1
00:00:01,133 --> 00:00:07,133
[musical tones]
[electronic sounds of data]

2
00:00:16,566 --> 00:00:21,766
So welcome to this year's
NASA Ames Summer Series.

3
00:00:21,766 --> 00:00:26,033
This year's series includes
18 talks.

4
00:00:26,033 --> 00:00:28,466
The talks vary in topics

5
00:00:28,466 --> 00:00:31,533
from science to science fiction,

6
00:00:31,533 --> 00:00:36,500
from talks that are about
early beginnings of innovations

7
00:00:36,500 --> 00:00:40,300
to mature stages in careers.

8
00:00:42,000 --> 00:00:44,733
All of the talks will give you
a different way

9
00:00:44,733 --> 00:00:48,033
of seeing both what NASA does

10
00:00:48,033 --> 00:00:52,133
and what the world is.

11
00:00:52,133 --> 00:00:55,800
It is important for us
to understand

12
00:00:55,800 --> 00:01:00,733
that vision plays
a really critical step

13
00:01:00,733 --> 00:01:05,700
in how we process what's
around us, how we operate,

14
00:01:05,700 --> 00:01:09,733
and at the end of the day,
how innovation starts.

15
00:01:09,733 --> 00:01:12,233
Today's seminar is entitled

16
00:01:12,233 --> 00:01:15,633
"Brain Function Through
the Eyes of the Beholder."

17
00:01:15,633 --> 00:01:19,266
It will be given
by Dr. Lee Stone.

18
00:01:19,266 --> 00:01:23,333
Dr. Stone received his BA
in biophysics in 1980

19
00:01:23,333 --> 00:01:26,600
from John Hopkins University.

20
00:01:26,600 --> 00:01:31,233
He then finished an MS
in engineering in 1983

21
00:01:31,233 --> 00:01:34,566
from the University
of California at Berkeley,

22
00:01:34,566 --> 00:01:38,733

followed by a PhD in 1987
in neuroscience

23
00:01:38,733 --> 00:01:42,566
from the University
of California at San Francisco.

24
00:01:42,566 --> 00:01:44,733
After finishing his degree,

25
00:01:44,733 --> 00:01:48,733
he decided that Ames
is his future

26
00:01:48,733 --> 00:01:51,600
for multiple reasons.

27
00:01:51,600 --> 00:01:56,533
So he came to Ames and did
a postdoctoral fellow

28
00:01:56,533 --> 00:01:59,300
in the human factors division
at Ames

29
00:01:59,300 --> 00:02:03,666
under Dr. Watson
who introduced him

30
00:02:03,666 --> 00:02:07,566
to the art of human
psychophysical measurements,

31
00:02:07,566 --> 00:02:09,400
and also at the same time,

32
00:02:09,400 --> 00:02:12,766
he fell in love with Ames.

33

00:02:12,766 --> 00:02:15,900
In 1990, Dr. Stone took
a research position

34
00:02:15,900 --> 00:02:19,300
in the life sciences division
at Ames,

35
00:02:19,300 --> 00:02:21,866
where he besides doing research
also served

36
00:02:21,866 --> 00:02:25,900
as a project scientist
for the RHESUS project.

37
00:02:25,900 --> 00:02:29,366
In 1995, he transferred

38
00:02:29,366 --> 00:02:31,700
to the human systems
integration division,

39
00:02:31,700 --> 00:02:35,466
and established the Visuomotor
Control Laboratory.

40
00:02:36,900 --> 00:02:40,300
Please join me in welcoming
Dr. Stone.

41
00:02:40,300 --> 00:02:44,300
[applause]

42
00:02:47,166 --> 00:02:49,833
Uh, good afternoon
or good morning.

43
00:02:49,833 --> 00:02:51,366
The first thing I want to say is

44
00:02:51,366 --> 00:02:54,600
I want to thank the Office
of the Chief Scientist

45
00:02:54,600 --> 00:02:57,500
for inviting me
to give the talk,

46
00:02:57,500 --> 00:03:01,500
so there's
a shameless plug there.

47
00:03:01,500 --> 00:03:05,966
But, um, so this talk is
about using eye movements

48
00:03:05,966 --> 00:03:09,933
to explore and characterize
human brain function.

49
00:03:11,266 --> 00:03:15,700
In an effort to bridge
the gap between

50
00:03:15,700 --> 00:03:18,666
psychologists who are studying
visual perception,

51
00:03:18,666 --> 00:03:22,500
and neuroscientists
who are studying

52
00:03:22,500 --> 00:03:25,533
the eye movement neurophysiology
and behavior,

53
00:03:25,533 --> 00:03:29,266
the Visuomotor Control Lab
has developed

54
00:03:29,266 --> 00:03:31,966
over a period
of the last 20 years

55
00:03:31,966 --> 00:03:35,766
a number of eye movement-based
methodologies

56
00:03:35,766 --> 00:03:39,466
or oculometric methodologies

57
00:03:39,466 --> 00:03:43,566
that we've used to perform
scientific research,

58
00:03:43,566 --> 00:03:46,300
to do human factors testing,

59
00:03:46,300 --> 00:03:49,166
and our latest effort
in the laboratory

60
00:03:49,166 --> 00:03:51,033
is to apply oculometrics

61
00:03:51,033 --> 00:03:54,200
to establish a clinical tool

62
00:03:54,200 --> 00:03:58,733
that could be used to assess
impaired brain function

63
00:03:58,733 --> 00:04:01,366
due to disease or injury.

64
00:04:04,900 --> 00:04:08,733
So the talk has five parts.

65
00:04:08,733 --> 00:04:10,133
I'm going to give you
a quick background

66
00:04:10,133 --> 00:04:12,500
on the status of things
20 years ago

67
00:04:12,500 --> 00:04:15,633
when the Visuomotor Control Lab
was established.

68
00:04:15,633 --> 00:04:18,733
I'm going to talk about
three main achievements

69
00:04:18,733 --> 00:04:21,300
over the last two decades.

70
00:04:21,300 --> 00:04:24,633
First and foremost,
the validation of oculometrics

71
00:04:24,633 --> 00:04:27,366
as a tool that can be used to
measure visual perception

72
00:04:27,366 --> 00:04:29,900
and higher-order brain function.

73
00:04:29,900 --> 00:04:33,233
Secondly, the use
of oculometrics

74
00:04:33,233 --> 00:04:35,766
as a scientific research tool.

75
00:04:35,766 --> 00:04:37,800
And lastly,

76
00:04:37,800 --> 00:04:41,100
the recent application
of oculometrics

77
00:04:41,100 --> 00:04:45,200
as a clinical tool and then I'll
have a few concluding remarks.

78
00:04:45,200 --> 00:04:49,400
So, now for the quick background

79
00:04:49,400 --> 00:04:51,466
of the status of things

80
00:04:51,466 --> 00:04:53,533
in the late 20th century.

81
00:04:53,533 --> 00:04:58,266
So the conventional wisdom
20 years ago

82
00:04:58,266 --> 00:05:01,966
was that human visual system

83
00:05:01,966 --> 00:05:04,433
had two main pathways.

84
00:05:04,433 --> 00:05:07,133
Everything obviously starts
with the retina in your eye.

85
00:05:07,133 --> 00:05:08,566
It goes to a thalamic nucleus,

86
00:05:08,566 --> 00:05:11,500
and then to
the primary visual cortex

87
00:05:11,500 --> 00:05:14,166
in the back of your brain,
and then from there

88
00:05:14,166 --> 00:05:17,666
it's split into two different
distinct pathways.

89
00:05:17,666 --> 00:05:22,000
One that ended up in
posterior parietal cortex,

90
00:05:22,000 --> 00:05:25,400
and one--
that's the dorsal pathway--

91
00:05:25,400 --> 00:05:27,200
and one ventral pathway

92
00:05:27,200 --> 00:05:30,166
that ended up in the inferior
temporal cortex,

93
00:05:30,166 --> 00:05:32,766
and Ungerleider and Mishkin
originally pointed out

94
00:05:32,766 --> 00:05:35,766
that most of the areas in
posterior parietal cortex

95
00:05:35,766 --> 00:05:39,600
were involved in processing
spatial relationships and motion

96
00:05:39,600 --> 00:05:42,066
and other things related
to where things are,

97

00:05:42,066 --> 00:05:46,400
and the ventral pathway had
neurons that were involved

98
00:05:46,400 --> 00:05:49,866
in identifying things and
identifying objects, faces,

99
00:05:49,866 --> 00:05:53,700
and were involved in what
they called "what" questions.

100
00:05:53,700 --> 00:05:56,866
But actually,

101
00:05:56,866 --> 00:05:59,333
that dichotomy morphed

102
00:05:59,333 --> 00:06:02,666
into a more extreme dichotomy

103
00:06:02,666 --> 00:06:05,833
where Goodale and Milner
in the beginning of the '90s

104
00:06:05,833 --> 00:06:07,100
proposed a hypothesis

105
00:06:07,100 --> 00:06:09,333
that really dominated the field
at the time,

106
00:06:09,333 --> 00:06:11,800
which is that
the dorsal pathway was involved

107
00:06:11,800 --> 00:06:16,133
in controlling motor action, and
the ventral pathway was involved

108
00:06:16,133 --> 00:06:17,433
in visual perception

109
00:06:17,433 --> 00:06:20,600
and that these two pathways
were distinct.

110
00:06:20,600 --> 00:06:26,500
Now, um, that pi--
that tidy dichotomy there,

111
00:06:26,500 --> 00:06:28,100
you know,
neglected a number of things.

112
00:06:28,100 --> 00:06:32,733
You know, there was
a low-level brain stem pathway

113
00:06:32,733 --> 00:06:37,033
that evolutionarily existed
in reptiles and all the way up,

114
00:06:37,033 --> 00:06:39,800
but it's involved
in controlling eye movements,

115
00:06:39,800 --> 00:06:43,233
and in primates,
that subcortical pathway

116
00:06:43,233 --> 00:06:46,966
also connects up with the cortex
in an indirect pathway,

117
00:06:46,966 --> 00:06:50,966
and also highest-order
visual processing

118

00:06:50,966 --> 00:06:52,966
and cognitive processing
at the frontal cortex

119
00:06:52,966 --> 00:06:56,966
feeds back both
the brain stem areas--whoops--

120
00:06:56,966 --> 00:06:59,733
brain stem areas
and parietal cortex.

121
00:06:59,733 --> 00:07:02,333
And so the reason
for showing you this slide

122
00:07:02,333 --> 00:07:06,766
is to show you that the story
really isn't that tidy.

123
00:07:06,766 --> 00:07:11,366
And indeed, even 20 years ago,

124
00:07:11,366 --> 00:07:14,700
Van Essen's lab and others
basically had pointed out

125
00:07:14,700 --> 00:07:16,100
that when you go
from the retina,

126
00:07:16,100 --> 00:07:17,400
there may be a ventral path

127
00:07:17,400 --> 00:07:19,700
and a dorsal path,
but the fact is,

128
00:07:19,700 --> 00:07:22,900
prefrontal cortex and

all these areas all interconnect

129
00:07:22,900 --> 00:07:26,100
in a very complicated network.

130
00:07:26,100 --> 00:07:29,433
And so there really is
no clean dichotomy

131
00:07:29,433 --> 00:07:31,333
between the dorsal
and ventral pathways

132
00:07:31,333 --> 00:07:34,400
for action and perception.

133
00:07:34,400 --> 00:07:38,066
Well, simultaneously
with those efforts in...

134
00:07:38,066 --> 00:07:40,633
[stammers]

135
00:07:40,633 --> 00:07:43,833
in visual perception
and neuroscience,

136
00:07:43,833 --> 00:07:45,966
there was
an almost separate field

137
00:07:45,966 --> 00:07:49,933
of ocular motor behavior
and physiology.

138
00:07:49,933 --> 00:07:53,866
Oh, whoops.

139
00:07:53,866 --> 00:07:56,700

That basically was
dominated and started

140
00:07:56,700 --> 00:07:59,700
by David A. Robinson at Hopkins,

141
00:07:59,700 --> 00:08:03,200
and he pushed forward

142
00:08:03,200 --> 00:08:07,533
an exciting new quantitative
computational way

143
00:08:07,533 --> 00:08:10,766
of looking at eye movements
based on linear system theory.

144
00:08:10,766 --> 00:08:14,033
So this slide shows
a typical eye movement

145
00:08:14,033 --> 00:08:17,200
that would occur in response
to a sinusoidally moving target,

146
00:08:17,200 --> 00:08:19,966
so you follow that target
as it moves back and forth.

147
00:08:19,966 --> 00:08:23,400
And what you can see is
there's these smooth components,

148
00:08:23,400 --> 00:08:26,333
but every so often
when you get behind the target,

149
00:08:26,333 --> 00:08:29,933
you have these quick jumps
to catch up

150
00:08:29,933 --> 00:08:32,766
because you're behind the
target, you want to catch up.

