TELLER ACUITY CARDS® TAC II
TAC II

REFERENCE AND INSTRUCTION MANUAL

Revised Edition, 2014

Precision Vision®

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Version 08-20

TELLER ACUITY CARDS® II HANDBOOK

The Teller Acuity Cards® II were developed at the Department of Psychology, University of Washington, Seattle, Washington through the efforts of Dr. Davida Teller and a research team. Dr. Velma Dobson of the University of Arizona, Dr. Luisa Mayer of the New England College of Optometry and Dr. Rowan Candy of Indiana University have conducted follow-up development and testing of the Teller Acuity Cards® II.

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2009 Editions

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INTRODUCTION

Standard assessments of adult visual acuity are based on subjective verbal responses from the patient. With well-motivated children and adults this type of procedure is adequate. Assessment of vision in infants and pre-verbal children, however, necessarily requires unique strategies.

A widely-used strategy for measuring visual acuity in infants and young children, called Preferential Looking Testing, takes advantage of infants' and children's natural preference for looking at a bold pattern rather than a blank, homogeneous area. The Teller Acuity Card® procedure, a Preferential Looking Testing method that was developed for use in clinical settings, provides a quantitative assessment of visual acuity for pattern detail that can be helpful in evaluating vision in patients with bilateral and unilateral ocular disorders.

As described in Appendix A, the Teller Acuity Cards® were developed to fill the gap between formal, quantitative but time-consuming, research-laboratory preferential looking techniques for acuity assessment (Teller et al. 1974; Gwiazda et al. 1978; Teller 1979) and informal, qualitative assessment of fixation and tracking of visual targets typically used clinically to evaluate the presence of vision in infants and young children. The Teller Acuity Card® procedure combines the high-quality grating stimuli used in formal laboratory testing with the observer's subjective judgment concerning qualitative aspects of the child's response to those stimuli. The procedure is easy to use and requires only uncomplicated equipment.

It is important to emphasize that grating acuity (the type of visual acuity that is measured with the Teller Acuity Cards® and other preferential looking methods) is not equivalent to acuity for symbols or letters, the type of acuity that is typically measured in older children and adults. Grating acuity is a measure of "resolution" acuity, while symbol or letter acuity is a test of "recognition" acuity. In some disorders, grating acuity overestimates visual acuity, in comparison to recognition acuity, most notably in disorders of the macula and the optic nerve, and in strabismic amblyopia. Thus, whenever a child is capable of symbol matching or naming, recognition acuity should be tested in preference to grating acuity.

The original Teller Acuity Cards® were manufactured by Vistech Consultants, Inc. When they ceased production of the cards in 2003, the original developers worked with Precision Vision Inc. to develop a new version of the cards called Teller Acuity Cards® II.

EQUIPMENT

ACUITY CARDS

Complete set

A complete set of Teller Acuity Cards® II consists of sixteen 25.5 x 55.5 cm cards, each of which has an approximately 4-mm diameter peephole at the center. Fifteen of the cards contain patches of square-wave gratings (vertical black-and-white stripes), approximately 12.5 x 12.5 cm in size, centered on one half of the card. The gratings have a 50/50 duty cycle (black bar width = white bar width), with a contrast of approximately 60-70%. The left and right edge of each grating is finished with a black or white stripe of 1/2 of the usual width in order to minimize the visibility of the edge of the grating. These 15 cards have the following spatial frequencies (specified in cycles/cm): 0.32, 0.43, 0.64, 0.86, 1.3, 1.6, 2.4, 3.2, 4.8, 6.5, 9.8, 13.0, 19.0, 26.0, and 38.0, with approximately one-half (½) octave difference in spatial frequency between cards. [NOTE: A cycle consists of one black and one white stripe. An octave is a halving or doubling of spatial frequency, e.g. from 10 to 20 cycles/cm, or in Snellen terms a halving or doubling of the denominator of the Snellen fraction, e.g. from 20/40 to 20/80. See Appendix D for details.]

The 16th ("Low Vision") card contains a larger, 0.23 cy/cm grating (2.2 cm/stripe). This grating begins at the edge of one side of the card and continues for about 22 cm, with the grating spanning from the top to the bottom of the card within this area. That is, the grating fills most of one side of the card. The 17th card is a blank gray similar to the gray of the other cards in the set. Labels on the back of each card indicate the grating size on that card.

Partial set

Use of the complete set of Teller Acuity Cards® II is recommended. However, if a rougher estimate of acuity is sufficient, or if budgetary limitations preclude purchasing the complete set, a half set of cards are also available under the catalog number TACIIH. A half set consists of the following cards: 0.23, 0.43, 0.86, 1.6, 3.2, 6.5, 13.0, 26.0 cy/cm.

Quality control

For the cards to be a test of acuity, it is important to ensure that the fixation preference shown by the infant is based on detection of the pattern, not on detection of a brightness difference between the pattern and the background. Therefore, considerable effort has been made in the production of the cards to match the grating and the background of each card closely in overall perceived brightness.

During the manufacturing process, each individual grating is viewed by an adult with normal vision from a distance at which it cannot be resolved, and the gray of the surround is individually tailored to match the gray of the unresolved grating patch. This close brightness match minimizes the chances that the patient will fixate the grating patch when the stripes in the grating are not resolved. The small variations of the shade of gray of the surround are caused by making these careful brightness matches, and are not a defect in the cards. If brightness mismatches between the unresolved grating and the background are visible in any purchased set of cards, contact **Precision Vision Inc.**

CARE OF THE CARDS

To avoid surface variations that could distract the child during testing, the cards must be kept clean and unblemished. This can be accomplished by handling the cards only by the edges and by preventing the cards from rubbing against each other or other objects. Durability of the cards can be increased by having the tester wear gloves when handling the cards. The cards should not be touched by children with sticky hands. The cards can be wiped with a clean cloth that has been dampened with water, not with any solvent or other cleaner. It is important to put the water on a cloth and not directly on the cards.

STAGE APPARATUS

With the Vistech Consultants Teller Acuity Cards® a stage apparatus could be purchased and used for presentation of the cards during testing. All normative data for the Teller Acuity Cards® were collected using the stage (Courage & Adams 1990; Mayer et al. 1995; Salomão & Ventura 1995). However, clinical users of Teller Acuity Cards® rarely used the stage, as they found presenting the cards without the stage to be more efficient and easier. In addition, no stage is available for use with the Precision Vision Teller Acuity Cards® II. Unfortunately, norms are not available for testing without the stage apparatus. However, one study has shown that acuity results are significantly better when 1.5-year-olds (who are easily distractable) were tested with the stage apparatus than when tested without the stage apparatus (Clifford et al. ARVO 2004). In contrast, acuity results for 3.5 month-old, 11 month-old, and 30 month-old children were similar with and without the stage apparatus (Clifford et al. 2004).

TESTER'S SCORE SHEET AND AGE NORM CHART

Tester's Score Sheets and Age Norm Charts for binocular and monocular testing are available in Appendix C and online at www.precision-vision.com

HAND PUPPETS, BELLS, AND COLORFUL, NOISY OR SQUEAKY TOYS

It is useful to have a collection of these to attract the child's attention and keep the child interested in the test procedure.

Important information regarding your Teller Acuity Cards II

This set of Teller Acuity Cards II (TAC) has been manufactured using a process which offers the highest quality product, improving accuracy and the lifespan. The gratings are higher in contrast (>85%) and are more consistent in gray background color than previous TAC sets.

Care & Handling:

TAC cards should be stored in the protective sleeves with the paper cover sheets and placed inside the storage box when not being used. During testing, TAC cards should be placed on a soft, clean surface to avoid any damage to the printed surface. Objects, oils and writing instruments should not be used or placed near the TAC cards. White cotton gloves may be the ideal way to minimize damage to cards. With proper care & handling TAC cards can be used for years.

Cleaning:

If cleaning becomes necessary, use a soft, clean, lint free microfiber cloth and a solution of warm water with one to two drops of a mild dish soap and gently wipe the area in a circular motion. Carefully use the cloth to pat the cleaned area dry of a majority of the moisture and let the remaining moisture air-dry before storing the card in the proper manner described above.

Reflectance Considerations:
The current TAC sets have a more matte surface than previous TAC sets. This matte surface reduces unwanted reflectance from the front surface. There may be slight variances in relative reflectance of the grating patch and the gray surround; however, if a card is tilted significantly relative to the light source, the grating patch may become visible against the surround as a result of the surface reflectance variation. Therefore, it is recommended that care be taken when orienting the card to test a participant's visual acuity. The card must must be presented perpendicularly to the participant's gaze. Do not tilt the card forward, backward, or sideways. The tester may experiment with positioning the higher spacial frequency cards in specific lighting conditions to minimize the difference in reflectance.

