Additional Information

Virtual SVV by Interacoustics

Interacoustics

D- 0116084-A – 2017/09

Table of Contents

1 Introduction

1.1 About this manual

This manual is valid for the Virtual SVV software version 2.0. This product is manufactured by:

Interacoustics A/S
Audiometer Allé 1
5500 Middelfart
Denmark
Tel.: +45 6371 3555
Fax: +45 6371 3522
E-mail: info@interacoustics.com
Web: www.interacoustics.com

1.2 Warnings and precautions

Throughout this manual the following meaning of warnings, cautions and notices are used:

	**WARNING** indicates a hazardous situation which, if not avoided, could result in death or serious injury.
	**CAUTION**, used with the safety alert symbol, indicates a hazardous situation which, if not avoided, could result in damage of the equipment.
NOTICE	**NOTICE** is used to address practices not related to personal injury or damage of the equipment.

2 The subjective visual vertical

2.1 What is SVV?

The Subjective Visual Vertical represents a method to test one's ability to adjust a line to be parallel with gravity in the absence of any other visible cues. The sensory information required to perform this task is provided predominantly by the vestibular organs of the inner ear, and in particular by the utricles.

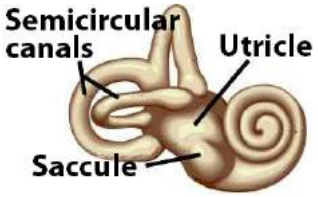


Figure 2-1 The Vestibular Organ

2.2 Physiological background

The vestibular organs consist of the three semicircular canals, which perceive angular acceleration, and the two otolith organs, the utricle and saccule, which transduce linear acceleration, including gravity, with respect to the head. Of critical importance, the information from the otolith organs facilitates correct perception of the orientation of the head with respect to gravity. The otolith organs function so that any linear acceleration displaces the otoconial mass and accordingly shears the embedded sensory hair bundles against the otolith maculae. This results in a potential change in the sensory cell and consequently a change in the afferent discharge rate of the cell. Since the Earth's gravity constitutes a constant linear acceleration, the orientation of the head relative to gravity is constantly signaled from the otolith organs to the central nervous system. As a result the individual is able to accurately estimate the so-called subjective visual vertical (SVV). Any dysfunction of the otolith apparatus is usually accompanied by incorrect spatial orientation and postural instability. The estimation of the SVV thus serves as a diagnostic indicator of otolith dysfunction.

2.3 Measurement principle

In principle the SVV is determined by presenting the patient with a luminous line in otherwise total darkness and requesting that she/he rotates it to be parallel to the gravity in a vertical alignment. In the case of a healthy patient, correct estimation of the direction of gravity is performed.

The SVV is determined by measuring the deviation of the set angle of the luminous line from the tilt angle of the head. With the head in the upright position this tilt angle will effectively be zero, i.e. parallel to gravity. In practice, testing will be performed with the head in a number of positions with the head tilted to the left or right.

Additionally, it is possible to test the SVV during unilateral centrifugation, which permits exclusive stimulation to the right or to the left utricle.

2.4 References

- Clarke A.H., Schönfeld U., Hamann C., Scherer H.–2001: *Measuring unilateral otolith function via the otolith-ocular response and the subjective visual vertical; ActaOtolaryngol(Stockh) Suppl 545, 84-87*
- Clarke A.H. – 2002: *The many facets of the otolith – a review*; J Vestib Res 11(3-5), 314
- Clarke A.H., Schönfeld U., Helling K. – 2003: *Unilateral examination of utricle and saccule*; J Vestib Res 13, 215–225
- Helling K., Schönfeld U., Scherer H., Clarke A.H. – 2006: *Testing utricular function by means of on-axis rotation*; ActaOtolaryngolica 1-8
- Schönfeld U., Helling K., Clarke A. H. – 2010: *Evidence of unilateral isolated utricular hypofunction*; ActaOtolaryngol 130(6):702-707

Schönfeld U., Clarke A. H. – 2011: *A Clinical Study of the Subjective Visual Vertical during Unilateral Centrifugation and Static Tilt*; ActaOtolaryngol 131(10):1040-50

3 Test routines

The sensitivity and specificity of the SVV test are dependent on the stimuli employed in the test. The two general approaches may be termed **static tilt** and **unilateral centrifugation.**

3.1 Static tilt in an upright position

As a starting point the SVV test can be performed with the patient in a comfortable upright position. In the presence of an otolith disorder the patient is likely to experience a sensation of tilt and accordingly, will set the SVV with some deviation relative to head axis, i.e. relative to gravity.

This can be understood as follows. In the head upright position the stimulation by gravity to the right and left utricles is equal and opposite. However, while the healthy labyrinth correctly signals the stimulation, the diseased labyrinth would provide a deficit signal. In the acute phase of the disease the central nervous system would interpret this discrepancy as a head tilt to the side of the healthy labyrinth and the patient would set the projected line to a corresponding degree toward the diseased labyrinth.

