The external environment

2021-08-01 11:53:15

1
00:00:09,830 --> 00:00:07,430
today

2
00:00:11,509 --> 00:00:09,840
i will be talking about my research on

3
00:00:14,230 --> 00:00:11,519
the 3d trajectories

4
00:00:16,310 --> 00:00:14,240
of locomotory movements of mice and

5
00:00:17,029 --> 00:00:16,320
extensions of it that have applications

6
00:00:20,630 --> 00:00:17,039
in the field

7
00:00:21,670 --> 00:00:20,640
of astrobiology a defining

8
00:00:24,630 --> 00:00:21,680
characteristic

9
00:00:25,189 --> 00:00:24,640
of all living organisms is their ability

10
00:00:27,429 --> 00:00:25,199
to make

11
00:00:28,710 --> 00:00:27,439
controlled movements at either some part

12
00:00:32,470 --> 00:00:28,720
of their life cycle

13
00:00:34,950 --> 00:00:32,480

or throughout their entire lifetime

14
00:00:37,990 --> 00:00:34,960
movement is a component of behavior that

15
00:00:39,910 --> 00:00:38,000
is critically important to survival

16
00:00:41,350 --> 00:00:39,920
whether it is to get from one place to

17
00:00:44,790 --> 00:00:41,360
another to find

18
00:00:47,110 --> 00:00:44,800
food escape predators or find a mate

19
00:00:49,029 --> 00:00:47,120
it is an essential component of all

20
00:00:51,590 --> 00:00:49,039
these behaviors

21
00:00:54,470 --> 00:00:51,600
in mammals movement reflects the

22
00:00:57,029 --> 00:00:54,480
function of the central nervous system

23
00:00:59,110 --> 00:00:57,039
in fact even minor changes in the

24
00:01:01,590 --> 00:00:59,120
internal states of an organism

25
00:01:02,389 --> 00:01:01,600
either physiological states such as some

26
00:01:05,429 --> 00:01:02,399
illness

27
00:01:06,149 --> 00:01:05,439
or emotional states such as fear are

28
00:01:09,190 --> 00:01:06,159
reflected

29
00:01:11,990 --> 00:01:09,200
in movement therefore it is

30
00:01:13,429 --> 00:01:12,000
highly likely that even mind new changes

31
00:01:14,469 --> 00:01:13,439
in the functioning of the central

32
00:01:18,870 --> 00:01:14,479
nervous system

33
00:01:22,070 --> 00:01:21,270
it was the need to navigate complex

34
00:01:24,310 --> 00:01:22,080
environments

35
00:01:25,990 --> 00:01:24,320
that led to the formation of the very

36
00:01:29,590 --> 00:01:26,000
first centralized nervous

37
00:01:31,749 --> 00:01:29,600
systems in fact enriched environments

38
00:01:33,190 --> 00:01:31,759

are known to enhance learning and

39
00:01:35,670 --> 00:01:33,200
promote intelligence

40
00:01:37,670 --> 00:01:35,680
even at the level of the individual

41
00:01:38,789 --> 00:01:37,680
these changes can then be passed to the

42
00:01:40,630 --> 00:01:38,799
next generation

43
00:01:41,990 --> 00:01:40,640
through epigenetic changes that will

44
00:01:45,670 --> 00:01:42,000
manifest themselves

45
00:01:46,389 --> 00:01:45,680
in future generations here i refer to

46
00:01:49,429 --> 00:01:46,399
the physical

47
00:01:51,749 --> 00:01:49,439
environment that the organism exists in

48
00:01:52,710 --> 00:01:51,759
broad examples from our planet are

49
00:01:55,190 --> 00:01:52,720
aquatic

50
00:01:58,149 --> 00:01:55,200
aero and terrestrial and underground

51
00:02:01,270 --> 00:02:00,550
gravity is a general property of the

52
00:02:03,590 --> 00:02:01,280
environment

53
00:02:05,429 --> 00:02:03,600
that critically influences the movements

54
00:02:07,429 --> 00:02:05,439
made by an organism

55
00:02:10,550 --> 00:02:07,439
the physical state of the environment

56
00:02:13,190 --> 00:02:10,560
that is whether the environment is solid

57
00:02:14,630 --> 00:02:13,200
liquid or gaseous also profoundly

58
00:02:16,710 --> 00:02:14,640
affects the strategy

59
00:02:18,390 --> 00:02:16,720
of locomotion that an organism will

60
00:02:20,309 --> 00:02:18,400
adapt

61
00:02:21,830 --> 00:02:20,319
further properties of the environment

62