Highest Spatial Frequency Card (38 cy/cm):
This card is not included in the current TAC set. The expert consultants note that the 38 cy/cm card is not mandatory due to the complex nature of this card. A more flexible and reliable approach to testing participant's without using the 38 cy/cm card is as follows (and is shown in the table below). If the participant detects the 26 cy/cm grating then test the 19 cy/cm and 26 cy/cm cards at an increased test distance until the 19 cy/cm grating is seen and the 26 cy/cm grating is not seen. Doubling the 55 cm test distance to 110 cm should be adequate; in this case, doubling the distance results in having the denominator of the equated acuity value. For example, the acuity for the 26 cy/cm grating at 55 cm is 26 cy/deg (equated to 20/24) and the acuity at 110 cm distance is 52 cy/deg (equated to 20/12). Acuity for the 19 cy/cm grating at 55 cm test distance is 19 cy/deg (equated to 20/32) and at a 110 cm test distance is 38 cy/deg (equated to 20/16). If necessary a very high acuity can be tested at a test distance of 165 cm.

Viewing Distance (cm)	Card (cy/cm)	Spatial Frequency (cy/deg)	Approximate Snellen Value[1]
55	19	19	20/32
	26	26	20/24
110	19	38	20/16
	26	52	20/12
165	19	57	20/11
	26	78	20/08

1 This is an equivalent based on literal angular subtense of the black or white bar in the grating, assuming that 30 cy/deg is equivalent to 20/20. It does not incorporate the effects of crowding or contour interaction.

TESTING CONDITIONS

LIGHTING

Luminance of the Teller Acuity Cards® II should be at least 10 candelas/m2 during testing. Typically, illumination from overhead diffuse fluorescent lights in clinical settings is adequate. If the light level is too low, underestimation of acuity (i.e., artificially low acuity values) can occur. If more light is required, spotlights directed toward the ceiling are strongly preferred over direct illumination of the cards. Shadows, uneven illumination, and reflections from the cards must be avoided. Tilting the cards away from the vertical may result in lower luminance (tilted down) or higher luminance (tilted up toward ceiling lights).

TEST DISTANCE

The test distance is measured from the child's eyes to the peephole in the cards. A known, fixed test distance must be maintained, as the acuity values in cycles/deg or approximate Snellen equivalents depend upon the distance. Testing the child with nystagmus or strabismus may be easier using cards held vertically rather than horizontally. However, a constant test distance must be carefully maintained.
The acuity values given in the Tables in Appendix D and on the backs of the cards are based on specific test distances. The following test distances are recommended for different age ranges:

- Infants between birth and six months of age at 38 cm (15 in)
- Between age seven months and three years at 55 cm (21.7 in)
- Older than age three years at 84 cm (33 in)
- Children with very poor acuity may require an unusually close test distance between 19 cm and 9.5 cm (7.5 in and 3.7 in)

The test distance must be measured at the beginning of the test, and held constant throughout the test. If a different test distance is used, for example, in an eye with poor acuity, acuities must be calculated separately for each eye based upon the actual test distance used.

Using a guideline like the tester's "fingertips to elbow" (with the elbow bent at a 90 degree angle) allows easy measurement of the distance. For some testers, this metric will be 38 cm. The length of the acuity card is 55 cm and can be used to estimate the 55 cm test distance.

SCORING THE RESULTS FOR DIFFERENT DISTANCES

The child's acuity can be calculated from the spatial frequency (specified in cycles/cm) and the test distance (in cm). Values for conversion of cycles/cm to cycles/deg are provided on the Age Norm Charts for test distances of 38, 55, and 84 cm, and in Table 1, Appendix D, for test distances of 38, 55, and 84 cm, as well as 9.5 and 19 cm.

NOTE: Values for conversion to approximate Snellen equivalents are presented in Table 2, Appendix D. However, we recommend that the resolution acuity results obtained with the Teller Acuity Cards® II NOT be reported in terms of Snellen equivalents. Snellen acuities (e.g. 20/20 or 20/40) refer to acuities obtained with a recognition acuity test (letters or Landolt Cs) at a distance of 20 feet. The acuity obtained with the Teller Acuity Cards® II is resolution (grating) acuity, not recognition acuity, and it is obtained at distances considerably closer than 20 feet. If acuity estimates are reported in Snellen equivalents, specification of the type of test used should be made, e.g. 20/130 grating acuity.

PERSONNEL

TESTERS AND ASSISTANTS

Acuity Card testing is conducted by a trained tester, who displays the cards and estimates the child's acuity.

For tests of infants less than four months of age, it is recommended that an experienced assistant hold the infant during testing. Children four months of age and older can usually be tested while seated on a parent's lap. The proper test distance should be indicated to the person holding the child and that person must be instructed not to cue the child as to the location of the grating. Although older children and adults do not need to be held, it may be helpful to have an assistant monitor the test distance.

TRAINING OF TESTERS

Handbook

The first step in training is for the new tester to read this Handbook. It may also be helpful to read several of the referenced articles, especially the paper by Teller et al. (1986).

Observe an experienced tester

The second step is for the new tester to watch an experienced tester conduct the procedure. This may not be possible for all new testers; however, it is generally very useful.

Practice with infants and children

The third step is for the new tester to practice the procedure with infants or children. Ideally, an experienced tester will watch the new tester's first tests, to offer suggestions and answer questions. This will not be possible in many cases. However, it will always be possible for new testers to call one of the experienced testers in their geographic region to discuss issues that arise during training or testing.

Binocular testing

In practicing the procedure, a new tester should begin by doing assessment of binocular acuity in normal infants/children. At least five infants/children should be tested from each of three or more age ranges and their acuity scores should not fall outside the upper or the lower 99% limits of binocular acuity normal for age. [It is more common for the new tester to overestimate acuity than to underestimate acuity.] If the values are outside the normal limits, further practice with normal infants/children should be undertaken. Once a tester is comfortable with assessment of binocular acuity in normal infants/children, he or she can begin to assess binocular acuity in patients with known or suspected ocular or neurological problems.

Monocular testing

If the tester's goal is to assess monocular acuity in patients, he or she should first practice monocular testing on at least five normal infants/children from each of three or more age ranges. The resulting acuity scores should not fall above or below the normal 99% monocular acuity limits for age. If they do, further practice in monocular testing of normal infants/children should be undertaken before the tester begins to test monocular acuity in patients with known or suspected ocular or neurological problems.

Assess the new tester's competence

An excellent means of assessing a tester's competence is with the "scrambled cards procedure". In the scrambled cards procedure, the tester must sort randomly ordered cards into two stacks - one stack containing stripes that the tester judges that the child can see and the other stack containing stripes that the tester judges that the child cannot see. During the test, the set of acuity cards is placed face down on the table beside the tester, with the order of stripe sizes unknown to the tester. The tester is not allowed to look at the front side of any card until a decision has been made for all cards; that is, the tester must remain unaware of the size of the stripes on each card. A well-trained tester should be able to sort the cards into two non-overlapping stacks, one stack containing only stripe widths wider than some arbitrary value (which will depend on the child's age and visual status) and the other stack containing only stripe widths narrower than that arbitrary value, with a maximum of one error per sorting.

TESTING PROCEDURES

THE BASIC PROCEDURE

The child is either held or seated alone at the correct distance from the acuity cards, facing the tester. The tester attracts the child's attention so that the child looks straight ahead, and then holds a card up. Based on a variety of the child's cues in response to repeated presentations of the card, including fixation, pointing, and/or verbalization, the tester makes an initial decision as to whether the child can see the grating. Coarser or finer gratings are then presented and repeated until the tester can select the finest grating that the child can see. This grating indicates the child's acuity.

TESTING WITHOUT A STAGE OR OTHER APPARATUS

The space around the testing area should be cleared of all visually distracting objects. During testing, the cards are held within the viewing field of the child. The tester should be alert to the child's misleading fixations of the edges of the cards where the tester's hands are visible. Other individuals seated behind or to the side of the tester may be distracting to the child.

STRATEGY FOR PRESENTING ACUITY CARDS

Arrangement of the cards

Before the child arrives, select the set of cards that you will need, based on the child's age and condition (see below). The left-right position of the grating should be varied across cards so that neither the tester nor the child comes to anticipate where the grating will be located on the next card.

