

## **Tactile spatial resolution measured manually: A validation study**

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### **Abstract**

The purpose of this study was to investigate the validity of manual application of the grating orientation task (GOT), as currently used in fundamental and clinical research. Six examiners tested 12 subjects following recommendations of the literature. The results show that the normal force applied with the domes on the skin varied from one examiner to the next. Nevertheless, it did not affect the performance of the subjects, whose thresholds were consistent with those reported in the literature. This study highlights the inter-examiner reliability in the manual application of this test and validates this procedure.

**Keywords:** *Tactile sensitivity, spatial resolution, grating orientation task, manual application, validation*

### **Introduction**

The assessment of tactile spatial resolution is of major interest in both peripheral (Van Boven and Johnson 1994b) and central (Krumlind-Sundholm and Eliasson 2002) neurological pathologies, as well as in the detection of hand impairment with aging (Stevens and Choo 1996; Sathian et al. 1997; Tremblay et al. 2003). The grating orientation task (GOT) is a valid and objective test of tactile spatial resolution (Craig and Johnson 2000) based on the application of domes presenting different grating widths on the skin. In both fundamental research and clinical assessments, this test continues to replace the conventional but invalid two-point discrimination test (Johnson and Phillips 1981; Craig and Johnson 2000). As GOT performance was initially described as relatively insensitive to the applied force (Craig and Johnson 2000), a manual application of the domes is currently used. However, recent papers using mechanical devices to control the forces and duration of application more precisely have reported a significant effect of contact force on GOT threshold (Goldreich and Kanics 2003; Vega-Bermudez and Johnson 2004). Therefore, the manual application of domes is questionable. The aim of this study was to investigate the inter-examiner reliability in a

manual application of the domes. To achieve this goal, first we investigated the differences in the subjects' performances while tested by different examiners. Second, we measured the differences between examiners in forces and the duration of application. We hypothesized that if the examiners used different forces and durations of application, the threshold would remain the same within each subject.

### **Experiment 1**

#### *Methods*

Six examiners measured the tactile spatial resolution threshold on the dominant index finger of 12 subjects with the GOT. Subjects were aged between 22 and 40 years old and presented with no disease or injury that could affect their tactile spatial resolution. An assessment was conducted in a quiet place where subjects sat on an adjustable seat with the forearm lying on a table in a supine position. The index finger was immobilized on the support using double-sided adhesive tape applied to the nail (Sathian and Zangaladze 1996). The subjects were blindfolded before starting the test.

The GOT consisted of a set of eight different hemispherical JVP domes (JVP Domes, Stoelting Co., Wood Dale, IL, USA) that presented gratings with equidistant bar and groove widths (0.35, 0.50, 0.75, 1.00, 1.20, 1.50, 2.00, and 3.00 mm). Examiners were asked to apply each dome normal to the skin for 1–2 s, with approximately 2 mm perpendicular skin deformation.<sup>1,9</sup> (van Boven and Johnson 1994b; Johnson et al. 1994) The bars and grooves were pressed randomly against the index finger with the grooves parallel or transverse to the long axis of the finger. Subjects were required to identify the orientation of the grooves before the stimulus was removed. A procedure adapted from that of Van Boven and Johnson (1994a) was used (Bleyenheuft et al. 2006). The largest grating (3 mm) was first applied for ten consecutive trials using a randomized orientation of the bars, the next smaller grating (2 mm) was applied with the same procedure and so forth. The test was stopped when the probability of correct answers for the grating reached approximately 50%. The tactile spatial resolution threshold was a simple linear interpolation estimate of the 75% correct grating width.

All subjects met the six examiners in a different order (see Table I) so as to study a potential trial effect. The first appointment with an examiner was considered a training session and the five following

were testing sessions. One complete testing session included 70–80 applications of the domes (seven or eight domes tested).

*Results*

Figure 1(a) plots the median and interquartile GOT performance of all subjects for each testing session. No trial effect emerged (Friedman repeated measures analysis on ranks;  $p=0.116$ ): The GOT performance did not improve or worsen gradually along the testing sessions.

Figure 1(b) illustrates the median and interquartile GOT threshold of all subjects for each examiner, whatever the testing session. No significant difference was detected between examiners (Friedman repeated measures analysis on ranks;  $p=0.813$ ).

This first experiment clearly demonstrates that there is no trial or examiner effect when using manual application of GOT.