151
00:08:32,766 --> 00:08:35,633
Now if you look at that as a
plot of eye velocity over time,

152
00:08:35,633 --> 00:08:39,166
what you see is a nice,
smooth, sinusoidal oscillation

153
00:08:39,166 --> 00:08:42,766
in eye movements
with these interspersed jumps.

154
00:08:42,766 --> 00:08:46,200
These pulses
of rapid eye movements.

155
00:08:46,200 --> 00:08:50,900
And so humans have
two voluntary systems

156
00:08:50,900 --> 00:08:53,566
for tracking moving targets.

157
00:08:53,566 --> 00:08:56,666
You use this smooth component
or called pursuit,

158
00:08:56,666 --> 00:09:00,200
which generates the smooth
main component of the response,

159
00:09:00,200 --> 00:09:02,633
and then there's also
these catch-up saccades.

160
00:09:02,633 --> 00:09:05,300
And what David A. Robinson

161
00:09:05,300 --> 00:09:10,233
and his progeny

162
00:09:10,233 --> 00:09:13,066
in eye movement research
developed were

163
00:09:13,066 --> 00:09:14,766
these simple control systems
that work

164
00:09:14,766 --> 00:09:18,833
to drive the retinal error image
to zero.

165
00:09:18,833 --> 00:09:20,733
So if you're tracking something

166
00:09:20,733 --> 00:09:22,266
it has an image on
the back of your eye.

167
00:09:22,266 --> 00:09:24,300
If you move your eye such
that you get that image

168
00:09:24,300 --> 00:09:27,766
to stop moving, then you can
actually track the target

169
00:09:27,766 --> 00:09:29,800
and so you have a simple
negative feedback loop

170
00:09:29,800 --> 00:09:31,566
and it's independent

of any higher order

171
00:09:31,566 --> 00:09:32,800
of visual processing,

172
00:09:32,800 --> 00:09:35,200
consistent with the dichotomy

173
00:09:35,200 --> 00:09:37,900
of Goodale and Milner.

174
00:09:37,900 --> 00:09:41,966
Now that view culminated
in some very elaborate

175
00:09:41,966 --> 00:09:45,233
and quantitative models
at the end of the '80s

176
00:09:45,233 --> 00:09:47,600
where, you know,
all of these models

177
00:09:47,600 --> 00:09:49,700
were based on
retinal image motion

178
00:09:49,700 --> 00:09:51,733
being controlled by pursuit,

179
00:09:51,733 --> 00:09:56,233
and they all start off
with a retinal error--

180
00:09:56,233 --> 00:09:59,100
whoops,
these buttons are too close.

181
00:09:59,100 --> 00:10:01,200

Um, bad human factors.

182
00:10:01,200 --> 00:10:02,333
[laughter]

183
00:10:02,333 --> 00:10:04,833
So there's this
retinal image motion

184
00:10:04,833 --> 00:10:06,466
which is the difference between
what your eyes are doing

185
00:10:06,466 --> 00:10:08,366
and your target--
and with a delay,

186
00:10:08,366 --> 00:10:10,266
it goes up into visual cortex

187
00:10:10,266 --> 00:10:13,166
and with a few
static nonlinearities

188
00:10:13,166 --> 00:10:14,833
and a bunch
of linear processing,

189
00:10:14,833 --> 00:10:17,533
drives a simple
negative feedback loop,

190
00:10:17,533 --> 00:10:19,933
so the second component is
there's a negative feedback loop

191
00:10:19,933 --> 00:10:22,000
that you can drive
the error to zero.

192
00:10:22,000 --> 00:10:24,266
And then in order
to keep the eye moving

193
00:10:24,266 --> 00:10:25,666
when you've reached
that steady state

194
00:10:25,666 --> 00:10:26,900
where there's no more error,

195
00:10:26,900 --> 00:10:30,200
you have a velocity
memory pathway

196
00:10:30,200 --> 00:10:33,066
that you use to sustain
eye movement

197
00:10:33,066 --> 00:10:34,600
when there's no more error.

198
00:10:34,600 --> 00:10:37,266
So once again, all these models,
pursuit is driven by

199
00:10:37,266 --> 00:10:39,400
a simple retinal image
motion control loop,

200
00:10:39,400 --> 00:10:40,533
with two main components:

201
00:10:40,533 --> 00:10:43,133
negative feedback
and an internal memory.

202
00:10:43,133 --> 00:10:46,833
So, um,

203
00:10:46,833 --> 00:10:50,833
that was the dominant view
of the field

204
00:10:50,833 --> 00:10:54,600
when I got my PhD
and came to Ames.

205
00:10:54,600 --> 00:10:56,933
But there were always some
troubling little details

206
00:10:56,933 --> 00:10:59,933
out there in the world
where folks just tended

207
00:10:59,933 --> 00:11:01,466
to not pay attention to it,

208
00:11:01,466 --> 00:11:05,800
but they were very important
little pieces of information.

209
00:11:05,800 --> 00:11:11,400
I think I have to do this...
and it will work.

210
00:11:11,400 --> 00:11:15,566
So imagine a rolling wagon wheel
with three--four red dots on it.

211
00:11:15,566 --> 00:11:16,866
And each one of those red dots

212
00:11:16,866 --> 00:11:19,800
is moving along a nice
cycloidal path like that.

213

00:11:19,800 --> 00:11:22,566
And so when you have all
four of them moving together,

214
00:11:22,566 --> 00:11:24,200
you know, you see
a rolling wagon wheel

215
00:11:24,200 --> 00:11:28,800
but all of the motion
there is actually cycloidal.

216
00:11:28,800 --> 00:11:32,233
So there's no image motion
that's purely horizontal,

217
00:11:32,233 --> 00:11:33,900
but when you look at this
and you track this

218
00:11:33,900 --> 00:11:35,100
you see a rolling wheel

219
00:11:35,100 --> 00:11:38,900
and you generate smooth pursuit
horizontally.

220
00:11:38,900 --> 00:11:42,266
And so what--um, whoops.

221
00:11:42,266 --> 00:11:45,400
Okay, it runs again.
But, ah, good.

222
00:11:45,400 --> 00:11:46,966
What Steinbach concluded is that

223
00:11:46,966 --> 00:11:48,500
pursuit is a complex
control system

224
00:11:48,500 --> 00:11:51,333
that works to match eye motion
with a brain--

225
00:11:51,333 --> 00:11:54,766
an internal brain representation
of perceived object motion.

226
00:11:54,766 --> 00:11:56,733
So it's something much
more complicated

227
00:11:56,733 --> 00:12:00,300
than simply driving
retinal motion to zero.

228
00:12:00,300 --> 00:12:02,633
However, the linear system
theory folks

229
00:12:02,633 --> 00:12:04,866
pointed out that there's
a flaw in this experiment.

230
00:12:04,866 --> 00:12:09,166
If you blur this, you know,
you basically--

231
00:12:09,166 --> 00:12:11,766
you can generate a blurry thing
that moves rightwards.

232
00:12:11,766 --> 00:12:14,233
And so maybe you don't
have anything complicated.

233
00:12:14,233 --> 00:12:16,400
You just have a low-pass
linear filter of some kind

234
00:12:16,400 --> 00:12:18,133
that blurs the dots,

235
00:12:18,133 --> 00:12:20,566
and so you see this
blur moving to the right

236
00:12:20,566 --> 00:12:22,366
and that's what you're tracking.

237
00:12:22,366 --> 00:12:25,366
And so because of that flaw
in the experiment,

238
00:12:25,366 --> 00:12:28,833
folks basically dismissed this.

239
00:12:28,833 --> 00:12:31,600
And so that was the state
of affairs.

240
00:12:31,600 --> 00:12:35,766
So when I got here, there were
two dominant theories.

241
00:12:35,766 --> 00:12:38,366
The neuroscience theory of,
you know, Goodale and Milner

242
00:12:38,366 --> 00:12:42,000
that visual processing for
perception and motor action

243
00:12:42,000 --> 00:12:43,566
were distinct and separate,

244
00:12:43,566 --> 00:12:45,633
and there was this whole

ocular motor crowd

245
00:12:45,633 --> 00:12:50,566
that had models of eye movements
based on retinal image motion,

246
00:12:50,566 --> 00:12:52,233
simple negative feedback,

247
00:12:52,233 --> 00:12:55,800
devoid of any reference to
higher-order visual processing

248
00:12:55,800 --> 00:12:58,366
or perception.

249
00:12:58,366 --> 00:13:01,366
So, um,

250
00:13:01,366 --> 00:13:03,500
in order to bridge that gap, um,

251
00:13:03,500 --> 00:13:05,666
the Visuomotor Control Lab
focused

252
00:13:05,666 --> 00:13:09,000
on actually measuring
visual perception

253
00:13:09,000 --> 00:13:10,666
and eye movements as well,

254
00:13:10,666 --> 00:13:12,900
and in particular
what we wanted to do

255
00:13:12,900 --> 00:13:14,466
is to measure them

simultaneously

256
00:13:14,466 --> 00:13:16,000
so we could make comparisons

257
00:13:16,000 --> 00:13:19,033
about what the eyes were doing
and what perception was doing.

258
00:13:19,033 --> 00:13:23,433
And what we really wanted to do
in order to develop oculometrics

259
00:13:23,433 --> 00:13:25,733
as a faithful measure
of visual perception

260
00:13:25,733 --> 00:13:28,233
is we needed to have
quantitative measures

261
00:13:28,233 --> 00:13:29,700
from the eye movements

262
00:13:29,700 --> 00:13:31,933
but we wanted to be sure that
they were actually measures

263
00:13:31,933 --> 00:13:36,100
of higher-order brain function
related to visual perception,

264
00:13:36,100 --> 00:13:39,166
and not some other
visual system,

265
00:13:39,166 --> 00:13:42,566
the way that Goodale and Milner
had proposed.

266
00:13:42,566 --> 00:13:47,300
Um, in order to validate
a new way of doing things,

267
00:13:47,300 --> 00:13:49,100
you have to look
at the state of the art

268
00:13:49,100 --> 00:13:50,366
of the old way of doing things.

269
00:13:50,366 --> 00:13:53,500
And so psychophysics is
the state of the art

270
00:13:53,500 --> 00:13:55,800
on how you measure--
it's the gold standard

271
00:13:55,800 --> 00:13:57,100
of how you measure perception.

272
00:13:57,100 --> 00:13:58,566
And what you typically do,

273
00:13:58,566 --> 00:14:01,066
is you have subjects sit in
front of a screen, they fixate.

274
00:14:01,066 --> 00:14:03,433
Then at some point later,

275
00:14:03,433 --> 00:14:05,800
a stimulus comes up,
or maybe two,

276
00:14:05,800 --> 00:14:07,200
and then a little while long--

277
00:14:07,200 --> 00:14:09,533
you know, it shows for
a couple seconds maybe,

278
00:14:09,533 --> 00:14:11,333
and then at the end you have
to do a button press.

279
00:14:11,333 --> 00:14:12,766
The visual stimulus, you know,

280
00:14:12,766 --> 00:14:14,966
it could be a target motion,

281
00:14:14,966 --> 00:14:18,266
but the motion is typically
constant within a single trial.

282
00:14:18,266 --> 00:14:20,466
But you can vary the direction
or vary the speed

283
00:14:20,466 --> 00:14:23,566
or vary some other parameter
slightly trial by trial.

284
00:14:23,566 --> 00:14:28,400
And at the end, what you do is
you give a single binary answer.

285
00:14:28,400 --> 00:14:31,566
You say the first one was
faster than the second one,

286
00:14:31,566 --> 00:14:36,100
or you say that the target moves
to the left of straight down

287
00:14:36,100 --> 00:14:37,600

or moved to the right
of straight down.

288
00:14:37,600 --> 00:14:40,866
So you make a single binary
answer at the end of the trial

289
00:14:40,866 --> 00:14:42,433
and you record that.

290
00:14:42,433 --> 00:14:46,700
Um...

291
00:14:46,700 --> 00:14:49,033
I think this will work.
There we go.

292
00:14:49,033 --> 00:14:52,100
So the point to make here

293
00:14:52,100 --> 00:14:53,566
is that a single bit
of information

294
00:14:53,566 --> 00:14:55,100
from the button press
is recorded

295
00:14:55,100 --> 00:14:56,933
for every
one- to three-second trial,

296
00:14:56,933 --> 00:15:01,766
and that's not a very efficient
way of collecting information.

297
00:15:01,766 --> 00:15:03,866
So, um,

298

00:15:03,866 --> 00:15:07,633
the way it works in
a little bit more detail is,

299
00:15:07,633 --> 00:15:09,000
you know, you have a target,
it moves down,

300
00:15:09,000 --> 00:15:11,100
you have to answer
left or right, okay,

301
00:15:11,100 --> 00:15:14,433
that one is clearly
to the right, and um,

302
00:15:14,433 --> 00:15:16,100
that one's clearly to the left,

303
00:15:16,100 --> 00:15:18,800
and this one's a little bit
harder to tell

304
00:15:18,800 --> 00:15:21,466
but I'm going to say right,
you know.