Accordingly, SVV testing in the upright position represents a useful instrument for initial screening for vestibular disorder. Any deviation from a normal response should be taken into consideration, along with further testing for subsequent differential diagnosis.

3.2 Static tilt in tilt positions

During static tilt the right and left otolith organs are variously stimulated. While the tilt angle is identical for right and left labyrinths, the orientation of the sensory hair cells is, in principle, opposite and unequal. Here again a healthy subject will adjust the SVV angle to be near equal to the actual angle of head tilt. In the case of a patient with otolith dysfunction a deviation from the healthy response can be expected, dependent on whether the disease is acute or whether vestibular compensation may have occurred.

3.3 Unilateral centrifugation

The unilateral centrifugation paradigm provides a lateral acceleration stimulus exclusively to the right or to the left labyrinth.

3.3.1 Unilateral stimulation

Unilateral centrifugation tests require a rotating chair with the possibility of eccentric positioning of the patient. If you move the subject at a constant rotational speed by about 3.5cm (half the intra-labyrinthine distance) from the axis of rotation, the eccentric labyrinth is exposed to a centrifugal force, while the labyrinth lying in the axis of rotation is free of any radial acceleration. This unilateral stimulation of the utricles triggers a tilt sensation similar to a lateral oblique position. The luminous line is aligned at a corresponding angle. This lateral shift allows the function of the utricles to be examined separately and possible side effects of central compensation processes are minimized. By using this examination variant it is possible to diagnose a dysfunction or hypofunction of the utricles with significantly higher specificity than in the static tilt test.

3.3.2 Rotational speed

In order to achieve adequate stimulation of the utricles, a rotational speed of 300º/s (at least 240º/s) is recommended. Throughout the SVV measurement, the selected rotational speed must remain constant to that there is no irritation of the semicircular canals.

3.3.3 On-Axis rotation

Compared to static tilt, a differentiated statement can also be made in centric rotation. That means the rotation axis is located exactly in the middle of the head or body axis between two equilibrium organs, such that both utricles are simultaneously stimulated with the same intensity but in the opposite direction. In a healthy person, the central processing of the afferents of the opposing right and left utricles repeal so that the perception of the (perpendicular) vertical remains unchanged. The person aligns the luminous line as he/she would in the measurement without rotation, approximately parallel to vertical (0º). For patients with unilateral dysfunction, however, this already leads to measureable inclinations of the SVV, as the better functioning utricle responds to the stimulation, while the affected side responds less (Clarke et al, 2001; Helling et al, 2006). The patient senses a tilt to the healthy side and correspondingly aligns the luminous line oblique.

4 Test procedures

4.1 Preparation

With the virtual reality goggle mounted, it is important for the patient to remain in total darkness. This is of critical importance for correct performance of the test because the patient's estimate of vertical is based on information from the otolith organs in the SVV test. Any visual cues from light leakage would be detrimental to the performance and is likely to obscure test accuracy and produce incorrect findings.

4.2 Procedure

When preparations are complete the operator initiates a measurement using the application software. The luminous line appears on the patient's display at a random angle. The patient is instructed to set the line to vertical using the left and right buttons on the handheld remote, and to confirm the estimation with the OK button.

When the patient confirms the estimate, the difference between the set angle of the luminous line and the current tilt angle of the head (as measured by the sensors) is calculated. All data is stored and the result is visualized on the graphic display for the operator to view all information.

In general, this procedure is repeated three to five times for each head tilt position to the left and to the right.

4.3 Testing with static tilt

The specific procedure for static tilt testing is detailed in the Virtual SVV Instructions for Use manual. Please refer to that manual for information on this test.

4.4 Testing with unilateral centrifugation

4.4.1 Operation requirements

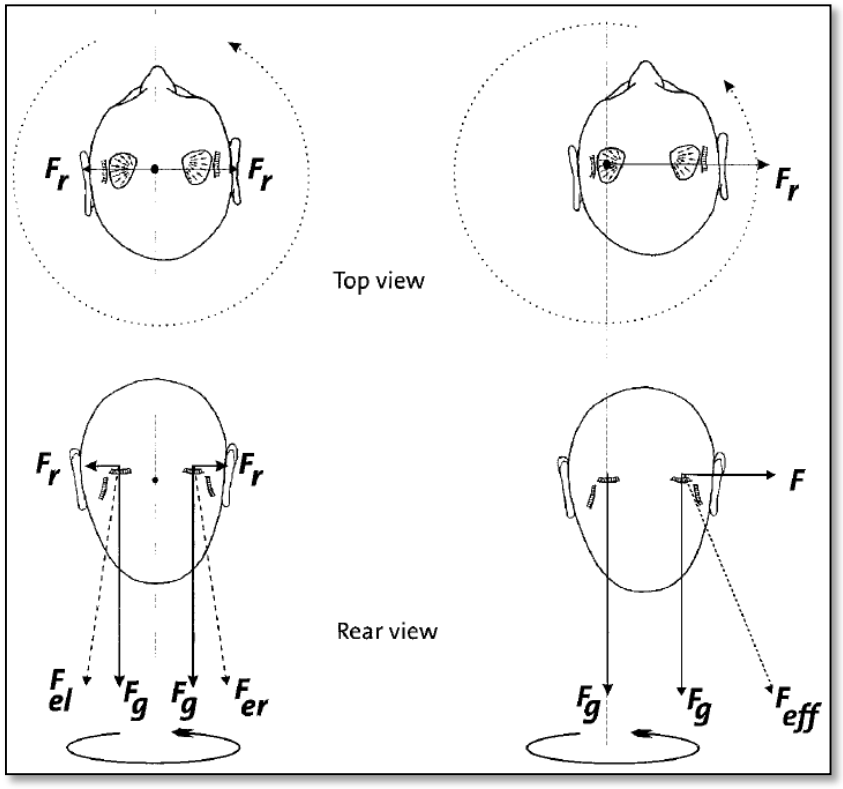
The following requirements are necessary in order to employ unilateral centrifugation (UC) as a stimulus with the Virtual SVV system;

