and Adams, 1999; Cameron, Adams and Maher, 2003). Currently, there is still a lack of a widely agreed upon definition of proprioception (Beard and Refshauge, 2000). The definition employed here is that proposed by Dickinson (1974), of proprioception as "…the appreciation of movement and position of the body and parts of the body based on information from other than visual, auditory or superficial cutaneous sources". For active movement, this definition incorporates the concept of corollary discharge, as well as many afferent sources, all providing information when judgments are made of active movement extent. The study of the use ofproprioception in neck movements has a unique difficulty, in that the source of vision (the eyes) are located in the body part being moved (the head). Indeed, visual, vestibular, and cervical proprioceptive information all normally contribute to neck movement control (Gimse, Tjell, Bjorgen and Saunte, 1996)and it has been suggested that there is a hard-wired association between the visual and cervical proprioceptive systems (Rosenhall, Tjell and Carlsson, 1996; Heikkila and Wenngren, 1998). However, there are presently no data available regarding the consequences of judging neck movements with vision, compared to not having vision during the movement.

From an ecological standpoint, Gibson (1986) has proposed that to assess any discrimination ability, the test should be functional and conducted under normal sensory conditions. An implication of assessing movements of specific body parts in an ecologically valid fashion is that other limbs or segments are not restrained with straps or clamps. Russell (1976) noted that a continuously updated representation of the body in space was needed for all movements, so that, for example, directed arm movements would have to take any trunk movement into account. Even though a movement being assessed is primarily made at one joint from one limb, it could still be regarded as part of a movement grouping, or synergy (Kelso, 1995). For these reasons, a functional test of neck movements should not involve restraint or fixing of any body part. Accordingly, an apparatus was developed to assess neck movement discrimination which would enable the subject to move their neck actively without any equipment attached to the head or other body part.

Midrange movements made from physical contact to physical contact were employed. Rotation and retraction movements were chosen, as rotation is the movement most commonly used when exploring the external environment, and retraction is the neck movement most affecting posture (Taylor and McCloskey, 1988; Rubin, Woolley, Dailey and Goebel, 1995; Hanten, Olson, Russell, Lucio and Campbell, 2000).

The measure of sensitivity to the extent of neck movements employed here was the just-noticeable-difference. This is defined as that distance either side of the standard distance which is able to be discriminated from this standard on at least 50% of the trials (Magill and Parks, 1983; Choi, Meeuwsen and Arnhold, 1995). The aim of this study was to investigate: (1) any sensitivity difference between different directions of neck movement:

neck retraction, and left and right rotations; and (2) whether the just-noticeable-difference for extent is affected when neck movements are made with vision or without vision.

II. Materials and Methods

A. Subjects

Nineteen volunteers (10 men, 9 women) took part, all of whom were students at the University of Sydney, aged 18 to 30 years (mean=23.2; SD=3.3). The advertisements placed on noticeboards sought subjects over 18 years of age, with no experience of neck, upper back, or spinal problems that had resulted in a restriction of normal activity or any timeoff from work, and having no current neck symptoms. Subjects who had sought medical attention for neck pain or related problems within the last 6 months were excluded from participation in the study, as was anyone with any medical condition likely to affect mobility of the cervical spine, e.g., ankylosing spondylitis. Approval for the study was obtained from the Human Ethics Committee of the University of Sydney, and each subject gave informed consent prior to testing.

