Towards Computer-Assisted Optometry*

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ABSTRACT

Computer-assisted opthalmic refraction could provide significant health and economic benefits if it were practicable. The basic problem is can a computer with the necessary ancillary equipment be programmed to make automatic acuity measurements on untrained subjects? Simulated automatic visual acuity measurements, such as might be made by a computer, were made on three relatively naive subjects. The results were compared with the usual "human operated" measurements and showed relative clinical agreement. The feasibility of computer-measured visual acuity and the possibility of computer-assisted ophthalmic refraction is demonstrated.

An on-line, digital computer with an analog converter can, in principle, be programmed to aid the refractionist by taking case histories, visual acuities, performing subjective refractions and other tests. Additionally, the computer can at otherwise idle times perform various office chores such as billing, inventory control, and the automatic generation of periodic recall notices. It is assumed that for the foreseeable future the final prescription, as well as certain other aspects of ophthalmic refraction, will require human skill and judgement, at least until the art of refraction can be programmed as well as the science. It may be some years, if ever in our time, before a computer will be able to control the performance of tonometry, ophthalmoscopy, retinoscopy, frame fitting, or their successors although these results from a human operator can be fed into the computer and become part of the total program.

A significant economic gain could be realized by having the computer relieve the refractionist of those functions which the computer can perform, at least as well as they are performed at present. A computer-assisted refractionist might care for more than twice as many patients as he can now. It is assumed that there would be no additional load requiring human help for himself[1] or his secretary and with no drop in the quality of service. Moreover, the digital instrument could be specially programmed for specialized examinations for group visual screening in public health programs which are demanded in schools and industry.

COMPUTER TECHNOLOGY IN HEALTH SERVICE

Ophthalmic refractions aside, the digital computer already is showing its potential in the health field. It handles clinical

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records,[2] takes medical narrative data[3], and statistically analyzes them.[4] A computer system under development will not only store medical data but suggest examinations, diagnoses, and treatments to physicians.[5] Medical histories have been taken successfully by the computer, which, unlike some clinicians, is consistent, tireless, and never bored.[6] This particular computer program is limited to symptoms of allergy, but in principle it can be applied equally well to visual complaints. Sequences have been incorporated which teach the patient the meaning of some of the words used. This improves the quality of communication between him and the machine.[7] The computer-health field is blossoming rapidly; this narrative is not meant to give a complete listing but to convey some idea of the breadth and depth of activity and progress.

SUBJECTIVE REFRACTION

The key to subjective refraction by computer lies in automatic visual acuity measurements. Once acuity measurement is automated, the rest of the subjective examination will follow, if we may say so, automatically. Psychophysical threshold measurements have been automated since first proposed by von Bekesy, in 1947, for audiometry.[8] It has been widely applied to clinical patients as follows: the subthreshold test tone is slowly increased in intensity; when the patient hears it, he presses a button which reverses the direction so that the tone slowly decreases in intensity until he no longer hears it and therefore releases the button, and so on. The sound intensity is continuously recorded on a graph, whose saw-tooth oscillations bracket the threshold. This method, which has been called "the method of ups and downs" or "the staircase method," was used for visual thresholds by Fry and Irig,[9] but on sophisticated research subjects only. The method has been improved by Cornsweet,[10] but to our knowledge it has not been used for visual acuity measurements with naive subjects or with unselected patients.

If acuity can be obtained automatically, using some kind of "ups and downs" method, there appears to be no fundamental barrier to computer-controlled subjective refraction. It is generally agreed among refractionists that no test or battery of tests thus far devised can be satisfactorily substituted for the subjective refraction examination. This procedure is the heart of ophthalmic refraction and cannot ordinarily be bypassed.

We have obtained visual acuity measurements by simulating a computer-controlled program designed for this purpose, on three relatively naive subjects who had no training in psychophysical observation.

EQUIPMENT AND PROCEDURE

A continuously-variable-magnification projector (Claison Visual Acuity Meter) provided letters on a screen at six meters' distance from the subject. The projector was modified to provide a permanent recording of the size of the target. This was done by attaching a pen to the movable lens system which slides on a track for a distance of 35 cm. A roll of paper was fed across the track in small increments for each acuity measurement trial so that a bar or a histogram-like graph was plotted, the top of which gave a threshold boundary. (See Figure 1).

