Manual of the Freiburg Vision Test 'FrACT', Version 3.10.0
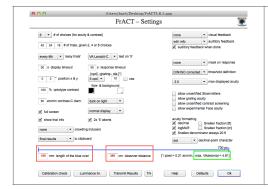
For those who don't like to read manuals: at least use michaelbach.de/fract/checklist.html for mandatory settings.

This manual assumes that the user of FrACT has a working knowledge of the principles and practice of the assessment of human visual acuity. Besides acuity, FrACT3 also can assess the contrast threshold and vernier resolution. FrACT is freely available at michaelbach.de/fract/.

Important for acuity

Two things need to be calibrated:

(1) The observation distance. Measure from screen to eye; enter value at the Settings screen (see figure below).

(2) The length of the blue ruler line on the Settings screen. This allows the program to calculate the screen resolution (pixels per mm), necessary for visual angle determination.
(1) and (2) together allow the program to calculate the visual angle of the optotypes.

- The "max VA" value (bottom right, green in the figure below, in decimal acuity units) tells you about the maximal acuity that can be obtained with your distance and screen resolution. To adequately measure normal acuity, this needs to be at decimal 2.0 or higher (VA $2.0_{decimal}$ equals -0.3_{logMAR} or $20/10_{Snellen}$).

Red left rectangle:
   the length of the blue ruler line, measured in mm.

Red middle rectangle:
   the distance from screen to eye, measured in cm.

Green rectangle:
   the maximum acuity that can be measured;
   should > 1.6 (higher means better resolution at high VA).

How to get rid of the intentionally annoying start message "Note: Calibrate…"

FrACT unfortunately has too often been used without calibration. Thus from version 3.2 onwards a strong warning message appears on every start unless you have changed both the observer distance entry and the length of the blue calibration ruler (see preceding paragraph). Both are defaulted to numbers that are unlikely to occur in practice (399 cm and 169 mm). As long as one of these remains at the default value, they are highlighted in red and that obnoxious message appears upon every start of FrACT.

Acuity

There are many possibilities to measure the 'minimum visibile', a common and sensible approach is to present an "optotype", be it a letter, a tumbling E or a Landolt C. Letters (e.g. Sloan) have the advantage of offering many choices, but require literacy and the resolution limit is not identical for the different letters.

The basic procedure starts with a very large (= easy to recognize) optotype, and having the subject or patient indicate recognition (name the letter, name the orientation of the gap in the Landolt C). Depending on the correctness of the response, next an easier or more difficult to recognize optotype is presented, ultimately aiming to determine the spatial resolution limit or threshold. Since there is a gradual loss of likelihood to respond correctly with decreasing size, the threshold must be expressed as a probability. The best choice is to set the threshold recognition rate in the middle between 100% and the guessing rate (12.5% in the case of 8 choices), 56.25% for this example. This means that at the "acuity value" nearly half the optotypes are not recognized correctly. This may initially appear counter-intuitive.

An additional procedural detail is the "forced choice" principle. This means that the subject needs to respond even if they cannot even make out the optotype at all. They have to give their best guess, which may be a random guess. This is a way to reduce the influence of the "response criterion", that is whether the subject is timid (only responding when absolutely certain) or dashing (making wild guesses). Thus incorrect responses will enter into the procedure, which also may appear counter-intuitive.

To control the sequence of optotype presented and arrive at a threshold estimate, FrACT employs the "Best PEST" procedure. This means that the program determines the most likely position of the threshold, given the optotype sizes and responses so far, and then presents the optotype exactly at the current threshold estimate, thus maximizing information gain.

Acuity with tumbling

The E shape in the tumbling E has the same basic dimensions as the Landolt C, but is only presented in one out of 4 possible orientations.

Acuity (Sloan) Letters

In ETDRS charts these 10 Sloan letters are used: CDHKNORSVZ. In FrACT, the letters are vector shapes derived from measurements of the Sloan font. As response the appropriate letter is typed. Any non-Sloan letter is ignored.