B. Procedure

As in Magill and Parks (1983) study of arm movements, the method of constant stimuli was used to determine the difference threshold for neck movements, as a measure of neck movement sensitivity. With this method, the subject judges pairs of movement stimuli, one the standard and the other the variable stimulus (Woodworth and Schlosberg, 1954). Comparisons between each of the six

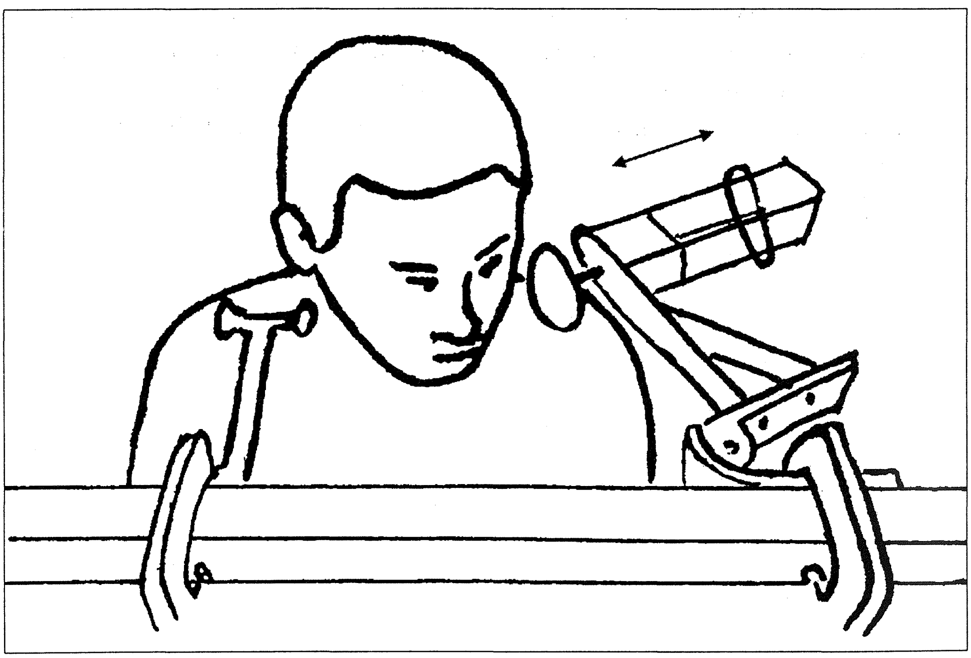

Figure 1. The testing positions for rotation movements. The subject sat on a chair in a comfortable sitting position with the stepper motor shaft moving the mushroom-shaped contact backward and forward as indicated by the arrow heads.

variable movements and the standard movement were presented in random order. After carrying out both movements, the subject told the experimenter which of the two movements appeared to be the greater in extent. Three directions of neck movements (ie retraction and left and right rotations of movement were tested on separate occasions, with order of testing randomly determined. All movement sets were performed once with and once without vision.

The apparatus used to measure discrimination of neck rotation movements is shown in Figure 1. A stepper motor (RS Components Pty. Ltd., 129-137 Beaconsfield St., Silverwater NSW 2141, Australia) was clamped to a height-adjustable bar attached across twofixed poles, and connected to a laptop computer. The program allowed the stepper motor shaft to move in and out to any one of seven preset positions. Before

moving to the test position, the stepper motor was programmed to make additional movements of randomly-determined duration, to remove any auditory cues which could aid in judgments of distance moved to the test location. There was a fixed plate on the opposite side to the motor and shaft, for the subjects to contact as the test starting position.

C. Testing method

Starting position: Before a test began, each subject was set for each testing position and testing range. The location of a stepper motor was adjusted for the subject sitting height on a horizontal plane (a spirit level was used), a CROM device was used for rotation movement testing range, between 25 and 43 degrees, and a rubber piece was used for setting the starting position of retraction movement, a 1cm gap between subject's occipital contact point and the moving plate. The subject sat comfortably on a height-adjustable chair, with their feet placed flat on the floor at 90 degrees of knee flexion, and their hands placed in their laps. Each subject was asked to maintain their normal sitting posture and was told to focus their eyes on a spot on the front wall, and to feel the movement as they