Select the appropriate Start Card to begin the test (see below). This grating should be seen by most children with normal eyes at the stated age. To test children with visual impairment, the 0.64 cy/cm card is recommended as the Start Card.

AGE	START CARD
<6 months / any child with visual impairment	0.64 cy/cm
6 to 18 months	1.3 cy/cm
>18 Months	2.4 cy/cm

The physical arrangement of the cards is left to the discretion of the testers. However, experienced testers usually prefer to use the following arrangement of cards during testing:

The cards are placed face down into two separate stacks at a reachable distance. The stacks of cards should always be face down so that the tester and child are not aware of the left-right location of the grating before testing each card.

On the top of the first stack place the Start Card (refer to the table above). Beneath this card are placed acuity cards containing gratings of higher spatial frequencies (narrower stripes) than the Start Card. The gratings in this stack are arranged sequentially in increasing spatial frequency (progressively narrower stripes) toward bottom. We call this the Not-Seen Stack.

The second stack of cards contains cards with spatial frequencies lower than the Start Card. They are also arranged sequentially, but with the highest spatial frequency grating (narrowest stripes) on top, going in decreasing spatial frequency (wider stripes) toward the bottom. We call this the Seen Stack.

Thus, the two stacks together are a continuous ordered series of gratings. The tester shows cards in sequence, taking one card at a time from the Not-Seen Stack. If the child sees the grating on that card, it is placed on top of the Seen Stack. The card containing the highest spatial frequency (finest) grating the child sees should be on the top of the Seen Stack at the end of the test.

The order of the cards in the stacks should be checked after each test and before proceeding to the next test. Be sure that the right-left position of the gratings is scrambled and not all in the same location.

Beginning the test

The tester shows the child the Start Card and then presents the blank card (or a piece of gray cardboard when using the partial set of cards). Presenting these two cards and observing the child's responses helps to acquaint the tester with the child's behavior when gratings can and cannot be seen. (Note: If the child is visually attentive and yet doesn't look with interest at the coarse grating, show a finer grating. Gratings that are easily seen may be uninteresting and may not elicit a strong visual response.)

During the test

Next, present the acuity cards in descending order toward finer gratings, in octave or half-octave steps. Show each grating two or three times. For each grating shown, make a tentative decision about whether the child sees the grating. Some testers prefer to begin the test in octave (two-card) steps, and, when gratings close to the acuity limit are presented, then show the cards in half-octave (one-card) steps. As the child's acuity limit is approached, indications that the child sees the gratings often become subtle, requiring that these cards be presented to the child several times.

It is useful when testing near the acuity limit to show the child a card containing a coarse grating (e.g. the Start Card), to restore the child's interest in the procedure and to establish that the child's lack of clear responding to finer gratings was due to his or her inability to see the grating, not to a general lack of attention or fatigue.

Each card should be presented at least twice, once with the grating on one side (e.g., the right), then with the card turned 180 degrees so that the grating is on the opposite side (e.g., the left). Turning the grating to the opposite side is particularly important for monocular testing or for children who show a side preference. On the other hand, because some children develop a right-left alternating response, the tester should occasionally show the gratings on the same side on subsequent presentations. If the child's responses are unclear, the tester may have to present the card several times to reach a judgment as to the visibility of the grating to the child.

Masked testing: Grating location

On the initial presentation, the tester makes a judgment about the location of the grating based on the child's looking, and then rotates the card by 180 degrees to check that the child's response changes appropriately when grating location is changed. Thus, if the child looks strongly to the left on the first presentation and strongly to the right on the second presentation, the tester can be pretty sure where the grating is located. If the tester has any doubt about the location of the grating, the tester shows the grating again, either on the same side or rotating it by 180 degrees again. All presentations are done without looking at the front of the card to check the grating location. If the child's responses are clear, and the tester has a strong impression of the location of the grating on the front of the card, the tester can look at the front of the card to check his or her judgment against the actual grating location. If the child's responses are unclear, the tester should present the card several more times, until he or she can make a confident judgment about grating location and thus say that the patient can see the grating, or can decide that the child cannot see the grating.

We recommend that the tester NOT look at the front of the card to check the grating location unless the tester is SURE the child can see the grating. This is to avoid bias caused by the tester's knowledge of the grating location.

Also, the tester should not look at the eyes/face of the person holding the child during the test, as the holder will often glance at the stripes and this will provide a cue to the location of the stripes. We need to remind ourselves as testers and parents and holders that it is the child's acuity being tested and not the parent's.

Masked testing: Grating size

If there is a question of possible tester bias or uncertainty, "fully masked" testing can be used. An assistant sets up a subset of the cards, covering the labels indicating the size of the stripes. Cards may be in descending order according to grating size, or, for truly "masked" testing, grating size may be in random order from card to card (see page 9 for a description of the "scrambled cards procedure").

Masked retesting by a second tester

If a second tester is used to check the results in difficult cases, this tester should not know the results found by the first tester or the clinical description of the patient. Use of a second tester is especially useful in cases where the first tester had a low confidence in his/her acuity estimate.

Testing patients

It is important for testers to compare test results in clinical settings where two or more examiners will test the same patients on different visits. Large discrepancies between results on the same child tested by an experienced tester and a new tester may occur when new testers begin testing children with visual impairments. This may be remedied by the experienced and new testers testing some children together to be sure their testing procedures are similar.

TESTING IN CLINICAL SETTINGS

In most clinical settings, the examiner will be responsible for all aspects of conducting acuity card tests in patients. The young patient is best seated in a parent's lap for testing. A patient in a wheelchair can be tested there.

It is preferable for the examiner to sit so that the patient's eyes are directly aligned with the examiner's eyes. This allows the examiner a direct view of the patient's face through the peephole. For some patients, it may be easier to view the patient's gaze and motor responses over the top of the horizontal card or to the side of the vertically presented card. Adjustable height chairs for both parent/patient and examiner provide flexibility in presenting the cards in the optimal position for the patient's view of the grating and the examiner's view of the patient. The examiner must maintain the constant distance between the card and the patient's face during the test. This can be done using a ruler along the edge of a surface next to the examining chair, or using the examiner's calibrated finger-to-elbow (38 cm) length, or the length of the acuity card (55 cm). Parents should be informed that the examiner does not know the position of the grating and uses the patient's visual responses to determine whether the patient detects the grating. Thus, parents are instructed not to give guidance to the patient nor give clues to the examiner as to the grating position.

For optimal efficiency in testing patients, the gratings are presented in sequential order, from coarse to fine, in octave and then half-octave steps (some prefer to use half-octave steps throughout the test). Before commencing the acuity test, several presentations of coarse gratings in patients with poor vision, eye movement abnormalities, and/or developmental disabilities help the patients to accommodate to the test process and to the examiner. Similarly, the examiner can use these initial presentations to guide and evaluate the patient's visual responses.

Obtaining a visually guided motor response, such as pointing, reaching to touch, touching with a soft brush, or knocking, can be very helpful in sustaining a young patient's interest in the test stimuli especially if both binocular and monocular tests are needed. [If the patient's hands will come in contact with the front surface of the cards, they should be clean.] Once a reliable response is established, testing the patient's threshold for the gratings (acuity) will become more efficient.

The decision as to whether to conduct binocular testing should be based on the information that is needed. Binocular testing provides a measure of the child's everyday, functional vision. Monocular testing should be conducted if there is a question about the vision in either eye alone. A break between monocular tests may be helpful. The second eye tested may have lower acuity than the first eye because of boredom, or resistance to patching. Rechecking the acuity of the first eye tested, or the binocular acuity, may be required.
The front surface of the cards should be monitored for dirt, scratches and marks, as these may cause the child to look toward or away from the side of the card on which the grating is located, thereby resulting in an inaccurate measure of the child's acuity.
In clinical settings where several testers may use the same set of acuity cards, the tester should check on the order of the cards before testing each patient.

TEST DURATION

For most children in the 2-month to 6-year age range, Teller Acuity Card® II testing requires less than 5 minutes per eye. Testing usually takes slightly longer in infants less than 2 months of age, because of their sleepiness. Children with severely restricted vision or other disabilities may require as much as 10 to 15 minutes per eye.

INDICATIONS THAT THE CHILD SEES A GRATING

The tester uses a variety of behavioral cues, some of which depend on the child's age and developmental status, to decide whether the child sees each grating. These cues may also give an indication of the relative size of the grating, such as whether the grating is well above or near the acuity limit.