00:02:23,990 --> 00:02:21,840
such as pressure

63
00:02:24,869 --> 00:02:24,000

and temperature are also important

64
00:02:29,510 --> 00:02:24,879
factors that

65
00:02:34,070 --> 00:02:32,470
moreover properties of the environment

66
00:02:36,470 --> 00:02:34,080
immediate to the organism

67
00:02:38,710 --> 00:02:36,480
such as friction and three-dimensional

68
00:02:41,190 --> 00:02:38,720
shape of media in the environment

69
00:02:42,309 --> 00:02:41,200
and minor fluctuations in temperature

70
00:02:45,509 --> 00:02:42,319
and pressure

71
00:02:47,830 --> 00:02:45,519
also impact the modes of locomotion

72
00:02:49,670 --> 00:02:47,840
therefore the scale at which we need to

73
00:02:50,550 --> 00:02:49,680
quantify the complexity of the

74
00:02:52,949 --> 00:02:50,560
environment

75
00:02:54,630 --> 00:02:52,959
is at this scale the scale of the

76
00:02:57,830 --> 00:02:54,640
immediate properties

77
00:03:00,710 --> 00:02:57,840
because this is what necessitates robust

78
00:03:02,550 --> 00:03:00,720
navigational strategies and this is

79
00:03:05,430 --> 00:03:02,560
reflected in the variability of

80
00:03:07,830 --> 00:03:05,440
movements that an organism makes

81
00:03:09,830 --> 00:03:07,840
therefore there is a need to quantify

82
00:03:10,790 --> 00:03:09,840
the correspondence between environmental

83
00:03:14,229 --> 00:03:10,800
complexity

84
00:03:17,990 --> 00:03:17,030
ideally i would like to quantify this

85
00:03:20,229 --> 00:03:18,000
correspondence

86
00:03:22,309 --> 00:03:20,239
between environmental complexity and

87
00:03:24,149 --> 00:03:22,319
movement complexity

88
00:03:25,670 --> 00:03:24,159

and this would allow us to use

89
00:03:28,630 --> 00:03:25,680
environmental complexity

90
00:03:29,110 --> 00:03:28,640
to ascertain what types of organisms may

91
00:03:32,229 --> 00:03:29,120
exist

92
00:03:34,149 --> 00:03:32,239
in a given environment but in order to

93
00:03:37,830 --> 00:03:34,159
do this we also need to quantify

94
00:03:41,670 --> 00:03:40,470
there are many reliable behavioral

95
00:03:44,470 --> 00:03:41,680
models

96
00:03:44,869 --> 00:03:44,480
however many behavioral studies make use

97
00:03:46,869 --> 00:03:44,879
of

98
00:03:48,070 --> 00:03:46,879
highly artificial and reductive

99
00:03:49,990 --> 00:03:48,080
conditions and

100
00:03:52,070 --> 00:03:50,000
lack the resolution to capture more

101
00:03:55,110 --> 00:03:52,080
complex natural movements

102
00:03:57,750 --> 00:03:55,120
in three-dimensional space therefore

103
00:03:58,830 --> 00:03:57,760
movement complexity in three dimensions

104
00:04:02,710 --> 00:03:58,840
is highly

105
00:04:05,509 --> 00:04:02,720
understudied in my research

106
00:04:06,470 --> 00:04:05,519
i am interested in quantifying movement

107
00:04:10,470 --> 00:04:06,480
complexity

108
00:04:12,470 --> 00:04:10,480
in mice therefore in order to study

109
00:04:13,990 --> 00:04:12,480
complex movement with a high level of

110
00:04:17,509 --> 00:04:14,000
precision in freely

111
00:04:20,550 --> 00:04:17,519
behaving mice in three-dimensional space

112
00:04:23,670 --> 00:04:20,560
our lab has developed the first

113
00:04:26,710 --> 00:04:23,680

marker-based 3d motion capture system

114
00:04:30,150 --> 00:04:26,720
adapted to observe mice

115
00:04:30,950 --> 00:04:30,160
we use seven high-speed high-resolution

116
00:04:33,790 --> 00:04:30,960
cameras

117
00:04:35,510 --> 00:04:33,800
to record the 3d trajectories of

118
00:04:37,189 --> 00:04:35,520
retro-reflective markers

119
00:04:39,350 --> 00:04:37,199
that are permanently attached to the

120
00:04:42,710 --> 00:04:39,360
skin at strategic locations

121
00:04:45,830 --> 00:04:42,720
on the body of the mouse this gives

122
00:04:46,950 --> 00:04:45,840
us 3d movement trajectories recorded at

123