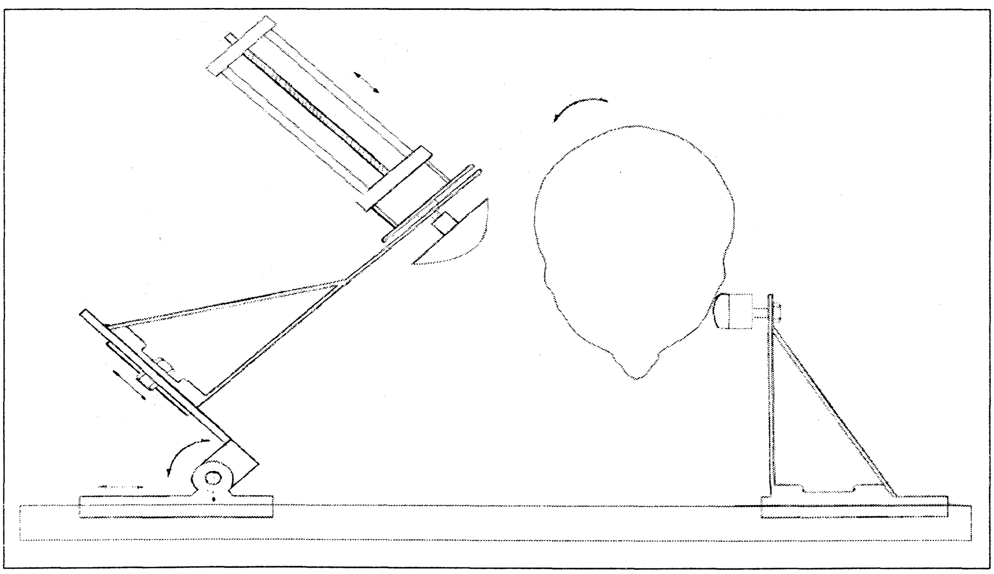

Figure 2. The left cheek contacting the fixed plate for the right rotation test

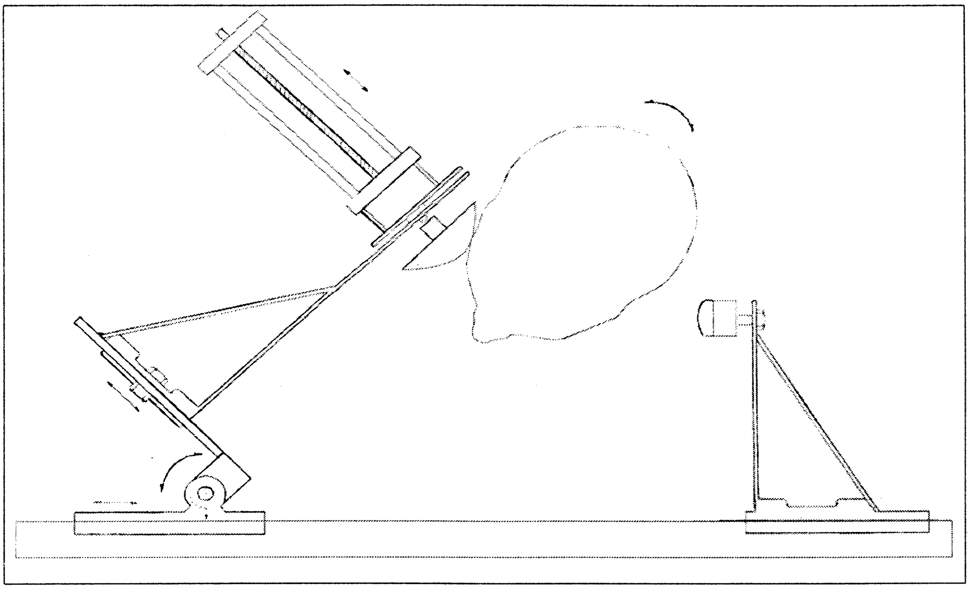

Figure 3. Rotating the head to the right till the right cheek touches the moving plate for the final testing position

moved their head to contact the moving plate.