General indications

Most children at any age will gaze quickly at the location of a coarse grating when it is first presented and then hold fixation on it for a second or two. The child's response to a grating near his or her acuity limit, on the other hand, may be much more subtle, consisting of a slight preference for the grating side or a widening of the eyes upon viewing the grating. When the child cannot see the grating, there is a tendency toward more random scanning of the card, looking away from the acuity card entirely, and a rapid loss of attention.
Any consistent cue from the patient can be used in arriving at an acuity estimate. This includes verbal responses, pointing, touching, eye movements, or a dampening or change in the quality of nystagmus. Fussiness and/or refusal to look at a fine grating, followed by a clear response to a coarse grating, is a good indicator that the fine grating is below the patient's acuity limit.
Assessment of monocular acuity is more difficult than assessment of binocular acuity, because many infants/children do not like to wear an eye patch or occluder and because eye movements toward the grating may be different when the grating is located nasally than when the grating is located temporally. Occasionally (e.g., in some cases of strabismus), the child may show an eye movement only when the grating is located nasally or only when the grating is located temporally.

Indications from infants (< 5months)

A very young infant may continue to fixate a coarse grating even when the person holding the infant (the assistant) begins to turn the patient away from the grating. Young infants tend to hold fixation longer than toddlers on gratings that are above the acuity limit.

Indications from infants and toddlers (5 months to 2 years)

With children between 5 months and 2 years of age, the most useful cue is the child's initial eye movement when the acuity card is presented. This means that it is important for the tester to be looking through the peephole (or at the child's eyes) as the card is presented, so that the initial eye movement is not missed. It is also important that the patient's gaze be centered before the card is

shown, so that the patient will have an equal opportunity to respond to the grating, regardless of which side it is on.

Indications from children older than age 2 years

Children who can point can often be taught to point to the grating. Even younger and disabled patients will reach to touch the grating if they are cued by the tester to point or reach. The tester can model “knocking on” the grating which toddlers and disabled patients enjoy doing. Pointing and reaching may not be reliably to the side where the grating is located, but the tester should nevertheless encourage this visual motor response, since it keeps the patient’s attention on the grating stimulus and reinforces the patient’s visually guided motor behaviors. Also, the tester can use the patient’s eye movements to judge whether or not the child sees the grating. When presented with a grating near their acuity limit, patients may say that they cannot see any lines and may be unwilling to point. However, they may still reliably fixate the side of the card where the grating is located.

HINTS FOR TESTING

INFANTS

The tester should attract the infant's attention so that the infant is looking straight ahead. The tester can talk to or touch the infant, show an interesting toy, or play "peek-a-boo". While the card is held up, the tester can make noises from behind the card to attract the infant's attention. However, any sounds from behind the card should be made at the CENTER of the card or equally on both sides of the card, so that the location of the sound does not influence the infant's direction of gaze.

Present each card for several short presentations rather than one long presentation. This helps prevent the infant from becoming bored. Remember, as the infant's acuity limit is approached, the whole card probably looks gray to the infant; a blank gray stimulus rapidly becomes boring.

Testing with an assistant who holds the infant/patient

The assistant, who must be experienced and comfortable with infants, is responsible for maintaining a constant test distance between the infant's eyes and the acuity cards. The tester may also give the assistant instructions on how to position the infant. For example, the tester may ask the assistant to turn a very young infant slowly to face first one side of the card and then the other, so the infant can scan the card. Between card presentations, the infant usually remains facing the tester. This allows the tester to center the infant's attention before showing the next card. Warning: when turning the infant to face first one side of the card and then the other, it is important to keep the location of the infant's head constant, so that the distance from the infant to the grating does not vary.

For infants up to three or four months of age, the "flying hold" is recommended. One hand supports the infant's tummy while the other hand and forearm are placed under the infant's chin and chest to support the head and keep the infant looking forward. Infants are typically more alert when held away from the assistant's body in this manner.

Infants from three or four months to one year of age may be tested while the parent or assistant stands or sits. Since most infants in this age range will not allow the assistant to support them under the chin, the parent or assistant may have to reposition the infant often to keep the infant looking forward. The parent or assistant may also have to hold an older infant's hands so that the infant does not look at his or her hands or try to remove the occluder used in monocular testing.

Infants older than about six months are often afraid of strangers, so that most will be held by the parent rather than by the assistant.

Suggestions for dealing with a fussy or bored infant

1. Give the infant a pacifier or piece of food. Testing the infant while he or she is sucking on a bottle can work well, if the bottle does not block the infant's view. BE CAREFUL to keep all food and dirty hands away from the cards.

2. Rock the infant.

3. Talk or make noises to the infant.

4. Show the infant a toy, puppet, or mirror; make testing a game.

5. Have the assistant holding the infant turn the infant away between presentations of the cards. Hold up a card and then have the assistant turn the infant around to look at the card. This often produces a clear look in the direction of the grating.

6. "Zoom" the child toward the acuity card from a few steps away. DON'T go closer than the test distance.

7. Have the person holding the infant turn his or her back to the tester and hold the infant over his or her shoulder, so the infant faces the tester.

8. Give the infant a break, change the diaper, or let the parent walk around with the infant for a few minutes.

ONE-TO THREE-YEAR-OLD CHILDREN

A 55 cm test distance is recommended.

Toddlers are usually tested while sitting on a parent's lap. The parent's view of the gratings should be blocked to avoid inadvertent cues from the parent to the child about the position of the grating. The parent can wear an eye shield and/or be instructed to avoid any cues to the child about the location of the grating. Since a constant test distance must be maintained, the child should be prevented from leaning forward when finer gratings are presented.

Older children should be encouraged to point to the gratings. The test can take the form of a game, i.e. "Find the stripes (or lines)". Children can be rewarded with verbal praise or by seeing a special toy between card presentations. When the gratings become too fine to distinguish, the child may refuse to point or may say that there are no stripes on the card. The tester or parent should encourage the child to look at both sides of the card.

Because children may develop strategies such as alternating (i.e. indicating L-R-L-R) or pointing to one side only, it is important that the tester not present the gratings on only one side or in an alternating fashion.

Children should be praised for any response, not just for a correct response to grating location. This helps to keep them interested when the gratings approach their acuity limit.

The following suggestions may also be helpful in holding a young child's attention:

1. Play peek-a-boo with the cards.

2. Let the child blow at the gratings.

3. Give the child a “magic wand” (paintbrush or something that will not mark the cards) to point to the gratings.

4. Use a hand puppet to “kiss” or “eat” the stripes. This helps to teach or reinforce the concept of stripes to the child who does not readily point to or fixate the gratings.

5. Ask the child to show his or her parent where the lines are or to “help” the parent point to the lines.

6. Praise the child liberally and enthusiastically - “That’s very good”; “Good job!”, etc.

7. Let the child chew on a pretzel or cracker. However, BE CAREFUL not to let the child’s hands or the food get near the cards.

FOUR- TO SIX-YEAR-OLD CHILDREN

The Acuity Card procedure is not recommended for children who can be tested with a recognition acuity task, such as Lea Symbols, HOTV letters, Allen cards, the E test, or Sloan letters. The major reasons are that recognition acuity is a more broadly validated measure of acuity; and that children over the age of four years have high contrast sensitivity, so they may be able to see small brightness differences between the patch of grating and the background that adults can sometimes see in the cards.

If it is necessary to test a typically developing four-year-old or older child with the acuity cards, an 84 cm test distance is recommended.

Most children this age will sit or stand for the test. The parent may stand behind the child’s chair, but must NOT give the child any indication of the location of the stripes. Children are told to point to the grating, and they are allowed to tell the tester when the grating is no longer visible. If a child says a grating is not visible, he or she should be shown a card with somewhat larger stripes, to assure that he or she is still willing to point to visible stripes. Children should be praised for any response, not just for a correct response to grating location. This helps to keep them interested when the gratings approach the acuity limit.

MONOCULAR TESTING

1. Encourage the child to play “pirate”.

2. Demonstrate how an adhesive eye patch works by putting one on the parent, or on a doll.

3. Put attractive stickers on the eye patch.

4. Use toys to distract the child.

5. Have the parent hold a soft toy or put his or her hand over the child’s eye. A scarf can also be tied across the face over one eye.

6. Let the child eat crackers or drink from a bottle during testing.

OLDER DEVELOPMENTALLY DELAYED OR NON-VERBAL PATIENTS

For young developmentally delayed and/or non-verbal patients, the general procedures for infants or toddlers should be followed. Many of the suggestions given in previous sections are also helpful for testing older developmentally delayed or non-verbal patients who are unable to perform standard visual acuity tests. The tester or parent may find variations to the procedures that are more appropriate for a particular patient's capabilities. Some suggestions follow:

1. A test distance of 84 cm is recommended for patients with acuity of 12 cycles per degree (20/50 Snellen) or better (typical for normally developing children age four to five years).

