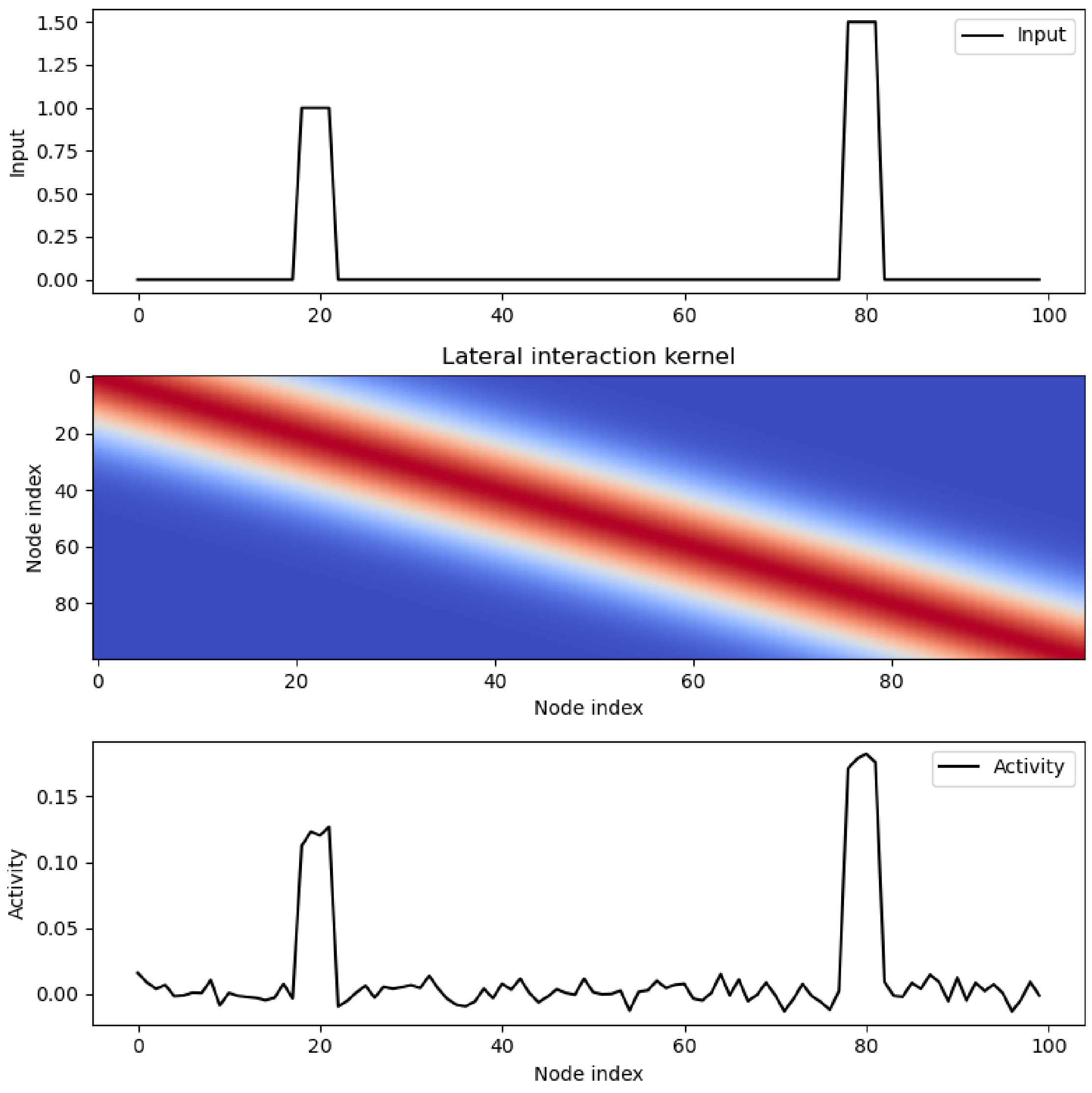
NEUR 416 Final Project - Main Code

May 2, 2023

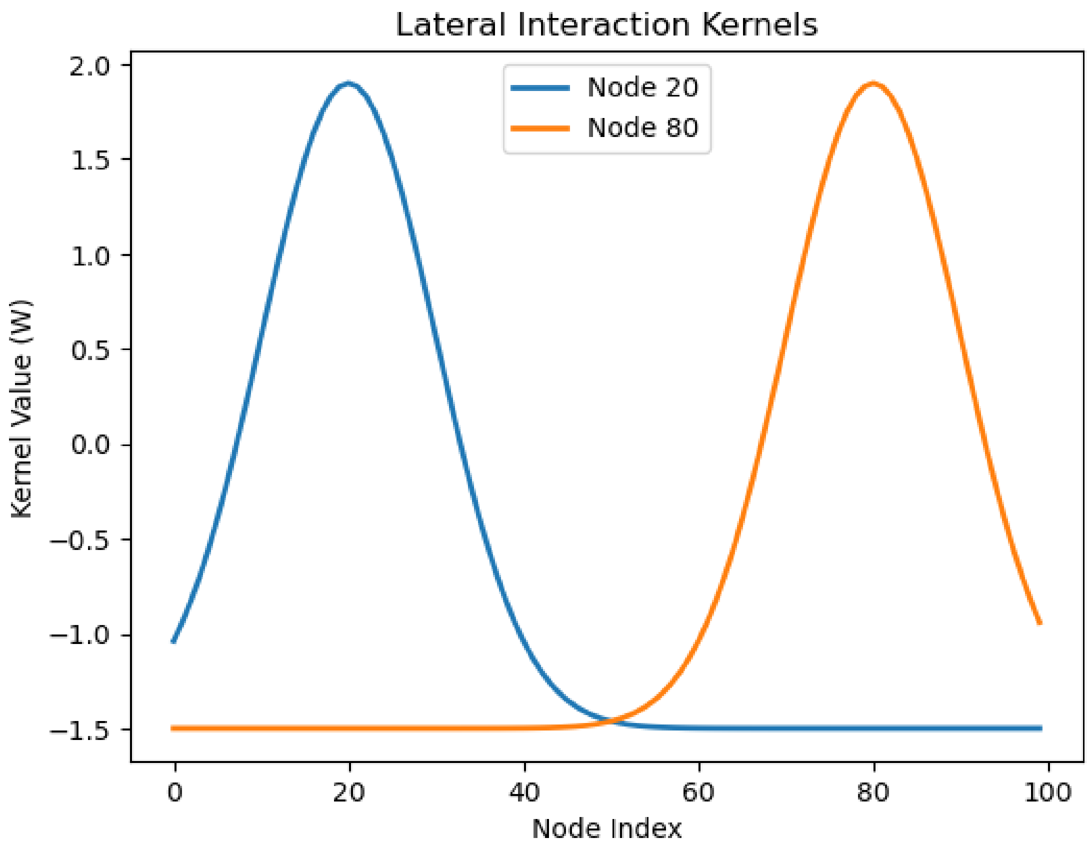
[177]:
```
import numpy as np
import matplotlib.pyplot as plt

# Define parameters
Th = 0.1791
C = 0.35
Ir = 1
Ip = 1.5
 1 = 0.01685
 1 = 0.003
 2 = 0.0065
 2 = 0.0016
T = 50 # ms
sigma = 2 * np.pi / 10
Delta_x = 2 * np.pi / 100
A = 1
N = 100
beta = 0.5
theta = 0.5
mu_n = 0
sigma_n = 0.05
ntrials = 5000

# Define the sigmoid function
def sigmoid(x, beta, theta):
    return 1 / (1 + np.exp(-beta * x)) - theta

# Define the lateral interaction kernel
def lateral_kernel(i, j, B, C, sigma):
    return B * (1 / (np.sqrt(4 * np.pi) * sigma) * np.exp(-((i - j) *␣
 ↪Delta_x)**2 / (4 * sigma**2)) - C)

# Initialize variables
x = np.zeros(N)
r = np.zeros(N)
w = np.zeros((N, N))
```

```
# Populate the lateral interaction kernel
for i in range(N):
    for j in range(N):
        w[i, j] = lateral_kernel(i, j, 1, C, sigma)

# Define the external inputs
I = np.zeros(N)
I[18:22] = Ir
I[78:82] = Ip
#I[:3] = Ir
#I[N//2-1:N//2+2] = Ip

# Run the simulation
for t in range(5000):
    # Calculate the total input to each node
    I_net = I + np.dot(w, r) + np.random.normal(mu_n, sigma_n, N)

    # Update the activity of each node
    x += -x + I_net
    r = sigmoid(x, beta, theta)

    # Check for threshold crossing
    if np.any(r > Th):
        RT = t + 30
        break

# Plot the dynamics
fig, ax = plt.subplots(3, 1, figsize=(8, 8))

ax[0].plot(np.arange(N), I, 'k', label='Input')
ax[0].legend()
ax[0].set_ylabel('Input')

ax[1].imshow(w, cmap='coolwarm', aspect='auto')
ax[1].set_xlabel('Node index')
ax[1].set_ylabel('Node index')
ax[1].set_title('Lateral interaction kernel')

ax[2].plot(np.arange(N), r, 'k', label='Activity')
ax[2].legend()
ax[2].set_xlabel('Node index')
ax[2].set_ylabel('Activity')

plt.tight_layout()
plt.show()
```



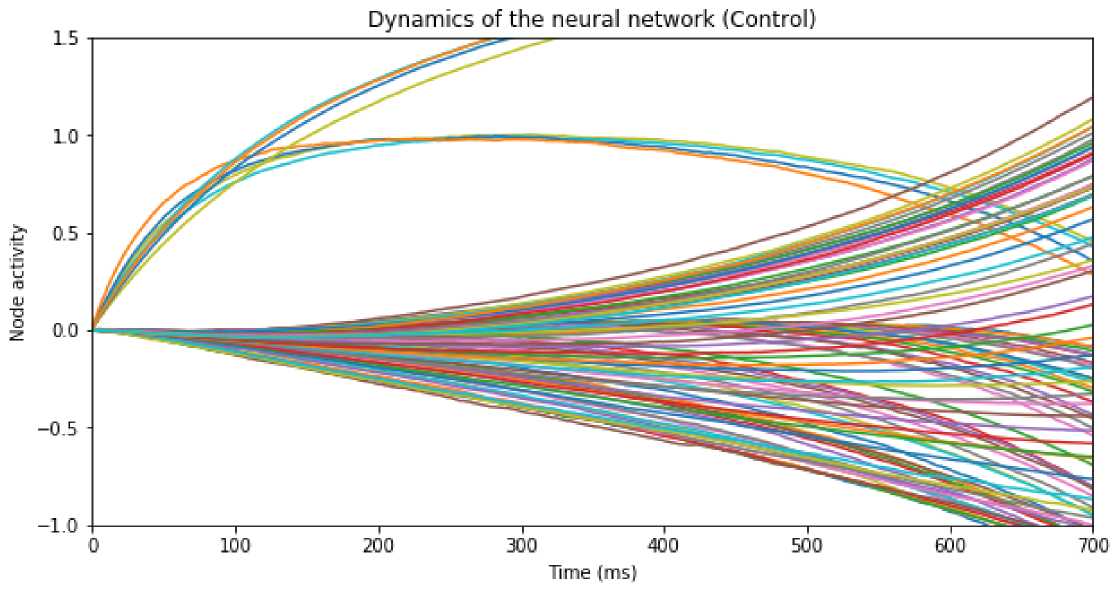
```
[71]: import numpy as np
      import matplotlib.pyplot as plt

      # Define the parameters
      N = 100  # number of nodes in the SC
      sigma = 2*np.pi/10  # standard deviation of the Gaussian
      delta_x = 2*np.pi/N  # spacing between the nodes
      A = 3.4  # amplitude of the Gaussian
      beta = 1.5 # shift factor of the Gaussian

      # Define the kernels for nodes 20 and 80
      node20_kernel = np.zeros(N)
      node80_kernel = np.zeros(N)
```

```
for i in range(N):
    distance_from_20 = np.abs(i - 20)
    distance_from_80 = np.abs(i - 80)
    node20_kernel[i] = A * np.exp(-((distance_from_20 * delta_x)**2) / (2 *␣