1) Rotation movements:

The starting position: the subject's right gonion (point of the cheekbone) to contact the fixed plate, which can be adjusted for each subject's neutral sitting position. The movable plate which is attached to the shaft of the stepper motor is located in the target range (ie between 25 and 43 degrees rotation).

The test procedure: For right rotation, from the starting position with the left cheek contacting the fixed plate (see Figure 2), the subject was asked to rotate their head to the right till their right gonion touched the variable plate, which was the moveable plate (see Figure 3). Then the subject returned the head to the starting position while the examiner used the computer to move the variable plate either closer to or further from the original position. The subject then repeated the task, always touching the variable plate in a new position, and making judgments. On each trial, the task was to compare two movements before judging relative neck position at the end of the second movement, ie. which of the two was further from the neutral position, eg. first one or second was further away from the neutral position. For left rotation testing, the variable plate was located to the subject'left side, and the subject's left gonion touched by left rotation. The test procedure was the same as for right rotation.

2) Retraction:

The starting position: the subject's forehead (glabella) was required to contact the fixed plate when they were in their neutral sitting position. The movable plate attached to the shaft was located in the target range (ie between 1 and 1.9cm). (see Figure 4)

The test procedure: the subject was asked to pull their head backward (tucking their chin in) from their neutral position till the back of their head touched the variable plate (see Figure 5). The subject then returned their head to the starting position while the examiner used the computer to move the

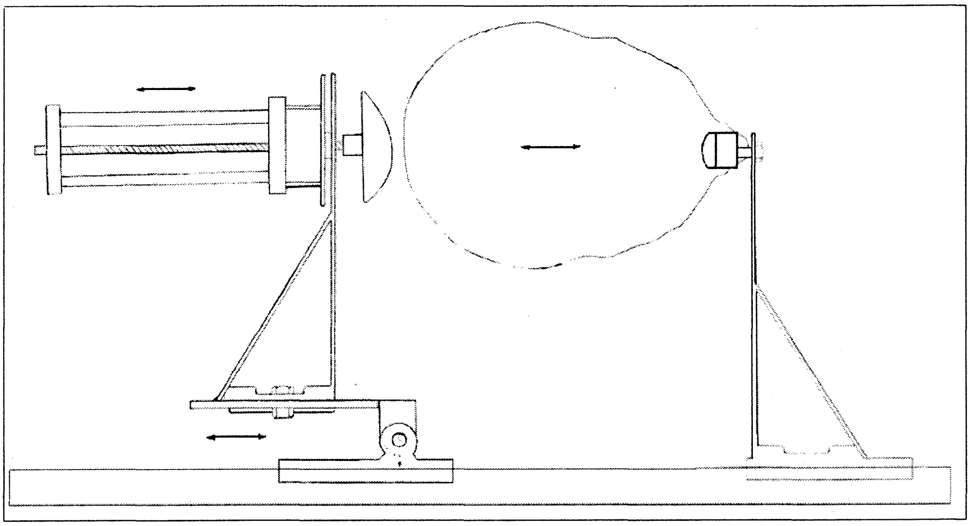

Figure 4. Starting point with the subject's glabella (the point between the eyebrows) against the fixed plate for the retraction test.