2. Some disabled patients with limited ability to reach or point can follow a request to "look at the stripes" after the examiner or a familiar adult has demonstrated the stripes. Some patients may not understand the word "stripes". The parent may have a more appropriate verbal guide, for example "look at the picture".

3. The tester can observe the patient's responses to each card through the peephole. Alternatively, if the patient is not distracted by the tester's face, the tester may prefer to watch the patient's responses over the top of the card.

PATIENTS WITH VERY POOR ACUITY

The 0.23 cycles/cm ("low vision (LV)") card is intended to extend the lower end of the test range for low vision patients. The overall size of the patch of grating is increased on this card. Because of the large grating size, the low vision card may not give acuity values on the same scale as those of the original series. Conversion to cycles/deg or Snellen equivalents is not recommended if no grating finer than the 0.23 cycle/cm stripes is detected. Only "LV seen" or "LV not seen" should be recorded.

Initially, the tester tries a test distance of 38 cm. If no response is obtained, the tester moves in to 19 cm. If no response is obtained at 19 cm, the tester can try the test at 9.5 cm. At 19 and 9.5 cm, testers often find it easier to observe the child over the top of the card rather than through the peephole. Note that the visual angle between the peephole and the grating increases with decreasing test distance. This means that at close distances the grating stimulus is at more eccentric locations in the patient's visual field. Testing a patient suspected or known to have visual field defect (e.g. hemianopia) at less than 38 cm distance is not recommended.

In the very low vision patient who does not respond to static gratings, it is sometimes possible to elicit optokinetic nystagmus by moving the 0.23 cycles/cm low vision card in front of the patient. The 0.23 cycles/cm low vision card is the ONLY Teller Acuity Cards® II that should be moved during presentation (although repositioning of any card within the child's visual field is appropriate).

OTHER PATIENT GROUPS

Horizontal nystagmus and convergent strabismus

If an infant or child has horizontal nystagmus or convergent strabismus, it may be helpful to hold the card vertically. This allows vertical eye and head position changes in response to the grating to be distinguished from the horizontal nystagmus or strabismus. However, since norms have not been established for this form of testing, acuity values obtained with this method should be interpreted with caution.

When using vertically oriented cards, the tester should be careful not to place the card so high in the patient's upper field that he or she cannot detect the grating in the upper location. We suggest biasing the card down toward the patient's lower field by 2 or 3 inches (5-8 cm).

USE OF THE BLANK CARD

If the tester is unsure how to interpret the child's looking behavior, the blank card (or a piece of gray cardboard) should be presented. Comparing responses to the blank card with responses to a card containing a low spatial frequency grating (coarse stripes) will help the tester differentiate the child's behavior when a grating is versus is not present. This may be especially useful for testing two types of patient: (1) patients with nystagmus, wandering eye movements, or uncontrollable head movements, in whom it is difficult to differentiate eye movements in response to the grating from eye and head movements unrelated to the presence of the grating; and (2) older children who sometimes point to all cards, whether or not they can see the grating. In the case of the older child, the tester can use the blank card to illustrate to the child that sometimes the stripes will "hide" or "disappear". By using this card, the tester can also instruct the child to point only when he or she sees the stripes, and to say "no stripes" when the grating is not seen.

SCORING THE TEST

TESTER'S SCORE SHEET AND AGE NORM CHARTS

Sample Tester's Score Sheets and Age Norm Charts are available in Appendix C and online at www.precision-vision.com

USE OF TESTER'S SCORE SHEET

A Tester's Score Sheet for use during testing is provided (sample available in Appendix C). This score sheet is especially useful for individuals learning to conduct the Teller Acuity Card® procedure. (More experienced testers may elect to move directly to an Age Norm Chart, as described below.)

To use the Tester's Score Sheet:

1. Fill in the patient information at the top of the sheet and the test distance at the bottom of the sheet. The test distance is particularly important.

2. Decide whether binocular (B), monocular right (MR), or monocular left (ML) will be tested first, and circle the appropriate letters under Test #1. Circle whether the child was tested with corrective lenses (Y or N).

3. For each card used, record either + (seen), ? (unsure if seen), or -- (not seen) under Test #1. This helps you remember the sequence of cards and the child's responses. Brief comments about the child's reaction can also be recorded.

   Note: Very experienced testers sometimes do not bother to record judgments on all cards presented. They find that it is possible to remember the patient's responses, pick out the finest grating that the patient is judged to see, and record this information directly. Usually the tester works out a system of placing the cards to help him or her remember which cards were judged to be seen and which were not.

4. After you reach a judgment about the finest grating that the patient can see, mark your decision with an arrow (←), enter your confidence in the accuracy of your test result at the bottom of the sheet, and proceed to the next test.

5. Enter any additional comments about the test at the bottom of the sheet.

6. For children under four years of age, plot the results of the tests on the Age Norm Charts (see below). The Tester's Score Sheet and Age Norm Chart can be kept in the patient's medical record.

USE OF AGE NORM CHARTS

Two sample Age Norm Charts (one for binocular and one for monocular test results) are provided in Appendix C. The graph on the lower half of the sheet is used to plot the patient's acuities, to compare

them to normal acuity for age, and to follow changes in acuity over time.

For infants born prematurely (<37 weeks gestation), plot acuity according to “corrected age”, which is the age from due date. Use the child’s corrected age up to age 12 months.

USE OF AGE NORM CHARTS:

1. Choose the appropriate (Binocular or Monocular) Age Norm Chart and fill in the patient information at the top of the sheet.

2. Circle whether the child was tested without (SC) or with (CC) corrective lenses for each test (binocular (binoc), monocular right eye (RE), or monocular left eye (LE)).

3. Circle whether the tester held the cards Horizontally (H) or Vertically (V) for each test (binocular (binoc), monocular right eye (RE), or monocular left eye (LE)).

4. For each test, the cycles/cm value of the grating that is scored as the patient’s acuity is filled in under “card”. The acuity in “cy/deg” and in “Snellen” equivalent can be obtained by referring to the card value (cy/cm) and test distance from Tables 1 and 2, respectively, or can be read off the label on the back of the card.

5. Recording the test distance is a crucial part of scoring the patient’s acuity. Test distance is indicated by circling the distance used (38, 55, or 84 cm) on the columns at the right of the graph. Then the grating card value under the test distance used (e.g., 6.5 cy/cm at 55 cm) is circled. Using a ruler that is lined up with the 6.5 mark in the 55 cm column, plot the acuity on the graph at the location that is lined up with the patient’s age on the x-axis. The point that plots the patient’s acuity shows the acuity relative to the normal range for the patient’s age. For example, if an acuity score of 6.5 cy/cm at 55 cm is plotted at age 6 months, it is within normal limits for age. If it is plotted at age 30 months, it is at the lower limit of normal for age, and if it is plotted at age 42 months, it is below the normal limits. It is useful to indicate on the graph the eye or eyes for which the acuity result is being plotted (e.g., “RE”, “LE”, or “Binoc”).

6. For children less than 12 months of age, plot the acuity at the child’s age, corrected for gestational age at birth. This can be done by subtracting the number of weeks the child was born before 40 weeks gestation from the child’s age from birth in weeks. This correction is not important for children older than 12 months of age. Circle (at top of form, after Age) whether the child’s age is plotted as Corrected Age or Chronological Age.

7. The difference in acuity between eyes is indicated on the right of the upper portion of the score sheet in approximate octave differences (0.5 octave = the difference between two adjacent acuity cards). A difference between eyes of 0.5 octave (one card) is within the variability of the test for patients. However, if it can be repeated consistently, it may be a reliable difference for a given patient. A 1.0 octave difference (two cards) is considered significant.

RETESTING

For retesting the same patient, e.g., at a subsequent visit, the tester should be as unaware as possible

of prior test results. Careful testers make it standard practice not to look at the patient's earlier scores until current testing has been completed. When retesting is completed, the results can be plotted on the Age Norm Chart previously placed in the patient's medical record. In this way, changes in acuity with age or treatment can be easily represented.

CRITERIA FOR BELOW NORMAL ACUITY

Reduced visual acuity should be suspected when the child's acuity falls on the lower border or below the range appropriate to his or her age. The graphs on the Age Norm Charts show the upper and lower 99% and 95% prediction limits for age as solid and dashed lines. An acuity below the 99% prediction limit for age should occur only 1 out of 200 times (0.5% lower, 0.5% upper limit) in children with normal vision. An acuity below the 95% limit will occur only 2 to 3 times out of 100 in children with normal vision.