 ↪sigma**2)) - beta
    node80_kernel[i] = A * np.exp(-((distance_from_80 * delta_x)**2) / (2 *␣
 ↪sigma**2)) - beta

# Plot the kernels
fig, ax = plt.subplots()
ax.plot(node20_kernel, linewidth=2, label='Node 20')
ax.plot(node80_kernel, linewidth=2, label='Node 80')
ax.set_title('Lateral Interaction Kernels')
ax.set_xlabel('Node Index')
ax.set_ylabel('Kernel Value (W)')
ax.legend()
plt.show()
```



[29]:
```
# Control Dynamics

import numpy as np
import matplotlib.pyplot as plt

# Define parameters
Th = 0.1791
C = 0.35
Ir = 1
Ip = 1.5
 1 = 0.01685
 1 = 0.003
 2 = 0.0065
 2 = 0.0016
T = 50
  = 2*np.pi/10
Δx = 2*np.pi/100
B = 1
N = 100
  = 0.5
  = 0.5
 _n = 0
 _n = 0.05
ntrials = 5000

# Define sigmoid function
def sigmoid(x):
    return (1 / (1 + np.exp(-x))) -

# Define lateral interaction kernel
def lateral_kernel(i, j):
    return B*(1/(np.sqrt(4*np.pi) *  ) * np.exp(-((i-j)*Δx)**2 / (4* **2)) - C)

# Initialize variables
x = np.zeros(N) # internal state of nodes
tau = np.zeros(N) # integration time constant
for i in range(N//2):
    tau[i] = np.random.normal( 1,  1)
for i in range(N//2, N):
    tau[i] = np.random.normal( 2,  2)
w = np.zeros((N,N)) # synaptic efficacies
for i in range(N):
    for j in range(N):
        w[i,j] = lateral_kernel(i, j)
I_ext = np.zeros(N) # external input
I_ext[18:22] = Ir
I_ext[78:82] = Ip
```

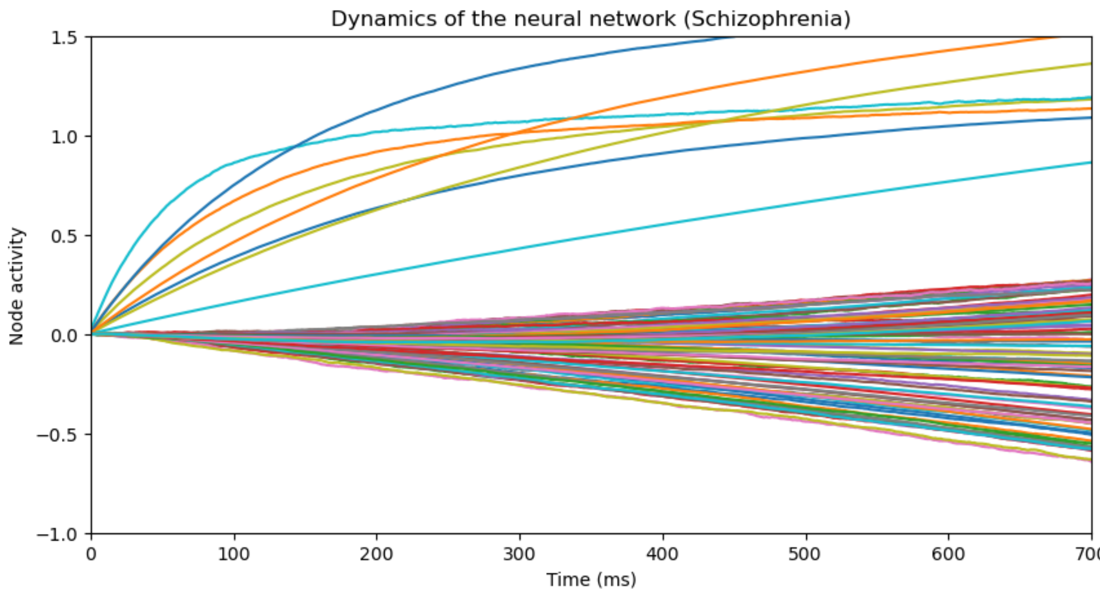
```
In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
dt = 1 # time step
tmax = 0.65 # maximum time to simulate
nt = 5000 # number of time steps
x_hist = np.zeros((N, nt)) # history of node activity

# Simulate network
for i in range(nt):
    dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
    x += dxdt * (tau)
    x_hist[:,i] = x

# Plot node activity over time
fig, ax = plt.subplots(figsize=(10,5))
for i in range(N):
    ax.plot(np.arange(nt)*dt, x_hist[i,:])
ax.set_xlabel('Time (ms)')
ax.set_ylabel('Node activity')
ax.set_title('Dynamics of the neural network (Control)')
ax.set_xlim([0,700])
ax.set_ylim([-1,1.5])
plt.show()
```



[90]:
```
# Schizophrenia Dynamics

import numpy as np
import matplotlib.pyplot as plt
```

```
# Define parameters
Th = 0.1791
C = 0.35
Ir = 1
Ip = 1.5
 1 = 0.0135
 1 = 0.005
 2 = 0.004
 2 = 0.002
T = 50
  = 2*np.pi/10
Δx = 2*np.pi/100
B = 1
N = 100
  = 0.5
  = 0.5
 _n = 0
 _n = 0.05
ntrials = 5000

# Define sigmoid function
def sigmoid(x):
    return (1 / (1 + np.exp(-x))) -

# Define lateral interaction kernel
def lateral_kernel(i, j):