- A clinically approved rotational chair fitted with a lateral shift capacity is necessary for this procedure. In order to generate an adequate UC stimulus, a constant angular velocity of at least 240º/s is required. With a suitable rotational chair, testing can be performed up to 400º/s. The angular acceleration should be regulated to be no greater than 2-3º/s^2 to avoid unnecessary discomfort to the patient.
- The lateral shift mechanism is required to shift the patient's chair to 3.5-4.0 cm off center in both directions. Optimally, this mechanism should be motor-driven. Otherwise the lateral shift must be performed manually before rotation. This has the disadvantage that a number of rotation starts and stops must be performed, which is time-consuming and could cause discomfort to the patient.
- Throughout testing on the rotational chair the patient's head must be secured in an upright position, parallel to the rotation axis. This ensures that the UC-generated stimulus is exclusively along the lateral-medial axis of the head. The head fixation device should also be height-adjustable.
- It is recommended that an intercom be installed in the rotational chair in order to communicate with the patient. A video camera for monitoring is also recommended as an additional safety precaution.

4.4.2 Background information

The right and left labyrinths are each assumed to be 3.5 cm from the central head axis. Accordingly, when rotating at a constant angular velocity around the head axis, both right and left labyrinths are subject to equal and opposite centrifugal forces. When the patient is shifted eccentrically to the right or left by 3.5 cm the eccentric labyrinth then rotates at a radius of 7.0 cm and experiences a corresponding centrifugal force, while the opposite labyrinth is situated on-axis and experiences no centrifugal force. The unilateral centrifugal stimulation is perceived as a tilt toward the eccentric labyrinth.

The concept permits specific testing of the right and left utricle function, providing considerable refinement for the differential diagnosis.



Left Centric Rotation **Right** Eccentric Rotation

Figure 4-1 Illustration of centric and eccentric stimulation to the utricles (from Acta Otolaryngol 2001: Suppl 545: 84-87)

4.4.3 Expected tilt sensation

The intensity of the tilt sensation during eccentric rotation is determined by the angular velocity and the lateral shift. The vestibular organs are then subject to two forces:

The force of gravity F_g and *The centrifugal force* F_r

The resulting force F_{eff} of the two forces determines the expected angle to which a healthy person would set the luminous line.

In contract to static tilt, the unilateral centrifugation test uses the tilt sensation of the patient affected by the eccentric rotation. It is assumed that the patient's head is secured in an upright position on the rotary chair during the test procedure. The tilt angle of the virtual reality goggle positioned on the patient will not change significantly during unilateral centrifugation.

To identify the real tilt sensation of the patient, the sensor values of the virtual reality goggle are analyzed to determine an effective tilt angle. Analog to the tilt angle at the static tilt test, the effective tilt angle represents the perceived lateral tilted position of the patient at unilateral centrifugation tests and is displayed in the left angle gauge in the application software.

Even small changed from ideal upright head position or small head movements from the patient during the examination will lead to deviations between the expected tilt sensation and the calculated effective tilt angle of the sensors.

Example
Rotational speed: 300º/s

Axis shift: 3.5 cm

→ **Expected tilt angle: 5.59º**

4.4.4 System configuration for unilateral centrifugation

In order to configure the parameters for the rotary chair, click on the gear icon located in the upper left panel of the user interface to access Settings. Select the Examination tab from the left panel.

Enter the constant angular velocity to be employed.
Permissible range: 100 – 400º/s.

Enter the magnitude of the lateral shift.
Permissible range: 1 cm – 4 cm

These two parameters determine the resulting effective tilt angle. Nominally, three measurement sequences are expected for unilateral centrifugation.

