Aging Effects on the Tactile Spatial Sensitivity of Orientation Discrimination by the JVP Domes

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Abstract: The JVP domes were widely used to detect the tactile sensitivity reported by participants, which declined with the influence of aging. However, it is still unknown how the decline of tactile spatial sensitivity can influence orientation discrimination. In the current study, we used JVP domes to test the orientation discrimination of older participants (n = 22, age 63 – 77, means = 69.9). Our results found that the accuracy of the wider grating of JVP domes was higher than the narrow grating. Moreover, it is easier for our participants to discriminate vertical and horizontal orientation than left and right. The current study evaluated the decline of tactile ability for older participants and further expanded the application of JVP domes.

1 INTRODUCTION

Previous studies developed a new index of tactile spatial sensitivity based on the refined human ability to discriminate gratings, named JVP Domes. The JVP domes are a set of small grating surfaces used for cutaneous spatial resolution measurement (Boven, 1991). Boven and Johnson (Boven, 1994) used the JVP domes in the grating orientation task required participants to identify the orientation of grooves and bars and further provided an estimate of the spatial resolution limit at the lip, tongue, and fingers.

Humans' sensory spatial acuity will decrease with aging effects (Bruce, 1980). Moreover, the sensory neural pathways serving the fingers are specialized for spatial information processing. Thus, the damage to these pathways is likely to be manifested most prominently as a loss of tactile spatial acuity (Boven, 1994). As an effective device to evaluate the spatial acuity in the tactile domain, the JVP dome was used to determine the spatial acuity of elderly participants and further confirmed that the grating orientation task was more difficult for elderly participants than younger participants (Tremblay, 2000). However, the width of JVP domes used in Tremblay, et al. (Tremblay, 2000) was only 2mm and 3mm, which was probably not adequate for spatial acuity measurement at the fingertip of older adults. We supposed that older participants could determine the orientation information in the JVP domes with larger grating dimensions.

To further explore the influence of aging on spatial acuity, the current study developed a new device to present the JVP domes. Additionally, we added larger grating dimensions (4mm) to evaluate the direction discrimination of elderly participants.

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2 METHOD

2.1 The Parameter of JVP Domes

The tactile spatial sensitivity varies depending on the groove width. In the current study, the tactile sensitivity was evaluated by identifying the dome direction in the horizontal, vertical, or inclined left or right direction to the participants.

Two different JVP domes were used in our experiment, which has 25 mm in diameter and divided into 3 mm and 4 mm in width.

2.2 Present Device

A conveyor device was used to press the grooves of the JVP domes against the participants' skin in four different orientations (0° [Horizontal], 180° [vertical], 120° [left], or 60° [right]). This conveyor device consists of one closed box with an adjustable shelf, two pairs of gears, two step motors, and a group of JVP domes. Almost all of the components were made of acrylic and assembled using resin glue and gears, and the entire device was controlled by a computer. In the tactile task, the participants put their index finger on an adjustable stand to ensure that it was held in place in a comfortable position. The JVP dome was installed under a round gear, and a one-step motor was used to rotate it; the other gear and step motor were placed above the round gear to control the upward and downward motion of the stimuli. An API (Application Programming Interface) program was used to control the rotation speed and distance of the step motors, ensuring that the stimuli could be applied to

the participant's index finger under different experimental conditions (see Figure 2 in our previous study (Guo, 2021)).

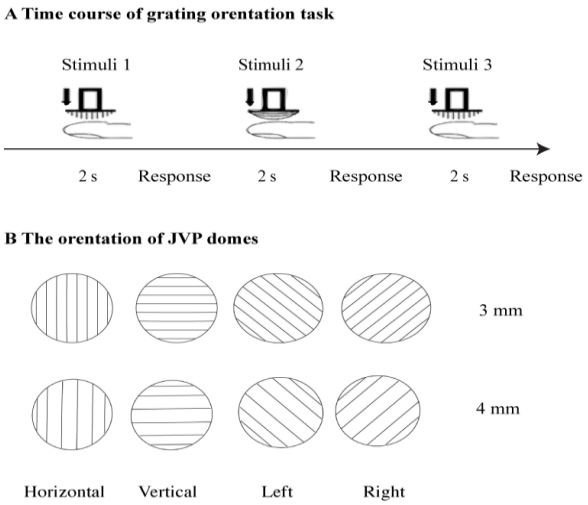

Figure 1. Illustrate of grating orentation task. Figure 1A presented the time course of our experiment, Figure 1B presented the width and grating orientation used in this task.