Contrast

Like the Pelli-Robson or the Mars charts, contrast is not assessed selective per spatial frequency using sine-wave gratings. Rather, the large Landolt C optotype is composed of a mixture of low to medium spatial frequencies (as can be determined via a Fourier analysis). Contrast sensitivity at high spatial frequencies and acuity tap the same physiological bottleneck and thus would be redundant. Since disease effects are not specific for spatial frequency, assessing the mixture contrast sensitivity besides visual acuity best preserves precious measurement time.

Contrast format
Of the 4 different contrast definitions in use, FrACT reports Michelson and Weber values in the thresholding contrast test. Contrast c_M based on the Michelson formula:

$$c_M = 100\% \cdot \frac{l_{max} - l_{min}}{l_{max} + l_{min}}$$

where l_{max} & l_{min} are the luminances of the bright and dark parts, respectively. Contrast c_W based on the Weber formula:

$$c_W = 100\% \cdot \frac{l_{max} - l_{min}}{l_{max}}.$$

Conversion Michelson↔Weber:

$$c_W = 2 \cdot \frac{c_M}{1 + c_M}, \quad c_M = \frac{c_W}{2 - c_W}.$$

Thus for low contrasts, the Weber contrast value is close to 2× the Michelson contrast. For automatic export the unit depends on the test type, the contrast

unit is given next to the value. When there is no unit given, it's Michelson. For conversion between formats see above and also the appendix. Grating contrast is always in Michelson.

Grating

Starting with version 3.7.1, a grating test has been added by request. This is currently in an experimental phase, feedback welcome. Since the grating test does not use anti-aliasing (yet), ceiling effects are to be expected in normal subjects around the peak of the CSF. The grating is presented in a circular window with a narrow Gaussian taper. Gratings are always presented in 1 of 4 orientations; spatial frequency (in cpd) and stimulus extent (in degrees diameter) are selected under Settings in the second column.
Response keys: for vertical use cursor up or down, for horizontal left or right; for oblique directions the corresponding choices on a numerical keypad (as depicted on the main screen, right).

Contrast Screening DEACTIVATED

This type of contrast assessment follows the rules for German traffic licensing. The resultant value is the "contrast ratio" contrast$_{Ratio}$, yet another measure for contrast other than Michelson or Weber (see appendix). Landolt Cs corresponding to an acuity of $0.1_{decimal} = 1.0$ logMAR are presenting in a descending sequence with up to 5 presentations per contrast level. The number of orientations of the Landolt C (4/8) is controlled via the appropriate Settings entry. The criterium for "seen" is 3 of 5 correct responses. Aiming for rapid assessment, and following the DOG (Aulhorn) rules, only the following levels are tested: 1:23, 1:5, 1:2.7, 1:2, 1:1.67, 1:1.47, 1:1.25, 1:1.14. To achieve DOG luminance levels, an appropriate neutral density filter has to be placed in front of the screen or worn by the subject. To convert to Michelson/Weber for the DOG/Aulhorn formats see appendix.

Calibration (Luminance Linearization) is mandatory. To check on contrast calibration, hold the shift key while pressing the "Contr. Screening" button. A contrast staircase appears, allowing to measure contrast levels with a spot-meter. Any key-press returns you to the main screen.

[Contrast Screening is disabled by default and can be enabled in the Settings screen.]

Vernier acuity

Vernier acuity is nearly 10× better than optotype acuity. In FrACT, Vernier acuity is based on two-line-segment-alignment. Since only 2 choices are possible, many trials are necessary; the default setting is the lowest limit, more is better. Enter the displacement of the upper line relative to the lower line through the cursor keys or the digits 4 / 6. Since Vernier acuity is so high, the considerations in "Note on display resolutions" (below) are particularly pertinent – you may need 10× higher distance to your display unit.

Nomenclature

There exist too many traditions to format visual acuity; FrACT caters for a number of them. The Snellen fraction or Snellen ratio or Snellen acuity indicates both the distance where the optotype was recognized and the distance where a normal observer would have recognized it. While this detail is welcome, there are disadvantages:

- Depending on whether basing distance measures on feet or yards, marked rounding errors occur.

- Ensuring a logarithmic progression of acuity values can lead to awkward Snellen fractions.

- It is difficult to average Snellen fractions.