    return B*(1/(np.sqrt(4*np.pi) *  ) * np.exp(-((i-j)*Δx)**2 / (4* **2)) - C)

# Initialize variables
x = np.zeros(N) # internal state of nodes
tau = np.zeros(N) # integration time constant
for i in range(N//2):
    tau[i] = np.random.normal( 1,  1)
for i in range(N//2, N):
    tau[i] = np.random.normal( 2,  2)
w = np.zeros((N,N)) # synaptic efficacies
for i in range(N):
    for j in range(N):
        w[i,j] = lateral_kernel(i, j)
I_ext = np.zeros(N) # external input
I_ext[18:22] = Ir
I_ext[78:82] = Ip
In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
dt = 1 # time step
tmax = 0.65 # maximum time to simulate
nt = 5000 # number of time steps
```

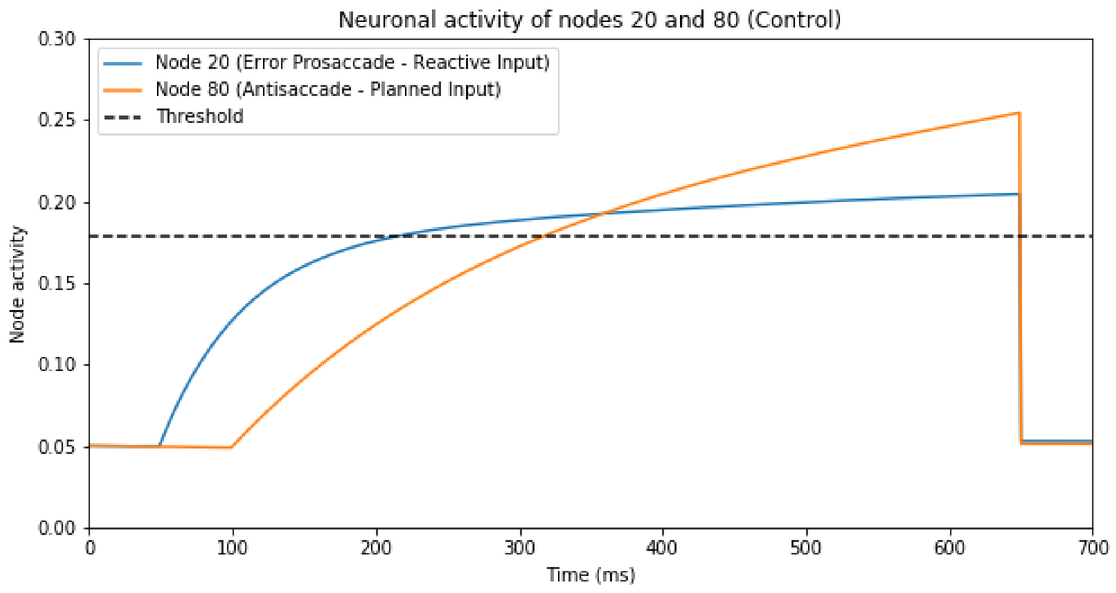
```
x_hist = np.zeros((N, nt)) # history of node activity

# Simulate network
for i in range(nt):
    dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
    x += dxdt * (tau)
    x_hist[:,i] = x

# Plot node activity over time
fig, ax = plt.subplots(figsize=(10,5))
for i in range(N):
    ax.plot(np.arange(nt)*dt, x_hist[i,:])
ax.set_xlabel('Time (ms)')
ax.set_ylabel('Node activity')
ax.set_title('Dynamics of the neural network (Schizophrenia)')
ax.set_xlim([0,700])
ax.set_ylim([-1,1.5])
plt.show()
```



[4]:
```
# Control Condition

import numpy as np
import matplotlib.pyplot as plt

# Define parameters
Th = 0.1791
C = 0.35
```

```
Ir = 1
Ip = 1.5
 1 = 0.01685
 1 = 0.003
 2 = 0.0065
 2 = 0.0016
T = 50
  = 2*np.pi/10
Δx = 2*np.pi/100
B = 1
N = 100
  = 0.5
  = 0.5
 _n = 0
 _n = 0.005
ntrials = 5000

# Define sigmoid function
def sigmoid(x):
    return (1 / (1 + np.exp(-x))) - 

# Define lateral interaction kernel
def lateral_kernel(i, j):
    return B*(((1/(np.sqrt(4*np.pi) *  )) * np.exp((-((i-j)*Δx)**2) / (4* **2)))␣
  ↪- C)

# Initialize variables
x = np.zeros(N) # internal state of nodes
tau = np.zeros(N) # integration time constant
for i in range(N//2):
    tau[i] = np.random.normal( 1,  1)
for i in range(N//2, N):
    tau[i] = np.random.normal( 2,  2)
w = np.zeros((N,N)) # synaptic efficacies
for i in range(N):
    for j in range(N):
        w[i,j] = lateral_kernel(i, j)
I_ext = np.zeros(N) # external input
I_ext[18:22] = Ir
I_ext[78:82] = Ip
I_ext[20] = 0
I_ext[80] = 0
In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
dt = 1 # time step
nt = 5000 # number of time steps
x_hist = np.zeros((N, nt)) # history of node activity
```

```
# Simulate network
for i in range(nt):
    if i*dt >= 50:
        I_ext[18:22] = Ir
    if i*dt >= 100:
        I_ext[78:82] = Ip
    if i*dt >= 650:
        x[20] = 0
        x[80] = 0
    dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
    x += dxdt * (tau)
    x_hist[:,i] = x * (0.126)

# Plot node activity over time
fig, ax = plt.subplots(figsize=(10,5))
ax.plot(np.arange(nt)*dt, x_hist[20,:] + 0.05, label='Node 20 (Error Prosaccade␣
 ↪- Reactive Input)')
ax.plot(np.arange(nt)*dt, x_hist[80,:] + 0.05, label='Node 80 (Antisaccade -␣
 ↪Planned Input)')
ax.axhline(y=Th, color='black', linestyle='--', label='Threshold')
ax.set_xlabel('Time (ms)')
ax.set_ylabel('Node activity')
ax.set_title('Neuronal activity of nodes 20 and 80 (Control)')
ax.set_xlim([0,700])
ax.set_ylim([0,0.3])
ax.legend()
plt.show()
```



```
[9]: # Control Condition Error Rate and Rate of Error Correction

     import numpy as np

     # Define parameters
     Th = 0.1791
     C = 0.35
     Ir = 1
     Ip = 1.5
      1 = 0.01685
      1 = 0.003
      2 = 0.0065
      2 = 0.0016
     T = 50e-3
       = 2*np.pi/10
     Δx = 2*np.pi/100
     B = 1
     N = 100
       = 0.5
       = 0.5
      _n = 0
      _n = 0.005
     ntrials = 5000

     # Define sigmoid function
     def sigmoid(x):
         return (1 / (1 + np.exp(-x))) -

     # Define lateral interaction kernel
     def lateral_kernel(i, j):
         return B*(((1/(np.sqrt(4*np.pi) *  )) * np.exp((-((i-j)*Δx)**2) / (4* **2)))␣
       ↪- C)

     count = 0  # initialize count
     count2 = 0 # initialize count2

     for i in range(500):
         # Initialize variables
         x = np.zeros(N) # internal state of nodes
         tau = np.zeros(N) # integration time constant
         for i in range(N//2):
             tau[i] = np.random.normal( 1,  1)
         for i in range(N//2, N):
             tau[i] = np.random.normal( 2,  2)
         w = np.zeros((N,N)) # synaptic efficacies
         for i in range(N):
             for j in range(N):
```

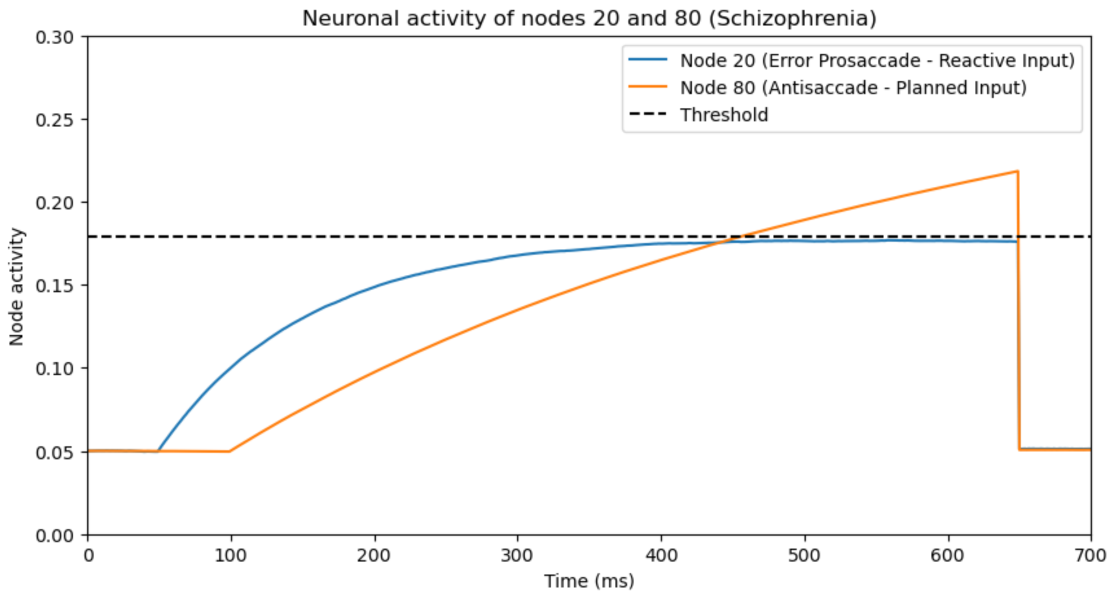
```
            w[i,j] = lateral_kernel(i, j)
    I_ext = np.zeros(N) # external input
    I_ext[18:22] = Ir
    I_ext[78:82] = Ip
    I_ext[20] = 0
    I_ext[80] = 0
    In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
    dt = 1 # time step
    nt = 5000 # number of time steps
    x_hist = np.zeros((N, nt)) # history of node activity
    # Simulate network
    for i in range(nt):
        if i*dt >= 50:
            I_ext[18:22] = Ir
        if i*dt >= 100:
            I_ext[78:82] = Ip
        if i*dt >= 650:
            x[20] = 0
            x[80] = 0
        dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
        x += dxdt * (tau)
        x_hist[:,i] = x * (0.126)

