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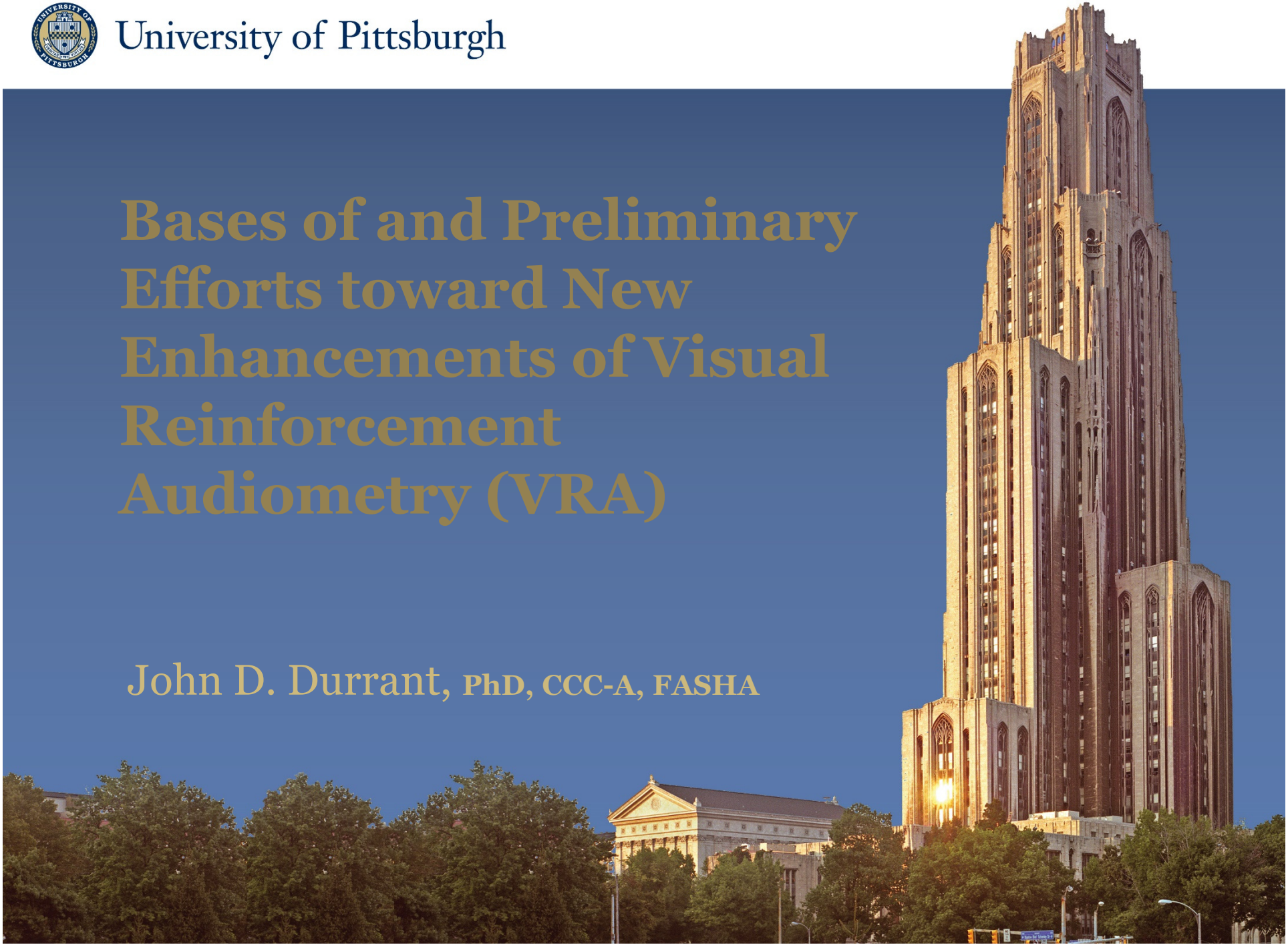
Bases of and Preliminary Efforts toward New Enhancements of Visual Reinforcement Audiometry (VRA)

John D. Durrant, PhD, CCC-A, FASHA



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CHAPTER 14

Assessment of hearing in infants and children

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Can Visual Reinforcement Audiometry and Its Information Yield Be Improved?”

- *Sheila Pratt, PhD*
  and
- *John D. Durrant, PhD*
  with
- *Gregory J. Genna, AuD*

Background and Significance

Background and Significance

VISUAL REINFORCEMENT AUDIOMETRY

Version of VRA called IVRA brought computer assisted testing +

Further developments over the ensuing years:

- Improvements of audiogram display and tools (incl. variety of stimuli)
- Introduction of (optional) Beysian-statistics-based audiometric configuration estimation with min. points
- Video reinforcement and/or animated toys options

Analysis in Adults of Head-Turn Behavior Fundamental to Visual Reinforcement Audiometry—Potential New Source of Information

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[*Work developed in collaboration with*
**Intelligent Hearing Systems, Edward Miskiel, CEO, Miami,*
and enabled by instrumentation developed through a prior Science and Technology Transfer Research grant,
thanks to the NIDCD and NIA of the NIH]

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Background and Significance

- VRA remains the standard clinical testing procedure for verifying prior physiologic results and documenting hearing thresholds, for infants 6 to 24 months of age (developmental age).
- Well developed and accepted behavioral hearing test thus that enables reliable frequency-specific hearing thresholds to be obtained from infants and children who too young to respond to more conventional hearing testing techniques.
- However: Infants 4-months and younger typically lack the motor control, localization skills and cognitive function to complete VRA.
- Many children older than 24 months quickly become bored with the procedure and are more easily tested with play and conventional audiometric procedures.
- On the other hand: Some studies have shown that approximately half of typically developing infants with normal hearing can complete VRA testing at 5 months of age.
- In the future other measurement techniques, such as eye-tracking, might permit adaptation of VRA method to the rest or still younger children.
- Still other reasons to pursue further development of the VRA/VRA-related methods, as follows:

Background and Significance

- VRA is a relatively inefficient method, and can be even more so for many infants with hearing, cognitive and motor impairments.
- Multiple visits may be needed to obtain adequate information.
- Results never as comprehensive as routine audiometry in older children and adults.
- Thereafter, practical estimates of loudness are difficult over an even broader age range.
- “Objective” measures offer alternatives but have their own drawbacks.
- “Objective” methods also cannot not show unequivocally that the child literally hears.