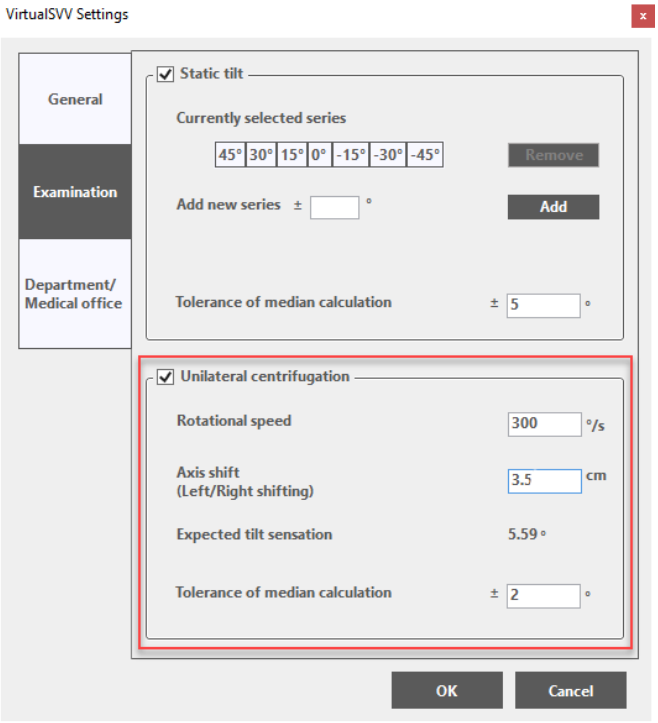


Figure 4-2 Configuring Virtual SVV for Unilateral Centrifugation

As with static tilt mode, an optional median tolerance range (i.e. 5º) can be user-specified as deemed appropriate.

Any setup changes can be confirmed by clicking OK.

4.4.5 Performing measurements

Select the Unilateral Centrifugation tab in the upper left corner of the application software to enter this testing mode. The following message will appear.

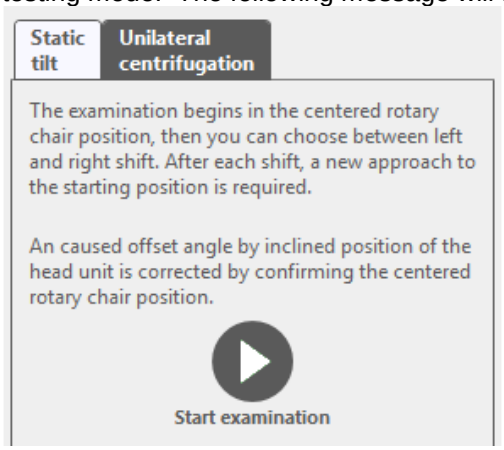


Figure 4-3 Unilateral Centrifugation examination tab

When the patient is secured in the rotary chair, select the Start Examination button to initiate the test procedure. Select Next to confirm that the patient is secured with his/her head in an upright position. To assist with the effective tile (α) adjustment, the tolerance range for the respective effective tilt is indicated green on the effective tilt angle indicator. The center of the dial remains green as long as the effective tilt is within the tolerance range.

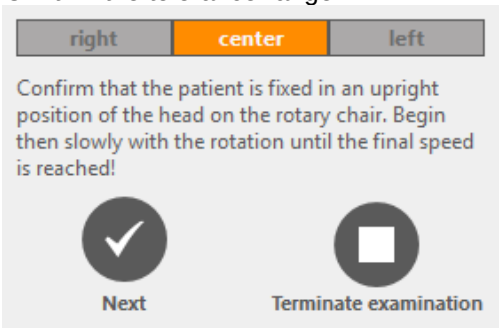


Figure 4-4 Confirmation of patient position

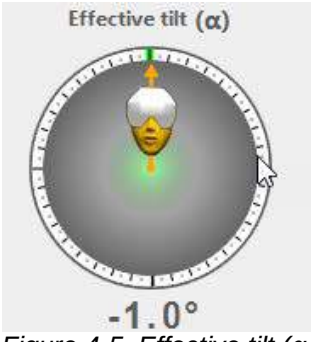


Figure 4-5 Effective tilt (α)

Select Next to confirm that the rotary chair is in a centered position and that the defined speed has been reached.

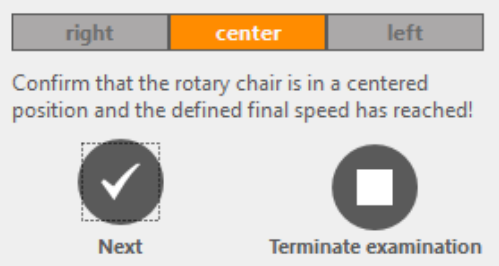


Figure 4-6 Confirmation of chair position and speed

The examination must begin with the chair in the centered position. The selected position will be shaded orange to alert the examiner.

Check the serial measurement box to perform serial measurements. Select Start to begin the testing sequence.

At the completion of all measurements for the center position, select right or left to perform UC testing at the corresponding rotary chair positions.

Select Next to confirm that the rotary chair has been moved to the specified axis to the left or right.