        # Check if node 20 reaches threshold before node 80
        if x[19] >= Th and x[79] < Th:
            count += 1
            break  # exit loop if condition is satisfied

for i in range(500):
    # Initialize variables
    x = np.zeros(N) # internal state of nodes
    tau = np.zeros(N) # integration time constant
    for i in range(N//2):
        tau[i] = np.random.normal( 1,  1)
    for i in range(N//2, N):
        tau[i] = np.random.normal( 2,  2)
    w = np.zeros((N,N)) # synaptic efficacies
    for i in range(N):
        for j in range(N):
            w[i,j] = lateral_kernel(i, j)
    I_ext = np.zeros(N) # external input
    I_ext[18:22] = Ir
    I_ext[78:82] = Ip
    I_ext[20] = 0
    I_ext[80] = 0
    In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
    dt = 1 # time step
    nt = 5000 # number of time steps
    x_hist = np.zeros((N, nt)) # history of node activity
    # Simulate network
    for i in range(nt):
        if i*dt >= 50:
            I_ext[18:22] = Ir
        if i*dt >= 100:
            I_ext[78:82] = Ip
        if i*dt >= 650:
            x[20] = 0
            x[80] = 0
        dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
        x += dxdt * (tau)
        x_hist[:,i] = x * (0.126)

        if x[79] >= Th and x[19] >= Th:
            count2 += 1
            break

print("Control Condition")
print()
print(f"(Error) Node 20 reached the threshold before node 80 in {count} out of␣
 ↪500 trials.")
percentage = float((count/500)*100)
print("(Error) Node 20 reached the threshold before Node 80 in {:.2f}% of␣
 ↪simulations".format(percentage))

print(f"(Correction) Node 80 reached the threshold after node 20 in {count2}␣
 ↪out of {count} times.")
percentage2 = float((count2/count)*100)
print("(Correction) Node 80 reached the threshold after Node 20 in {:.2f}% of␣
 ↪simulations".format(percentage2))
```

```
Control Condition

(Error) Node 20 reached the threshold before node 80 in 62 out of 500 trials.
(Error) Node 20 reached the threshold before Node 80 in 12.40% of simulations
(Correction) Node 80 reached the threshold after node 20 in 51 out of 62 times.
(Correction) Node 80 reached the threshold after Node 20 in 82.26% of
simulations
```

[95]:
```
import numpy as np
import matplotlib.pyplot as plt

# Schizophrenia Condition

# Define parameters
```

```
Th = 0.1791
C = 0.35
Ir = 1
Ip = 1.5
 1 = 0.0135
 1 = 0.005
 2 = 0.004
 2 = 0.002
T = 50
  = 2*np.pi/10
Δx = 2*np.pi/100
B = 1
N = 100
  = 0.5
  = 0.5
 _n = 0
 _n = 0.005
ntrials = 5000

# Define sigmoid function
def sigmoid(x):