When dividing the Snellen acuity, that is recognizing the Snellen fraction as a fraction, a single number results: the decimal acuity. So a decimal acuity of 1.0 corresponds to a Snellen acuity of 20/20 and is usually considered normal (although young normals typically have nearly twice this value when measured correctly). A disadvantage of the decimal acuity is that its progression is not logarithmic, and while seemingly easy to average this should not be done, the geometrical mean would be correct. Another measure of acuity is "logMAR". Since MAR = the Minimum Angle of Resolution is just the inverse of decimal acuity, logMAR is the logarithm (base 10) of this. This measure has the advantage that it has the right logarithmic progression built-in and it can be easily averaged. A major disadvantage is that the better acuity the lower the logMAR val-

ue, quite counter-intuitive. A pity that "logVA" has not been chosen. logVA is just the negative of logMAR and has all of its advantages without the disadvantage.

Whichever of these measures you prefer, they can be easily converted into each other when distance is known. Here are formulas and more detail: https://michaelbach.de/sci/acuity.html.

Limitations in accessible acuity

There are technical limits on the highest and lowest acuity, which depend on the display resolution in pixels per inch and on the distance. For distances of ≥ 3 m the standard monitor resolution is fine. Lower distances only work with devices with very high spatial resolution (e.g. OLEDs, readily available in 2018) or in low acuity situations, see the "Note on display resolutions" below. If you want to assess low vision (0.1 = 20/200 and below) a distance to the display of 0.5–1.0 m is sufficient (possibly necessary).

Limitations in contrast

Assessment of the contrast threshold requires good gamma correction (display linearization). The *best* approach is to use a dedicated screen calibrator (e.g. Spyder by DataColor) to set your computer's system gamma to 1.0, and then set FrACT's gamma to 1.0 as well (on the screen Settings>Luminance linearization). The screen will look washed out, but that's fine here.

The human contrast threshold is about 0.3% Michelson contrast. Thus, the usual 8 bit screen depths are not enough. FrACT solves this by dithering [Bach 1997], increasing luminance resolution by a factor of 4, thus allowing to resolve human thresholds.

Observation distance is not so critical as for acuity, since the optotype's size typically is markedly above the spatial resolution limit. 1 m or more is fine. To short a distance might resolve the dithering, you don't want that.

Options on the Settings screen

Numerous options have been added to FrACT over the years, often on user request. The following list follows the sequence in FrACT's "Settings" dialog.

- **# of choices (for acuity and contrast)**
  The number of optotype directions (or response choices) for Landolt Cs can be selected between 4 and 8, and the threshold algorithm accordingly selects a guessing rate of 25% or 12.5%, respectively. Tumbling E has always 4 choices, Sloan letters always 10, Hyperacuity always 2 choices. *{Default: 8}*

- **# of trials {for 2 / 4 / 8 choices}**
  The number of trials can be set to any reasonable number. A multiple of 6 (e.g., 18 or 24) is preferred so that the last trial is a "bonus trial" (see next item below), leaving the subject with a success experience for the last trial. The number of trials is separate for the 4 vs. 8 direction condition, because the latter will require fewer trials for comparable accuracy. For the hyperacuity test, there are only 2 possible choices, and consequently even more trials are necessary. Tumbling E will use the 4 choices selection, the trial number of the Sloan letters will be based on the 8 choices selection (because the guessing rate of 12.5% and 10% does not differ much). *{Default: 42 / 30 / 18}*

- **'easy trials' or 'bonus trials'**
  These are trials where the presented optotype is a multiple of the currently assumed threshold. When enabled, every 6th trial, starting with trial 12, is such a bonus trial (or every trial, which was a special request). While this motivates many subjects, these trials do not gain much information on the threshold. The number of 6 was chosen on informal experience. Bonus trials increase the test value by 3 for acuity and contrast, and by 5 for hyperacuity (Vernier). *{Default: every 6th}*

- **Which test on '5'**
  For extended measurements, it can be useful to control everything through the remote keypad (see the note on response keys below). This setting selects which test is started by pressing the central '5' key. Options are:
  «VA Landolt C | VA tumbling E | VA Sloan letters | VA Grating | Contrast Landolt C | Contrast grating | Vernier | none».
  {Default: Landolt C}