Background and Significance

- There are several inherent procedural problems with VRA:
- Infants vary in their responsiveness to sound, and habituate quickly to the tonal and narrowband noise stimuli (but this is not a focus for the present study).
- It is necessary develop a conditioned response, a very time-intensive process.
- Much also rests on the ability of the examiner to judge a true response.
- Infants not only habituate to stimuli but also to the reinforcement.
- Infants demonstrate a fair amount of “ambient” head movement;…
- …thus, it may be necessary to discern small/less obvious behaviors than the human observer can faithfully score.

Introduction

- We hypothesize that such small head turns and/or "noisy" head movements can be scored adequately with the assistance of sensitive and consistent measurements of head-turn.
- Responses acquired with the aid of computer permit consistent rule-based scoring.
- The same technology is also expected to permit the measurement of reaction times.
- Reaction time has been known, since Chocholle (1940), to decrease with increased stimulus loudness, but RT has yet to be incorporated into clinical audiometry.
- Reaction time could also help to improve computer-assisted VRA (more on this momentarily).
- Human observers are not capable of running statistical sampling of responses, let alone measuring reaction time, without technical assistance.

Introduction

- Consequently, it was deemed useful, first in cooperative adults, to characterize head-turn responses during audiometry akin to VRA.
- Furthermore, it was deemed useful to look at such behavior in reference to the familiar simple RT of push-button response .

Methods

- This study was primarily descriptive in nature, utilizing a within subjects design.
- Two types of head-turn measurement were used, namely for cross-validation as video-detection methods had yet to be shown to be reliable.
- Again, simple reaction time of button pressing was also made for comparison.
- A sample of 10 adult participants were examined—female graduate students with normal hearing sensitivity by conventional audiometry and negative otologic and neurotologic histories.

Methods

The protocol consisted of two components: threshold search and loudness-RT scaling.

<u>Preliminary threshold:</u>

- Thresholds were obtained for a 2 kHz warble tone, presented in the sound field.
- Determined using the up-down (staircase) method with 1 dB resolution.
- 10 reversals were taken, averaging levels of the last 8 reversals for threshold.
- Thie value was taken as the reference for the SL of stimuli for the main threshold and loudness test components.

Methods

- Component 1—Threshold:
- (1) Push-button Response audiometry: The classical psychophysical method of constant stimuli (MCS) was used as it yields a full psychometric function directly.
- Expected to follow overall the "ogive" function (cumulative normal distribution).
- A range of 20 dB was used centered on 0 dB SL (re: results of the up-down tracking), using a total of 11 2-dB steps.
- Each stimulus was repeated 10 times per step, randomized over steps and repetition.

Methods

- (2) VRA-like (Head-turn Response) Audiometry: essentially the same protocol
- Response was a head turn toward the apparent origin of the sound.
- The sound could occur randomly to the right or left with the loudspeakers situated at $\pm$45 degrees azimuth.
- Video imaging was obtained with a digital camera, recorded direct to DVD, and interfaced later to a personal computer for processing for tracking of a high-contrast moving feature.
- For direct/mechanically measured head movement, a Watson rate sensor was used.
- A light helmet band held this sensor plus a white cloth with a black target:
  - (1) to obscuring the participant's visual fixation on the loudspeakers;
  - (2) to permitting use of software developed for tracking the pupil [i.e. for head-only rotational testing].