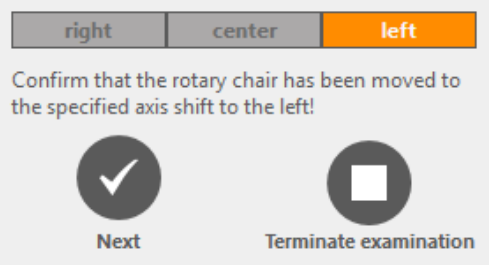


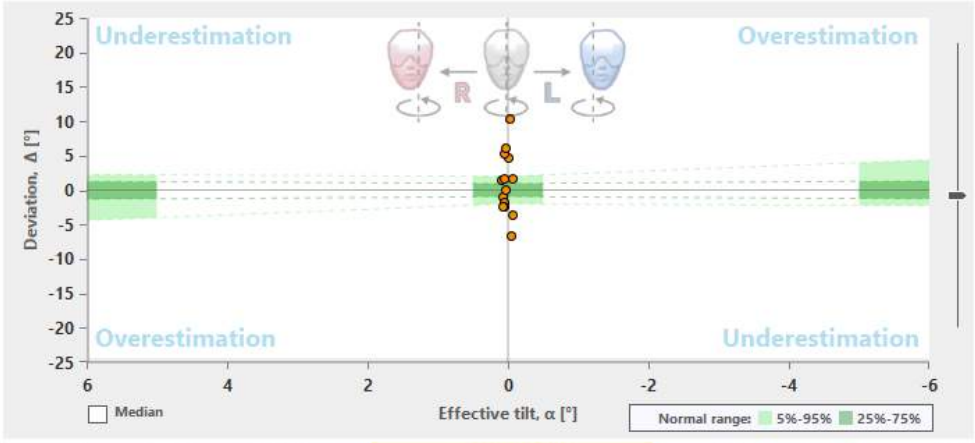
Figure 4-7 Confirmation of chair position

Repeat the steps above to complete serial measurements in the right or left positions.

4.4.6 Results diagram and measurement data table

To assist in interpretation of the results, the normal response range is indicated in the graphical diagram. The dark green shaded region represents the 25-75% range, while the light green shaded region represents the 5-95% range.

The normal range displayed for UC is based on **experimental** data obtained with an angular velocity of 300º/s and lateral displacement of 3.5 cm, yielding an expected angle of tilt of 5.59º.



right (expected: 3.6°)		center (0.0°)		left (expected: -3.6°)	
α	Δ	α	Δ	α	Δ
0.0	4.7	0.0	-35.9	0.0	6.0
0.1	-1.0	-0.1	-3.6	0.0	-2.5
0.0	-1.8	0.0	10.3	0.1	-2.4
0.0	0.1	-0.1	1.6	0.1	1.5
0.0	5.2	0.0	-6.6	0.0	1.7

Figure 4-8 UC results diagram and measurement data table

The vertical slider bar to the right of the results diagram can be adjusted up or down to change the y-axis display for Deviation Δ (º). Sliding the bar down .The permissible range (in degrees) is from -5/5º to -50/50º.

The data table displaying numerical values can be hidden by clicking the down arrow located to the right of the table. By default it will always be displayed until the examiner clicks the arrow to hide the table. The data table can again be brought back by clicking the up arrow.

When opening the findings sheet, the UC data will always be presented after the Static Tilt findings, regardless of the order in which tests were performed.

4.4.7 Unilateral centrifugation – step procedure

The following is a short form procedure for the UC test mode:

The operating instructions and the safety precautions defined by the rotational chair manufacturer must be followed!

1. Select the **Unilateral Centrifugation** tab in the navigation area of the Virtual SVV program and select Start.
2. Position the patient in the rotary chair and secure the safety harness according the instructions of the manufacturer.
3. Mount the Virtual SVV virtual reality goggle on the patient's head. Check that the head strap is secure and the virtual reality goggle is comfortable and light occluded.
4. Secure the patient's head in the rotary chair. Use the sensor display in the Virtual SVV program to check that the head is positioned upright. To avoid damage to the virtual reality goggle, ensure that it is not under pressure by the rotary chair head immobilization device!
5. Secure the handheld remote safety loop around the patient's wrist and give the handheld remote to the patient.
6. Activate the rotary chair and run it up to the selected constant angular velocity. The angular acceleration should not exceed 3°/s^2 in order to minimize patient discomfort or vertigo.