305
00:15:21,466 --> 00:15:23,666
This one's harder to tell,
I'm going to say left,

306
00:15:23,666 --> 00:15:26,733
and what you can do is you
collate all of those answers,

307
00:15:26,733 --> 00:15:30,400
those single-bit answers,
into a graph

308
00:15:30,400 --> 00:15:33,666

where you plot
the probability of let's say,

309
00:15:33,666 --> 00:15:35,433
saying rightward as a function

310
00:15:35,433 --> 00:15:37,200
of the direction
of the stimulus,

311
00:15:37,200 --> 00:15:39,733
and when the stimulus
is moving very far to the left,

312
00:15:39,733 --> 00:15:42,266
you always say left
so you never say right.

313
00:15:42,266 --> 00:15:43,633
And when it it's moving
very far to the right,

314
00:15:43,633 --> 00:15:46,100
you always say right
100% of the time.

315
00:15:46,100 --> 00:15:49,233
And in between there's
this transition,

316
00:15:49,233 --> 00:15:52,566
the smooth sigmoidal transition

317
00:15:52,566 --> 00:15:56,666
from leftward answers
to rightward answers.

318
00:15:56,666 --> 00:16:00,100
And from that curve--that curve
is called a psychometric curve--

319
00:16:00,100 --> 00:16:03,966
you can generate two
quantitative measurements.

320
00:16:03,966 --> 00:16:05,866
The first is called bias.

321
00:16:05,866 --> 00:16:09,166
You look at the 50% point--
the point of equality there--

322
00:16:09,166 --> 00:16:11,200
and that tells you where
you're equally likely to say

323
00:16:11,200 --> 00:16:15,266
left and right or that's where
you think straight down is.

324
00:16:15,266 --> 00:16:17,233
And so you measure that
and you look at--

325
00:16:17,233 --> 00:16:19,966
in this particular case,
straight down is, you know,

326
00:16:19,966 --> 00:16:21,433
1 degree to the left.

327
00:16:21,433 --> 00:16:23,100
And so what this means is

328
00:16:23,100 --> 00:16:24,833
you have to move the target
1 degree to the left

329
00:16:24,833 --> 00:16:26,700

in order to see it
as going straight down

330
00:16:26,700 --> 00:16:29,833
because you have
a 1-degree rightward bias.

331
00:16:29,833 --> 00:16:31,600
The second bit of information

332
00:16:31,600 --> 00:16:33,666
that you can gather
from a psychometric curve

333
00:16:33,666 --> 00:16:36,500
is the precision or the slope
of the curve.

334
00:16:36,500 --> 00:16:38,133
Now if you're really good
at the task

335
00:16:38,133 --> 00:16:39,700
and you have high precision,

336
00:16:39,700 --> 00:16:41,133
then you're going
to say leftward

337
00:16:41,133 --> 00:16:43,766
until it's really very close
to straight down,

338
00:16:43,766 --> 00:16:45,333
and then you're immediately
going to say rightward

339
00:16:45,333 --> 00:16:49,433
on the other side and so
there's a very steep slope

340
00:16:49,433 --> 00:16:52,500
indicating very high precision
whereas, you know,

341
00:16:52,500 --> 00:16:55,733
if the task is very, very hard,
the object is hard to see,

342
00:16:55,733 --> 00:16:59,133
there may be a wider range over
which you have uncertainty.

343
00:16:59,133 --> 00:17:02,266
And so that gradual slope
or the lower slope

344
00:17:02,266 --> 00:17:05,800
indicates a lower precision.

345
00:17:05,800 --> 00:17:08,433
Now, so what psychophysics
really is,

346
00:17:08,433 --> 00:17:11,666
it's a mathematically rigorous
method for measuring biases

347
00:17:11,666 --> 00:17:13,033
which are systematic errors,

348
00:17:13,033 --> 00:17:16,933
by looking at the offset
of the psychometric curve,

349
00:17:16,933 --> 00:17:18,766
and also measuring precision,

350
00:17:18,766 --> 00:17:20,933

which are measures
of random error

351
00:17:20,933 --> 00:17:24,266
and that is indicated by the
slope of the psychometric curve.

352
00:17:24,266 --> 00:17:27,733
Now, the se--

353
00:17:27,733 --> 00:17:31,100
the downside is that this is
an inefficient methodology

354
00:17:31,100 --> 00:17:34,133
in that it typically takes hours
to collect a full set of data

355
00:17:34,133 --> 00:17:35,600
for every observer,

356
00:17:35,600 --> 00:17:37,800
and it's also somewhat obtrusive

357
00:17:37,800 --> 00:17:39,866
because it's hard
to embed that task

358
00:17:39,866 --> 00:17:42,233
into a relevant applied task.

359
00:17:42,233 --> 00:17:45,366
So those are some
of the motivating reasons

360
00:17:45,366 --> 00:17:47,833
for trying to find
a different methodology.

361

00:17:47,833 --> 00:17:51,766
Now, as I said,
the first thing we had to do

362
00:17:51,766 --> 00:17:53,166
is to validate oculometrics,

363
00:17:53,166 --> 00:17:54,900
and I'm going to show you
four sets of experiments

364
00:17:54,900 --> 00:17:59,800
by which we did simultaneous
psychophysics and oculometrics.

365
00:17:59,800 --> 00:18:02,200
We measured the data both ways
and we compared them

366
00:18:02,200 --> 00:18:04,966
to show that really, it is
giving you the same answer.

367
00:18:04,966 --> 00:18:06,466
And so the first thing
I'm going to talk about

368
00:18:06,466 --> 00:18:10,600
is about precision of motion
signals, direction, and speed.

369
00:18:10,600 --> 00:18:15,366
And the first thing we had to do
is, you know,

370
00:18:15,366 --> 00:18:17,133
you have this eye movement
response.

371
00:18:17,133 --> 00:18:18,466

It's got a whole lot
of data there.

372
00:18:18,466 --> 00:18:20,133
But you want to compare it
to psychophysics

373
00:18:20,133 --> 00:18:22,600
which is a single binary
button press.

374
00:18:22,600 --> 00:18:25,200
So what we did is we converted
the eye movement trace

375
00:18:25,200 --> 00:18:26,633
into a single answer.

376
00:18:26,633 --> 00:18:28,833
So you take the average
direction of the trace,

377
00:18:28,833 --> 00:18:30,100
and there's your answer.

378
00:18:30,100 --> 00:18:31,766
If the average direction's left,
you say left,

379
00:18:31,766 --> 00:18:33,900
if the average direction
is right, you say right.

380
00:18:33,900 --> 00:18:36,500
And you can therefore convert
all of the eye movement data

381
00:18:36,500 --> 00:18:39,566
into single binary decisions
and plot them

382
00:18:39,566 --> 00:18:41,633
the same way you'd plot
a psychometric curve.

383
00:18:41,633 --> 00:18:43,966
Now when you do this for a
direction discrimination task,

384
00:18:43,966 --> 00:18:45,333
this is what you get.

385
00:18:45,333 --> 00:18:47,233
What you see
is the oculometric curve

386
00:18:47,233 --> 00:18:49,500
and the psychometric curve
superimposed--

387
00:18:49,500 --> 00:18:50,733
these were collected
at the same time

388
00:18:50,733 --> 00:18:52,300
from the same observer.

389
00:18:52,300 --> 00:18:56,300
And, um, uh,

390
00:18:56,300 --> 00:18:57,600
so as I said, the first thing
you have to do

391
00:18:57,600 --> 00:19:00,100
is you have to convert
the binary pursuit decisions

392
00:19:00,100 --> 00:19:02,700

to build an oculometric curve,
and then secondly,

393
00:19:02,700 --> 00:19:05,466
you can compare the two curves
and what you see

394
00:19:05,466 --> 00:19:08,133
is that they indicate
that direction discrimination

395
00:19:08,133 --> 00:19:11,100
has the same precision for
eye movements and perception,

396
00:19:11,100 --> 00:19:12,800
they have the same
signal-to-noise ratio,

397
00:19:12,800 --> 00:19:17,166
which is that ability to resolve
small differences in direction.

398
00:19:17,166 --> 00:19:19,100
More interestingly,
is if you measure this

399
00:19:19,100 --> 00:19:24,266
for cardinal directions--
up, down, left, right--

400
00:19:24,266 --> 00:19:25,933
which is what I showed before,
once again,

401
00:19:25,933 --> 00:19:28,733
this new experiment,
you know, confirmed

402
00:19:28,733 --> 00:19:31,700

that the psychometric and
oculometric curves superimposed.

403
00:19:31,700 --> 00:19:33,133
But we also looked
at the obliques,

404
00:19:33,133 --> 00:19:36,066
and what you see there is
they superimpose again

405
00:19:36,066 --> 00:19:38,600
but they're much shallower.

406
00:19:38,600 --> 00:19:41,033
And that's because both
the psychometric

407
00:19:41,033 --> 00:19:43,933
and oculometric curves indicate
the same lower precision

408
00:19:43,933 --> 00:19:47,633
for oblique motion which is what
they call the oblique effect.

409
00:19:47,633 --> 00:19:49,100
Both eye movements
and perception

410
00:19:49,100 --> 00:19:52,966
have an oblique effect and an
oblique effect of the same size.

411
00:19:52,966 --> 00:19:55,933
So what about speed perception?

412
00:19:55,933 --> 00:19:59,933
Um, and in basically
the earliest paper

413
00:19:59,933 --> 00:20:01,666
with oculometrics in it,

414
00:20:01,666 --> 00:20:04,533
Eileen Kowler and Susan McKee,
at Smith-Kettlewell

415
00:20:04,533 --> 00:20:07,066
in San Francisco, they did
a study in the late '80s

416
00:20:07,066 --> 00:20:09,366
where they looked
at speed discrimination,

417
00:20:09,366 --> 00:20:12,200
and they looked at eye movements
and perception simultaneously.

418
00:20:12,200 --> 00:20:14,600
They calculated the precision
of the speed perception,

419
00:20:14,600 --> 00:20:16,166
they plotted the inverse of it,

420
00:20:16,166 --> 00:20:20,333
and what they showed is,
you know, pursue or perceive,

421
00:20:20,333 --> 00:20:22,633
basically the psychometric
and oculometric functions

422
00:20:22,633 --> 00:20:25,166
have the same precision.

423
00:20:25,166 --> 00:20:27,233

But more importantly,

424
00:20:27,233 --> 00:20:28,766
in addition to the fact
that it confirms

425
00:20:28,766 --> 00:20:31,266
that they have
the same precision,

426
00:20:31,266 --> 00:20:34,966
it has the same speed tuning
in that

427
00:20:34,966 --> 00:20:38,133
as the targets move slower
and slower and slower,

428
00:20:38,133 --> 00:20:39,900
it's harder to determine
their speed

429
00:20:39,900 --> 00:20:43,733
and the precision goes down or
the inverse precision goes up,

430
00:20:43,733 --> 00:20:46,200
and both of them show
exactly that same tuning

431
00:20:46,200 --> 00:20:47,933
below 1 degree per second.

432
00:20:47,933 --> 00:20:53,133
So, as far as precision goes,
it matches.

433
00:20:53,133 --> 00:20:56,133
So if you do
the oculometric task,

434
00:20:56,133 --> 00:20:58,066
and you calculate
the oculometric function,

435
00:20:58,066 --> 00:20:59,966
you're going to be able
to collect the same information

436
00:20:59,966 --> 00:21:02,933
you would have
had you used psychophysics.

437
00:21:02,933 --> 00:21:06,200
But one of the problems
with this is, well, okay,

438
00:21:06,200 --> 00:21:09,866
so they give the same--they
show the same amount of noise.

439
00:21:09,866 --> 00:21:13,133
But that doesn't show
that it's the same noise.

440
00:21:13,133 --> 00:21:15,266
Maybe they're
equally sized noise

441
00:21:15,266 --> 00:21:17,333
but it's still
different systems.

442
00:21:17,333 --> 00:21:20,766
And so the logic
that you can bring up is,

443
00:21:20,766 --> 00:21:22,633
well, what if you have a system

444
00:21:22,633 --> 00:21:24,666
where there's separate
but equal processing?

445
00:21:24,666 --> 00:21:26,533
So you have a stimulus,
different set of neurons

446
00:21:26,533 --> 00:21:28,666
are calculating
direction for perception,

447
00:21:28,666 --> 00:21:30,366
a different set of neurons
are calculating it

448
00:21:30,366 --> 00:21:31,800
for the eye movement.

449
00:21:31,800 --> 00:21:33,700
They have the same amount
of noise,

450
00:21:33,700 --> 00:21:35,166
but the noise is different,

451
00:21:35,166 --> 00:21:38,000
versus a situation
where they're shared.