A meaningful interocular difference should be suspected if the measured interocular difference is 1 octave (two cards) or more. Acuity estimates 0.5 octave (one card) or less below the normal range for age, and/or interocular differences of 0.5 octave (one card), should be considered marginal and should be verified by retesting, preferably by a different tester who does not know the results of the first tester. Repeated retesting may be appropriate when a higher degree of accuracy is needed for a critical diagnosis or for the selection or monitoring of treatment.

AGE NORMS

The normal prediction limits shown on the Age Norm Charts were obtained using the Vistech Consultants, Inc. version of the Teller Acuity Cards®. Norms for the Precision Vision Inc. version of the cards have not yet been obtained. Preliminary results from 3.5 month-old, 11 month-old, and 30 month-old children indicate that these norms may be slightly (about one card or one-half octave) lower than those obtained with the Vistech Consultants, Inc., cards (Clifford et al., 2005). Updates on norms may be obtained periodically by correspondence with Precision Vision Inc.

FURTHER ANALYSIS OF NUMERICAL ASPECTS AND AVERAGING METHODS

For further analysis of numerical aspects, and for averaging methods, see Appendix D.

POINTS TO REMEMBER WHEN INTERPRETING ACUITY VALUES

1. Clinical interpretation. The acuity cards are intended for the use of trained eye care practitioners and their assistants. They are not a replacement for a thorough optometric or ophthalmologic examination. The acuity values obtained should be interpreted in the context of the overall clinical presentation and the results of full optometric or ophthalmologic examination. It is advisable to retest any child whose acuity results are inconsistent with the overall clinical presentation. If possible, the retest should be done by a tester who is unaware of the results of the first test.

2. Test distance. The acuity cards provide a measure of near acuity, not distance acuity. Near acuity measures are insensitive to a variety of refractive errors, especially mild or moderate myopia.

3. Resolution vs. recognition acuity. Acuity gratings produce a measure of resolution acuity, NOT recognition acuity, which is measured with letter or picture charts. Measures of resolution acuity can underestimate the degree of acuity loss (for example, in strabismic amblyopia). Snellen equivalents (which are typically used to report recognition acuity results) are listed in the Appendices only because they are familiar. Use of cycles/deg notation, rather than conversion to Snellen equivalents, is recommended.

4. Accuracy. As a rule of thumb, the accuracy (test-retest reliability) of the acuity card test is one octave. Interpret cautiously or verify the test results when acuity values near the lower limit of the age norm, or when interocular differences are marginal (0.5 octave). Experienced testers sometimes consider one-half octave differences to be meaningful, but only if they are found on repeated masked testing.

5. Predictive validity. The acuity cards provide a measure of acuity that can be compared against normative data to indicate whether the child currently has acuity within the normal range for his or her age. The extent to which current acuity status is predictive of a child's acuity in the future is not known. Research is ongoing to examine the predictive validity of acuity card results for various categories of patients.

6. Continued validation. At the time this Handbook was updated, no studies were in progress to norm the Teller Acuity Cards® II. Updates on studies using the Teller Acuity Cards® II can be obtained from Precision Vision Inc.

APPENDIX A

HISTORY AND DOCUMENTATION

A variety of techniques have been developed over the years in attempts to assess the visual acuity of infants and young children (see Dobson and Teller 1978; Simons 1983; McDonald 1986, for reviews). Some of the most successful of these techniques have been a group of procedures termed preferential looking (PL) procedures. These procedures are based on the fact that an infant, when shown a boldly patterned target paired with a blank target of equal luminance, i.e., equal in brightness, will preferentially fixate the patterned target (Fantz 1958). During acuity testing, the infant is shown a number of presentations of black-and-white gratings (i.e. black-and-white striped patterns) paired with a blank gray target of equal space-average luminance. From one presentation to the next, the left-right location of the grating varies. The spatial frequency (stripe width) also varies, either randomly or according to a pre-established sequence.

A variant of the PL procedure, termed forced-choice preferential looking (FPL), is the most formal and objective PL method (Teller 1979). In the FPL procedure, an adult observer, watching the child's eye and head movements, knows that the pattern must be on either the right or left side of the display (i.e. there are two alternatives). However, the observer does not know the pattern's true location. The observer uses the child's response to make a judgment about the physical left-right location of the grating. This judgment is termed a "two-alternative forced-choice" judgment. The objectivity of the technique stems from the fact that the observer's response can be scored as correct or wrong on each trial, and that above-chance performance on the part of the observer must mean that the infant can resolve the grating.

Another modern variant of PL testing requires the observer to judge the side of the display at which the infant prefers to look (Gwiazda et al. 1978). Older infants and children may be operantly reinforced (rewarded) for looking, pointing or reaching toward the grating (Mayer and Dobson 1982; Birch et al. 1983).

Numerous researchers have used PL procedures for the assessment of visual acuity, and other visual functions such as stereopsis or color vision, in normal infants and children in laboratory settings (see Dobson and Teller 1978; Atkinson 1984; Teller 1997 for reviews). PL procedures are also used to assess the acuity of infants and young children with known or suspected visual disorders, and to guide the course of therapeutic treatments (e.g. Jacobson et al. 1983a,b; Lennerstrand et al. 1983; Mayer et al. 1982, 1985, 1989; van Hof-van Duin and Mohn 1984; Jenkins et al. 1985; Maurer et al. 1985; Stager and Birch 1986; Birch et al. 1987; Birch and Hale 1988; Dobson et al. 1995a, b; Carlson et al. 1996; Innis et al. 1996, 1997; Quinn et al. 1996; Harvey et al. 1997a,b; Msall et al. 2000; Austad et al. 2001; van Splunder et al. 2003).

Unfortunately, most PL procedures have one or more limitations that restrict their use in the average clinical or office setting. First, all well-standardized versions of the testing equipment are bulky, expensive, and/or in need of constant monitoring of alignment and calibration. Second, the percentage of 1- to 2-year-old children who can be tested successfully with some procedures is low. A third, and major, limitation of PL procedures is the problem of speed-accuracy trade-offs. With the two-alternative, forced-choice procedure that is an integral part of most PL methods, a minimum of 60 to 100 presentations of the gratings is needed to obtain a stable estimate of acuity, and the accuracy of

acuity estimates (standard errors and confidence intervals) is limited even with this number of presentations (Teller 1983; McKee et al. 1985). This statistical limitation makes testing based on formal PL procedures prohibitively time-consuming for routine clinical use.

Because of the limitations of formal PL procedures for clinical testing, an alternative procedure, the Teller Acuity Card® Procedure, was developed. As described in the Introduction, this procedure combines the high-quality grating stimuli used in laboratory testing with the observer's subjective judgments concerning qualitative aspects of the infant's response to those stimuli. Standard laboratory PL procedures dictate that the observer can make only a "left" or "right" response concerning the location of the stripes or the direction of the child's looking. The observer is not allowed to respond with qualitative information regarding the clarity of the infant's response to the target.

Extensive experience using this protocol with infants suggested that, in fact, the observer is "throwing away" information. If a pattern is easy for an infant to detect, looking behaviors tend to be rapid and direct. An observer's left versus right response might be qualified by a confidence judgment such as: "I'm absolutely positive the stimulus is on the right. The infant looked immediately to that side." Alternatively, near the child's acuity limit, the observer will usually evaluate the two-alternative forced-choice as more of a guess. "I really can't tell where the infant was looking, but given my choices, I'll guess that the pattern is on the right." The Teller Acuity Card® Procedure allows the observer to integrate this valuable qualitative information into his or her judgment. The Teller Acuity Card® observer's task is not to identify the location of the pattern, but rather to evaluate the question "Can the child see the stripes?" This subtle but critical difference in protocols has yielded a rapid test that can be conducted in clinical settings, because repeated presentations are not needed except near the child's acuity limit.

Validation studies have been in progress since 1984. Initial studies were conducted in the laboratory, with normal, healthy, full-term infants and young children serving as subjects. The results indicated that the procedure was fast (approximately 3 to 5 min per test), success rates were high (over 90% at most ages), intra- and inter-observer test-retest reliabilities were high, and acuity results were similar to those found in normal infants of the same age tested with the FPL procedure (McDonald et al. 1985, 1986a,b; Kohl et al. 1986; Dobson et al. 1987; Kohl and Samek 1988; see Teller et al. 1986, Dobson 1993, Mayer and Dobson 1997; Mayer and Arendt 2001 for reviews).