**Experiment 2**

*Methods*

In the second experiment, we measured the forces and duration of application used by each examiner during a complete testing session

Table I. Testing session order.

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Subject 7	Subject 8	Subject 9	Subject 10	Subject 11	Subject 12
Examiner 1	Training	TS2	TS5	TS4	TS5	TS3	TS2	TS1	TS4	TS3	TS1	Training
Examiner 2	TS5	TS1	Training	TS3	TS4	TS2	TS3	TS2	TS5	TS4	Training	TS1
Examiner 3	TS4	Training	TS1	TS2	TS3	TS1	TS4	TS3	Training	TS5	TS5	TS2
Examiner 4	TS3	TS5	TS2	TS1	TS2	Trainig	TS5	TS4	TS1	Trainig	TS4	TS3
Examiner 5	TS2	TS4	TS3	Training	TS1	TS5	Training	TS5	TS2	TS1	TS3	TS4
Examiner 6	TS1	TS3	TS4	TS5	Trainig	TS4	TS1	Training	TS3	TS2	TS2	TS5

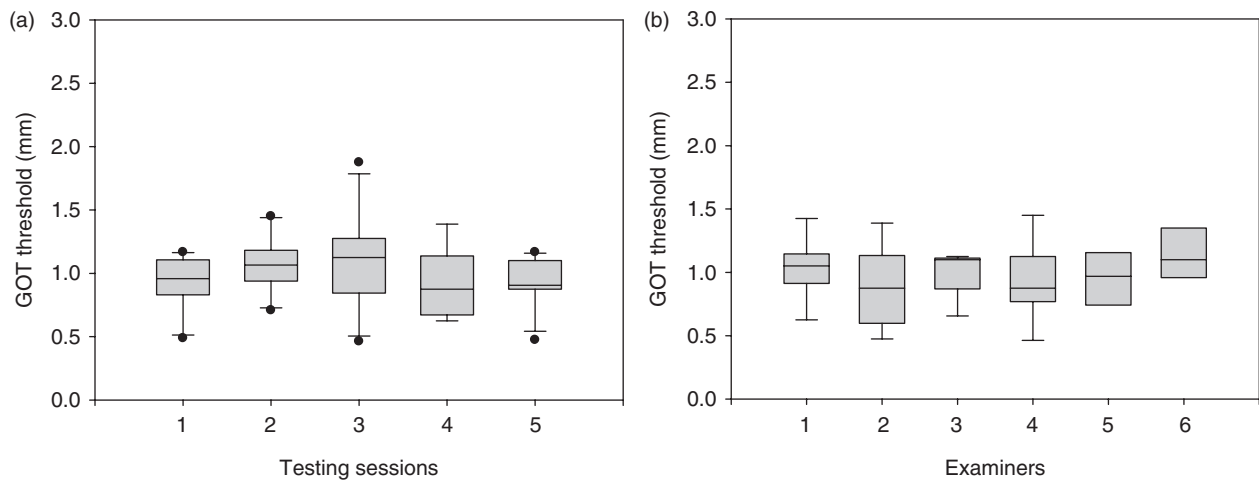


Figure 1. Box plots showing the tactile spatial resolution of all subjects taken together for (a) each testing session and (b) each examiner. Horizontal bars outside the box indicate the 10% and the 90% limits; the box shows the 25% and the 75% limits and the horizontal bar inside the box shows the median value.

(70–80 applications). For this purpose, the evaluation of one subject of the sample (female, 23 years old) was performed by the six examiners with a force sensor under the index finger. The force sensor (Mini40 F/T transducer, ATI Industrial Automation, Apex, NC, USA) allowed us to measure the normal force,  $F_z$ , which had sensing ranges of  $\pm 120$  N with 0.006 N resolution. The sampling acquisition was 1000 Hz (timing resolution 1 ms). The procedure followed was identical to that used in experiment 1.

### Results

Figure 2(a) shows the mean force and standard deviation ( $\pm$ SD) exerted by the different examiners, all domes pooled together. Figure 2(b) illustrates the mean application time ( $\pm$ SD) exerted by the different examiners, all domes pooled together.

As illustrated in Figure 2(a), the forces applied were significantly different across examiners (repeated measure, ANOVA<sub>RM</sub>,  $p < 0.001$ ). Mean forces ranged from 0.4 to 6.5 N. However, the forces (Figure 2(a)) applied were very reproducible for each examiner as no differences in forces were detected from one dome to another (ANOVA<sub>RM</sub>,  $p = 0.836$ ).