- **Timeouts**
  There are two timeouts, one controls the time the optotype is visible, the other limits reaction time.
  – Display time can be limited to a certain number of seconds from 0.1 to 999; when exceeded, the optotype disappears.
  – Response time can be limited to a certain number of seconds from 1 to 999, e.g. 10 s; when exceeded, an incorrect response is assumed and a new trial is started. Such time limitation was required for a European traffic expertise (not any more). Ten seconds can already be challenging for elderly subjects. *{Defaults: 30 s / 30 s}*

- **Position**
  The optotype can be displaced relative to the center of the screen. This allows for systematic variation of eccentricity. *{Default: (0°, 0°)}*

- **Optotype contrast**
  For acuity testing, the contrast value of the optotype must be near 100% for the standard definition of visual acuity; its value can be set from 1%–100% for specific questions. For precise high contrast values stray light must be avoided. Contrast is entered in Michelson (!) format, see "Contrast format" above for the definition or appendix.
  Negative values: inverted optotype (light Landolt C on dark background). *{Default: 100%}*

- **Optotype color (fore- & background)**
  A color for the Landolt C ("foreground") and the color for the background can be separately selected. Since this is very difficult to match correctly to the **Optotype contrast** setting (immediately to the left), the following rule applies: whenever the colors are changed, the contrast is reset to 100%. Whenever the contrast is set, the colors are reset to black and white.
  {Default: black on white}

- **Contrast-C: dia(meter)**
  The diameter for contrast testing, measured in arc minutes. The Pelli-Robson letters are suggested to be used at 0.5° full letter width.
  {Default: 30'}

- **Contrast-C: polarity**
  The optotype can be shown **dark-on-light** or **light-on-dark**. *{Default: dark-on-light}*

- **Full screen**
  Controls whether FrACT will cover the full screen or stay in window mode. *{Default: on}*

- **Display transformation**
  To manipulate observation distance, mirror arrangements (high-quality front surface, of course) or afocal telescopes can be used. Since these can flip the orientation, corrective transformations can be applied. Options are: «normal | mirror horizontally | mirror vertically | rotate by 180°». *{Default: normal}*

- **Show trial info**
  When on, shows current trial number, total number of trials, and the current threshold (acuity: in decimal) in tiny letters at top left. In the "ESU" setting the font size is increased.
  {Default: on}

- **2× '5' aborts**
  To abort any run at any time by pressing the key '5' twice (once would not be enough, could be pressed accidentally loosing valuable data). For some situations, users wanted to disable this feature. *{Default: on}*

- **Crowding inducers**
  Options are:
  «none | flanking rings | row of optotypes | frame (ring) | frame (square) | flanking optotypes».
  The distance to the flankers can be selected at «2·gapsize | 2.6 arcmin | 30 arcmin».
  {Default: none}

- **Vernier type**
  Options are:
  «2 lines | 3 lines». There's also a "scale" for low vision work. *{Default: none}*

- **Results → clipboard**
  To facilitate in-depth analysis, all trial-by-trial results can copied to the clipboard at the end of a run. Then one can –without quitting FrACT!– switch to a concurrently running spreadsheet and paste-in the run details. They comprise date, time, and final acuity. When the "full history" option is chosen, for each trial the presented orientation, responded orientation and reaction time is provided as well. See below for a full format specification. [The clipboard is the place in the computer were any copy or cut operation places its result, ready to be pasted elsewhere.] For correct transfer of data, you *must* set the appropriate character (for your country, comma or dot) for the decimal mark beforehand. Copying to the clipboard does not work when FrACT is embedded in a browser window (a security restriction), only when stand-alone. Options are: «no | final results only | full trial history».
  {Default: off, to be less invasive on the host computer system}

- **Visual feedback**
  Feedback can be given on the correct position by an enlarged red target. Options are: «none | always | on correct | with info | info on incorrect».
  {Default: «none»}
  To give feedback that a key was pressed, it is possible to add the information on the correct direction, or only when incorrect. Version 3.8.1 extended the feedback options and harmonised the visual and auditory feedback options. The visual feedback with info of direction is a very large Landolt C. See next item for more info in feedback.