    return (1 / (1 + np.exp(-x))) -

# Define lateral interaction kernel
def lateral_kernel(i, j):
    return B*(((1/(np.sqrt(4*np.pi) *  )) * np.exp((-((i-j)*Δx)**2) / (4* **2)))␣
  ↪- C)

# Initialize variables
x = np.zeros(N) # internal state of nodes
tau = np.zeros(N) # integration time constant
for i in range(N//2):
    tau[i] = np.random.normal( 1,  1)
for i in range(N//2, N):
    tau[i] = np.random.normal( 2,  2)
w = np.zeros((N,N)) # synaptic efficacies
for i in range(N):
    for j in range(N):
        w[i,j] = lateral_kernel(i, j)
I_ext = np.zeros(N) # external input
I_ext[18:22] = Ir
I_ext[78:82] = Ip
I_ext[20] = 0
I_ext[80] = 0
In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
dt = 1 # time step
nt = 5000 # number of time steps
```

```
x_hist = np.zeros((N, nt)) # history of node activity

# Simulate network
for i in range(nt):
    if i*dt >= 50:
        I_ext[18:22] = Ir
    if i*dt >= 100:
        I_ext[78:82] = Ip
    if i*dt >= 650:
        x[20] = 0
        x[80] = 0
    dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
    x += dxdt * (tau)
    x_hist[:,i] = x * (0.126)

# Plot node activity over time
fig, ax = plt.subplots(figsize=(10,5))
ax.plot(np.arange(nt)*dt, x_hist[20,:] + 0.05, label='Node 20 (Error Prosaccade␣
 ↪- Reactive Input)')
ax.plot(np.arange(nt)*dt, x_hist[80,:] + 0.05, label='Node 80 (Antisaccade -␣
 ↪Planned Input)')
ax.axhline(y=Th, color='black', linestyle='--', label='Threshold')
ax.set_xlabel('Time (ms)')
ax.set_ylabel('Node activity')
ax.set_title('Neuronal activity of nodes 20 and 80 (Schizophrenia)')
ax.set_xlim([0,700])
ax.set_ylim([0,0.3])
ax.legend()
plt.show()
```

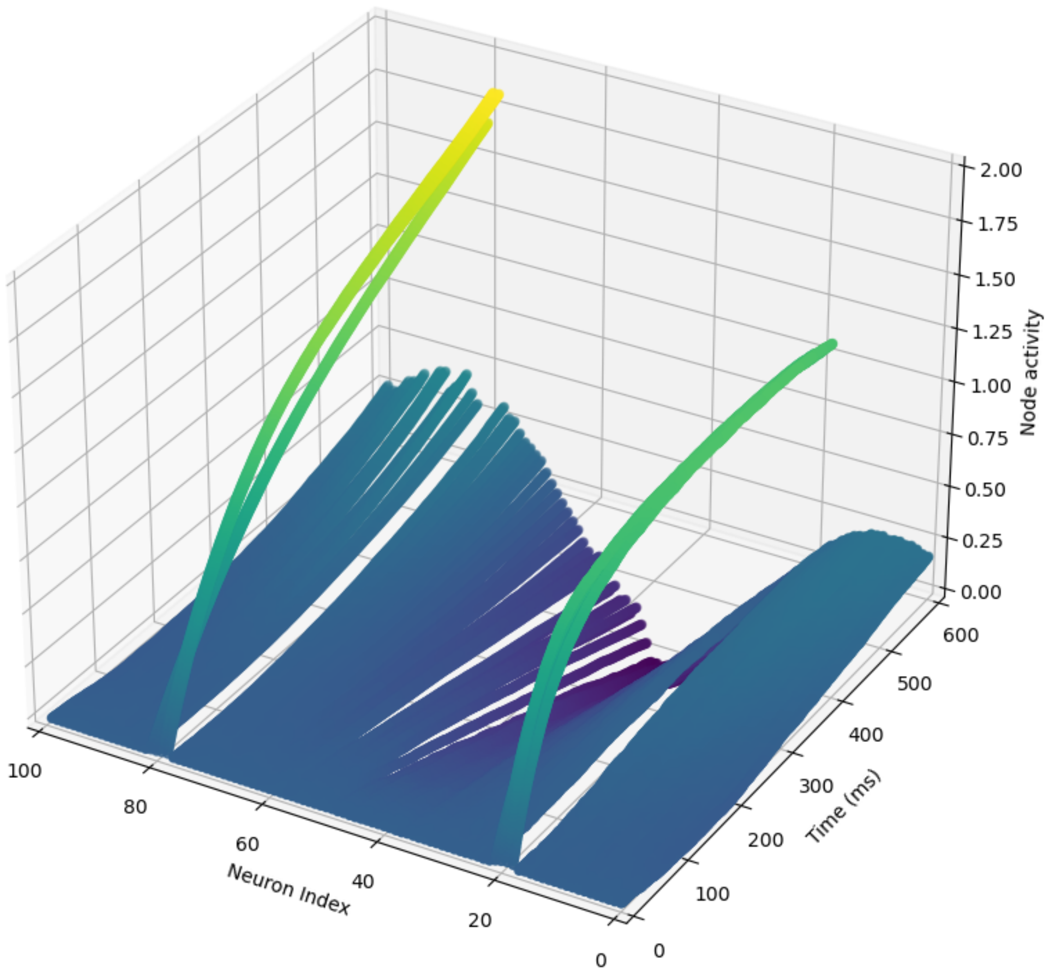


[36]:
```
# Schizophrenia Condition Error Rate and Rate of Error Correction

import numpy as np

# Define parameters
Th = 0.1791
C = 0.35
Ir = 1
Ip = 1.5
 1 = 0.0135
 1 = 0.005
 2 = 0.004
 2 = 0.002
T = 50
  = 2*np.pi/10
Δx = 2*np.pi/100
B = 1
N = 100
  = 0.5
  = 0.5
 _n = 0
 _n = 0.005
ntrials = 5000
trials = 1000

# Define sigmoid function
def sigmoid(x):
    return (1 / (1 + np.exp(-x))) - 

# Define lateral interaction kernel
def lateral_kernel(i, j):
    return B*(((1/(np.sqrt(4*np.pi) *  )) * np.exp((-((i-j)*Δx)**2) / (4* **2)))␣
  ↪- C)

count = 0  # initialize count
count2 = 0 # initialize count2

for i in range(trials):
    # Initialize variables
    x = np.zeros(N) # internal state of nodes
    tau = np.zeros(N) # integration time constant
    for i in range(N//2):
        tau[i] = np.random.normal( 1,  1)