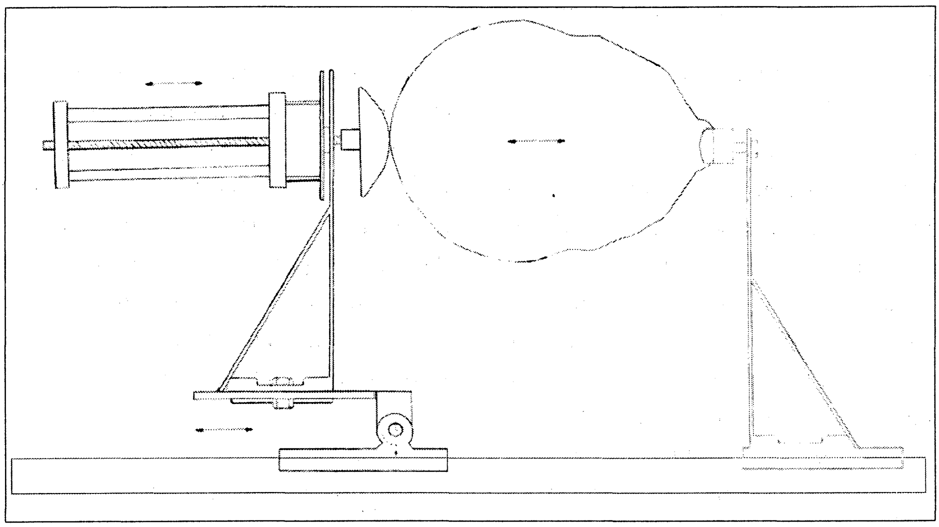

Figure 5. Moving the head backward from the start position while tucking the chin in, till the back of the head (the occipital protuberance) touches the movable plate at the final testing position.

variable plate either closer to or further from the original position. The subject thereafter repeated the task, touching the variable plate in a new position, and then making their judgment.

Seven different positions were used for the test. The task was always to compare two movements before judging relative neck/head position at the end of the second movement, saying which of the two was further from the neutral position, eg. first one or second wasfurther away from the start. Random allocation determined whether vision or no vision was used in the initial session. During testing, all six pairs of movements were presented 12 times in random order. Therefore, the subjects moved their head 144 times for each condition (vision or no-vision) and total of 288 times for both the vision and no-vision tests. After completing one direction /condition of movement, subjects were able to rest for 5 minutes before commencing the next direction/condition of movement. Therefore each session took 45 minutes to complete. Three sessions were required to complete all directions of neck movement testing. In order to avoid cues from end ROM testing and to minimize stress on the subjects'necks, the ROM required for each test movement was a few degrees or millimeters (for the rotation and retraction respectively) in the subjects'mid range. Since fatigue is an issue when a subject is required to make a large number of jugements, the test was paused any time that the subject wished.

For retraction, the 6 variable positions were 1.00, 1.15, 1.30, 1.60, 1.75 and 1.90 cm, with the standard position at 1.45 cm. The set of lengths from the stepper motor shaft used in testing was the same in both retraction and rotation movements. The 6 variable positions used for rotation were therefore the same linear translations, corresponding to 25.0, 28.0, 31.0, 37.0, 40.0, and 43.0 degrees of rotation, with the standard position always at 34 degrees. Each test set in the rotationand retraction directions was in midrange, so as not to cause any stress on the neck. For this subject population, the average total ranges for left and right rotations have been found to be 73.1 and 71.7 degrees, respectively, and for retraction, average total range was found to be 2.9 cm (Lee, Nicholson and Adams, 2004).

Ⅲ. Results

Raw scores for the 'further from' judgment category were collated, and data were analysed using Probit, a SPSS-Windows subroutine (SPSS for Windows, Release 10.05, 233 Wacker Drive, 11th floor, Chicago, Illinois 60606). The just noticeable difference was defined as that movement extent difference which could be discriminated 75% of the time (Coren, Ward and Enns, 1994). Each subject's just noticeable difference was obtained for both retraction and rotation movements, under the vision and no-vision conditions.