Subsequent studies have been conducted with clinical populations. Preston et al. (1987) showed that when infants with ocular disorders were tested in the laboratory with the acuity card procedure, success rates and interobserver test-retest reliability remained high, and the results agreed well with the results obtained on the same infants tested with the FPL procedure. Studies in which the acuity cards were used in clinical settings with infants, young children, and older disabled patients have also reported high success rates, good interobserver agreement, and good agreement with FPL results (Brown and Yamamoto 1986; Mohn and van Hof-van Duin 1986; Hertz 1987; Sebris et al. 1987; Hertz and Rosenberg, 1988; Mohn et al. 1988; Marx et al., 1989, 1990; Dobson et al., 1990; Hertz and Rosenberg, 1992; O'Dell et al., 1993; Mash et al., 1994, 2005; Harvey et al., 1999).

Since the production of the first Teller Acuity Cards®, measures of grating acuity have been obtained in patients with many different specific ocular and neurological disorders. Publications describing results obtained with Teller Acuity Cards® in a variety of patients, in a variety of settings, are listed in References, below.

APPENDIX B

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APPENDIX C

SCORE SHEETS

1. **TESTER'S SCORE SHEET**
2. **AGE NORM CHART: BINOCULAR**
3. **AGE NORM CHART: MONOCULAR**

SCORE SHEET - Teller Acuity Card® II Test

Name: ______________________________ Birth Date: _____/_____/_____

Test Date: ___________________________ Due Date: _____/_____/_____

Age Group: __________________________

Test with Correction: Y N

Tester: _______________ Tester: _______________ Tester: _______________

B MR ML | B MR ML | B MR ML

CY/CM	±	Comments
Low Vision Card		
0.32		
0.43		
0.64		
0.86		
1.3		
1.6		
2.4		
3.2		
4.8		
6.5		
9.8		
13.0		
19.0		
26.0		
38.0		
Blank		

CY/CM	±	Comments
Low Vision Card		
0.32		
0.43		
0.64		
0.86		
1.3		
1.6		
2.4		
3.2		
4.8		
6.5		
9.8		
13.0		
19.0		
26.0		
38.0		
Blank		

CY/CM	±	Comments
Low Vision Card		
0.32		
0.43		
0.64		
0.86		
1.3		
1.6		
2.4		
3.2		
4.8		
6.5		
9.8		
13.0		
19.0		
26.0		
38.0		
Blank		

Confidence: ___________ Confidence: ___________ Confidence: ___________

Distance: __________cm Distance: __________cm Distance: __________cm

NOTES:

Precision Vision Inc.
1725 Kilkenny Ct. Woodstock , IL 60098 USA 1-815-223-2022 Facsimile: 1-815-223-2224
E-mail: info@precision-vision.com Website: www.precision-vision.com

	Patient Name: Date of Birth: MR#:

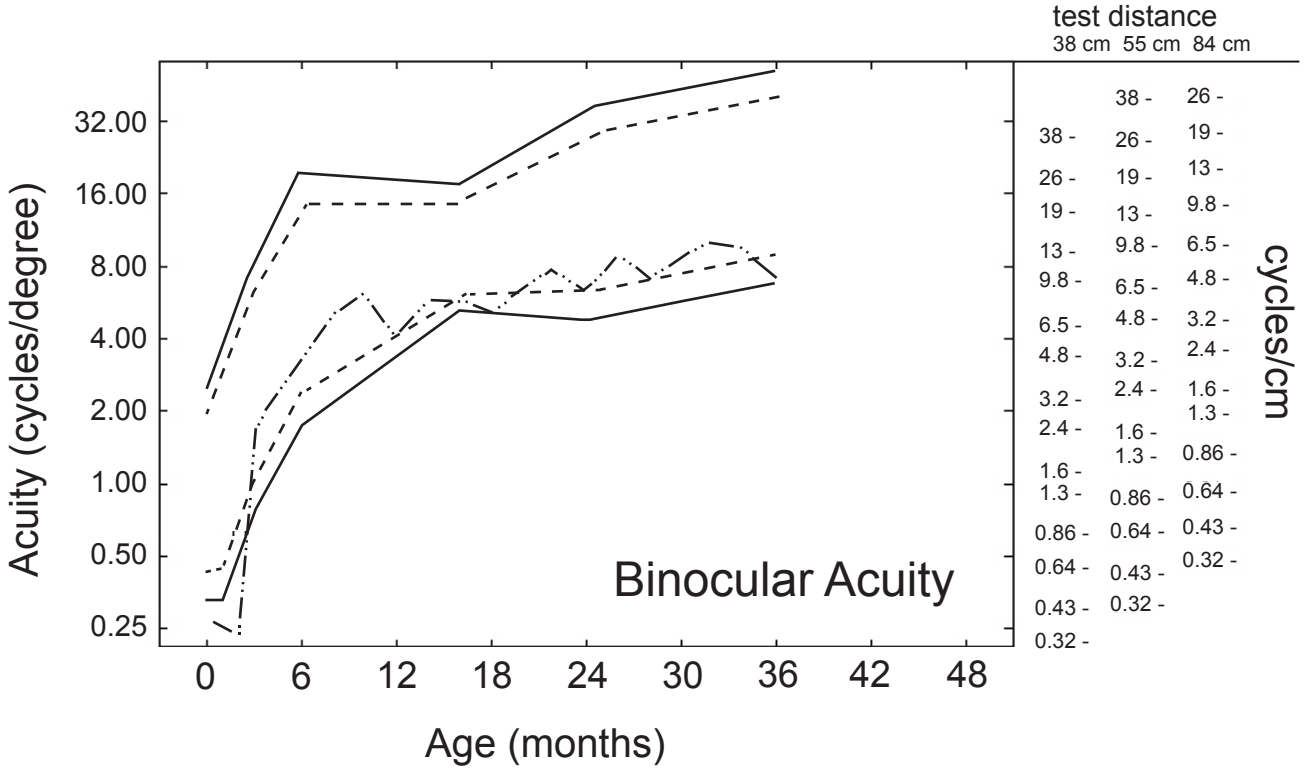
TELLER ACUITY CARDS® II - BINOCULAR AGE NORM CHART

Test Date ___/___/___ Gest. Age ___ (wks) Age ___ (chron/corr) ___

Dx

RESULTS	card	cy/deg	Snellen	Diff between eyes
Both (Binoc) [sc/cc] [H/V]				☐ None ☐ 0.5 oct ☐ 1 oct ☐ >1 oct
Right eye (RE) [sc/cc] [H/V]				
Left eye (LE) [sc/cc] [H/V]				

COMMENTS Examiner ___



—·—·— Salomao & Ventura - 90% tolerance limits with 95% confidence, *Invest Ophthalmol Vis Sci*, 1995
——— Courage - 99% prediction limits, *Optom Vis Sci*, 1990
- - - - - Courage - 95% prediction limits, *Optom Vis Sci*, 1990

	Patient Name: DOB: MR#:

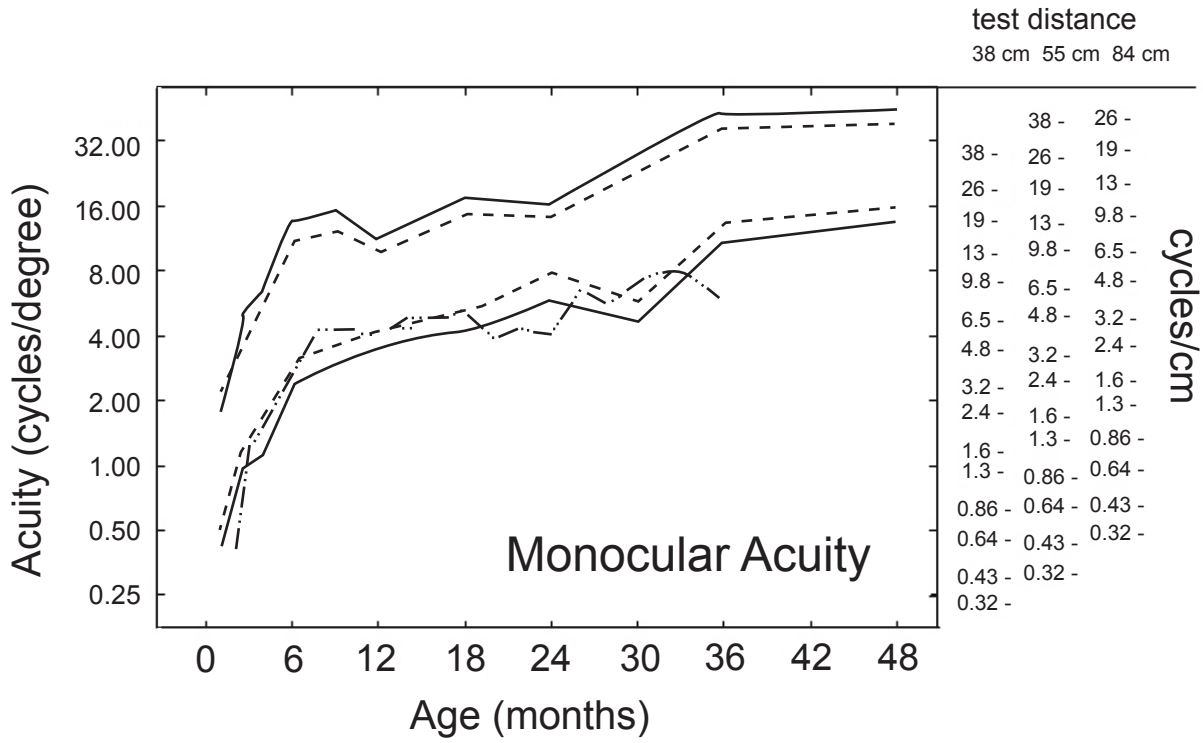
TELLER ACUITY CARDS®II - MONOCULAR AGE NORM CHART