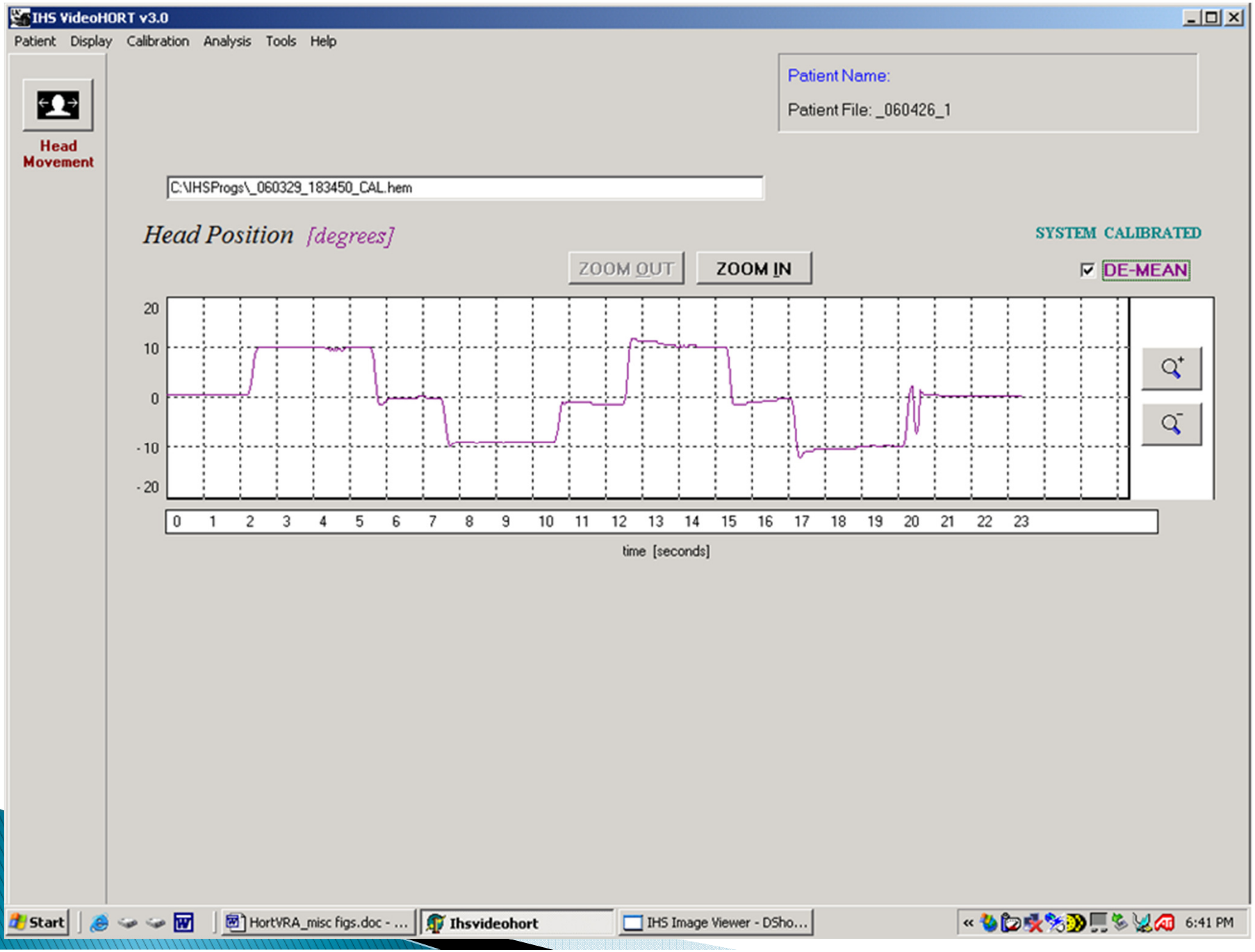
Methods

- <u>Component 2—Loudness-related RT:</u>
- Set of 2 kHz tones spanned 20 to 80 dB SL (re: "preliminary" threshold).
- Steps were 4 dB; stimulus level was randomized across steps and repetitions (10 per step for a total of 11 steps)
- It was expected (a priori) that with increasing SL, reaction time would decrease systematically.
- Button-pushing RT was measured from recordings of the input stimuli captured by the same direct-to-DVD recording, analyses off-line.
- As before, right and left head orientations was elicited randomly.

Methods

Fig. 1a. Head tracking (subject: Baby Doe)

Methods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Patient Display Calibration Analysis Tools Help
Head Movement
Patient Name:
Patient File: _060426_1
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Head Position [degrees]
SYSTEM CALIBRATED
ZOOM OUT
ZOOM IN
DE-MEAN
20
10
0
-10
-20
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
time [seconds]
Start
HortVRA_misc figs.doc - ...
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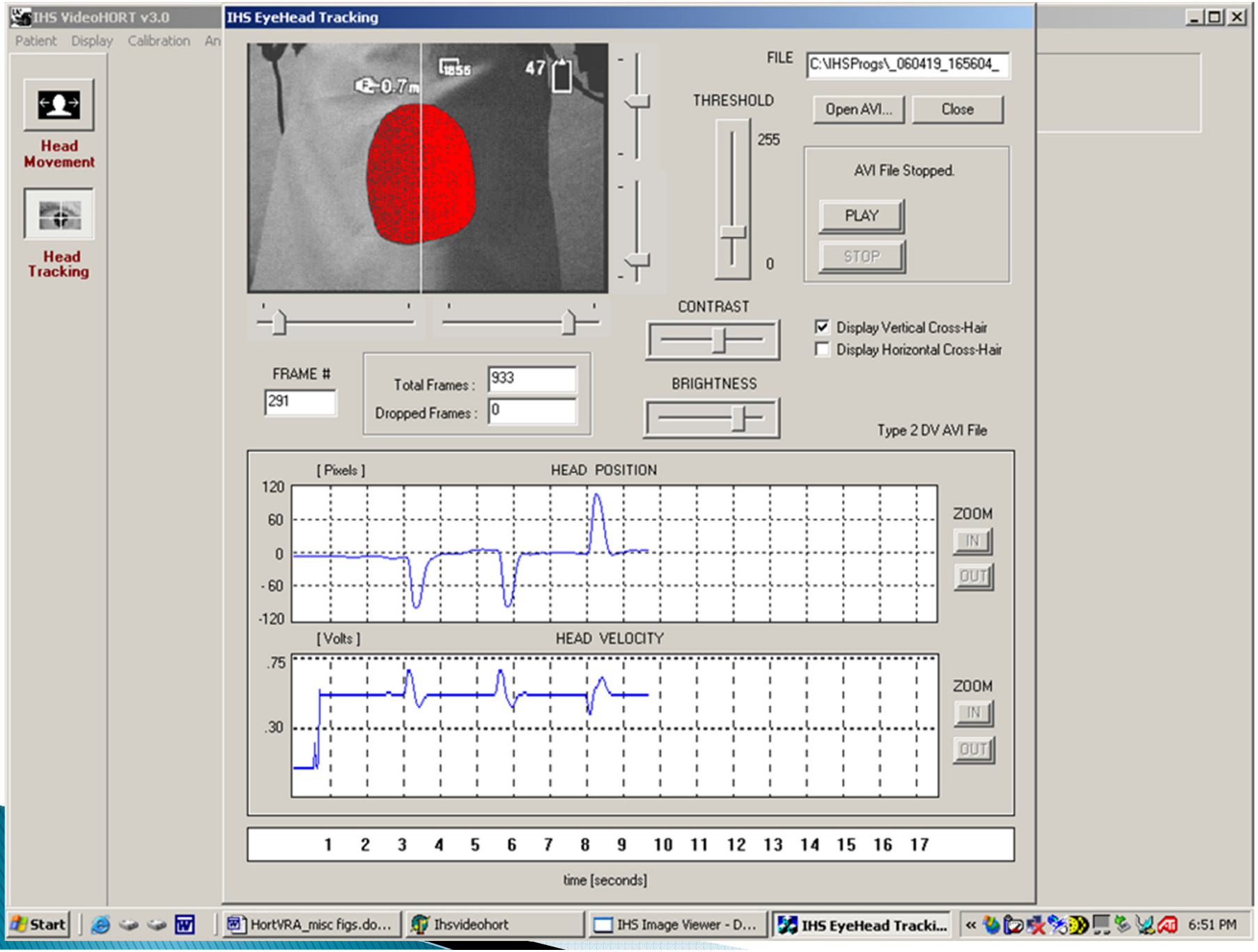
IHS Image Viewer - DSho...
6:41 PM