00:04:50,070 --> 00:04:46,960
a rate of

124
00:04:50,469 --> 00:04:50,080
300 frames per second with a resolution

125
00:04:53,430 --> 00:04:50,479
of

126
00:04:55,270 --> 00:04:53,440
200 micrometers allowing us to see

127
00:04:59,189 --> 00:04:55,280
details of mouse movement

128
00:05:01,830 --> 00:04:59,199
at an unprecedented level of precision

129
00:05:02,790 --> 00:05:01,840
previous studies in my lab used this

130
00:05:04,950 --> 00:05:02,800
methodology

131
00:05:06,550 --> 00:05:04,960
to observe mice as they performed

132
00:05:09,110 --> 00:05:06,560
different tasks

133
00:05:10,150 --> 00:05:09,120
even the simplest of tasks the movement

134
00:05:13,350 --> 00:05:10,160
of a mouse

135
00:05:15,749 --> 00:05:13,360
walking in open field involved highly

136
00:05:18,230 --> 00:05:15,759
complex movements that were hard to

137
00:05:21,350 --> 00:05:18,240
quantify

138
00:05:22,230 --> 00:05:21,360

therefore in order to start simple in my

139
00:05:24,629 --> 00:05:22,240
research

140
00:05:25,830 --> 00:05:24,639
i aim to quantify the complexity in

141
00:05:28,150 --> 00:05:25,840
mouse movements

142
00:05:30,629 --> 00:05:28,160
as they locomote on a treadmill at

143
00:05:32,950 --> 00:05:30,639
constant speed

144
00:05:34,550 --> 00:05:32,960
by observing the mice using the 3d

145
00:05:37,029 --> 00:05:34,560
motion capture system

146
00:05:39,110 --> 00:05:37,039
as their locomote on a treadmill i

147
00:05:42,870 --> 00:05:39,120
obtain highly resolved

148
00:05:46,070 --> 00:05:45,430
here you can see a 3d reconstructed

149
00:05:59,270 --> 00:05:46,080
video

150
00:06:02,870 --> 00:06:01,749
i make use of tools from dynamical

151
00:06:05,430 --> 00:06:02,880
systems theory

152
00:06:06,950 --> 00:06:05,440
to quantify the variability of these

153
00:06:09,430 --> 00:06:06,960
movements

154
00:06:10,469 --> 00:06:09,440
i first transform the 3d movement

155
00:06:13,029 --> 00:06:10,479
trajectories

156
00:06:15,110 --> 00:06:13,039
into an animal-centric coordinate system

157
00:06:19,110 --> 00:06:15,120
this is depicted in the schematic here

158
00:06:22,790 --> 00:06:22,309
i then embed these movements by making

159
00:06:25,350 --> 00:06:22,800
use

160
00:06:26,629 --> 00:06:25,360
of the singular spectrum analysis method

161
00:06:29,430 --> 00:06:26,639
of embedding

162
00:06:30,230 --> 00:06:29,440
which uses windowed principal component

163
00:06:33,350 --> 00:06:30,240

analysis

164
00:06:35,430 --> 00:06:33,360
to embed the trajectories this

165
00:06:37,110 --> 00:06:35,440
provides me with the right coordinate

166
00:06:41,749 --> 00:06:37,120
system to visualize

167
00:06:45,830 --> 00:06:44,309
here is a plot of a singular spectrum

168
00:06:49,510 --> 00:06:45,840
analysis of bedding

169
00:06:51,749 --> 00:06:49,520
of the trajectories of the mouse limbs

170
00:06:53,270 --> 00:06:51,759
it provides me with well-resolved step

171
00:06:55,670 --> 00:06:53,280
cycles

172
00:06:57,909 --> 00:06:55,680
and it is already apparent from this

173
00:06:59,189 --> 00:06:57,919
that there are two large classes of step

174
00:07:01,670 --> 00:06:59,199
cycles

175
00:07:03,510 --> 00:07:01,680
but also within these two classes there

176
00:07:05,749 --> 00:07:03,520
is a lot of variability

177
00:07:10,950 --> 00:07:05,759
and this is exactly the complexity that

178
00:07:14,950 --> 00:07:13,589
i then compute the recurrences in the

179
00:07:16,870 --> 00:07:14,960
movement trajectories

180
00:07:18,629 --> 00:07:16,880
in order to find the different types of

181
00:07:21,909 --> 00:07:18,639
step cycles

182
00:07:25,110 --> 00:07:21,919
so i do this as follows i would first

183
00:07:27,589 --> 00:07:25,120
consider one point in the trajectory

184
00:07:28,150 --> 00:07:27,599
and then find all the neighbors of this

185
00:07:30,870 --> 00:07:28,160