The mean duration of application also varied significantly between examiners (Figure 2(b)), ranging from 1 to 1.7 s (ANOVA<sub>RM</sub>,  $p < 0.001$ ). As was the case for force, duration of application was reproducible for each examiner (Figure 2(b)). Indeed, using repeated ANOVA, no differences in timing ( $p = 0.077$ ) were detected from one dome to another.

### Discussion and conclusion

The aim of this study was to investigate the inter-examiner reliability in a manual application of the

JVP domes. Since the manual application has been questioned by results of studies using mechanical devices, the invariance of tactile spatial resolution thresholds obtained manually by many examiners is crucial for the use of GOT in future studies, especially for those implying more than one examiner and for those comparing their results with data already published in the literature.

Our results showed that with the same instructions, there were large differences in the forces and timings used by the six examiners. However, these variations did not induce significant variations in the subjects' GOT thresholds. On the other hand, Goldreich and Kanics (2003), using mechanical devices, showed an effect of the force on GOT thresholds both in sighted and blind subjects. Nevertheless, Goldreich and Kanics worked with forces equivalent to 10 or 50 g. The very low pressure of 10 g could explain the effect of force on their results. Indeed, it has been recently demonstrated that most of the conformation of the fingerpad skin occurs at normal forces less than 0.4 N (40 g) (Vega-Bermudez and Johnson 2004). As the mechanoreceptors responsible for tactile spatial resolution respond not to pressure but to local tissue distortion (Johnson and Phillips 1981), it seems consistent that beyond a force of 0.4 N the neural responses are minimally affected by changes in contact force.

Considering our results, we could therefore hypothesize that the normal force applied does not influence the GOT thresholds obtained, as soon as this force is greater than 0.4 N. Our study tends to demonstrate that this minimum level of force is spontaneously reached when examiners are asked, as recommended in the literature, to apply the domes with approximately 2 mm of skin perpendicular deformation (Van Boven and Johnson 1994a; Van Boven et al. 2000). These results are of major interest

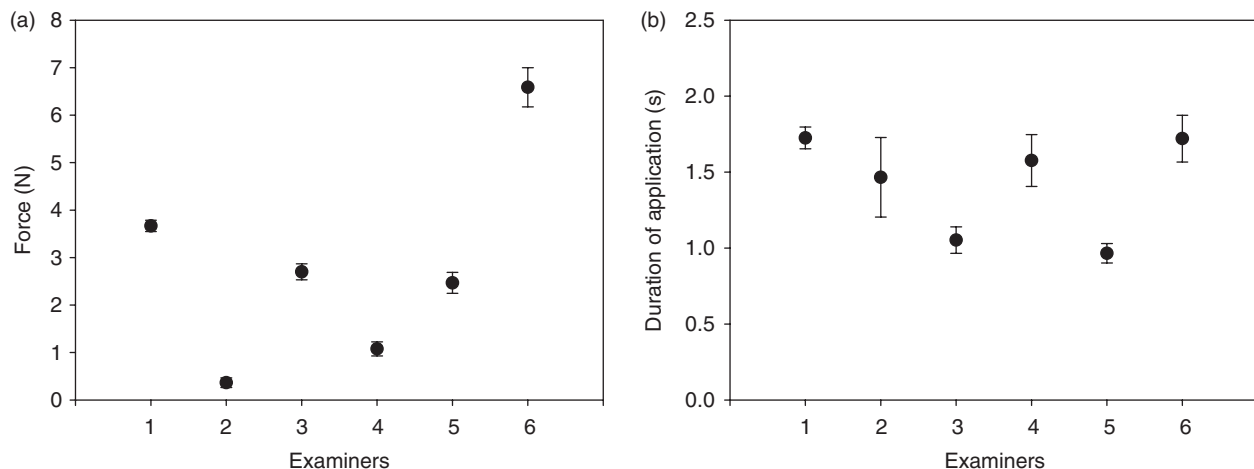


Figure 2. Plots showing the mean and SD values of each examiner for (a) the force applied and (b) the application duration. Each plot results from an average of 80 applications.

for all past and future studies using the GOT, giving confidence that, since the basic principles of application are respected, the results are not dependent on examiners and can be compared to results presented in the literature.

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