452
00:21:38,000 --> 00:21:40,533
A pool of neurons
is calculating direction

453
00:21:40,533 --> 00:21:42,333
for both perception and pursuit,

454
00:21:42,333 --> 00:21:44,700
and they actually have not only

the same size noise,

455
00:21:44,700 --> 00:21:46,333
they have the same noise.

456
00:21:46,333 --> 00:21:48,866
How can you distinguish
between these two?

457
00:21:48,866 --> 00:21:53,100
Well, the trick that Rich
Krauzlis and I decided to use--

458
00:21:53,100 --> 00:21:58,033
Rich is at--was--went to the
Salk and has returned to NIH--

459
00:21:58,033 --> 00:22:01,300
um, was, what if
we look at trials

460
00:22:01,300 --> 00:22:02,766
where there's no correct answer?

461
00:22:02,766 --> 00:22:05,033
If you look at
the straight down trials,

462
00:22:05,033 --> 00:22:09,133
the ones where your
left-right answers are random,

463
00:22:09,133 --> 00:22:12,100
well, if you have
different noise,

464
00:22:12,100 --> 00:22:17,100
then your eye movement guesses
and your perceptual guesses

465
00:22:17,100 --> 00:22:20,100
will be the same randomly,
50% of the time,

466
00:22:20,100 --> 00:22:23,933
whereas if your guesses
are correlated, are the same,

467
00:22:23,933 --> 00:22:25,800
then it's because
you're actually looking

468
00:22:25,800 --> 00:22:27,866
at the same set of neurons.

469
00:22:27,866 --> 00:22:31,333
And so we did that, and what
we found is, lo and behold,

470
00:22:31,333 --> 00:22:34,066
if you look at the directions

471
00:22:34,066 --> 00:22:37,000
where there's no correct answer
that you typically find

472
00:22:37,000 --> 00:22:40,800
between 70% and 80% correlation
in the answers,

473
00:22:40,800 --> 00:22:42,500
it's significantly higher
than chance.

474
00:22:42,500 --> 00:22:45,200
So you must be looking
at the same noise

475
00:22:45,200 --> 00:22:48,433

when you're guessing
to try to figure out

476
00:22:48,433 --> 00:22:51,166
what to give an answer
when you have no signal.

477
00:22:51,166 --> 00:22:53,300
And the reason why these
aren't actually completely

478
00:22:53,300 --> 00:22:57,166
correlated at 100% is that there
are independent noise sources.

479
00:22:57,166 --> 00:22:59,733
You know, the eye movement
has eye tracker noise in it

480
00:22:59,733 --> 00:23:02,200
that the perceptual response
doesn't,

481
00:23:02,200 --> 00:23:05,233
and the perceptual response
has button press noise in it

482
00:23:05,233 --> 00:23:06,933
that the eye movement
doesn't have.

483
00:23:06,933 --> 00:23:08,800
And so that's why they're
not fully correlated

484
00:23:08,800 --> 00:23:11,500
but they are correlated
significantly above chance,

485
00:23:11,500 --> 00:23:13,800

and so what we
can conclude is that

486
00:23:13,800 --> 00:23:16,300
these random
trial-by-trial fluctuations

487
00:23:16,300 --> 00:23:18,233
when there's no signal,

488
00:23:18,233 --> 00:23:20,500
co-vary even when
there's no correct answer

489
00:23:20,500 --> 00:23:23,033
and so at least some of the
neurons and coding direction

490
00:23:23,033 --> 00:23:24,700
are shared between
these two systems,

491
00:23:24,700 --> 00:23:29,100
and that clean dichotomy
cannot explain these results.

492
00:23:29,100 --> 00:23:32,900
Now, another way of looking
at validating whether or not

493
00:23:32,900 --> 00:23:34,633
visual perception
and eye movements are driven

494
00:23:34,633 --> 00:23:37,766
by the same motion signals
is to look at illusions.

495
00:23:37,766 --> 00:23:40,866
Illusions are when

the brain gets it wrong.

496
00:23:40,866 --> 00:23:43,033
It's--your brain
is a very powerful processor

497
00:23:43,033 --> 00:23:46,766
but sometimes it just gets the
wrong answer, and when it does,

498
00:23:46,766 --> 00:23:48,966
well, do the eye movements
get the wrong answer?

499
00:23:48,966 --> 00:23:52,233
The same wrong answer or
do they get a different answer?

500
00:23:52,233 --> 00:23:55,300
Well, in order to do that,
we looked at a visual illusion.

501
00:23:55,300 --> 00:24:00,266
And this particular illusion was
discovered by Brent Beutter--

502
00:24:00,266 --> 00:24:05,066
and let me move this
out of the way.

503
00:24:05,066 --> 00:24:08,666
And Mulligan and myself
in the lab

504
00:24:08,666 --> 00:24:10,200
back in the early '90s,

505
00:24:10,200 --> 00:24:13,533
and what do you think?

506
00:24:13,533 --> 00:24:14,833
Do you think this thing
is moving to the right

507
00:24:14,833 --> 00:24:17,300
or the left of straight down?

508
00:24:17,300 --> 00:24:20,033
- Somebody?
- [indistinct]

509
00:24:20,033 --> 00:24:21,900
- What?
- It's rotating.

510
00:24:21,900 --> 00:24:24,100
It's rotating.
That's interesting.

511
00:24:24,100 --> 00:24:29,066
I apologize for the jumpy video,

512
00:24:29,066 --> 00:24:31,033
because this is
PowerPoint and VGA,

513
00:24:31,033 --> 00:24:33,400
but basically typically subjects

514
00:24:33,400 --> 00:24:36,333
see this moving slightly
to the right of straight down.

515
00:24:36,333 --> 00:24:37,666
Is that what people
are basically seeing--

516
00:24:37,666 --> 00:24:38,800
hopefully, okay.

517
00:24:38,800 --> 00:24:41,866
So what the paper showed

518
00:24:41,866 --> 00:24:44,233
is that if you tilt the aperture

519
00:24:44,233 --> 00:24:48,400
that you're looking at
a pattern moving in,

520
00:24:48,400 --> 00:24:50,766
that you see a bias in the
direction of the long axis

521
00:24:50,766 --> 00:24:51,966
of the window.

522
00:24:51,966 --> 00:24:55,500
And so what happens
with eye movements?

523
00:24:55,500 --> 00:24:59,133
Well, we did simultaneous
psychophysics and oculometrics,

524
00:24:59,133 --> 00:25:01,233
and we had three conditions
that tilted right,

525
00:25:01,233 --> 00:25:03,300
tilted left,

526
00:25:03,300 --> 00:25:05,300
and a circularly
symmetric window.

527
00:25:05,300 --> 00:25:08,000
In the symmetric window--these

are the psychometric curves--

528
00:25:08,000 --> 00:25:10,733
there was no bias.
Straight down was straight down.

529
00:25:10,733 --> 00:25:14,233
But when you tilt them
you get a systematic bias

530
00:25:14,233 --> 00:25:16,033
of about 10 degrees,

531
00:25:16,033 --> 00:25:20,733
just as you'd expect from the
original study of the illusion.

532
00:25:20,733 --> 00:25:22,200
But if you look at
eye movements,

533
00:25:22,200 --> 00:25:23,566
you get the same thing.

534
00:25:23,566 --> 00:25:25,733
You get a same
shifting of the curve

535
00:25:25,733 --> 00:25:29,633
where they have the same biases
as the psychometric curves.

536
00:25:29,633 --> 00:25:33,666
So once again what this shows is
when the brain gets it wrong,

537
00:25:33,666 --> 00:25:38,133
the eye movements get it wrong
as well as visual perception.

538
00:25:38,133 --> 00:25:42,700
So once again they indicate
the same bias or errors.

539
00:25:42,700 --> 00:25:43,966
So last but not least,

540
00:25:43,966 --> 00:25:45,600
I've shown you when
there's no signal,

541
00:25:45,600 --> 00:25:47,733
I've shown you
when you get it wrong.

542
00:25:47,733 --> 00:25:51,900
What happens actually when
there's two correct answers?

543
00:25:51,900 --> 00:25:53,533
And that's another way
of looking at this.

544
00:25:53,533 --> 00:25:55,866
And in order to look at this,

545
00:25:55,866 --> 00:25:58,600
Jean Lorenceau
and Maggie Shiffrar

546
00:25:58,600 --> 00:26:03,433
discovered a very interesting
phenomenon in the early '90s

547
00:26:03,433 --> 00:26:06,033
where they showed that context

548
00:26:06,033 --> 00:26:09,566
dramatically changes

your visual perception.

549
00:26:09,566 --> 00:26:14,066
And in particular, they used
this occluded diamond stimulus,

550
00:26:14,066 --> 00:26:18,400
and what they showed was...

551
00:26:18,400 --> 00:26:22,166
If you show, you know,
the pieces of that diamond,

552
00:26:22,166 --> 00:26:23,766
you know, on a blank background

553
00:26:23,766 --> 00:26:25,866
where there's
no context whatsoever,

554
00:26:25,866 --> 00:26:28,266
what you see
is four moving segments

555
00:26:28,266 --> 00:26:31,233
just bopping up and down,
getting closer together,

556
00:26:31,233 --> 00:26:33,166
further apart,
and moving up and down.

557
00:26:33,166 --> 00:26:35,600
Is that what people see?
Vertical motion?

558
00:26:35,600 --> 00:26:36,600
Okay?

559

00:26:36,600 --> 00:26:39,066
Now...

560
00:26:43,866 --> 00:26:44,933
Ah.

561
00:26:47,433 --> 00:26:49,300
And this is what happens
when you make

562
00:26:49,300 --> 00:26:53,000
two parts of the background or,
you know,

563
00:26:53,000 --> 00:26:54,333
you make two parts
of the foreground

564
00:26:54,333 --> 00:26:56,033
turn into the background
by making them dark,

565
00:26:56,033 --> 00:26:58,500
then what you see is a diamond
moving up and to the left,

566
00:26:58,500 --> 00:27:01,000
down to the right, up and to the
left, down to the right,

567
00:27:01,000 --> 00:27:04,066
up and the left.
Does everybody see that?

568
00:27:04,066 --> 00:27:05,866
Yes, no, maybe?

569
00:27:05,866 --> 00:27:09,200
Okay, so the point here
is the motion in this stimulus

570
00:27:09,200 --> 00:27:10,600
is identical.

571
00:27:10,600 --> 00:27:13,166
Nothing changed
except for the context.

572
00:27:13,166 --> 00:27:15,133
Now it looks like
you're looking at this thing

573
00:27:15,133 --> 00:27:18,833
through two windows and it's
blocked so you can't see it all,

574
00:27:18,833 --> 00:27:21,633
and so you see it
moving back and forth

575
00:27:21,633 --> 00:27:23,066
between the two windows.

576
00:27:23,066 --> 00:27:24,833
And it's moving diagonally here

577
00:27:24,833 --> 00:27:26,666
whereas before
the exact same stimulus,

578
00:27:26,666 --> 00:27:28,900
because there's
no obvious window there,

579
00:27:28,900 --> 00:27:30,133
you don't know
what to make of it

580
00:27:30,133 --> 00:27:32,500

and you turn it into
four separate pieces.

581
00:27:32,500 --> 00:27:34,633
So this is different perception

582
00:27:34,633 --> 00:27:38,433
despite identical image motion.

583
00:27:38,433 --> 00:27:41,900
And this is what happens when
you look at the eye movements.

584
00:27:41,900 --> 00:27:45,033
If you give them the incoherent
segment motion stimulus

585
00:27:45,033 --> 00:27:47,066
and you move the diamond,
you know,

586
00:27:47,066 --> 00:27:48,366
diagonally to the left
and to the right,

587
00:27:48,366 --> 00:27:51,166
you always get vertical pursuit
eye movements

588
00:27:51,166 --> 00:27:53,233
in both those conditions.

589
00:27:53,233 --> 00:27:56,700
Perception and pursuit both see
vertical segment motion,

590
00:27:56,700 --> 00:27:59,866
and when you give them the
coherent diamond, lo and behold,

591
00:27:59,866 --> 00:28:02,166
when they go plus and minus
10 degrees diagonally,

592
00:28:02,166 --> 00:28:04,866
you get plus and minus
almost 10 degrees diagonally

593
00:28:04,866 --> 00:28:06,433
there in the eye movement.

594
00:28:06,433 --> 00:28:09,666
Perception and pursuit both see
the diagonal object motion

595
00:28:09,666 --> 00:28:13,300
just like--so they're
sharing that interpretation

596
00:28:13,300 --> 00:28:15,466
of the stimulus.

597
00:28:15,466 --> 00:28:18,866
So, in summary
on the validation studies,

598
00:28:18,866 --> 00:28:21,566
eye movements and visual
perceptions are linked

599
00:28:21,566 --> 00:28:24,333
because they share the same
precision in the direction

600
00:28:24,333 --> 00:28:25,766
and speed signals.