Methods


IHS VideoHORT v3.0
Patient Display Calibration An
IHS EyeHead Tracking
Head Movement
Head Tracking
FILE
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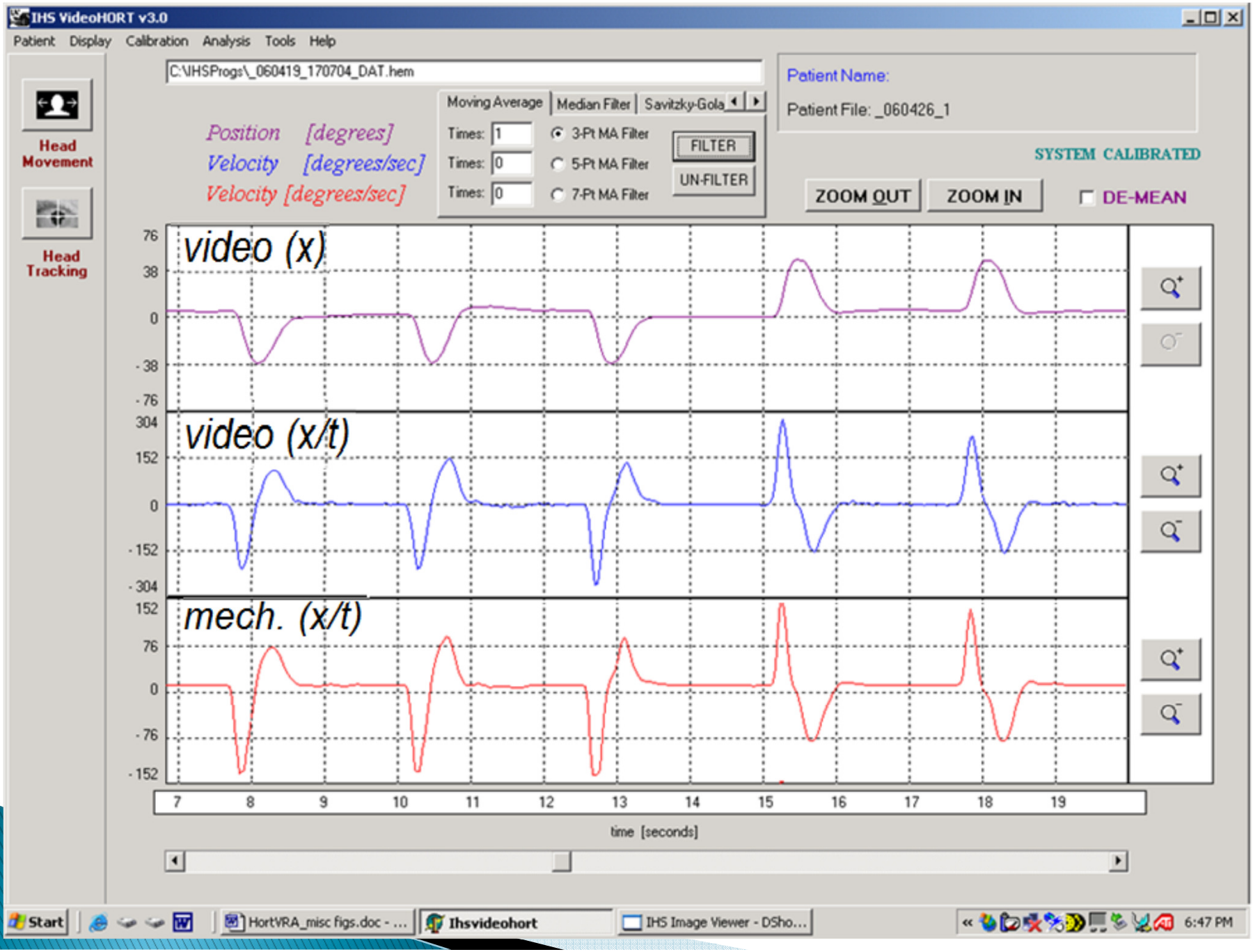
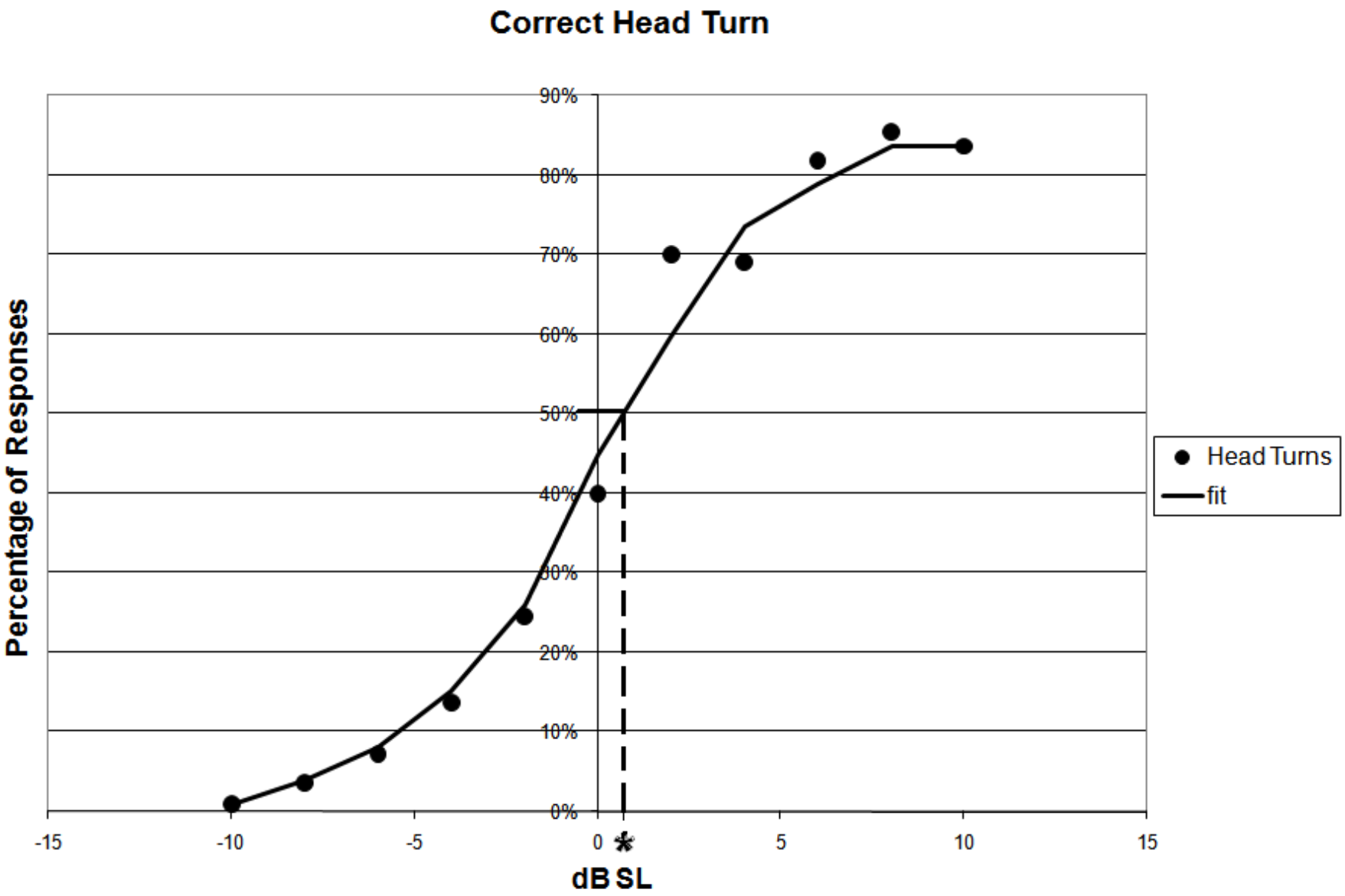
THRESHOLD
255
0
Open AVI...
Close
AVI File Stopped.
PLAY
STOP
CONTRAST
BRIGHTNESS
Display Vertical Cross-Hair
Display Horizontal Cross-Hair
Type 2 DV AVI File
FRAME #
291
Total Frames :
933
Dropped Frames :
0
[Pixels]
HEAD POSITION
120
60
0
- 60
-120
ZOOM
IN
OUT
[Volts]
HEAD VELOCITY
.75
.30
ZOOM
IN
OUT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
time [seconds]
Start
HortVRA_misc figs.do...
Ihsvideohort
IHS Image Viewer - D...
IHS EyeHead Tracki...
6:51 PM