    for i in range(N//2, N):
        tau[i] = np.random.normal( 2,  2)
    w = np.zeros((N,N)) # synaptic efficacies
    for i in range(N):
        for j in range(N):
            w[i,j] = lateral_kernel(i, j)
    I_ext = np.zeros(N) # external input
    I_ext[18:22] = Ir
    I_ext[78:82] = Ip
    I_ext[20] = 0
    I_ext[80] = 0
    In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
    dt = 1 # time step
    nt = 5000 # number of time steps
    x_hist = np.zeros((N, nt)) # history of node activity
    reached_th = np.zeros(N) # to keep track of which nodes have reached␣
↪threshold
    # Simulate network
    for i in range(nt):
        if i*dt >= 50:
            I_ext[18:22] = Ir
        if i*dt >= 100:
            I_ext[78:82] = Ip
        if i*dt >= 650:
            x[20] = 0
            x[80] = 0
            reached_th[20] = 0 # reset the threshold flag for node 20
        dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
        x += dxdt * (tau)
        x_hist[:,i] = x * (0.126)

        # Check if node 20 reaches threshold before node 80
        #if x_hist[20,i] + 0.05 >= Th and x_hist[80,i] + 0.05 < Th:
        #    count += 1
        #    break

        # Check if node 20 or node 80 reaches threshold
        if x_hist[20,i] + 0.05 >= Th or x_hist[80,i] + 0.05 >= Th:
            # Check if both node 20 and node 80 have reached the threshold
            if x_hist[20,i] + 0.05 >= Th and x_hist[80,i] + 0.05 >= Th:
                # Check if node 20 reached the threshold before node 80
                if np.argmax(x_hist[:,i] == x_hist[20,i]) < np.argmax(x_hist[:
↪,i] == x_hist[80,i]):
                    count += 1
                    break
            # Check if only node 20 reached the threshold
            elif x_hist[20,i] + 0.05 >= Th and x_hist[80,i] + 0.05 < Th:
                count += 1
                break

for i in range(trials):
    # Initialize variables
    x = np.zeros(N) # internal state of nodes
    tau = np.zeros(N) # integration time constant
    for i in range(N//2):
        tau[i] = np.random.normal( 1,  1)
    for i in range(N//2, N):
        tau[i] = np.random.normal( 2,  2)
    w = np.zeros((N,N)) # synaptic efficacies
    for i in range(N):
        for j in range(N):
            w[i,j] = lateral_kernel(i, j)
    I_ext = np.zeros(N) # external input
    I_ext[18:22] = Ir
    I_ext[78:82] = Ip
    I_ext[20] = 0
    I_ext[80] = 0
    In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
    dt = 1 # time step
    nt = 5000 # number of time steps
    x_hist = np.zeros((N, nt)) # history of node activity