7. After reaching the selected velocity, wait for approximately two minutes before commencing with the SVV measurements. Nominally after two minutes any rotary nystagmus or subjective rotational sensations should have ceased. Caution the patient to avoid making any head movement during testing since this would elicit vertigo and discomfort!
8. Select Next to confirm that the patient's head is secured in an upright position.
9. Select Next to confirm that the rotary chair is in the correct center position. Center is always performed first.
10. Select Start to initiate the first measurement in the measurement position.
11. Wait until the patient has set the luminous line to her/his subjective vertical and confirmed via the OK button; repeat this procedure three to five times. Alternatively, select the serial measurement check box to automatically perform a series of measurements.
12. After completion of all measurements in the center chair position activate the lateral shift mechanism on the rotational chair to displace the patient by 3.5 cm to the left or right. If the lateral shift is not motor-driven, the chair must at this point be decelerated to a standstill and the lateral shift made manually. The chair must then be re-accelerated to the constant angular velocity.
13. Select the appropriate right or left measurement position on the application software and select Next to confirm that the rotary chair is in the correct left or right position.
14. Select Start to continue with Virtual SVV measurements, again taking three to five measurements per position.
15. After completion of all three positions in this manner the rotary chair can be decelerated to standstill, again at a rate of 2-3°/s^2.
16. After the rotary chair has returned to a standstill the virtual reality goggle and handheld remote can be removed and the patient can be released from the head immobilization device and rotary chair safety harness.

During the acceleration and deceleration phases it can be more comfortable for the patient to have some form of visual fixation. This can be accomplished by starting a dummy SVV measurement so that the luminous line is visible to the patient, allowing them to fixate.

The patient will have been in total darkness for several minutes for the examination. Therefore, take precaution when removing the virtual reality goggle and reintroducing the patient to ambient room light. Allow several minutes for the patient to reorient to the light.

5 Interpretation of results

5.1 Polarity convention

The following polarity convention is employed in the Virtual SVV software:

Translation to the **right**	= positive
Translation to the **left**	= negative
Rotation to the **right** (clockwise)	= positive
Rotation to the **left** (counterclockwise)	= negative

However, the animation of the software application is “as seen by the physician”. This is directly inverse to the above convention.

5.2 Over- and underestimation

When the patient sets the luminous line angle to vertical with the correct polarity, but exceeds the expected value, this is designated as overestimation. Similarly, underestimation occurs when the set angle is less than the expected value.

5.3 Example cases

The following table illustrates possible results for 0º, 15º, and -15º static tilt testing (α):

Head Tilt Angle **α**	SVV-Angle **β**	Deviation **Δ**	Interpretation
0°	0°	0°	normal
0°	5°	5°	overestimation
0°	-5°	-5°	underestimation
15°	-15°	0°	normal
15°	-10°	5°	underestimation
15°	-20	-5°	overestimation
-15°	+15°	0°	normal
-15°	10°	-5°	underestimation
-15°	20°	5°	overestimation

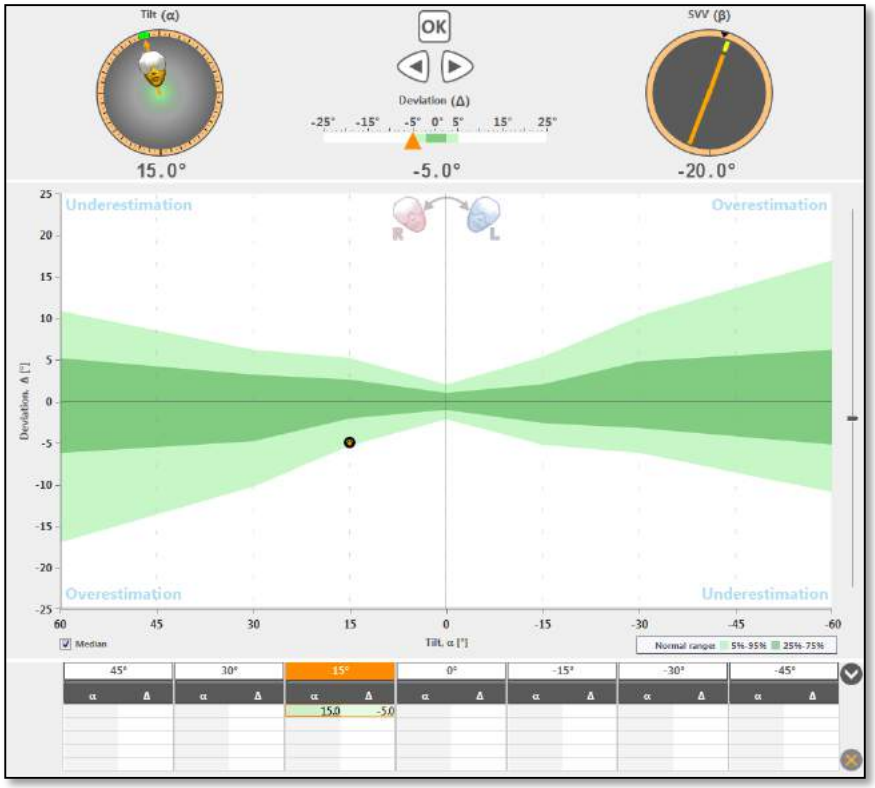


Figure 5-1 Example of a 15º tilt result (β = 20º)

6 Patient report

6.1 Notes

Notes and comments for the current examination can be entered in the Notes window located on the left side of the application at any time prior to, during, or after the tests have been performed. All comments entered will appear on the test report findings sheet.

In addition, there is free space at the bottom of the test report sheet for handwritten notes as needed.