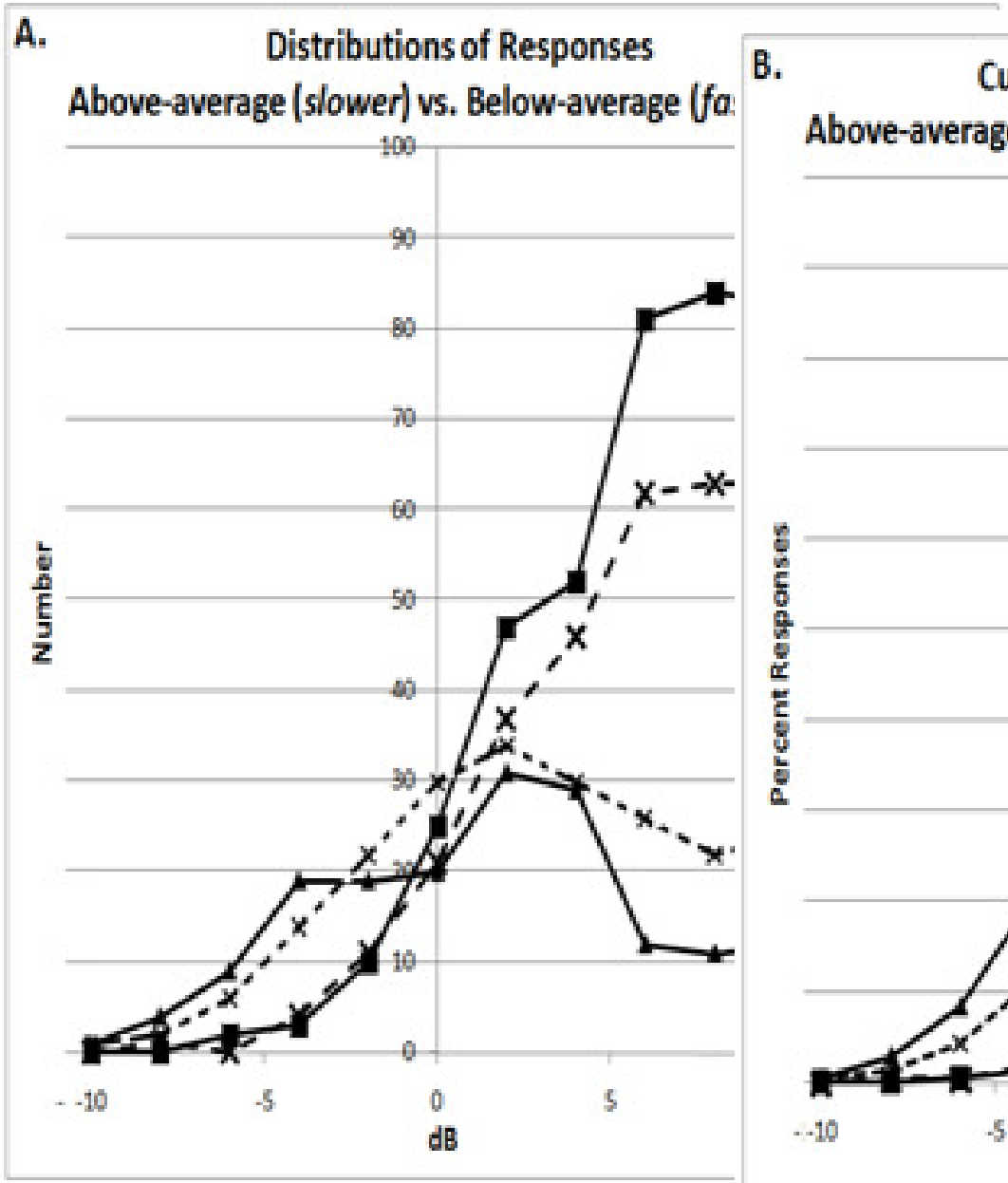
Methods

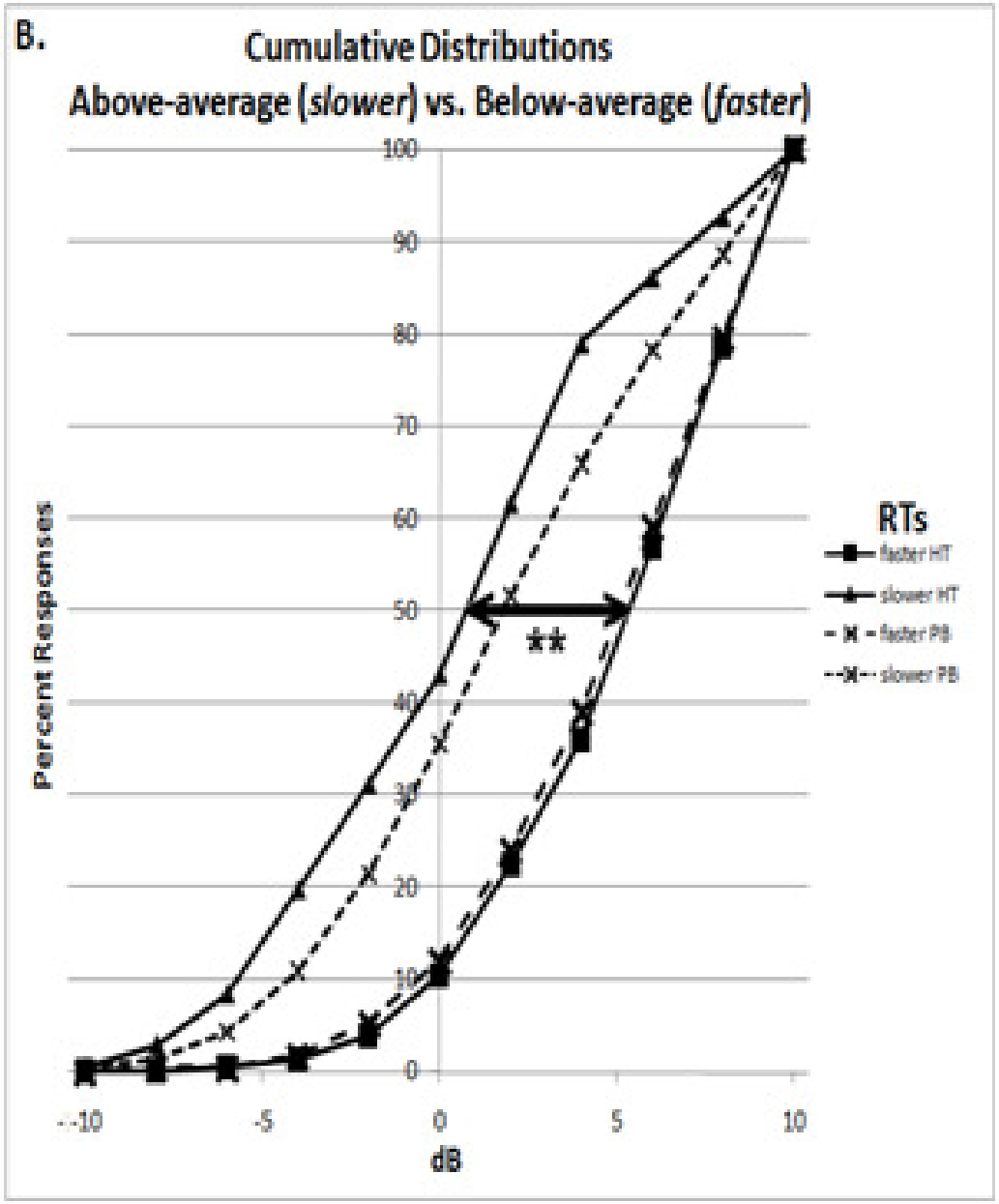

IHS VideoHORT v3.0
Patient Display Calibration Analysis Tools Help
C:\IHSProgs_060419_170704_DAT.hem
Head Movement
Head Tracking
Position [degrees]
Velocity [degrees/sec]
Velocity [degrees/sec]
Moving Average
Median Filter
Savitzky-Gola
Times: 1
Times: 0
Times: 0
3-Pt MA Filter
5-Pt MA Filter
7-Pt MA Filter
FILTER
UN-FILTER
Patient Name:
Patient File: _060426_1
SYSTEM CALIBRATED
ZOOM OUT
ZOOM IN
DE-MEAN
video (x)
video (x/t)
mech. (x/t)
76
38
0
-38
-76
304
152
0
-152
-304
152
76
0
-76
-152
7 8 9 10 11 12 13 14 15 16 17 18 19
time [seconds]
Start
HortVRA_misc figs.doc - ...
Ihsvideohort
IHS Image Viewer - DSho...
6:47 PM