- **Auditory feedback**
  It was unclear how feedback might affect the threshold outcome; Lew Harvey (personal communication) opined that feedback can improve criterion stability for inexperienced subjects, but may increase criterion fluctuation for highly experienced observers. Herzog MH & Fahle M (1997) [The role of feedback in learning a vernier discrimination task. Vision Research 37:2133–2141] does not sufficiently clarify it either. We found that feedback markedly enhances perceptual learning [Heinrich SP, Krüger K, Bach M (2011)]. More recently [Bach M, Schäfer K (2016)], we discovered that for typical clinical trials (up to 6 runs at 24 trials each) feedback does *not* affect the results *nor* reproducibility, but markedly *enhances* subject comfort. So you have the choice: The subject's response can be acoustically announced through a short tone, options are: «none | always | on correct | with info». "With info": two different sounds on correct/incorrect.
  {Default: «with info»}

- **Auditory feedback when done**
  Want to hear a "success sound" when the last trial has been responded to? Options are: «off | on». *{Default: «on»}*

- **Mask on response**
  There was justified criticism that immediate replacement of one optotype by the next one can convey hyperacuity cues. So a 200 ms intervening mask can be chosen. The mask is either the background color or a random pattern.
  Options are: «none | 200 ms background | 200 ms random 1500 ms background».
  {Default: «none», for historical reasons, but 200 ms background is recommended}

- **Threshold definition**
  A bracketing threshold strategy (called "psychometric" in the options list) will result in a higher threshold than an ascending strategy (as typical for chart testing, and detailed in EN ISO 859). Furthermore, in EN ISO the threshold criterion is "6 of 10" or 60%, whereas the Best PEST assumes 56.25% (for 8 directions). Assuming a typical psychometric slope, both effects lead to a slight underestimation of "psychometric acuity" by the EN ISO strategy, which can be corrected for by multiplying the results of the bracketing strategy by 0.892.
  {Default: DIN/ISO corrected}

- **Max displayed acuity**
  Due to the laws of chance, un-physiological high results can occasionally obtain ("lucky responders"). Not all users have a background in statistics, and they might see this as a defect of FrACT. So an "acuity ceiling" can be applied, from 1.2 to unlimited (conventional acuity charts implicitly also have such ceilings). The clipboard export will always contain the unlimited value. *{Default: 2.0}*

- **Display incomplete runs**
  This setting allows to display premature results. Normally, when a run is aborted (by pressing <esc> or '55'), no result is displayed but the message "aborted". *{Default: «off»}*

- **Allow uncertified Sloan letters**
  The test variant "Acuity letters" presents Sloan letters rather than Landolt Cs. Since I have not yet formally certified this option, it is disabled by default; use at your own discretion.
  The letter C from the Sloan font is identical in shape to a Landolt C, in FrACT it is also identical in size. Sloan letters are scaled exactly like Landolt Cs, and the corresponding acuity can be derived through the letter C (gap height is 1/5th letter height).
  The sloan letters are based on vector graphics that I based on the original definition, not on the slightly incorrect "Sloan font". *{Default: «on»}*

- **Allow uncertified Contrast Screening**
  This test variant was introduced in April 2011 and needs to be formally certified. *{Default: «off»}*

- **Allow experimental Face acuity**
  This test was used by [McCulloch, Loffler, Bruce, Dutton, Bach (2011)]. *{Default: «off»}*

- **Acuity formatting**
  There exist too many traditions to format visual acuity; still FrACT attempts to cater for them. Available are «decimal VA | logMAR | Snellen [m] | Snellen [ft]».
  "Snellen" is shorthand for the Snellen fraction. The best measure IMHO would be logVA, which is simply –logMAR. Like logMAR, logVA has the desirable property of approximately normal distribution, but has an intuitive direction (larger = better). If all formats are deselected, decimal VA is re-selected. Here are formulas and more detail: https://michaelbach.de/sci/acuity.html. *{Default: decimal VA + logMAR}*

- **Snellen denominator 20 ft**
  The Snellen fraction only makes real sense, if the true distance is put into the denominator. However, many are so attached to the "20" scheme, that they use it even with reading acuity. Thus I added this setting on request against my better judgment ;-). *{Default: «on»}*

- **Character for decimal mark**
  Different countries use different number formatting; furthermore different post-processing programs can require different formatting. The setting for the decimal mark, a dot or a comma, applies both to the clipboard export and to the large result display after a finished run. Be sure to select the right value, otherwise Excel might convert your results to dates! *{Default: '.'}*