601
00:28:25,766 --> 00:28:28,166
They share

trial-by-trial guessing

602
00:28:28,166 --> 00:28:30,100
when there is no correct answer.

603
00:28:30,100 --> 00:28:32,133
They have the same
vulnerability to illusions--

604
00:28:32,133 --> 00:28:33,566
at least the ones I showed you.

605
00:28:33,566 --> 00:28:34,800
There are more
that I could have shown,

606
00:28:34,800 --> 00:28:37,633
but due to time
I only could show you one.

607
00:28:37,633 --> 00:28:40,166
And they also share
the same interpretation

608
00:28:40,166 --> 00:28:42,000
when there are
two correct answers.

609
00:28:42,000 --> 00:28:45,066
And so you can conclude
that eye movements therefore

610
00:28:45,066 --> 00:28:47,366
can be used
as an indirect window

611
00:28:47,366 --> 00:28:50,466
into these higher-order
brain processing

612
00:28:50,466 --> 00:28:52,333
with oculometric technologies

613
00:28:52,333 --> 00:28:55,433
now being able to provide
a faithful quantitative measure

614
00:28:55,433 --> 00:28:57,333
of dynamic visual motion.

615
00:28:57,333 --> 00:29:01,466
Perception, sorry.
Visual motion perception.

616
00:29:01,466 --> 00:29:06,033
So, can we use these methods

617
00:29:06,033 --> 00:29:07,566
to do some science?

618
00:29:07,566 --> 00:29:11,400
Um, and I'm going to show you
four different experiments

619
00:29:11,400 --> 00:29:15,166
to hopefully persuade you
that it can be a useful tool.

620
00:29:15,166 --> 00:29:19,000
The first one is, remember,

621
00:29:19,000 --> 00:29:20,400
we're looking at eye movements

622
00:29:20,400 --> 00:29:22,533
so we're not only getting
information about vision,

623

00:29:22,533 --> 00:29:24,500
we can say something
about motor systems.

624
00:29:24,500 --> 00:29:28,933
And so there is an impact on
visual motor control modeling.

625
00:29:28,933 --> 00:29:30,466
And so...

626
00:29:30,466 --> 00:29:33,466
before I was emphasizing
the validation studies

627
00:29:33,466 --> 00:29:35,366
were sort of
an engineering study

628
00:29:35,366 --> 00:29:37,066
to validate a new technique.

629
00:29:37,066 --> 00:29:39,900
Now I can tell you what
the scientific value is

630
00:29:39,900 --> 00:29:42,200
of that--those
validation studies.

631
00:29:42,200 --> 00:29:44,366
And in particular,
the occluded diamond experiment

632
00:29:44,366 --> 00:29:48,233
shows that identical
image motion

633
00:29:48,233 --> 00:29:50,466
is pursued differently

when the object trajectory

634
00:29:50,466 --> 00:29:52,066
is perceived differently.

635
00:29:52,066 --> 00:29:56,400
And so what that data--
those data show, is that

636
00:29:56,400 --> 00:30:00,000
it rules out these image motion
models of visual motor control.

637
00:30:00,000 --> 00:30:03,166
What it is is, actually,
when you think about it,

638
00:30:03,166 --> 00:30:05,633
it's the Steinbach experiment.

639
00:30:05,633 --> 00:30:09,300
But this time
it's more cleverly designed

640
00:30:09,300 --> 00:30:12,833
so that the linear system folks
can't say,

641
00:30:12,833 --> 00:30:15,200
"Just filter it, just blur it."

642
00:30:15,200 --> 00:30:17,266
There is nothing you can do
with a linear filter

643
00:30:17,266 --> 00:30:19,533
to change
the incoherent diamond stimulus

644

00:30:19,533 --> 00:30:21,300
into
the coherent diamond stimulus.

645
00:30:21,300 --> 00:30:23,700
There is no motion energy
diagonally.

646
00:30:23,700 --> 00:30:26,066
You have to infer
the diagonal motion

647
00:30:26,066 --> 00:30:28,500
using higher-order cognition

648
00:30:28,500 --> 00:30:32,400
because the raw motion
is purely vertical.

649
00:30:32,400 --> 00:30:34,366
The centroid does not
move diagonally.

650
00:30:34,366 --> 00:30:37,066
And so it's basically the
Steinbach experiment over again

651
00:30:37,066 --> 00:30:40,866
but this time, there is
no way to get around it.

652
00:30:40,866 --> 00:30:44,266
And so it suggests
a new family of models

653
00:30:44,266 --> 00:30:45,600
worthy of further exploration

654
00:30:45,600 --> 00:30:48,233
with a new role for cortex

and the cerebellum

655
00:30:48,233 --> 00:30:49,733
in visuomotor control.

656
00:30:49,733 --> 00:30:54,566
And so...

657
00:30:54,566 --> 00:30:57,333
so this is the old retinal image
model that I talked about.

658
00:30:57,333 --> 00:31:02,233
You have a sensor signal,
negative feedback,

659
00:31:02,233 --> 00:31:06,066
visual cortex is just basically
processing that sensor signal,

660
00:31:06,066 --> 00:31:08,933
and then the brain stem
is merely providing

661
00:31:08,933 --> 00:31:12,433
eye movement memory.

662
00:31:12,433 --> 00:31:16,100
That is the retinal image
motion model.

663
00:31:16,100 --> 00:31:18,066
All of them basically have
this in common.

664
00:31:18,066 --> 00:31:21,233
And, you know, it's basically
a robotic model.

665

00:31:21,233 --> 00:31:23,633
And this is why I thought it was
important to point this out

666
00:31:23,633 --> 00:31:26,533
to folks here,
is that, you know,

667
00:31:26,533 --> 00:31:28,300
you can try to do robotics

668
00:31:28,300 --> 00:31:31,466
by having simple sensors
drive motor outputs directly

669
00:31:31,466 --> 00:31:33,666
without any higher-order
processing,

670
00:31:33,666 --> 00:31:35,966
but you have to make a different
loop for every single system

671
00:31:35,966 --> 00:31:37,466
you're trying to control.

672
00:31:37,466 --> 00:31:40,333
And then you have to make sure
that the loops work together.

673
00:31:40,333 --> 00:31:42,966
And so a smarter way
of doing this

674
00:31:42,966 --> 00:31:45,700
that's consistent with the data
that I've shown you,

675
00:31:45,700 --> 00:31:47,966
but obviously there's

a lot more to be proven,

676
00:31:47,966 --> 00:31:52,200
is that the visual processing

677
00:31:52,200 --> 00:31:53,200
in the cerebral cortex

678
00:31:53,200 --> 00:31:55,533
computes object trajectory,

679
00:31:55,533 --> 00:31:56,666
something much more complicated

680
00:31:56,666 --> 00:31:59,166
than simple motion
on your retina.

681
00:31:59,166 --> 00:32:01,800
It segments the image
into different objects,

682
00:32:01,800 --> 00:32:03,366
it integrates them
back together again

683
00:32:03,366 --> 00:32:05,066
so that you put
the diamond together

684
00:32:05,066 --> 00:32:07,800
and you know what belongs
with it, you know.

685
00:32:07,800 --> 00:32:10,433
You also use higher-order
expectation and knowledge

686
00:32:10,433 --> 00:32:13,533

and prediction
to see these things.

687
00:32:13,533 --> 00:32:15,033
And also there has
to be some kind of

688
00:32:15,033 --> 00:32:18,300
a coordinate transformation
because if all your information

689
00:32:18,300 --> 00:32:22,000
is in sensor coordinates but all
your actions are in the world,

690
00:32:22,000 --> 00:32:24,966
you have to somehow transfer
your coordinate system

691
00:32:24,966 --> 00:32:28,833
from the sensor coordinates
to...

692
00:32:28,833 --> 00:32:30,400
world coordinates.

693
00:32:30,400 --> 00:32:33,300
And so there's a much more
elaborate problem going on here

694
00:32:33,300 --> 00:32:34,966
being solved by the cortex
and, indeed,

695
00:32:34,966 --> 00:32:38,166
that is probably why
there's this massive evolution

696
00:32:38,166 --> 00:32:41,600
of the visual cortex and visual

processing areas in primates,

697
00:32:41,600 --> 00:32:44,566
because it's doing this
very complicated task.

698
00:32:44,566 --> 00:32:47,766
And the reason why that has
such a value evolutionarily

699
00:32:47,766 --> 00:32:50,600
is once you have
perceived object motion,

700
00:32:50,600 --> 00:32:53,333
then you can use that
to drive all your motor systems.

701
00:32:53,333 --> 00:32:56,666
You have one good or your
best solution to do that,

702
00:32:56,666 --> 00:32:59,666
and then all y--then the brain
stem's job at that point

703
00:32:59,666 --> 00:33:03,633
is to just filter the commands

704
00:33:03,633 --> 00:33:04,933
so that they match
the motor dynamics

705
00:33:04,933 --> 00:33:06,700
of the thing they're
controlling.

706
00:33:06,700 --> 00:33:08,933
So, you basically
have a pre-filter here,

707
00:33:08,933 --> 00:33:10,833
and here you can have
linear filters

708
00:33:10,833 --> 00:33:12,466
that are tuned to
the output device.

709
00:33:12,466 --> 00:33:14,766
So if you're driving an eyeball,
you filtered it some way,

710
00:33:14,766 --> 00:33:17,033
if you're driving an arm you
filtered it a different way.

711
00:33:17,033 --> 00:33:20,500
If you're driving a car,
you filtered it a different way,

712
00:33:20,500 --> 00:33:22,133
and the bottom line is,

713
00:33:22,133 --> 00:33:24,133
you can use that for
motor learning as well.

714
00:33:24,133 --> 00:33:27,166
So, this is a brand new
way of thinking about

715
00:33:27,166 --> 00:33:28,933
how the brain works
for visuomotor control,

716
00:33:28,933 --> 00:33:34,600
and it has useful applications
for roboticists as well.

717
00:33:34,600 --> 00:33:38,366
So, um, second scientific study,

718
00:33:38,366 --> 00:33:40,000
the oblique effect.

719
00:33:40,000 --> 00:33:43,100
Well, I told you already that
there's a directional variation

720
00:33:43,100 --> 00:33:45,833
in the precision,
the signal-to-noise ratio,

721
00:33:45,833 --> 00:33:48,600
varies as a function
of direction

722
00:33:48,600 --> 00:33:51,800
for both perception
and eye movements,

723
00:33:51,800 --> 00:33:54,300
but is that due to some
variation in the signal

724
00:33:54,300 --> 00:33:56,000
or variation in the noise?

725
00:33:56,000 --> 00:33:58,066
Now, if the signal is varying,
then what you're going to see

726
00:33:58,066 --> 00:34:01,000
in plots of pursuit
or perceived direction

727
00:34:01,000 --> 00:34:02,433
as a function

of target direction--

728
00:34:02,433 --> 00:34:04,033
you're going to see
a wiggly line

729
00:34:04,033 --> 00:34:06,033
and then the fatness
of that line is the noise

730
00:34:06,033 --> 00:34:08,666
and it stays the same,
but the signal wiggles.

731
00:34:08,666 --> 00:34:11,000
Whereas, if the noise
is what varies,

732
00:34:11,000 --> 00:34:12,433
you'll have a nice straight line

733
00:34:12,433 --> 00:34:15,366
between target direction
and perceived direction.

734
00:34:15,366 --> 00:34:18,600
But you'll have bulges here
where you have high noise

735
00:34:18,600 --> 00:34:22,100
in the obliques, and low noise
along the cardinals.

736
00:34:22,100 --> 00:34:24,333
So which one is the case?

737
00:34:24,333 --> 00:34:28,033
Well, because oculometrics isn't
giving you a binary answer

738
00:34:28,033 --> 00:34:30,133
and we can actually plot
pursued direction

739
00:34:30,133 --> 00:34:33,000
as a function of stimulus
direction, this is what we get.

740
00:34:33,000 --> 00:34:34,933
A fat, wiggly line.

741
00:34:34,933 --> 00:34:36,533
And so the first thing
we can conclude

742
00:34:36,533 --> 00:34:37,766
is that the signal is varying,

743
00:34:37,766 --> 00:34:40,200
and I can tell you
that was a surprise,

744
00:34:40,200 --> 00:34:43,066
because what that's telling you
is that small changes

745
00:34:43,066 --> 00:34:45,733
in direction are magnified
near the cardinal axes.

746
00:34:45,733 --> 00:34:47,600
You're blowing everything up.

747
00:34:47,600 --> 00:34:50,333
And then near the oblique axes,

748
00:34:50,333 --> 00:34:51,833
you're shrinking
everything down,

749
00:34:51,833 --> 00:34:54,833
so you're distorting the world
while keeping the noise

750
00:34:54,833 --> 00:34:56,300
actually the same.