Results

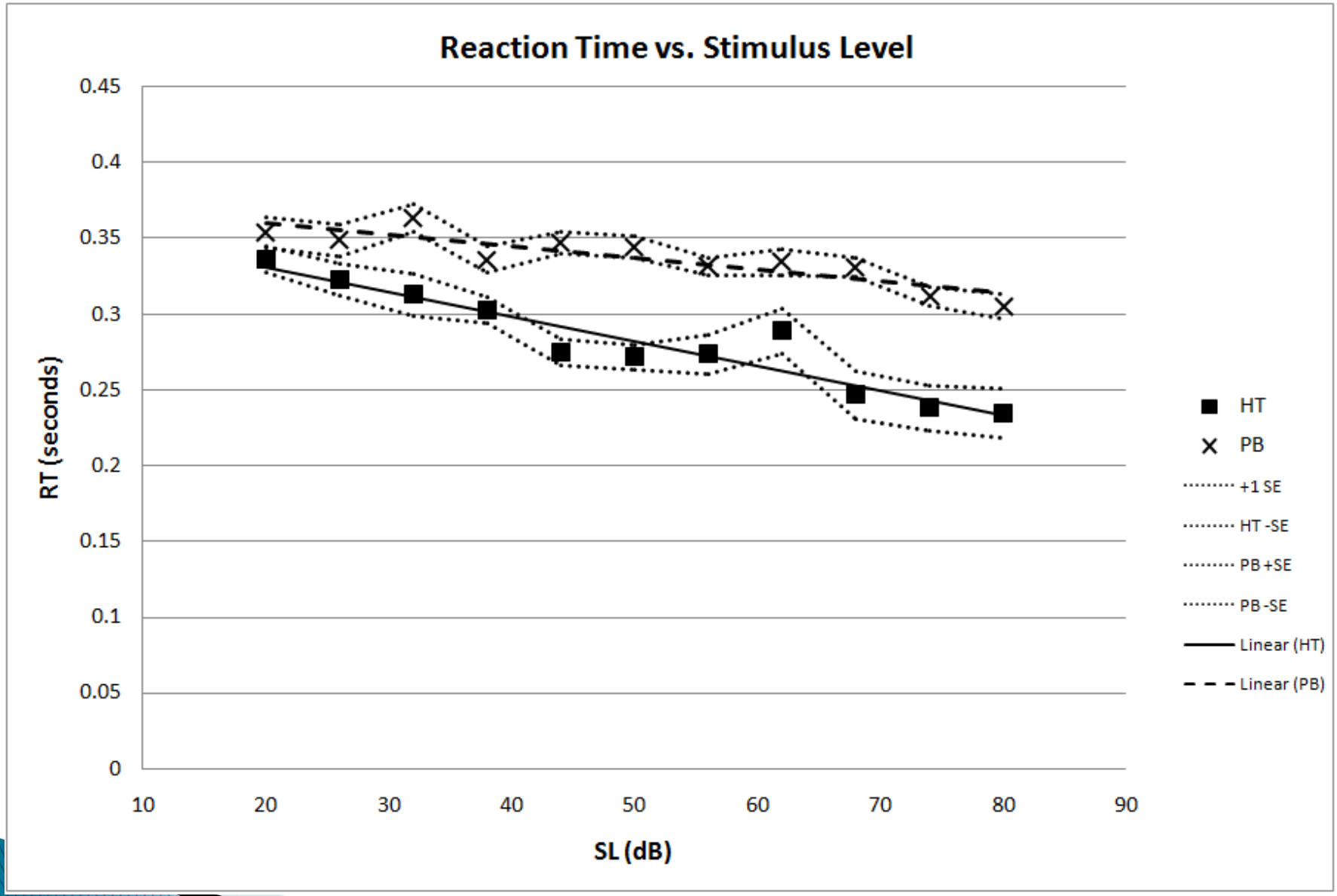

Correct Head Turn
Percentage of Responses
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-15
-10
-5
0
5
10
15
dB SL
Head Turns
fit

Results


A.
Distributions of Responses
Above-average (slower) vs. Below-average (fa
Number
dB
100
90
80
70
60
50
40
30
20
10
0
-10
-5
0
5


B.
Cumulative Distributions
Above-average (slower) vs. Below-average (faster)
Percent Responses
dB
RTs
faster HT
slower HT
faster PB
slower PB
**
100
90
80
70
60
50
40
30
20
10
0
-10
-5
0
5
10

Results


Reaction Time vs. Stimulus Level
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
RT (seconds)
10
20
30
40
50
60
70
80
90
SL (dB)
HT
PB
+1 SE
HT -SE
PB +SE
PB -SE
Linear (HT)
Linear (PB)

Conclusions

- Video tracking faithfully mimicked mechanical tracking of head turns.