A 2 (vision: yes, no) x3 (movement direction: retraction, left rotation, right rotation) repeated-measures analysis of variance using orthogonal planned contrasts (Winer, Brown and Michels, 1991) was performed on the just noticeable differences. Means (SD) of just noticeable difference with and without vision for each of the neck movements are shown in Table 1. There was a significant difference between the mean just noticeable difference for retraction and combined left and right rotation movements ($F_{1,17}$ =16.40, $p<0.001$), but not between left and right rotations ($F_{1,17}$ =1.48, ns). The mean just noticeable differences for

Table 1. Just-noticeable-difference (mm) for the three neck movement directions, obtained from sessions with and without vision

Condition	RetractionLeft rotation		Right rotationAll movements						
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Vision	1.9	0.5	2.7	0.8	2.7	1.0	2.4	0.5	
No-vision	2.2	0.6	3.2	0.3	2.7	0.8	2.7	0.7	
All-conditions	2.1	0.3	3.0	0.9	2.7	0.8			

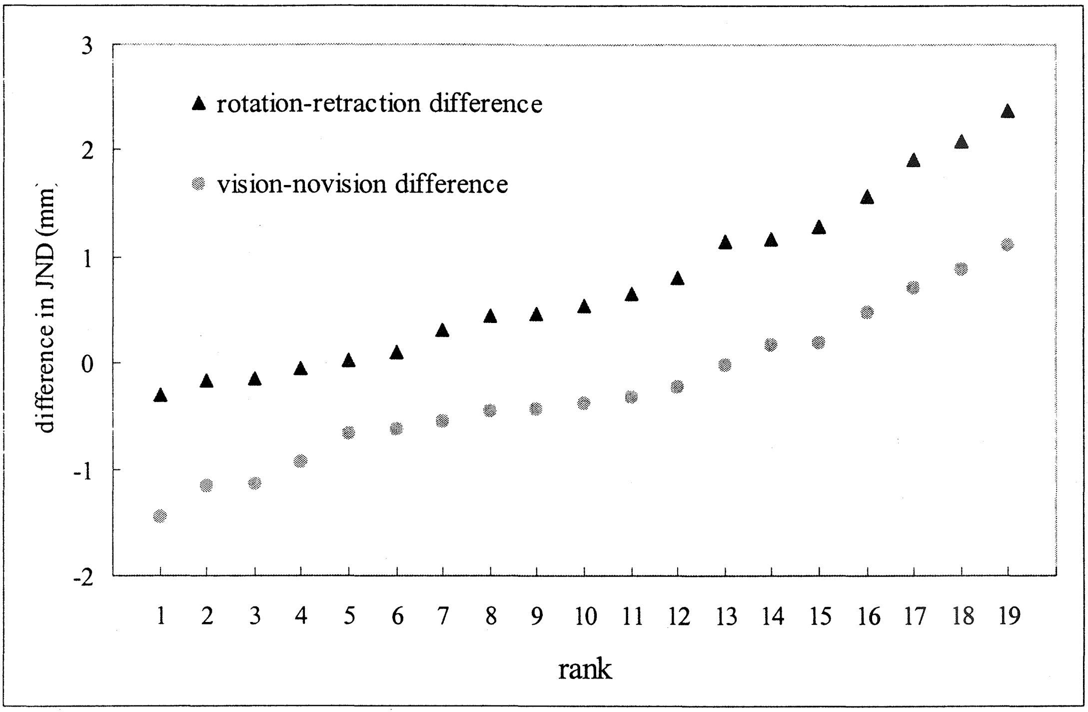

Figure 6. Individual subjects' data for differences between the just-noticeable-differences for rotation and retraction movements, andbetween vision and no-vision conditions, ranked across subjects. Retraction is more sensitive than rotation (most subjects'-differences in just-noticeable-difference are positive), whereas there is no significant sensitivity advantage from having vision available during testing (differences between the conditions are more distributed over negative and positive). Subject ranks refer to each difference plot separately.

retraction and combined rotations were 2.1 and 2.8 mm, respectively. As a lower value represents better discrimination, retraction movements were better discriminated than rotation movements. For each subject, the difference between their rotation and retraction just noticeable difference values was calculated and plotted in Figure 6.