751
00:34:56,300 --> 00:34:59,000
And so if you plot that
magnification, what you see is,

752
00:34:59,000 --> 00:35:02,600
you know,
these high magnification

753
00:35:02,600 --> 00:35:05,000
and the cardinal directions,
you know,

754
00:35:05,000 --> 00:35:09,033
minifying
in the oblique directions.

755
00:35:09,033 --> 00:35:11,833
And what one of the things
to remember is

756
00:35:11,833 --> 00:35:15,633
evolution is not driving
fidelity in your visual system.

757
00:35:15,633 --> 00:35:18,200
It's driving utility.

758
00:35:18,200 --> 00:35:20,533
And for some reason
it's really useful

759

00:35:20,533 --> 00:35:24,033
to magnify the cardinals
and to minify the obliques.

760
00:35:24,033 --> 00:35:25,400
There's a lot of theories
about why

761
00:35:25,400 --> 00:35:26,866
but it's telling us something.

762
00:35:26,866 --> 00:35:30,100
We evolved to do this because
it's useful somehow.

763
00:35:30,100 --> 00:35:33,666
And once again, there--
this is characterized

764
00:35:33,666 --> 00:35:35,500
by actually two parameters.

765
00:35:35,500 --> 00:35:39,100
One is this four-fold anisotropy
which is the cloverleaf.

766
00:35:39,100 --> 00:35:41,933
And there's also--and we gave
an extreme version here

767
00:35:41,933 --> 00:35:44,700
so you could see this--
is there's also sometimes

768
00:35:44,700 --> 00:35:46,666
a horizontal-vertical
asymmetry as well

769
00:35:46,666 --> 00:35:50,733
where it's taller than it is

wide or wider than it is tall.

770
00:35:50,733 --> 00:35:53,233
Okay? So...

771
00:35:53,233 --> 00:35:56,133
That comes from the fact that
oculometrics is giving you

772
00:35:56,133 --> 00:35:59,700
a lot more information
than a binary answer.

773
00:35:59,700 --> 00:36:00,833
What else?

774
00:36:00,833 --> 00:36:02,166
Well, binary answers--
the button press

775
00:36:02,166 --> 00:36:03,633
only tells you something
about what's happening

776
00:36:03,633 --> 00:36:07,100
at that instant in time
when you hit the button,

777
00:36:07,100 --> 00:36:11,366
and oculometrics actually
gives you a time course.

778
00:36:11,366 --> 00:36:15,533
So if you want to look at
coordinate transformations,

779
00:36:15,533 --> 00:36:19,400
well, if your head's upright,
the world is upright,

780
00:36:19,400 --> 00:36:21,300
your head's upright,
your eyes are upright,

781
00:36:21,300 --> 00:36:23,100
basically all these coordinate
systems are the same

782
00:36:23,100 --> 00:36:25,100
and so it's sort of hard
to distinguish.

783
00:36:25,100 --> 00:36:28,000
But if you tilt your head
to the right or to the left,

784
00:36:28,000 --> 00:36:30,366
your eye counter rolls
back the other direction

785
00:36:30,366 --> 00:36:33,433
but doesn't do it completely,
so when you tilt your head,

786
00:36:33,433 --> 00:36:36,400
let's say, 18 degrees--whoops.

787
00:36:36,400 --> 00:36:40,200
18 degrees...your eyes
are 14 degrees tilted

788
00:36:40,200 --> 00:36:42,200
and the world is
not tilted at all

789
00:36:42,200 --> 00:36:44,066
so you can actually
separate those.

790

00:36:44,066 --> 00:36:47,733
So then what we can do
is we can look at

791
00:36:47,733 --> 00:36:50,466
this coordinate frame change
over time.

792
00:36:50,466 --> 00:36:52,166
So this is the cloverleaf
pattern

793
00:36:52,166 --> 00:36:54,933
immediately as you begin
to move your eyes,

794
00:36:54,933 --> 00:36:59,066
and what you can see is it's
aligned with the tilted eye.

795
00:36:59,066 --> 00:37:01,233
It's not in head coordinates,
it's not in world coordinates.

796
00:37:01,233 --> 00:37:03,600
It's in eye coordinates,
and let's see what happens

797
00:37:03,600 --> 00:37:06,200
over the next 1/2 second.

798
00:37:13,700 --> 00:37:16,533
What you can see is actually
the oblique effect.

799
00:37:16,533 --> 00:37:19,066
The cloverleaf starts
to fade--it's fading.

800
00:37:19,066 --> 00:37:23,133

But as it fades, it also rotates
towards the world coordinates.

801
00:37:23,133 --> 00:37:25,633
So you can watch that over time
because you have data

802
00:37:25,633 --> 00:37:27,866
at a wide number of time points

803
00:37:27,866 --> 00:37:29,800
when you collect
the eye movement data.

804
00:37:29,800 --> 00:37:31,266
So--whoops.

805
00:37:31,266 --> 00:37:35,033
So the anisotropy rotates over
that 400-millisecond period

806
00:37:35,033 --> 00:37:37,400
from eye coordinates
to world coordinates.

807
00:37:37,400 --> 00:37:42,133
Um, lastly, as far as science--

808
00:37:42,133 --> 00:37:45,200
what about predicting
the effects of spaceflight,

809
00:37:45,200 --> 00:37:49,000
you know, when you're launching
on the top of a rocket like SLS,

810
00:37:49,000 --> 00:37:51,833
you know, you get
to elevated G-levels.

811
00:37:51,833 --> 00:37:54,533
When you're lying on your back
you have 1 G on Earth,

812
00:37:54,533 --> 00:37:57,100
but we--whoops. Aah. Good.

813
00:37:57,100 --> 00:37:59,500
We have a wonderful device
here at Ames

814
00:37:59,500 --> 00:38:01,166
called the 20 G centrifuge

815
00:38:01,166 --> 00:38:04,233
where you can bring people
up to 3.8 Gs,

816
00:38:04,233 --> 00:38:06,433
and you can actually simulate
the G conditions

817
00:38:06,433 --> 00:38:07,900
that are very similar
to the ones that you'd have

818
00:38:07,900 --> 00:38:09,966
when you're launching a rocket.

819
00:38:09,966 --> 00:38:11,433
And so the question we have
is, well,

820
00:38:11,433 --> 00:38:14,933
does vision change
when you're at G?

821
00:38:14,933 --> 00:38:19,366
And this shows the cloverleaf

measured at 1 G

822
00:38:19,366 --> 00:38:20,466
and measured at 3.8 G.

823
00:38:20,466 --> 00:38:22,033
And what you can see is that

824
00:38:22,033 --> 00:38:25,766
while the cloverleaf doesn't
go away, it's kind of squashed,

825
00:38:25,766 --> 00:38:30,133
and so increasing G-loading
similar to the launch conditions

826
00:38:30,133 --> 00:38:33,566
causes a vertical squashing
of the cloverleaf gain.

827
00:38:33,566 --> 00:38:37,100
And actually, if you plot
for all of the six observers

828
00:38:37,100 --> 00:38:39,600
we ran in this, what you can see

829
00:38:39,600 --> 00:38:43,233
is that while the anisotropy
bounced around a little bit,

830
00:38:43,233 --> 00:38:46,033
it was just as often
higher and lower.

831
00:38:46,033 --> 00:38:49,300
Oh, this is plot of the
anisotropy and the asymmetry

832

00:38:49,300 --> 00:38:51,800
at 3.8 G versus 1 G.

833
00:38:51,800 --> 00:38:53,766
And the dash line shows you
when they're equal.

834
00:38:53,766 --> 00:38:55,600
And so it's just as likely
to be higher as lower

835
00:38:55,600 --> 00:38:57,233
and the error bars show you
that they're not really

836
00:38:57,233 --> 00:39:01,033
significantly different, whereas
if you look at the asymmetry,

837
00:39:01,033 --> 00:39:03,100
all six observers show
a lower asymmetry

838
00:39:03,100 --> 00:39:04,833
and actually some
of these observers are

839
00:39:04,833 --> 00:39:06,200
actually significantly--

840
00:39:06,200 --> 00:39:08,533
individually significantly
different than that line.

841
00:39:08,533 --> 00:39:10,300
So what we can say is,

842
00:39:10,300 --> 00:39:11,800
that while there's
no systematic change

843
00:39:11,800 --> 00:39:13,800
in the cloverleaf anisotropy,

844
00:39:13,800 --> 00:39:17,600
there is a consistent reduction
in the vertical asymmetry

845
00:39:17,600 --> 00:39:20,100
of their perception.

846
00:39:20,100 --> 00:39:22,633
So lastly,

847
00:39:22,633 --> 00:39:26,566
we want to, in our latest
effort, see whether or not

848
00:39:26,566 --> 00:39:29,333
we can use oculometrics
as a tool to measure

849
00:39:29,333 --> 00:39:33,000
impairment in visual function.

850
00:39:33,000 --> 00:39:34,633
Um, in order to do that

851
00:39:34,633 --> 00:39:37,000
we have to devise
a very compact

852
00:39:37,000 --> 00:39:41,033
and simple test and...

853
00:39:45,566 --> 00:39:49,200
Okay, good. Um, nope,
that did not work. Sorry.

854
00:39:52,100 --> 00:39:53,633
Maybe this works. Yes.

855
00:39:53,633 --> 00:39:57,333
So we test all possible
directions of motion

856
00:39:57,333 --> 00:39:59,900
in 2-degree jumps--
2-degree steps,

857
00:39:59,900 --> 00:40:03,166
and we measure a range
of different speeds

858
00:40:03,166 --> 00:40:06,066
and we can collect 180 trials

859
00:40:06,066 --> 00:40:10,733
in order to look at
motion perception.

860
00:40:10,733 --> 00:40:12,766
And so this is our
compact version

861
00:40:12,766 --> 00:40:16,000
of our oculometric testing,

862
00:40:16,000 --> 00:40:18,300
and each one-second trial
theoretically yields

863
00:40:18,300 --> 00:40:21,733
up to 12 bits of information
for every 4 milliseconds,

864
00:40:21,733 --> 00:40:25,666
because we get a separate sample

every 4 milliseconds.

865
00:40:25,666 --> 00:40:28,566
So this shows you how much more
information potentially

866
00:40:28,566 --> 00:40:30,533
is in the eye movement traces,

867
00:40:30,533 --> 00:40:32,833
but the most important thing
is that

868
00:40:32,833 --> 00:40:36,300
in a one 12-minute
to 15-minute session,

869
00:40:36,300 --> 00:40:38,466
we can get a full set of
data for the observer

870
00:40:38,466 --> 00:40:40,333
yielding ten different measures.

871
00:40:40,333 --> 00:40:44,633
Two for response initiation,
three for steady-state tracking,

872
00:40:44,633 --> 00:40:48,633
three for direction tuning
and two for speed tuning.

873
00:40:48,633 --> 00:40:52,433
This shows you a typical

874
00:40:52,433 --> 00:40:53,800
summary chart

875
00:40:53,800 --> 00:40:56,366

from a normal,
healthy individual.

876
00:40:56,366 --> 00:40:57,900
We measured this in 40 people.

877
00:40:57,900 --> 00:41:01,633
And what you can see is these
two show you a reaction time

878
00:41:01,633 --> 00:41:05,266
of about 170 milliseconds,
you know,

879
00:41:05,266 --> 00:41:08,966
an initial vigorous response
of 150 degrees per second.

880
00:41:08,966 --> 00:41:12,366
These three tell you something
about steady-state tracking,

881
00:41:12,366 --> 00:41:15,266
and these two--this one
is familiar to you.

882
00:41:15,266 --> 00:41:18,000
This is showing you the
direction tuning and properties,

883
00:41:18,000 --> 00:41:20,633
and this is showing you
speed processing.

884
00:41:20,633 --> 00:41:22,766
You get all of that
in 12 minutes.

885
00:41:22,766 --> 00:41:26,033
And so this shows you what

a normal person looks like,

886
00:41:26,033 --> 00:41:30,600
but what happens if you have
a neural pathology?

887
00:41:30,600 --> 00:41:35,466
So this shows you what
a retinitis pigmentosa patient

888
00:41:35,466 --> 00:41:37,766
look like, and what you can see

889
00:41:37,766 --> 00:41:40,933
and I'll see if this animates
well--yeah, it does, kinda.

890
00:41:40,933 --> 00:41:42,933
What you can see is if you look
at the initiation,

891
00:41:42,933 --> 00:41:46,966
there's a dramatic increase
in the latency

892
00:41:46,966 --> 00:41:48,766
and a dramatic decrease

893
00:41:48,766 --> 00:41:53,266
in the initial acceleration,

894
00:41:53,266 --> 00:41:55,766
which is what you'd expect from
someone whose peripheral retina

895
00:41:55,766 --> 00:41:59,633
is not working very well,
and you also see a dramatic--

896

00:41:59,633 --> 00:42:01,566
whoops, here we go.