- Comparable head-turn and push-button behavior near threshold can permit more quantitative response analyses (e.g. response quality, variability, and/or bias).
- Head-turn monitored VRA results fall within ~1 dB (mean) of more conventionally determined thresholds.
- Comparable head-turn and push-button RTs to supra threshold stimuli, potentially provide loudness growth information.

Conclusions

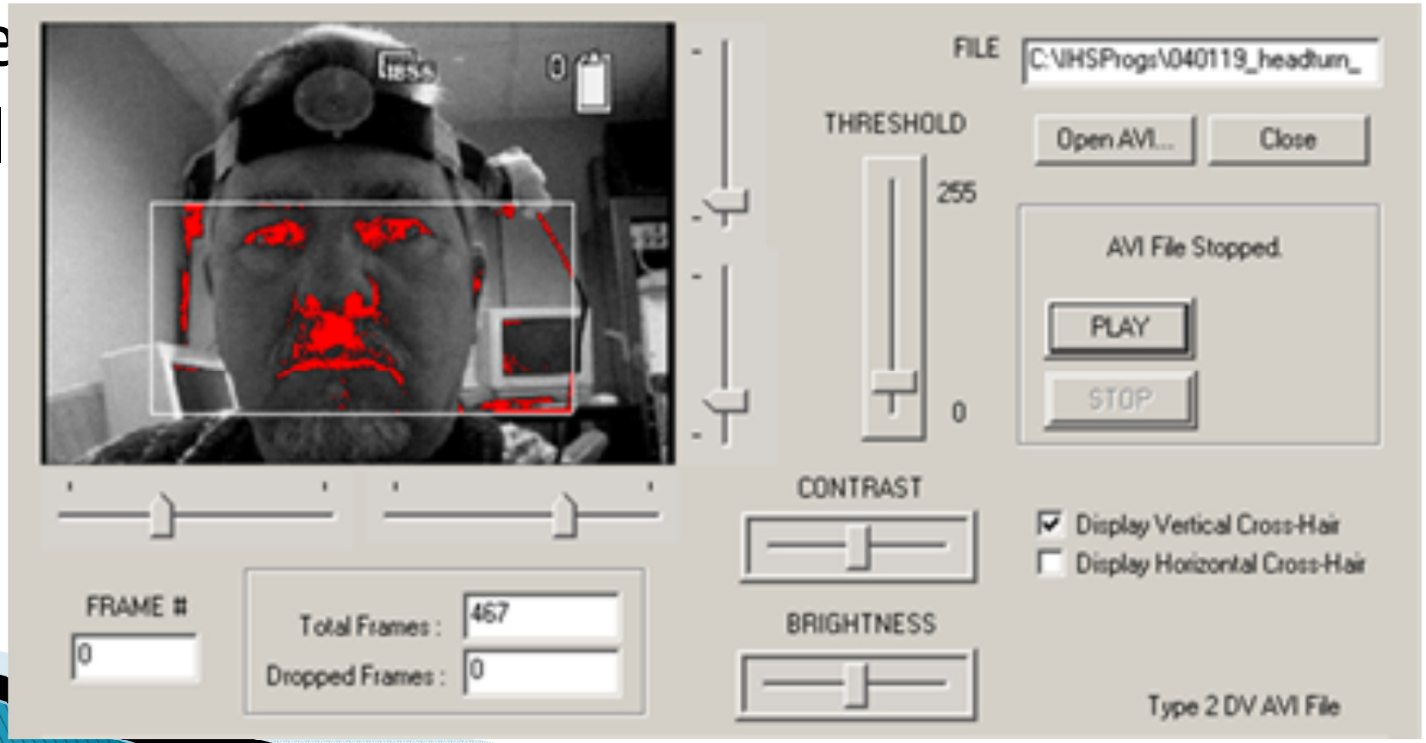
PREDICTIONS:

- Head-turn RT measures, demonstrated in cooperative young adults, will ultimately be shown to be equally applicable in infants/young children.
- These measures can be used via semi-automated methods to lead to the first substantial improvement in VRA in decades.
- Such advances will impact not only the traditional interest of threshold sensitivity but will expand the method's utility over the entire dynamic range of hearing.