point

186
00:07:32,870 --> 00:07:30,880
that means i find all the times at which

187
00:07:33,909 --> 00:07:32,880
the trajectory basically returns to the

188
00:07:37,670 --> 00:07:33,919

same neighborhood

189
00:07:39,909 --> 00:07:37,680
in space and then i would do this for

190
00:07:40,710 --> 00:07:39,919
all the points in the trajectory hence

191
00:07:42,950 --> 00:07:40,720
what i get

192
00:07:43,990 --> 00:07:42,960
is a recurrence matrix where i have

193
00:07:47,270 --> 00:07:44,000
basically

194
00:07:48,230 --> 00:07:47,280
the recurrences associated with each

195
00:07:51,670 --> 00:07:48,240
point

196
00:07:54,869 --> 00:07:51,680
on each row therefore

197
00:07:56,230 --> 00:07:54,879
the scales of this plot represent

198
00:07:57,990 --> 00:07:56,240
the different time points of the

199
00:08:01,510 --> 00:07:58,000
trajectory it is in frames

200
00:08:03,749 --> 00:08:01,520
over here and all the parts of the plot

201
00:08:05,830 --> 00:08:03,759
that are in white they signify parts of

202
00:08:07,510 --> 00:08:05,840
the trajectory that recur

203
00:08:11,589 --> 00:08:07,520
that is they return to the same point in

204
00:08:15,110 --> 00:08:13,670
and in this recurrence plot of the mouse

205
00:08:16,950 --> 00:08:15,120
heinlem trajectories

206
00:08:18,550 --> 00:08:16,960
we can also see that there are two

207
00:08:20,869 --> 00:08:18,560
different step cycles

208
00:08:22,150 --> 00:08:20,879
two different classes of them but within

209
00:08:24,070 --> 00:08:22,160
these two different classes

210
00:08:26,070 --> 00:08:24,080
there is still a lot of variability and

211
00:08:29,670 --> 00:08:26,080
this needs to be quantified this

212
00:08:35,589 --> 00:08:32,790
i will now quantify the complexity

213
00:08:37,430 --> 00:08:35,599

of these trajectories by making use of

214
00:08:40,550 --> 00:08:37,440
information theoretic measures

215
00:08:43,029 --> 00:08:40,560
of complexity i will be making use

216
00:08:43,990 --> 00:08:43,039
of two main measures the effective

217
00:08:46,790 --> 00:08:44,000
complexity

218
00:08:47,910 --> 00:08:46,800
and the total information the effective

219
00:08:50,150 --> 00:08:47,920
complexity

220
00:08:51,430 --> 00:08:50,160
measures the information needed to

221
00:08:53,509 --> 00:08:51,440
describe the

222
00:08:54,790 --> 00:08:53,519
regularities in the data of a given

223
00:08:57,430 --> 00:08:54,800
system

224
00:08:58,310 --> 00:08:57,440
while the total information can be used

225
00:09:01,509 --> 00:08:58,320
to describe

226
00:09:03,590 --> 00:09:01,519
fluctuations in the data therefore the

227
00:09:05,829 --> 00:09:03,600
next steps in my work are to compute

228
00:09:09,509 --> 00:09:05,839
these mathematical complexity measures

229
00:09:11,910 --> 00:09:09,519
for my data

230
00:09:12,949 --> 00:09:11,920
once this quantitative framework has

231
00:09:15,990 --> 00:09:12,959
been established

232
00:09:19,190 --> 00:09:16,000
for the simplest of cases a mouse

233
00:09:20,470 --> 00:09:19,200
walking on a treadmill i can then extend

234
00:09:23,350 --> 00:09:20,480
this methodology

235
00:09:25,509 --> 00:09:23,360
to study mice moving in more complex

236
00:09:28,230 --> 00:09:25,519
environmental settings

237
00:09:29,269 --> 00:09:28,240
i can then use my quantitative methods

238
00:09:31,350 --> 00:09:29,279

to compute

239
00:09:32,949 --> 00:09:31,360
movement complexity in these different

240
00:09:35,430 --> 00:09:32,959
settings

241
00:09:37,750 --> 00:09:35,440
additionally i can use these same

242
00:09:40,870 --> 00:09:37,760
mathematical measures of complexity

243
00:09:43,190 --> 00:09:40,880
to quantify environmental complexity

244
00:09:44,310 --> 00:09:43,200
and this will aid in establishing the

245
00:09:46,550 --> 00:09:44,320
correspondence