Exporting results

There are a number of ways to export the results obtained by FrACT for further processing. Obviously, they are depicted in large friendly letters on the testing screen in a format that you select in the Settings screen. I strongly believe that experimental results should never by manually typed, rather automatically transferred as efficiently as possible. Currently the following three options exist:

- **Export to clipboard after each run**
  This is controlled from the Settings screen by way of the "Results → clipboard" setting. If enabled, this copying is automatic, don't press ctrl-C or ⌘C. For details on the format of the "full history" see below. [Does not work when FrACT is embedded in a browser, for security reasons.]

- **Export to clipboard of last 10 runs (persistent history)**
  This is a "hidden" export option, designed for having a subject run a series of runs, then exit the program. Later you can start FrACT again and collect all the results at once. Format is "full history", in addition there is a line with the test name and another with an ever-incrementing run count. This "persistent history" (persistent because it survives FrACT start/stop) is retrieved and placed on the clipboard by typing the letter 'z' without any obvious indication what has happened. Does not work when FrACT is embedded in a browser window (security).

- **HTTP transmit results**
  This option transmits the run results by way of a HTTP GET protocol for immediate transfer to an on-line database (where a CGI script runs). The message consists of a self-descriptive key-value sequence. When enabled, buttons will appear so that after each run the message can be sent with info on eye tested (OS, OS, OU). There is also a case ID field with a time-out so that results from different patients are not intermingled. Obviously this requires an appropriate infrastructure which should be available from your competent IT persons. The details of target URL etc. are set on the "Transmit Results" screen which is reachable from the Settings Screen.

- **File »FrACT3_lastTrialResult.sol«**
  Somewhere on your computer a file named as above is created (search for it). Discard some leading bytes and you will have the same string that would be exported to the clipboard. Useful for fully automated environments.

Format of the "results → clipboard" feature

If enabled in Settings ("Results → clipboard"), the results are copied to the system clipboard after every run, ready to be pasted into any spreadsheet program. Be sure you have set the correct character for the decimal point *beforehand*. The format for the data exported to the clipboard is as follows:

Row 1									
date [yyyy-mm-dd]	time [hh:mm:ss]	<final result>	result unit	test name	<distance>	dist. unit	<n>	"nTrials"	
Subsequent rows									
Trial #	value presented (decimal)	orientation angle presented [°]	orientation angle responded [°]	correctness (1=yes, 0=no)	reaction time [ms]				

For Sloan letters, the letters rather than the angle are entered as "orientation". The "result unit" is "1/arcmin" for acuity, "% Weber" for Landolt C contrast, etc. For Sloan-letter acuity, the letters are given rather than orientation. For further processing, these simple calculations can be done in your spreadsheet or subsequent analysis:

logMAR (advised): $VA_{logMAR} = -\log10_{10}(VA_{decimal})$.

logCS (advised): For optotypes, the Weber contrast definition is the appropriate one. For further processing, convert the "%contrast$_{Weber}$" result as follows: $c_{logCS} = \log_{10}(100/\text{"%contrast}_{Weber}\text{"})$.

[In version 3.8.1, I also added the feedback options to the results – who needs that? xx]

Shortcuts

Key	Action
5	start a test as selected in Settings
a	start acuity Landolt C
e	start acuity tumbling E
l	start acuity Letters
c	start Contrast
m	start Contrast screening
v	start Vernier
g	start Grating
u	settings (from: setup)
b	aBout
h	Help
t	Test calibration
q or x	Quit = eXit
k	Kindergarten preset (careful!)
z	full history of last 10 runs → clipboard

A note on display resolution and possible acuity values

A severe limitation for all computer tests is set by the properties of the VDU (visual display unit). Typical CRTs (cathode ray tubes) and LCDs (liquid crystal displays) have a "dot pitch" (the distance between the centers of two pixels) of around 0.2 mm. Acknowledging that the smallest Landolt C has 1 pixel gap size, the highest possible acuity (VA_{max}) depends on pixel size s_{min} and distance d as follows:

$$VA_{max} = 1 / (60 \cdot \arctan(s_{min}/d))$$

or, easier and good enough for the small angles related to acuity:

$$VA_{max} = d/(s_{min} \cdot 3438).$$

As an example, assume a VDU with a pixel size of 0.2 mm at a distance of 1.35 m. Thus the smallest possible optotype would correspond to VA=2.0 or 40/20 Snellen fraction. So this VDU would be perfectly fine at 1.35 m and above, especially for standard testing distances of 4 m (EN ISO) or 20 feet, and even high acuities would be well resolved. However, for near vision (e.g. at 30 cm), the smallest possible optotype would correspond to a VA of 0.3/1.35= 0.2 or 20/1000, clearly not sufficient for normal subjects.