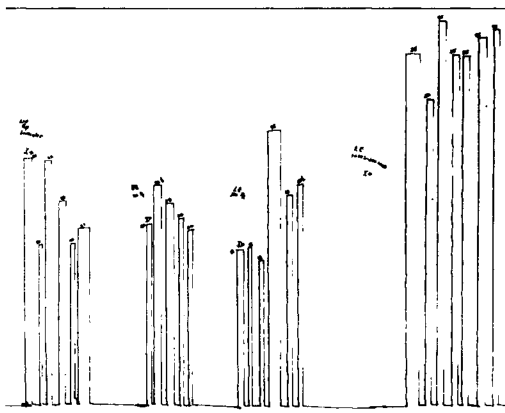

Figure 1: Bar graphs, an average of the height in each group gives the visual acuity. For explanation, see text.

We used a Snellen E Target in one of the four possible orientations ranging in letter size from 20/8 to 20/395. Three sets of slides were required to provide this range because of the limited range of magnification of the instrument. However, because of overlap, it was not usually necessary to change a slide during a given set of trials.

The target E, in one of the four random orientations was slowly increased in size

						Simulated Computer Acuity									
Subject	Eye	Rx		No Rx	With Rx	Simulated Myopia		Simulated Myopic Astigmatism (+Cyl)				Simulated Hyperopic Astigmatism (-Cyl)			
						Rx +1.00 D.S.	Rx +2.00 D.S.	+1.00 D.Cyl axis 90	+1.00 D.Cyl axis 180	+2.00 D.Cyl axis 90	+2.00 D.Cyl axis 180	-1.00 D.Cyl axis 180	-1.00 D.Cyl axis 90	-2.00 D.Cyl axis 180	-2.00 D.Cyl axis 90
I	R	-0.50 D.S.= -0.25 D.Cyl axis 165	C.A.	20	15-1	60+1	200	30	40	70	60+1	20-2	20+2	30	40
			$\bar{X}$	31.0		98.4	214.3	131.2	135.2	164.0	204.5	37.0	39.5	68.0	78.2
			S.D.	4.1		22.9	7.8	2.9	7.3	10.6	43.1	2.0	3.7	6.7	5.7
			n	5		5	4	4	5	5	6	4	4	6	4
	L	-0.25 D.S.	C.A.	20+	15-1	50-1	200	30+1	30-2	100:	60	20-1	15	50	30-2
			$\bar{X}$	24.5		178.5	258.5	81.7	65.5	171.7	182.4	42.2	44.2	62.3	68.0
			S.D.	1.8		10.6	5.2	15.3	10.2	13.9	15.8	6.0	4.9	3.8	8.5
			n	5		4	4	4	4	4	5	4	4	4	4
II	R	plano= 0.75 D.Cyl axis 85	C.A.	20	20+2	40	100-	25+2	25+1	60+2	50+2				
			$\bar{X}$	22.5		63.5	96.4	40.9	39.0	47.0	45.2				
			S.D.	0.7		0.7	25.7	5.9	7.4	1.4	1.3				
			n	5		5	5	7	6	4	5				
	L	plano= 0.75 D.Cyl axis 80	C.A.	20	20+2	60	100-	25	25+1	60+2	50+2	25+2	20+2		
			$\bar{X}$	21.75		79.6	135.0	48.5	51.2	61.0	85.4	38.8	30.0		
			S.D.	3.3		15.6	0.0	7.1	9.6	9.2	8.4	8.1	1.4		
			n	6		5	4	6	6	7	5	4	4		
III	R	-3.00 D.S.= -1.00 D.Cyl axis 110	C.A.	400-	20	50	200					20-2	30-1	40	40-2
			$\bar{X}$	224.0	22.0	85.1	153.6					22.2	43.4	33.2	48.0
			S.D.	38.0	1.8	20.2	26.6					1.7	5.1	3.9	0.0
			n	7	6	6	9					6	5	5	4
	L	-3.00 D.S.= -0.25 D.Cyl axis 55	C.A.	400-	25	25	200					30-2	30+2		
			$\bar{X}$	273.5	23.8	104.7	130.8					25.2	46.8		
			S.D.	3.3	2.1	8.7	37.6					3.2	1.2		
			n	7	6	7	9					5	4		

Table 1*

***Note: All acuities are given as the denominator of the Snellen fraction based on a 20 numerator. X is the arithmetic mean of the separate trials in the Snellen denominator. S. D. is the standard deviation. C. A. denotes acuity as measured by the usual clinical procedure. n is the number trials.**

until the subject was first able to identify the orientation correctly. Only one of four responses was possible: *up, down, left,* or *right*. Guessing was not encouraged and incorrect responses were ignored. Upon correct identification of orientation, the paper was moved, the letter size was returned to minimum, and the orientation of the E reset at random and the trial repeated. For simplicity only the upper (100%) threshold is taken. The resulting bar graph gives the threshold limit at a glance (scale not shown in the figure) and the average can be drawn or readily estimated. These results were compared with ordinary clinical acuity measurement.