From the vision/no-vision comparison, vision was found not to be a significant advantage in discrimination of movements ($F_{1,17}$ =2.47, ns). The individual subject differences between movement sensitivity with vision and without vision can also be seen in Figure 6. Subject ranks refer to each plot separately to, so the subject with the largest difference between scores on vision conditions is not the same subject with the largest difference on direction conditions. Retraction is more sensitive than rotation, as most subjects' differences in just-noticeable-difference are positive, whereas there is no significant sensitivity advantage from having vision available during testing, as differences between the conditions are more evenly distributed over negative and positive. Negative differences show a vision advantage.

Ⅳ. Discussion

Although the neck may be regarded as the moveable platform for vision, having vision available when judging the extent of neck rotation or retraction movements did not significantly improve discrimination accuracy. As Delgado-Garcia (2000) has noted, the eyes are not pasted on to thehead like postage stamps, but move separately. Head rotation movements are immediately accompanied by compensatory eye movements in the opposite direction (Gibson, 1986). If the rotation movement continues, the eyes then swing to a fixation in the new forward direction. In the absence of novel objects coming into view after turning to different extents, this automatic opposite-direction eye movement may be what makes 'visual proprioception' (Lishman and Lee, 1973) an insignificant source of additional information for extent of head turning movements.

Compensatory eye movements do not occur during head retraction, but without novel objects coming into view for deeper retractions, the expansion of the visual field accompanying neck retraction over the range employed here does not give significant useful additional information, over the 'feel' of the retraction movement. For some subjects, having vision during judgment of neck movements may have distracted attention from cervicocephalic proprioception, through the operation of visual dominance (Lee and Aronson, 1974; Klein, 1976).

Kinesthetic sensitivity, or proprioception, in the neck has been found to be dependent on input from proprioceptors in joint tissues (capsule and ligaments) and from muscle receptors (Golgi organs and spindles) (McCloskey, 1978; Gandevia, McCloskey and Burke, 1992). In the midrange, as used in the current study, muscle receptors are considered to be the major sensory sources for the discrimination of movement, since several studies have shown that muscle spindles are sensitive to stretch over a wide-range of muscle lengths including the midrange (Boyd and Roberts, 1953; McCall, Farias, Williams and BeMent, 1974; Clark and Burgess, 1975; McCloskey, 1978). Therefore, it is likely that subjects rely primarily on cervicocephalic kinesthesia to make their judgments about the extent of head movements, whether or not vision is available.

In terms of absolute sensitivity, retraction movements showed smaller just noticeable difference values than right or left neck rotation movements. An explanation of this effect can be put forward which considers the need to balance the head on the neck. The weight of the head is more destabilizing when it is retracted or protracted, as it moves the center of mass of the head closer to the balance periphery than when the head is rotated. For this reason, maintaining upright balance may require greater sensitivity of judgment of movement extent for retraction and protraction movements, than for head rotation movements. It has been found previously that there is a very high density of muscle spindles in the neck retractor muscles compared to the neck rotator muscle group (Peck, Buxton and Nitz, 1984). This factor may make backward movements of the head better controlled and better detected than other directions of neck movement.

The apparatus employed here permits a psychophysical method (constant stimuli) previously used to determine the accuracy of forearm and whole arm movements (Magill and Parks, 1983; Carlton and Newell, 1985; Choi et al., 1995; Naughton, Adams and Maher, 2002)to be employed in the measurement of sensitivity to movement extent at the neck. Previous testing of sensitivity to neck movement differences has involved blindfolding subjects in order to assess cervciocephalic kinesthetic sensitivity (Revel, Andre-Deshays and Minguet, 1991; Kristjansson, Dall'Alba and Jull, 2001). Neither any main effect or interaction effect involving vision was detected in the current analysis, suggesting that there was no movement direction where having vision available made a significant difference to sensitivity scores, and, therefore, that testing of proprioception at the neck can be carried out without blindfolding. Further studies can now evaluate this method of measurement of neck movement discrimination sensitivity with different populations, e.g., neck injury subjects.

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