Simple rule: standard VDUs are fine to assess acuity at a distance of 2 m and higher.

For closer distances, especially reading acuity, special VDUs are required. In 2018, this is not a problem anymore: either use OLED micro-displays, or other "retina-resolution" type of displays (contact me for suggestions).

At the low acuity range the limit is that one optotype fills the entire screen (this may transcend the definition of acuity). Should you be interested in (ultra) low vision, make sure to note the lowest acuity that can be obtained, to classify such results accordingly and recognizing possible floor effects.

For Vernier acuity, the same considerations apply, but are more stringent: Since the threshold angle for Vernier resolution is about 10 times smaller than that for standard acuity, one needs to aim for 10× better angle resolution – higher distance, or smaller pixels.

A note on the response keys (remote response entry)

I find it *very* advantageous for most situations if the subjects control the test themselves by pressing the appropriate buttons. They start a run by pressing '5' and use the pertinent response direction keys. For this, a remote numerical USB-keypad with extension cord is very useful.
See michaelbach.de/fract/ under button **Details**.

Another aspect: some subjects tend to press the keys for a prolonged time, triggering the keyboard auto-repeat, causing inadvertent response errors. So I suggest switching off keyboard repeat using the appropriate facilities of your operating system.

Calibration

Optotype size is measured in terms of visual angle, but rendered by the computer on a pixel raster. The two are easily related through resolution of the screen and observation distance, since VDUs typically have a sufficiently high spatial linearity. In the "Settings" dialog, a blue ruler line appears whose length is measured in mm, and the value entered in a field next to the observation distance in cm. FrACT calculates from these measures the highest obtainable acuity, assuming one pixel as the smallest gap size, and displays this next to the distance input field, thus immediately giving feedback whether the distance is suitable to the range of acuities to be measured. An optional calibration-check screen can draw an equidistant square grid in degree units to check on the aspect ratio –pixels must be square– and geometric screen linearity.

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Document History

2018-07-23	modify for 3.10.0
2017-06-03	added 3.9.9 changes
2016-10-27	added new options for 3.9.8
2014-11-24	for Vs 3.9.1: added incomplete run setting, clarified result conversion functions, info on threshold tracking is intentionally missing
2014-06-23	clarified contrast units and incorporated minor changes for vs. 3.8.2, some stylistic improvements
2013-11-30	added changes for vs 3.8.1, minor text improvements
2013-05-16	clarified number definitions in the contrast conversion sheet
2013-03-27	added changes as implemented in vs 3.8
2012-08-09	clarified aspects of the Results→Clipboard, especially for contrast
2012-01-30	added response keys for grating (thanks, Olivier!)
2012-01-20	typo correction (Vernier section), and more stress on needs for VDU resolution (thanks, Ralf!)
2011-11-09	added details to result exporting
2011-10-27	corrected a few typos, stressed that pixel limitations apply to Vernier even more than to acuity
2011-09-28	added clipboard format for Vernier and appendix on contrast definitions
2011-06-30	added info on the contrast staircase, extended display transformation
2011-05-20	clarified contrast screening being disabled by default
2011-05-12	corrected contrast definition transformations
2011-05-03	overhaul for vs 3.7
2010-09-01	corrected Weber contrast (surround luminance in the denominator), vs 3.6.3
2010-07-28	added "show trial info" info (3.6.2) and stylistic improvements
2010-05-07	overhaul for vs 3.6
2010-03-23	added rationale for the type of contrast test
2010-02-12	added info on Sloan letters and Vernier response, various stylistic corrections
2009-12-13	added shortcut info
2009-11-24	modified for vs 3.5.5, reformatted
2009-10-29	modified for vs 3.5.4 (blue ruler line, more calibration hints, Weber contrast)
2009-07-21	modified for vs 3.5.2 (contrast polarity) and stylistic corrections
2009-05-27	added modifications for Vs. 3.5 (mainly Preferences → Setup)
2009-04-21	added modifications of Vs. 3.4.3 (display-timeout, mask, sound)
2008-11-16	added explanation of the warning message at startup
2008-11-12	added advice on deactivating keyboard repeat
2008-09-18	corrected an outdated link from this manual to the site
2008-04-26	began to extend this to a full manual by writing the preamble, some changes because of FrACT3
2007-11-27	corrected and extended the formula for max acuity, added info on decimal point
2007-11-19	added contrast definition and bonus for contrast & hyperacuity
2007-06-21	added information about negative contrast for acuity
2007-06-06	added information on new preferences and micro-displays
2007-05-24	editorial corrections
2006-09-13	added clipboard format
2006-04-19	corrections
2005	begun, former file name "FrACT_Options.rtf"