Very Preliminary Efficacy (Phase I) Findings

Initial Strategy to for R&D with Target Population:

- Adapt tool in hand, knowing refinements in head tracking, per se, must follow (Phase II).
- Assumed focus thus on getting to threshold search algorithm (i.e. head-turn/RT suppleme
- Technical



Very Preliminary Efficacy (Phase I) Findings

REPLACEMENT SHEET

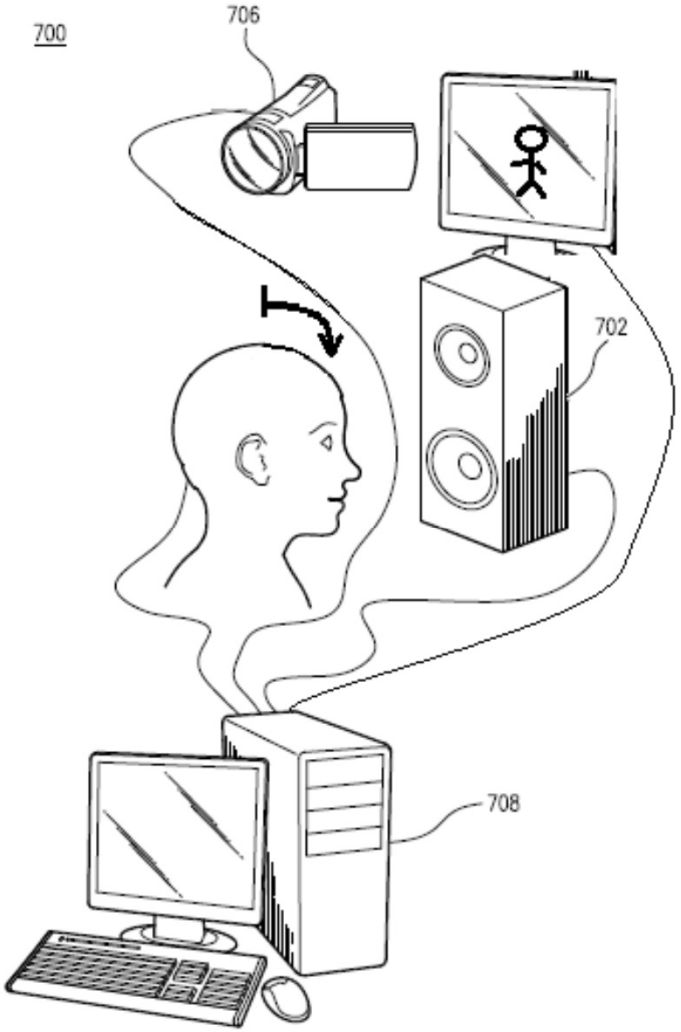
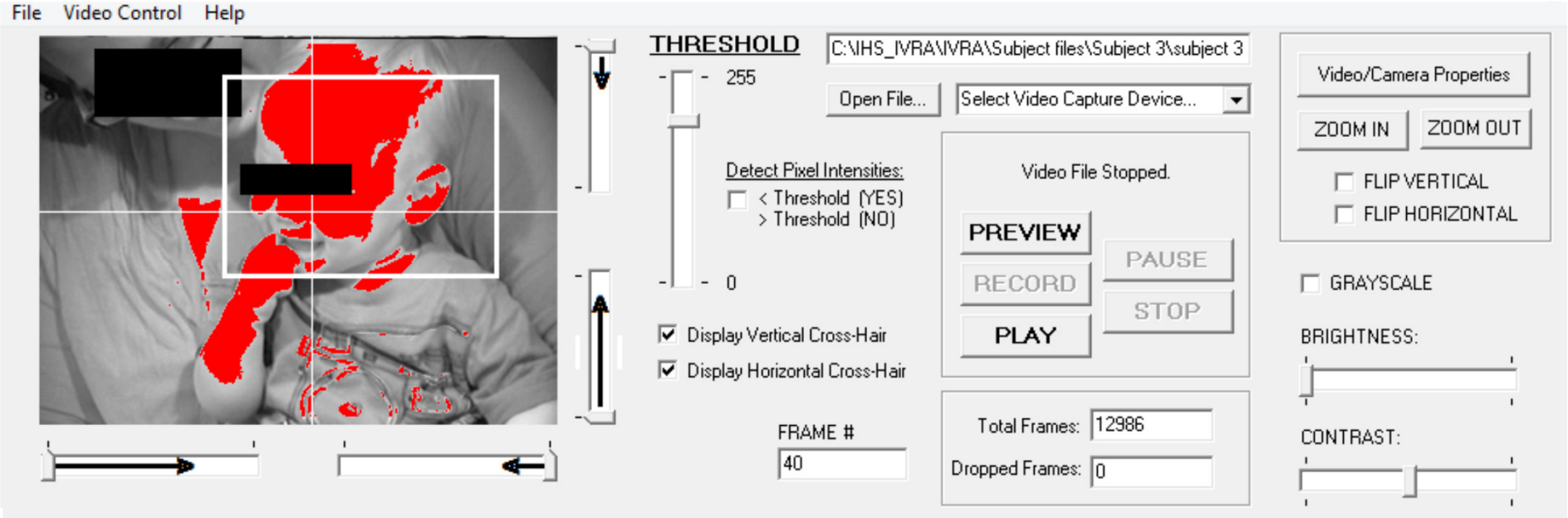


FIG. 7(B)

Initial Efficacy Findings



Initial Efficacy Findings

- But…

Early Efficacious Product Enhancement Potential

- Running video record
- Relatively inexpensive (especially, apropos added instrumentation) thanks to webcam type and other CPU-interfacable digital cameras.
- Logitech's orbits potentially of interest (steerability)

Initial Efficacy Findings

◆Economic retro-fitting of existing systems.

◆Multiple applications; general principle--”leveling the playing field”.

◆For experienced examiners, reviewing to confirm scoring, refresh memory (e.g. comments on general behavior).

◆Supplement supervision:

- Lesser experiences staff members.
- Student clinicians/externs/others.
- Staff case review/”grand rounds, other professional presentations.
- Tele-audiology.
- Parent orientation?

Initial Efficacy Findings

Moving On:

- Virtual library of head turn behavior during VRA (the good, bad, & ugly).
- R&D on “technical side” currently focused on adapting facial recognition/tracking software.
- Remaining loyal to original convictions…

Thank you for your attention.