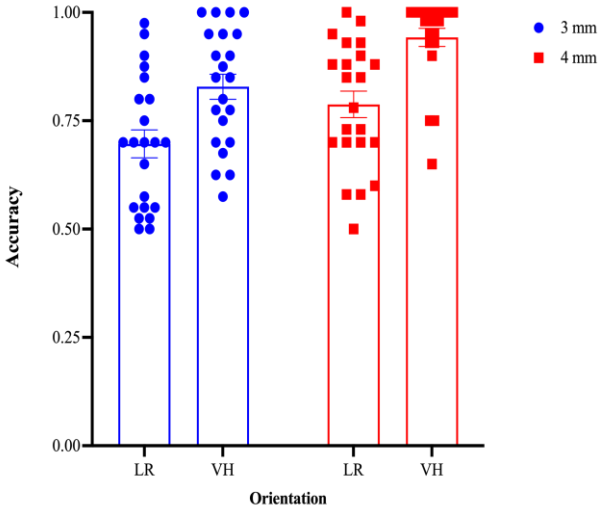

Figure 2. Mean accuracy under the conditions of the current study. The error bars represent the standard errors.

2.3 Time Course

The JVP dome was presented at presented against the index fingertips of the participants and assigned them to report the orientation of each JVP dome. Each JVP dome was presented for 2s, then we presented the new dome until participants reported the orientation of presented stimuli. Each orientation has 40 trails, so that each participant executed 160 trials in our experiment. The specific time course and the illustrate of JVP domes with different width and orientations were presented in Fig.1.

The orientation discrimination task was executed in a test room with normal lighting, and participants wore black eye masks throughout the experiment.

3 DATA ANALYSIS AND RESULTS

We calculated the accuracy of the orientation discrimination task as the evaluation index of tactile spatial sensitivity in the current study. The results for the mean accuracy of each condition in our experiment are summarized in Table 1.

Table 1 The accuracy of conditions in current study

			3 mm		4 mm	
Participants	Age	Gender	LR	VH	LR	VH
1	71	male	0.8	1	0.85	0.975
2	70	male	0.525	0.95	0.875	1
3	70	male	0.7	0.875	0.7	0.925
4	74	male	0.55	0.625	0.7	0.75
5	73	male	0.875	0.9	0.9	1
6	72	male	0.65	0.95	0.7	0.975
7	71	male	0.7	0.85	0.925	1
8	63	male	0.75	0.9	0.875	1
9	77	male	0.7	0.675	0.95	1
10	74	male	0.5	1	0.875	0.9
11	66	female	0.55	0.775	0.6	0.975
12	70	female	0.7	0.95	0.85	0.95
13	63	female	0.575	0.7	0.7	0.95
14	75	female	0.95	0.85	0.725	0.75
15	64	female	0.55	0.75	0.575	1
16	63	female	0.8	0.625	0.725	0.925
17	69	female	0.7	1	0.5	1
18	76	female	0.975	0.8	0.975	1
19	64	female	0.9	1	1	1
20	74	female	0.5	0.575	0.775	0.975
21	69	female	0.85	0.775	0.925	1
22	70	female	0.525	0.7	0.575	0.65
Means	69.91		0.7	0.83	0.79	0.94

a. Mean accuracy of each grating width and orientations.

Two-way repeated measures ANOVA was conducted on accuracy with the width (3 mm or 4 mm) and the orientation (Vertical – Horizontal (VH) or Left – Right (LR)), Main effects were observed for all two factors: Width [$F(1, 21) = 17.62$, $p < 0.001$], Orientation [$F(1, 21) = 28.4$, $p < 0.001$]. We did not observe any significant interactions between the factors of width and orientation (see Fig.2).

These results indicated that the mean accuracy of the JVP domes with 4 mm width was significantly higher than those was 3 mm. These comparisons were further suggesting that the wider domes were more easily discriminated against than the narrow ones for elder participants.

Moreover, from the results of the current experiment, we also found the influence of orientation on the grating orientation discrimination task. The mean accuracy of the VH orientation conditions was significantly higher than the conditions of LR orientation. These results suggested it is more difficult to distinguish the vertical and horizontal directions than the left and right directions.

4 DISCUSSION

The primary objective of this study was to investigate the influence of grating width and orientation on the tactile spatial sensitivity of elder participants. We evaluated the tactile sensitivity using JVP domes and further confirmed that the ability of orientation discrimination was changed with the change of grating width for elderly adults. Moreover, we also found that distinct discrimination orientations have different accuracy patterns. These results further investigated the influence of grating width and orientation on the tactile sensitivity of older adults, and further supplemented empirical data for the effects of aging on the tactile spatial sensitivity of humans.