Contrast values based on contrasting contrast definitions

| Luminance examples (constant surround) | | | | | *Prof. Michael Bach, Vs 2011-09* | | |
Luminance$_{Target}$	Lumance$_{Surround}$	Contrast$_{Michelson}$	Contrast$_{Weber}$	logCS$_{Weber}$	ContrastRatio	C$_{Aulhorn}$
99,9 cd/m²	100 cd/m²	0,050 %	0,1 %	3,00	1,001	
99,01 cd/m²	100 cd/m²	0,50 %	1,0 %	2,00	1,010	
97,56 cd/m²	100 cd/m²	1,235 %	2,4 %	1,61	1,025	
95,24 cd/m²	100 cd/m²	2,44 %	4,8 %	1,32	1,05	
87,72 cd/m²	100 cd/m²	6,54 %	12,3 %	0,91	**1,14**	**1 : 1,14**
80 cd/m²	100 cd/m²	11,1 %	20,0 %	0,70	**1,25**	**1 : 1,25**
68,03 cd/m²	100 cd/m²	19,0 %	32,0 %	0,50	**1,47**	**1 : 1,47**
59,88 cd/m²	100 cd/m²	25,1 %	40,1 %	0,40	**1,67**	**1 : 1,67**
50 cd/m²	100 cd/m²	33,3 %	50,0 %	0,30	**2,0**	**1 : 2,0**
37,04 cd/m²	100 cd/m²	45,9 %	63,0 %	0,20	**2,7**	**1 : 2,7**
20 cd/m²	100 cd/m²	66,7 %	80,0 %	0,10	**5,0**	**1 : 5,0**
4,35 cd/m²	100 cd/m²	91,7 %	95,7 %	0,02	**23**	**1 : 23**
1 cd/m²	100 cd/m²	98,0 %	99,0 %	0,004	100	
0,1 cd/m²	100 cd/m²	99,8 %	99,9 %	0,0004	1000	

Conversion between contrast definitions

Prof. Michael Bach 2011-09

$$\text{contrast}_{Michelson} = 100\% \cdot (L_{max} - L_{min}) / (L_{max} + L_{min})$$
$$\text{contrast}_{Weber} = 100\% \cdot (L_{max} - L_{min}) / L_{max}$$
$$\text{logCSWeber} = \log_{10}(1/\text{contrast}_{Weber}) \quad \text{[CS: contrast sensitivity]}$$
$$\text{contrast}_{Ratio} = L_{max} / L_{min}$$
$$\text{contrast}_{Aulhorn} = 1:\text{contrast}_{Ratio}$$

Note: 100%≙1.0	**Entry defininition**			
Target def.	Michelson	Weber	Ratio	logCS$_{Weber}$
Michelson	1	W / (2 − W)	(R − 1) / (R + 1)	[log(1/W(M))]$^{-1}$
Weber	2 · M / (1 + M)	1	1 − 1 / R	1/(10^{logCSW})
Ratio	(1 + M) / (1 − M)	1 / (1 − W)	1	[log(1/W(R))]$^{-1}$
logCSW$_{eber}$	log(1/W(M))	log(1/W)	log(1/W(R))	1