Date ____/____/_____ Gest. Age _____(wks) Age _____(chron/corr)

Dx

RESULTS card cy/deg Snellen	Diff between eyes
Both (Binoc)[sc/cc] [H/V] _____ Right eye (RE)[sc/cc] [H/V] _____ Left eye (LE)[sc/cc] [H/V] _____	G None G 0.5 oct G 1 oct G >1 oct

COMMENTS	Examiner _____



Salomao & Ventura - 90% tolerance limits with 95% confidence, *Invest Ophthalmol Vis Sci*, 1995
Mayer et al. - 99% prediction limits, *Optom Vis Sci*, 1995
Mayer et al. - 95% prediction limits, *Optom Vis Sci*, 1995

APPENDIX D

TABLE 1: CONVERSIONS FROM CYCLES/CM TO CYCLES/DEG

TABLE 2: CONVERSIONS FROM CYCLES/CM TO APPROXIMATE SNELLEN EQUIVALENTS

NUMERICAL ASPECTS AND AVERAGING METHODS

Definition of an octave

Calculation of means and standard deviations of acuity scores

Table 1

CONVERSIONS FROM CYCLES/CM TO CYCLES/DEG

CYCLES/CM	TEST DISTANCE[+]				
	9.5cm	19cm	38cm	55cm[*]	84cm
38.0	10	15	27	38	57
26.0	7.2	10	18	26	39
19.0	5.2	7.4	13	19	28
13.0	3.6	5.1	9.1	13	19
9.8	2.7	3.8	6.8	9.6	14
6.5	1.8	2.5	4.5	6.4	9.6
4.8	1.3	1.9	3.3	4.7	7.1
3.2	0.88	1.2	2.2	3.1	4.7
2.4	0.66	0.93	1.7	2.4	3.6
1.6	0.44	0.63	1.1	1.6	2.4
1.3	0.36	0.50	0.9	1.3	1.9
0.86	0.24	0.33	0.6	0.84	1.3
0.64	0.18	0.25	0.44	0.63	0.95
0.43	0.12	0.17	0.30	0.42	0.64
0.32	0.09	0.13	0.22	0.31	0.47
0.23	------	------	------	------	------

[+]Distance from patient's eyes to center of peephole. The distance from the patient's eyes to the near edge of the grating will be 38.8, 55.5, 84.3, 12.2, and 20.5 cm for the 38, 55, 84, 9.5, and 19 cm test distances, respectively. Cycles/deg values are calculated based on the angular subtense of the half cycle (i.e. the stripe) nearest to the peephole.

[*]Note that at 55 cm, cycles/cm values are numerically equal to cycles/deg values to within 2%. These small differences can be ignored for practical purposes, especially since test distance is not controlled with a high degree of accuracy. Therefore, the cycles/cm numerical values can be used directly for tests conducted at 55 cm.

For distances of 20 cm and greater, cycles/deg is approximately equal to:

$$\frac{\text{test distance}}{55} \times \text{cycles/cm}$$

For closer distances, this formula cannot be used, because of the relatively large distance between the peephole and the patch of grating.

Table 2

CONVERSIONS FROM CYCLES/CM TO SNELLEN EQUIVALENTS[*@]

CYCLES/CM	TEST DISTANCE[+]				
	9.5cm	19cm	38cm	55cm	84cm
38.0	20/57	20/40	20/23	20/16	20/11
26.0	20/84	20/59	20/33	20/24	20/15
19.0	20/110	20/81	20/45	20/32	20/21
13.0	20/170	20/120	20/66	20/47	20/31
9.8	20/220	20/160	20/89	20/63	20/41
6.5	20/340	20/240	20/130	20/94	20/63
4.8	20/460	20/320	20/180	20/130	20/84
3.2	20/680	20/490	20/270	20/190	20/130
2.4	20/910	20/650	20/360	20/260	20/170
1.6	20/1400	20/970	20/540	20/380	20/250
1.3	20/1700	20/1200	20/670	20/470	20/310
0.86	20/2500	20/1800	20/1000	20/710	20/470
0.64	20/3300	20/2400	20/1400	20/960	20/630
0.43	20/4800	20/3500	20/2000	20/1400	20/940
0.32	20/6400	20/4700	20/2700	20/1900	20/1300
0.23**	----------	----------	----------	----------	----------

[*]By convention, 30 cycles/deg is set equal to 20/20 Snellen equivalent. Quick conversion formulas are: Snellen denominator = 20 x [30/(cycles/deg)], or cycles/deg = (20/Snellen denominator) x 30. Snellen equivalents shown have been rounded to two significant figures.

[+]Distance from patient's eyes to center of peephole.

[@]Snellen equivalents are included because they are more familiar than cycles/deg in the clinical setting. However, Snellen acuity is a measure of recognition acuity, while the Acuity Cards measure grating (resolution) acuity. Therefore, conversion to Snellen equivalents is not recommended except for purposes of communication.

**The 0.23 cy/cm card is not given an acuity equivalent: see page 22.

NUMERICAL ASPECTS AND AVERAGING METHODS

Definition of an octave: An octave is a halving or doubling of stripe width, spatial frequency, or Snellen notation, e.g. from 15 to 30 cycles/cm, from 15 to 30 cycles/deg, or from 20/40 to 20/20 Snellen.

In judging acuity differences, octave values rather than linear values are used because visual acuity results are scaled according to a logarithmic (ratio) scale rather than according to a linear scale (Westheimer, 1979). That is, on a logarithmic scale, a just noticeable difference in acuity is scaled as the same interval, regardless of the starting point (baseline acuity), so that the change in discriminability between 15 cycles/deg and 30 cycles/deg is similar to the change in discriminability between 2 cycles/deg and 4 cycles/deg. Plotting acuity on a linear scale, e.g. with the difference between 15 cycles/deg and 30 cycles/deg plotted as equal to the difference between 2 cycles/deg and 17 cycles/deg, does not provide an accurate picture of the way the visual system operates. For the visual system, the change in discriminability between 15 and 30 cycles/deg is only about one-third as big as the change in discriminability between 2 and 17 cycles/deg.

Calculation of means and standard deviations of acuity scores: Because acuity scores are on algorithmic rather than a linear scale, means and standard deviations of acuity scores cannot be determined by simple linear addition and division. Instead, each acuity score must be converted to log(base 2) or log(base 10), the mean of the logs is calculated, and then the antilog of end result is reported as the mean acuity score. If the calculation is done in log(base 2), the resulting standard deviation is in octaves. If the calculation is done in log(base 10), the resulting standard deviation is in 0.1 log units. [The scale of modern letter acuity charts is in 0.1 log units (logMAR).] To derive the log(base 10) standard deviation in octaves, divide by 0.301.

For example, to find the mean acuity for a group of three patients with acuity scores of 9.6, 2.4, and 1.7 cycles/deg, first take the log of each score (0.98, 0.38, and 0.23). Then calculate the mean (0.53 log cycles/deg) and standard deviation (0.40 log units) of the log values. To convert the mean value to cycles/deg take the antilog of the mean of the logs (0.53 log cycles/deg). The resulting mean for the example is 3.4 cycles/deg. To convert the standard deviation to octaves, divide the standard deviation of the logs (0.40 log units) by 0.301. The resulting standard deviation for the example is 1.3 octaves.