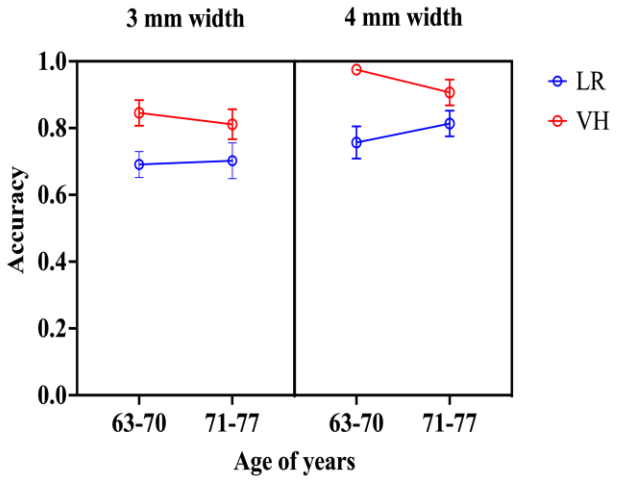

Figure 3. Mean accuracy was presented with the age groups divided by 70 years old. The error bars represent the standard errors.

Consistent with previous studies, our results further confirmed the influence of width on the tactile spatial sensitivity of older participants. Bleyenheuft, et al. (Bleyenheuft, 2006) used the grating orientation task to determine the age-related changes in tactile spatial sensitivity for children and adolescents. Bleyenheuft, et al. found that the performance of adolescents from 10-16 years was better than children from 6-9 years old. This study revealed the age-related change in the tactile ability of younger participants. Furthermore, it further confirmed that the tactile thresholds evaluated by JVP domes for younger age groups were less than 2 mm. Other studies used required younger adults in the grating orientation discrimination task. They reported that the finger's thresholds were almost 0.73 to 1.17 mm for younger participants from 23 to 25 years of age (Boven, 1994). Another similar experiment executed by elderly participants from 60 to 88 years of age indicated that the grating orientation task was challenging for most participants, and only a minority (14/32) was able to provide reliable reports of grating orientation even with the presentation of the widest dome available (3 mm) (Tremblay, 2000). The current study expanded the JVP domes' width range and used a 4 mm grating of domes to evaluate the spatial sensitivity for older participants. We further confirmed that the ability of direction of discrimination could be increased with the width of the grating. However, it is still objectively that the tactile spatial sensitivity will decline with the influence of aging.

Stevens and Patterson (Stevens, 1995) explored the changes in tactile spatial acuity over the life span. The participants ranged from 18 to 87 years. This study executed four dimensions of tactile spatial sensitivity tasks, such as discontinuity, a locus on the skin, length, and orientation. Their results further confirm that these four acuity dimensions of the tactile domain have deteriorated with aging. To further detected the influence of aging in current study, we divided our participants into two groups based on the age of 70 years old (see Fig.3). However, we did not found any significant main effects or interactions for the influence of aging. We speculate the reason is that the tactile spatial acuity declines slowly after 60 years old, so there is no significant difference in the age range we choose (63-77 age of years).

The Influence of orientation was significant In both age groups, and we found that the accuracy of VH suggested it is more difficult to judge the difference between left and right orientation than between horizontal and vertical orientation. The grating orientation discrimination task used visual grating and found a lower discrimination acuity for oblique orientation than for horizontal and vertical orientation. The visual domain explained these effects as “oblique effect” (Freeman, 1975). Essock, et al. (Essock, 1997) used a grating orientation task further confirm the oblique effect in the tactile domain. The influence of orientation in the current study was consistent with previous studies. We further confirmed that the influence of oblique effects was similar in elderly participants of our experiments and younger adults in previous studies (Craig, 1999).

5 CONCLUSION

To investigate the influence of the width and orientation of grating for elderly participants, The current study executed a grating orientation discrimination task used by JVP domes. Firstly, we confirmed that the tactile spatial sensitivity was lower for elderly participants than for younger adults. Secondly, the JVP domes with wider grating were easy to discriminate against elderly participants. Lastly, we also confirmed the oblique effects in the tactile domain, which indicated that the oblique grating orientation was more difficult to discriminate than the horizontal or vertical orientation. We expect these results to support understanding the tactile processing mechanism of elderly adults and further contribute to the rehabilitation of tactile spatial sensitivity for the participants suffering from the decline of tactile ability.

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