Simulated computer visual acuities also were taken with trial lenses before the eyes which simulated myopia, myopic astigmatism, and hyperopic astigmatism.

RESULTS

A typical set of acuities taken as described is seen in Figure 1. Table I gives the results of testing three subjects. The number of trials, N, ranged from 4 to 9, the larger numbers generally being used when the scatter was greater, as indicated by the standard deviation. S.D. The acuity is taken as the arithmetic mean of the set of N trials. The values in the table are the denominator of the 20/blank Snellen fraction.

There is reasonable relative clinical agreement between the acuities measured by the simulated computer and the ordinary clinical ones, considering that the methods were so different. Furthermore, there appears to be no special problem in simulated ametropia.

DISCUSSION AND CONCLUSIONS

One problem in computerized refraction may be that the patient, knowing that he is not communicating with a person, will become bored and uninterested. This could be minimized by programming suitable surprises or humor into the sequences. For example the computer may ask the patient (through a tape recorder) to read a series of letters. The patient responds that he is having difficulty distinguishing them, to which the computer replies, "Yes, they *are* rather small; I'm having trouble reading them myself."

There are numerous kinds of targets and modes of presentation possible in visual acuity testing. The simulated computer method here was chosen arbitrarily and is not likely to be the ultimate, ideal method, especially without changing the program or the targets to minimize the effect of astigmatism on the results. Farrer and

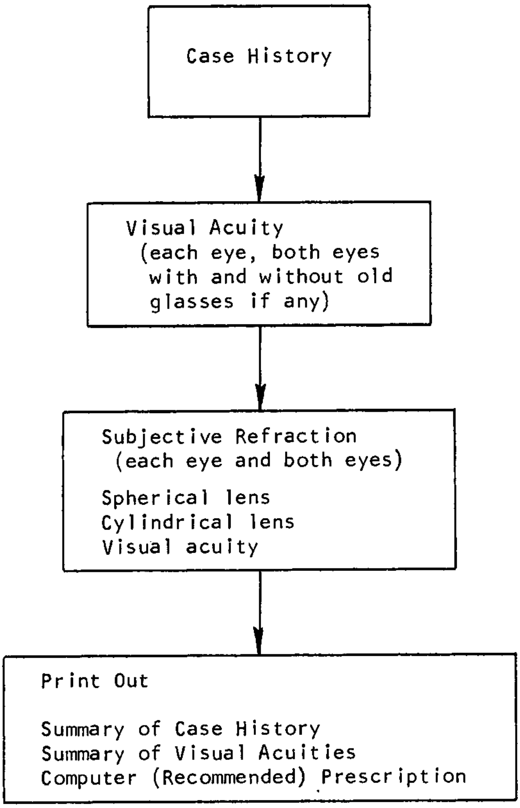

Figure 2: Flochart of basic program for computer-assisted refraction.

Graham,[11] for example, used a four choice method with four Landolt C, three of which were oriented the same way. The "odd" C was chosen by a suitably trained monkey in testing his visual acuity. A similar program for clinical use might prove superior to the one used here. Regardless, the method we used does work on untrained observers and therefore demonstrates the feasibility of computer-measured visual acuity and the possibility of computer-assisted ophthalmic refraction, a simple scheme of which is shown in Figure. 2.

REFERENCES AND NOTES

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Gesell Seminar Planned for Ohio

The Committee on Visual Problems of Children has planned a Gesell Institute of Child Development Seminar on optometric visual training for January 11, 12 and 13. The seminar will be held at the Ramada Inn, Route 161 and 171 in Columbus, and it will be presented by Drs. Richard Apell and John Streff. Registration fee is $100 payable in advance to the Ohio Optometric Association, 88 East Broad Street, Columbus, Ohio 43215.