6.2 Reporting median calculation results

Optionally, median values can be calculated for the set of values collected at each tested position by checking the box situated between the results diagram and the measurement data table. This is useful in eliminating outliers. The calculated median values are entered on results diagram as black circles. The median values are also shown on the findings sheet, if entered.

The median calculation setting will be remembered after closing and restarting the Virtual SVV application.

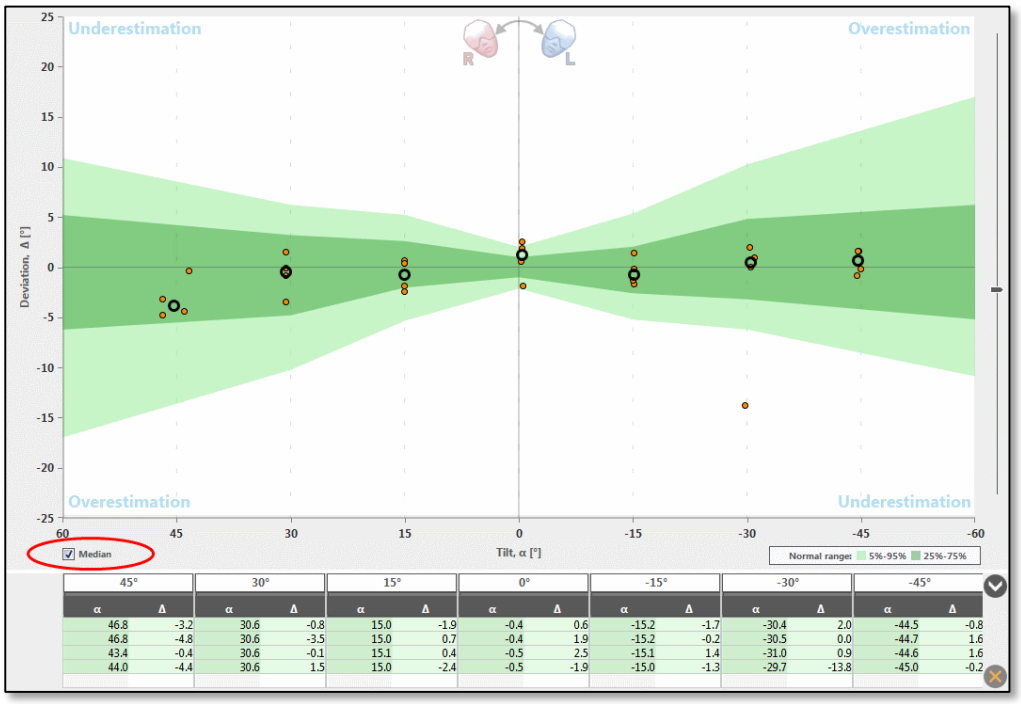


Figure 6-1 Example results with median calculation selected

6.3 Findings sheet

The Findings Sheet can be activated by clicking on the button at the top left corner of the Virtual SVV software application to obtain a screen display of the report sheet. This can then be stored in PDF format or printed as a hard copy. All test data can be exported in CSV format.

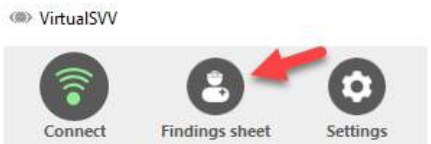


Figure 6-2 Findings sheet button

Prior to storing or printing the findings sheet, the ordinate scale can be adjusted as desired by using the slider on the right side of the results diagram. The modified scale view will then be displayed in the findings sheet.

A single-page summary is generated for each of the test modes completed. The notes area is automatically increased when additional space is required.