897
00:42:01,566 --> 00:42:04,066
A dramatic decrease
in motion processing,

898
00:42:04,066 --> 00:42:07,700
where both direction tuning
and speed tuning

899
00:42:07,700 --> 00:42:09,833
are severely compromised.

900
00:42:09,833 --> 00:42:11,800
Now I want to emphasize,
this person's driving a car,

901
00:42:11,800 --> 00:42:16,766
walking around, and in all other
respects is basically okay.

902
00:42:16,766 --> 00:42:19,466
And we're seeing these
dramatic differences.

903
00:42:19,466 --> 00:42:21,566
And if you compare
this person's performance

904
00:42:21,566 --> 00:42:25,933
to our normal distribution, all
ten parameters are decrement,

905
00:42:25,933 --> 00:42:28,900
and so the chance of that
is about one in 1000,

906
00:42:28,900 --> 00:42:31,700
and if you do

907
00:42:31,700 --> 00:42:34,400
very conservative
statistics on this,

908
00:42:34,400 --> 00:42:36,300
you basically can show
that five parameters

909
00:42:36,300 --> 00:42:40,233
are significantly deviated
from normal in this patient,

910
00:42:40,233 --> 00:42:43,366
and yet they're basically okay.

911
00:42:43,366 --> 00:42:45,100
So this shows you
it's very sensitive.

912
00:42:45,100 --> 00:42:47,733
And these deviations
are like four--

913
00:42:47,733 --> 00:42:50,833
up to four standard deviations
away from normal.

914
00:42:50,833 --> 00:42:54,333
So this is
a very sensitive measure.

915
00:42:54,333 --> 00:42:57,866
Now, hopefully this will work.
Yes.

916
00:42:57,866 --> 00:43:01,733
Um, we can't show you all ten
dimensions at the same time

917
00:43:01,733 --> 00:43:03,000
but we can show you three,

918
00:43:03,000 --> 00:43:05,066
so this is three dimensions
of the ten measures

919
00:43:05,066 --> 00:43:06,366
that we're looking at.

920
00:43:06,366 --> 00:43:09,433
And this is the population
of normal patients--

921
00:43:09,433 --> 00:43:10,766
normal population.

922
00:43:10,766 --> 00:43:13,666
And that red dot that just
came on is the RP patient.

923
00:43:13,666 --> 00:43:16,666
And what you can see
is that he's an outlier

924
00:43:16,666 --> 00:43:18,166
in a particular direction.

925
00:43:18,166 --> 00:43:19,966
But then what we did
is we waited 18 months

926
00:43:19,966 --> 00:43:21,333
and measured again.

927
00:43:21,333 --> 00:43:24,533
And there he is,
and what you can see is

928
00:43:24,533 --> 00:43:27,066
along a very similar axis

929
00:43:27,066 --> 00:43:31,633
he continued to have
the performance degrade.

930
00:43:31,633 --> 00:43:34,933
And so we were able to
watch that impairment

931
00:43:34,933 --> 00:43:39,233
increase over time due to
the degenerative pathology

932
00:43:39,233 --> 00:43:41,333
of his retina.

933
00:43:41,333 --> 00:43:43,733
In order to boil that down
into a single parameter,

934
00:43:43,733 --> 00:43:46,166
what we can do is

935
00:43:46,166 --> 00:43:50,966
you project the point
onto that RP vector,

936
00:43:50,966 --> 00:43:52,500
the direction of the impairment,

937
00:43:52,500 --> 00:43:54,700
and you get a single scale
or dot product

938
00:43:54,700 --> 00:43:58,600
which tells you what we call
the RP impairment index.

939
00:43:58,600 --> 00:44:02,200
It's a single scale that tells
you how impaired is the person

940
00:44:02,200 --> 00:44:04,366
along that RP direction.

941
00:44:04,366 --> 00:44:08,266
And when you show that
for this patient--

942
00:44:08,266 --> 00:44:10,133
this is the, you know,

943
00:44:10,133 --> 00:44:11,633
the impairment
of the normal population's

944
00:44:11,633 --> 00:44:13,000
on average zero,

945
00:44:13,000 --> 00:44:17,100
and what you can see is in 2013

946
00:44:17,100 --> 00:44:20,433
there was two
standard-deviation impairment

947
00:44:20,433 --> 00:44:23,033
and there's a four
standard-deviation impairment

948
00:44:23,033 --> 00:44:25,366
at this point in time.

949
00:44:25,366 --> 00:44:27,966
And so oculometrics allows us
to monitor impairment changes

950
00:44:27,966 --> 00:44:31,633
over time which will either
allow you to see degeneration

951
00:44:31,633 --> 00:44:33,533
or recovery from an illness,

952
00:44:33,533 --> 00:44:36,600
or to allow you
to estimate the value

953
00:44:36,600 --> 00:44:38,233
of a therapeutic intervention.

954
00:44:38,233 --> 00:44:40,433
If you do something,
is the person getting better?

955
00:44:40,433 --> 00:44:43,066
Well, you can measure whether
they're getting better.

956
00:44:43,066 --> 00:44:46,200
So this is
the normal person again,

957
00:44:46,200 --> 00:44:49,666
but what I want to do is compare
this to a different pathology

958
00:44:49,666 --> 00:44:51,266
which is traumatic brain injury.

959
00:44:51,266 --> 00:44:55,733
We looked at 31 patients
who had a brain injury

960
00:44:55,733 --> 00:44:58,333

at some point in the past--we're
not looking at them acutely--

961
00:44:58,333 --> 00:45:00,133
and it varied from mild
to moderate,

962
00:45:00,133 --> 00:45:01,866
and we started to look at
that population

963
00:45:01,866 --> 00:45:03,100
and see what we could see.

964
00:45:03,100 --> 00:45:06,966
And what you see here is this is

965
00:45:06,966 --> 00:45:11,766
an individual brain injury
patient, even after recovery.

966
00:45:11,766 --> 00:45:14,500
And what you can see is that
there is once again

967
00:45:14,500 --> 00:45:17,933
a very dramatic impairment
to motion processing.

968
00:45:17,933 --> 00:45:22,700
If you compare
this person's measurements

969
00:45:22,700 --> 00:45:24,666
to a normal population,

970
00:45:24,666 --> 00:45:29,166
all but one parameter
is actually decremented,

971
00:45:29,166 --> 00:45:32,333
which is 1 chance in 100
just from coin flipping.

972
00:45:32,333 --> 00:45:36,366
But if you do rigorous
and conservative statistics,

973
00:45:36,366 --> 00:45:38,900
at least two of these parameters
are dramatically reduced

974
00:45:38,900 --> 00:45:43,566
and this one by four sigma.

975
00:45:43,566 --> 00:45:47,000
So lastly,
as I showed you before,

976
00:45:47,000 --> 00:45:51,933
if you look at the three
particular dimensions,

977
00:45:51,933 --> 00:45:55,333
this is the normal population
along those three dimensions,

978
00:45:55,333 --> 00:45:57,166
and the red dots there show you

979
00:45:57,166 --> 00:46:00,333
what the population
of TBI patients look like.

980
00:46:00,333 --> 00:46:02,766
And once again--whoops.

981
00:46:02,766 --> 00:46:05,866
Ah. Ah.

982
00:46:05,866 --> 00:46:08,600
Why isn't it--

983
00:46:08,600 --> 00:46:10,666
Ah.

984
00:46:14,633 --> 00:46:17,300
So, um,
what I want to just say again is

985
00:46:17,300 --> 00:46:21,966
while I have the time actually,
if you notice this outlier here,

986
00:46:21,966 --> 00:46:25,233
we were concerned about this
person in our normal population,

987
00:46:25,233 --> 00:46:29,100
and we went back to the IRB and
asked them what we should do,

988
00:46:29,100 --> 00:46:32,333
and we ended up notifying them
that we have some concerns

989
00:46:32,333 --> 00:46:34,566
that they should follow up on

990
00:46:34,566 --> 00:46:36,733
because they stick out there
as well.

991
00:46:36,733 --> 00:46:42,200
But, you know, what you see is
this population of TBI patients,

992
00:46:42,200 --> 00:46:44,800

many of whom have recovered,
and they have

993
00:46:44,800 --> 00:46:46,800
a particular direction
of their deficit,

994
00:46:46,800 --> 00:46:49,500
all pointing generally
in that direction.

995
00:46:49,500 --> 00:46:51,866
And, once again, we can project
onto that direction

996
00:46:51,866 --> 00:46:54,300
to get a single scale or value,

997
00:46:54,300 --> 00:46:57,500
and this shows you
the TBI impairment index

998
00:46:57,500 --> 00:46:59,233
for the entire population.

999
00:46:59,233 --> 00:47:02,566
And what you see is that
the population is shifted

1000
00:47:02,566 --> 00:47:05,533
by almost two standard
deviations to the right,

1001
00:47:05,533 --> 00:47:07,266
which shows you that,
on average,

1002
00:47:07,266 --> 00:47:08,766
they have
a significant impairment

1003
00:47:08,766 --> 00:47:09,966
even though they've recovered

1004
00:47:09,966 --> 00:47:11,666
over quite a distinct period
of time.

1005
00:47:11,666 --> 00:47:14,400
But we were very interested
in actually looking at whether--

1006
00:47:14,400 --> 00:47:16,166
You know, these guys
look pretty normal,

1007
00:47:16,166 --> 00:47:18,000
and these guys are pretty
seriously impaired.

1008
00:47:18,000 --> 00:47:20,166
You know,
what's going on with that?

1009
00:47:20,166 --> 00:47:24,100
And what we did is we asked
each individual

1010
00:47:24,100 --> 00:47:28,666
what their self-assessed
residual impairment was

1011
00:47:28,666 --> 00:47:31,233
on a scale from 1 to 10,
where 1 is,

1012
00:47:31,233 --> 00:47:34,200
"I have little
or no residual impairment,"

1013
00:47:34,200 --> 00:47:36,666
and 10 is,
"I'm completely impaired.

1014
00:47:36,666 --> 00:47:38,633
I'm basically comatose."

1015
00:47:38,633 --> 00:47:41,266
And we wanted to divide--

1016
00:47:41,266 --> 00:47:44,133
We wanted to divide up
this population

1017
00:47:44,133 --> 00:47:45,333
into those different groups,

1018
00:47:45,333 --> 00:47:47,166
and this is what it looks like
when you do.

1019
00:47:47,166 --> 00:47:49,233
Well, if you look at the people
in group one,

1020
00:47:49,233 --> 00:47:53,133
the people who said they have
little or no residual problem,

1021
00:47:53,133 --> 00:47:57,133
they're almost not detectable.

1022
00:47:57,133 --> 00:47:59,433
There's a 60% detectability
here,

1023
00:47:59,433 --> 00:48:01,533
which isn't significantly
different than chance,

1024
00:48:01,533 --> 00:48:04,066
but all of the other groups
basically have

1025
00:48:04,066 --> 00:48:06,466
a 90% detectability.

1026
00:48:06,466 --> 00:48:09,533
So what this shows is we have
a very sensitive measure

1027
00:48:09,533 --> 00:48:12,000
for people who have mild
to moderate TBI.

1028
00:48:12,000 --> 00:48:16,233
They have recovered, and yet,
these are not acute patients,

1029
00:48:16,233 --> 00:48:19,100
but the ones who say,
"I still have a problem,"

1030
00:48:19,100 --> 00:48:21,900
we're able to detect that
with a 90% reliability.

1031
00:48:21,900 --> 00:48:25,333
Now, this self-reported severity
is not a gold standard.

1032
00:48:25,333 --> 00:48:26,433
And so what this shows is that

1033
00:48:26,433 --> 00:48:28,200
we've begun
the validation process.

1034

00:48:28,200 --> 00:48:30,900
What we need to do next
is a real clinical study

1035
00:48:30,900 --> 00:48:32,766
where we compare
our measurements

1036
00:48:32,766 --> 00:48:36,466
with the standard care that
would be given by a neurologist.

1037
00:48:36,466 --> 00:48:39,900
So, with that said,
I want to conclude

1038
00:48:39,900 --> 00:48:42,400
that what oculometric
technologies provide

1039
00:48:42,400 --> 00:48:45,833
is a powerful neuroscience tool
for basic research--

1040
00:48:45,833 --> 00:48:48,100
[sighs]

1041
00:48:48,100 --> 00:48:50,866
Basic--fat thumb
and I'm not even big.

1042
00:48:50,866 --> 00:48:53,600
"A powerful neuroscience tool
for basic scientific research

1043
00:48:53,600 --> 00:48:55,800
that we've used to explore
higher-order visual function

1044
00:48:55,800 --> 00:48:57,133

in the human brain,

1045
00:48:57,133 --> 00:48:59,566
a validated human-factors tool
for applied research

1046
00:48:59,566 --> 00:49:04,133
to quantify human performance
limits in aerospace conditions,"

1047
00:49:04,133 --> 00:49:06,266
and what we're working on now
is to generate

1048
00:49:06,266 --> 00:49:07,566
a sensitive clinical tool--

1049
00:49:07,566 --> 00:49:09,466
to validate
a sensitive clinical tool

1050
00:49:09,466 --> 00:49:11,933
for detecting and characterizing
mild impairments

1051
00:49:11,933 --> 00:49:14,933
of brain function
due to injury and disease.