246
00:09:50,389 --> 00:09:46,560
between environmental complexity and

247
00:09:53,509 --> 00:09:50,399
movement complexity

248
00:09:55,030 --> 00:09:53,519
to summarize i want to quantify movement

249
00:09:58,389 --> 00:09:55,040
complexity

250
00:10:00,550 --> 00:09:58,399
i do this by making use of a 3d

251
00:10:01,750 --> 00:10:00,560
marker-based motion capture system

252
00:10:05,430 --> 00:10:01,760
adapted to observe

253
00:10:07,750 --> 00:10:05,440
freely behaving mice this gives me

254
00:10:09,110 --> 00:10:07,760
highly resolved movement trajectories

255
00:10:11,509 --> 00:10:09,120
for the first time

256
00:10:12,470 --> 00:10:11,519
that enables us to quantify movement

257
00:10:16,150 --> 00:10:12,480
complexity

258
00:10:18,230 --> 00:10:16,160
in 3d i then make use of tools from

259
00:10:20,310 --> 00:10:18,240
dynamical systems theory and

260
00:10:21,990 --> 00:10:20,320
information theory to obtain a

261
00:10:25,030 --> 00:10:22,000
comprehensive quantification

262
00:10:27,030 --> 00:10:25,040
of movement complexity and then this

263
00:10:28,389 --> 00:10:27,040

can be used in establishing the

264
00:10:29,350 --> 00:10:28,399
correspondence between movement

265
00:10:35,990 --> 00:10:29,360
complexity

266
00:10:37,990 --> 00:10:36,000
so even the simplistic movements a mouse

267
00:10:39,990 --> 00:10:38,000
walking at the same speed

268
00:10:41,910 --> 00:10:40,000
is super complex it's more complex than

269
00:10:44,310 --> 00:10:41,920
we initially expected

270
00:10:47,910 --> 00:10:44,320
and in order to quantify this it is

271
00:10:49,670 --> 00:10:47,920
necessary to study 3d trajectories

272
00:10:51,509 --> 00:10:49,680
with this we can establish the

273
00:10:54,870 --> 00:10:51,519
connection between movement

274
00:10:57,910 --> 00:10:54,880
and environmental complexity therefore

275
00:11:01,670 --> 00:10:57,920
in conclusion precise measurement

276
00:11:05,030 --> 00:11:01,680
of 3d movement trajectories is necessary

277
00:11:08,230 --> 00:11:05,040
to unfold the complexity of behavior

278
00:11:09,190 --> 00:11:08,240
and therefore also the complexity of the

279
00:11:14,470 --> 00:11:09,200
environment

280
00:11:16,470 --> 00:11:14,480
in which the behavior occurs

281
00:11:18,710 --> 00:11:16,480
i would like to thank the members of the

282
00:11:21,509 --> 00:11:18,720
neuronal rhythms in movement unit

283
00:11:22,069 --> 00:11:21,519
at oyst for their invaluable guidance

284
00:11:25,269 --> 00:11:22,079
throughout

285
00:11:27,509 --> 00:11:25,279
my research and i would also like to

286
00:11:28,310 --> 00:11:27,519
thank the biological physics theory unit

287
00:11:30,710 --> 00:11:28,320
of oyste

288
00:11:31,350 --> 00:11:30,720

for all the useful discussion and

289
00:11:33,590 --> 00:11:31,360
guidance

290
00:11:37,110 --> 00:11:33,600
regarding the quantitative analyses

291
00:11:41,190 --> 00:11:38,790
finally i would like to thank the

292
00:11:42,310 --> 00:11:41,200
organizers of abradcon for giving me

293
00:11:45,190 --> 00:11:42,320
this opportunity

294
00:11:46,470 --> 00:11:45,200
to present my research i am lakshmi

295
00:11:49,350 --> 00:11:46,480
priya swaminathan

296
00:11:51,509 --> 00:11:49,360
a phd student at the okinawa institute

297
00:11:53,990 --> 00:11:51,519
of science and technology

298
00:11:54,629 --> 00:11:54,000
i work jointly in the neuronal rhythms

299
00:11:57,590 --> 00:11:54,639
in movement

300
00:11:58,069 --> 00:11:57,600
research unit and the biological physics

301
00:12:01,590 --> 00:11:58,079
theory

302
00:12:02,470 --> 00:12:01,600
research unit at oyst thank you for

303
00:12:04,629 --> 00:12:02,480
tuning in

304
00:12:06,790 --> 00:12:04,639
and if you have any questions you may

305
00:12:07,430 --> 00:12:06,800
contact me by making use of the contact