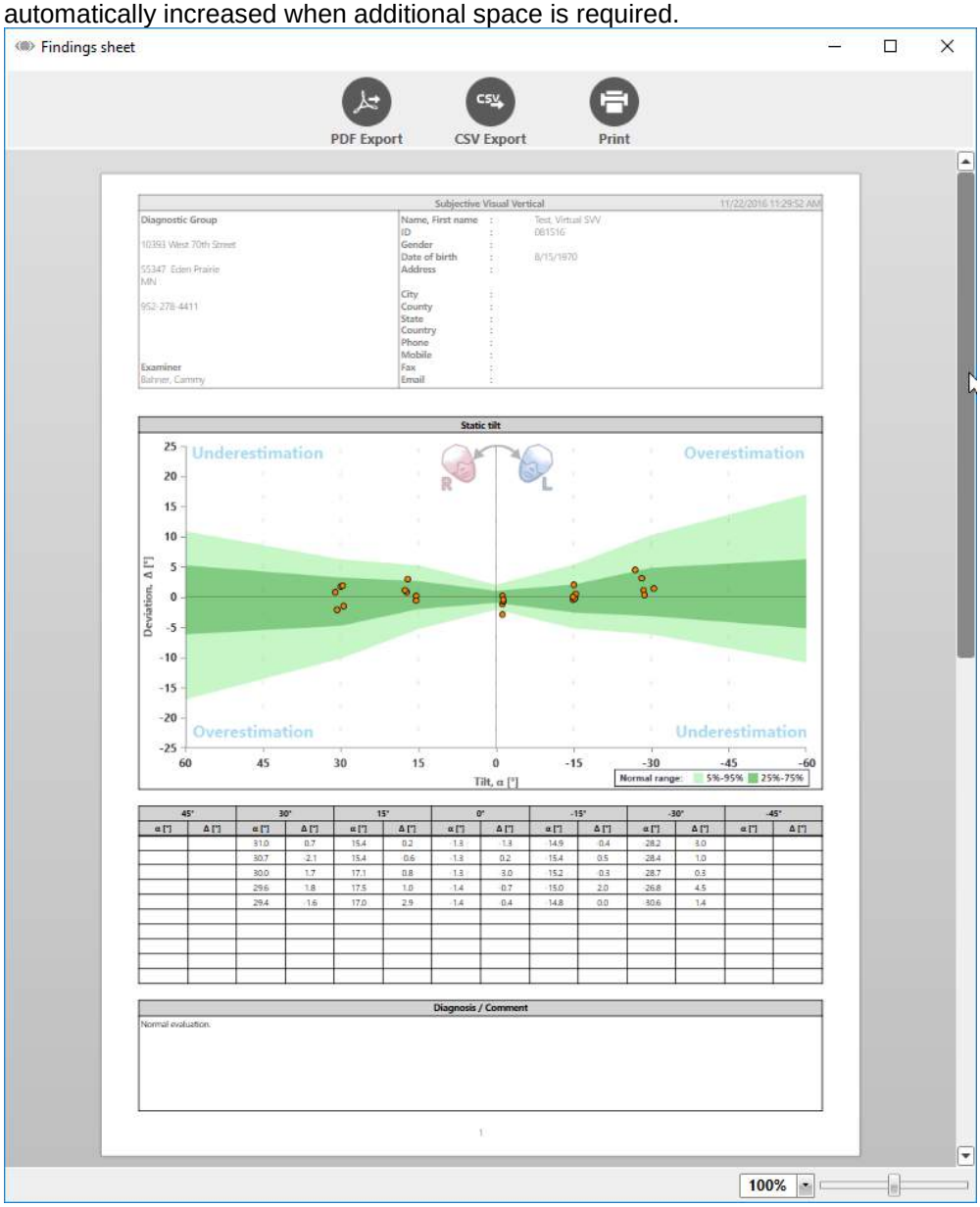


Figure 6-3 Preview of the Findings Sheet

6.4 Storing examination results

Do not forget to store the examination results prior to closing the Virtual SVV application and returning to OtoAccess™. Click the Save button in the lower left corner of the screen to store the examination results. Details of all performed tests and the associated data are transferred to OtoAccess™.

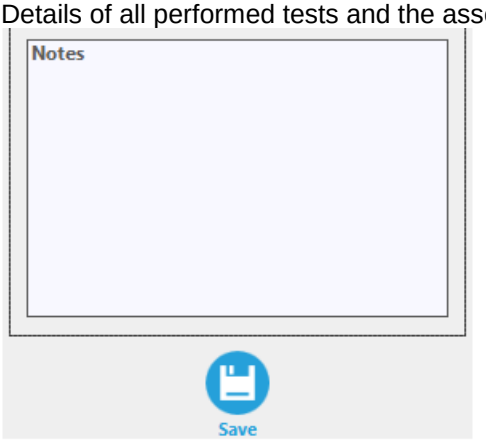


Figure 6-4 Storing examination data

Stored Virtual SVV examination results can be reopened by going to the Journal in OtoAccess™, opening the session date, then double-clicking on the Virtual SVV examination.

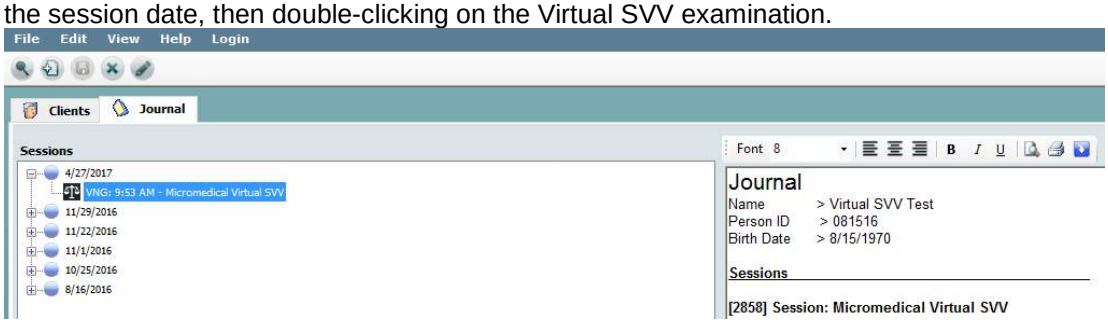


Figure 6-5 Reopening stored results from OtoAccess™ journal