1052
00:49:14,933 --> 00:49:17,366
We hope to apply that both
to NASA's problem

1053
00:49:17,366 --> 00:49:20,000
related to astronauts
who have visual problems

1054
00:49:20,000 --> 00:49:22,100
when they are in space
for long periods of time,

1055
00:49:22,100 --> 00:49:25,700
but we also could apply this
to mild concussions in sports

1056
00:49:25,700 --> 00:49:28,666
and/or in the military.

1057
00:49:28,666 --> 00:49:30,233
So that's the end of the talk.

1058
00:49:30,233 --> 00:49:33,766
I just want to thank NASA
for funding

1059
00:49:33,766 --> 00:49:37,300
and nurturing this low-TRL work
for several decades

1060
00:49:37,300 --> 00:49:40,633
so that it could come
to this higher-TRL fruition

1061
00:49:40,633 --> 00:49:43,666
while also enabling some science
on the way.

1062
00:49:43,666 --> 00:49:47,100
And I also want to thank
the people who did the work.

1063
00:49:47,100 --> 00:49:48,933
Dorion Liston,
who is in here somewhere.

1064
00:49:48,933 --> 00:49:51,500
Dorion?
Somewhere.

1065

00:49:51,500 --> 00:49:53,600
There he is on the side.

1066
00:49:53,600 --> 00:49:56,300
Dorion is a person
who is in charge

1067
00:49:56,300 --> 00:49:58,666
of all of the clinical study
that we're doing

1068
00:49:58,666 --> 00:50:03,366
in order to apply oculometrics
to clinical assessments.

1069
00:50:03,366 --> 00:50:07,400
Brent Beutter was in the lab
20 years ago and was--

1070
00:50:07,400 --> 00:50:10,133
And he's probably in
the audience here too as well.

1071
00:50:10,133 --> 00:50:13,033
Brent?
Anyway...

1072
00:50:13,033 --> 00:50:16,333
Brent was at the birth
of oculometrics

1073
00:50:16,333 --> 00:50:18,466
and did some
of the initial studies

1074
00:50:18,466 --> 00:50:21,666
of validating oculometrics.

1075
00:50:21,666 --> 00:50:24,900
Anton Krukowski was here about

ten years ago as a postdoc

1076
00:50:24,900 --> 00:50:27,800
and initiated all of the work
related to the oblique effect.

1077
00:50:27,800 --> 00:50:31,066
We have two San Jose State
students in the lab.

1078
00:50:31,066 --> 00:50:33,900
Lily Wong basically collected
all of the data

1079
00:50:33,900 --> 00:50:37,533
and analyzed all the data for
the clinical study that you saw.

1080
00:50:37,533 --> 00:50:42,166
Angie Godinez worked
on the centrifuge study

1081
00:50:42,166 --> 00:50:46,366
and is actually headed off
to a PhD program at Berkeley

1082
00:50:46,366 --> 00:50:49,033
in neuroscience,
so we're very proud of her.

1083
00:50:49,033 --> 00:50:51,700
I mentioned Rich.
Rich and I go way back.

1084
00:50:51,700 --> 00:50:53,066
We were graduate students
together,

1085
00:50:53,066 --> 00:50:55,100
but he and I,

at the very beginning of this,

1086
00:50:55,100 --> 00:50:57,866
went to NIH to use
their invasive

1087
00:50:57,866 --> 00:51:00,500
eye coil eye tracker
because our eye trackers here

1088
00:51:00,500 --> 00:51:03,500
had too much noise, and so some
of the initial studies

1089
00:51:03,500 --> 00:51:05,600
before we could improve
the eye tracker technology

1090
00:51:05,600 --> 00:51:08,800
were done at NIH
with that invasive tracker.

1091
00:51:08,800 --> 00:51:11,200
And then lastly,
Jean Lorenceau did a year

1092
00:51:11,200 --> 00:51:14,066
visiting the lab,
and brought his wonderful

1093
00:51:14,066 --> 00:51:16,366
occluded diamond stimulus
with him,

1094
00:51:16,366 --> 00:51:18,800
which enabled us to actually
make some major progress,

1095
00:51:18,800 --> 00:51:20,633
so thank you very much.

1096
00:51:20,633 --> 00:51:23,633
[applause]

1097
00:51:28,066 --> 00:51:31,133
(woman)
We have the time
for a few quick questions.

1098
00:51:31,133 --> 00:51:34,433
Please join--file through
the center aisle

1099
00:51:34,433 --> 00:51:35,800
and find the microphone
in the front, please.

1100
00:51:35,800 --> 00:51:37,433
(man)
Yes, very nice.

1101
00:51:37,433 --> 00:51:41,300
I have a question about your
model of the pursuit system.

1102
00:51:41,300 --> 00:51:46,333
You have a direct link
from V1 to the parietal zones

1103
00:51:46,333 --> 00:51:48,966
of MST and MSTd.

1104
00:51:48,966 --> 00:51:52,933
But the experiment suggests
that the pursuit system

1105
00:51:52,933 --> 00:51:56,666
actually uses the whole object
as a target.

1106
00:51:56,666 --> 00:52:00,200
So my question then is,
where in your model

1107
00:52:00,200 --> 00:52:04,566
would you fit the segmentation
of the image,

1108
00:52:04,566 --> 00:52:09,200
and wouldn't you agree
that additional parts

1109
00:52:09,200 --> 00:52:12,133
of the ventral pathway need
to be included in the model,

1110
00:52:12,133 --> 00:52:16,733
included the higher
as of V2, V3, V4?

1111
00:52:16,733 --> 00:52:17,766
Um...

1112
00:52:17,766 --> 00:52:21,000
Obviously the--

1113
00:52:21,000 --> 00:52:23,566
I'm trying to find the model so
we can actually talk about it,

1114
00:52:23,566 --> 00:52:25,066
but I think it's later.

1115
00:52:25,066 --> 00:52:26,666
Aah!

1116
00:52:26,666 --> 00:52:29,900
It's not that one, but it is--
okay.

1117
00:52:29,900 --> 00:52:35,833
Obviously, both the chart
through the cortex

1118
00:52:35,833 --> 00:52:38,900
is a bit of a cartoon

1119
00:52:38,900 --> 00:52:42,933
in that there--all of those
areas are involved.

1120
00:52:42,933 --> 00:52:45,600
Ah, here we go.
Bingo.

1121
00:52:45,600 --> 00:52:51,266
So the chart basically neglected
a whole bunch of areas,

1122
00:52:51,266 --> 00:52:56,700
but in this lump here...

1123
00:52:56,700 --> 00:53:00,433
there's a lot of information
about what MT does,

1124
00:53:00,433 --> 00:53:02,833
what MST does,
what the frontal eye fields do.

1125
00:53:02,833 --> 00:53:06,833
And you're actually correct
if your question was

1126
00:53:06,833 --> 00:53:11,233
that obviously there needs
to be more about information

1127

00:53:11,233 --> 00:53:12,966
about putting
the object together here

1128
00:53:12,966 --> 00:53:16,300
because shape mattered
and the diamond shape matters.

1129
00:53:16,300 --> 00:53:18,333
And a matter of fact, if you use
certain shape diamonds,

1130
00:53:18,333 --> 00:53:20,333
you can't see them as coherent,

1131
00:53:20,333 --> 00:53:21,600
and you use other shaped
diamonds,

1132
00:53:21,600 --> 00:53:23,133
you do see them as coherent.

1133
00:53:23,133 --> 00:53:25,200
And so what this shows is, yes,

1134
00:53:25,200 --> 00:53:28,433
there is a ventral pathway input
into this

1135
00:53:28,433 --> 00:53:31,266
that actually is involved
in perceived object motion,

1136
00:53:31,266 --> 00:53:35,166
because knowing something about
what the object is

1137
00:53:35,166 --> 00:53:40,200
does help you figure out what
direction it's moving in.

1138
00:53:40,200 --> 00:53:45,366
Do you see this system using
object-based coordinate frames--

1139
00:53:45,366 --> 00:53:48,300
external, extri--and extrinsic
coordinate frames--

1140
00:53:48,300 --> 00:53:50,166
or is it all internal?

1141
00:53:50,166 --> 00:53:52,033
What do you think?

1142
00:53:52,033 --> 00:53:55,233
Well, the only evidence
I have is the movie

1143
00:53:55,233 --> 00:53:59,000
that I showed you
about the oblique effect.

1144
00:53:59,000 --> 00:54:00,833
Clearly the initial
coordinate frame

1145
00:54:00,833 --> 00:54:03,400
that the information coming from
the sensor is in

1146
00:54:03,400 --> 00:54:04,866
is in sensor coordinates.

1147
00:54:04,866 --> 00:54:07,300
So the initial oblique effect

1148
00:54:07,300 --> 00:54:09,633
is in retinal coordinates,

for sure.

1149
00:54:09,633 --> 00:54:11,966
But then as you saw,
over 400 milliseconds,

1150
00:54:11,966 --> 00:54:13,866
it starts to tilt over to world.

1151
00:54:13,866 --> 00:54:18,566
So my guess is that this signal
that comes out here

1152
00:54:18,566 --> 00:54:21,300
that's driving your motor
control is actually a signal

1153
00:54:21,300 --> 00:54:23,366
about what the object
is doing in the world,

1154
00:54:23,366 --> 00:54:27,600
but obviously a lot more needs
to be done to prove that.

1155
00:54:27,600 --> 00:54:29,966
So, a question about
the centrifuge study.

1156
00:54:29,966 --> 00:54:33,000
So you went
from 1 G to about 4 Gs,

1157
00:54:33,000 --> 00:54:37,233
and could you go out on a limb
a little bit and speculate

1158
00:54:37,233 --> 00:54:40,800
as to the effects
that you found?

1159
00:54:40,800 --> 00:54:45,500
What sort of tasks would you
expect problems with at 4 G

1160
00:54:45,500 --> 00:54:48,500
and maybe the size
of those effects?

1161
00:54:48,500 --> 00:54:54,500
Well, what you would expect
from the scrunching of space

1162
00:54:54,500 --> 00:54:57,466
that we saw from the 4 G,
you know,

1163
00:54:57,466 --> 00:55:00,833
there's about, I'd say,
a 10% scrunching.

1164
00:55:00,833 --> 00:55:02,566
Maybe it gets worse at 5 G.

1165
00:55:02,566 --> 00:55:06,600
And during return, you know,
especially ballistic returns

1166
00:55:06,600 --> 00:55:10,066
on Soyuz and other things,
they can get up to 9 Gs.

1167
00:55:10,066 --> 00:55:11,266
You might expect
that the world

1168
00:55:11,266 --> 00:55:13,533
is getting scrunched
vertically more,

1169
00:55:13,533 --> 00:55:16,166
and it's not really
a spatial scrunching.

1170
00:55:16,166 --> 00:55:17,933
It's a directional scrunching.

1171
00:55:17,933 --> 00:55:20,933
So what you might think
is that...

1172
00:55:20,933 --> 00:55:26,766
that vertical tasks
might be impaired,

1173
00:55:26,766 --> 00:55:29,100
tasks that involve
some vertical deviation.

1174
00:55:29,100 --> 00:55:34,233
But once again, this is a motion
stimulus that we showed there,

1175
00:55:34,233 --> 00:55:39,033
so it would be hard to imagine
exactly what motion control task

1176
00:55:39,033 --> 00:55:41,600
you might have,
but if you're actually trying

1177
00:55:41,600 --> 00:55:44,066
to do some kind
of manual control task,

1178
00:55:44,066 --> 00:55:47,366
you might have
a diminished gain vertically

1179

00:55:47,366 --> 00:55:49,033
or an exaggerated gain
vertically

1180
00:55:49,033 --> 00:55:50,666
to compensate for this.

1181
00:55:50,666 --> 00:55:53,400
And so you asked me
to get out on a limb.

1182
00:55:53,400 --> 00:55:55,333
We don't have any solid evidence
for that,

1183
00:55:55,333 --> 00:55:57,566
but obviously something
is happening

1184
00:55:57,566 --> 00:55:59,700
and more needs to be done
to understand what's happening.

1185
00:55:59,700 --> 00:56:02,700
But you might expect
an asymmetry between behaviors

1186
00:56:02,700 --> 00:56:06,133
that require information
along the vertical axis

1187
00:56:06,133 --> 00:56:08,900
as opposed to along
the horizontal axis.

1188
00:56:12,166 --> 00:56:15,600
So please join me in thanking
Dr. Stone for a great seminar.

1189
00:56:15,600 --> 00:56:19,366

[applause]