    reached_th = np.zeros(N) # to keep track of which nodes have reached␣
 ↪threshold
    # Simulate network
    for i in range(nt):
        if i*dt >= 50:
            I_ext[18:22] = Ir
        if i*dt >= 100:
            I_ext[78:82] = Ip
        if i*dt >= 650:
            x[20] = 0
            x[80] = 0
            reached_th[20] = 0 # reset the threshold flag for node 20
        dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
        x += dxdt * (tau)
        x_hist[:,i] = x * (0.126)

        # Check if node 20 reaches threshold before node 80
        #if x_hist[20,i] + 0.05 >= Th and reached_th[20] == 0:
        #    reached_th[20] = 1 # set the threshold flag for node 20
        #    continue
        #if x_hist[80,i] + 0.05 >= Th and reached_th[20] == 1:
        #    count2 += 1
        #    reached_th[80] = 1 # set the threshold flag for node 80
        #    break
        # Check if both node 20 and node 80 have reached the threshold
        if x_hist[20,i] + 0.05 >= Th and x_hist[80,i] + 0.05 >= Th:
            # Check if node 80 reached the threshold after node 20
            if np.argmax(x_hist[:,i] == x_hist[20,i]) < np.argmax(x_hist[:,i]␣
 ↪== x_hist[80,i]):
                count2 += 1
                break

print("Schizophrenia Condition")
print()
print(f"(Error) Node 20 reached the threshold before node 80 in {count} out of␣
 ↪{trials} trials.")
percentage = float((count/trials)*100)
print("(Error) Node 20 reached the threshold before Node 80 in {:.2f}% of␣
 ↪simulations".format(percentage))

print(f"(Correction) Node 80 reached the threshold after node 20 in {count2}␣
 ↪out of {count} times.")
percentage2 = float((count2/count)*100)
print("(Correction) Node 80 reached the threshold after Node 20 in {:.2f}% of␣
 ↪simulations".format(percentage2))
```

```
C:\Users\micha\AppData\Local\Temp\ipykernel_7820\1850225509.py:28:
RuntimeWarning: overflow encountered in exp
  return (1 / (1 + np.exp(-x))) -

Schizophrenia Condition

(Error) Node 20 reached the threshold before node 80 in 511 out of 1000 trials.
(Error) Node 20 reached the threshold before Node 80 in 51.10% of simulations
(Correction) Node 80 reached the threshold after node 20 in 333 out of 511
times.
(Correction) Node 80 reached the threshold after Node 20 in 65.17% of
simulations
```

[14]:
```
import numpy as np
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D

# Define parameters
Th = 0.1791
C = 0.35
Ir = 1
Ip = 1.5
 1 = 0.01685
 1 = 0.003
 2 = 0.0065
 2 = 0.0016
T = 50
  = 2*np.pi/10
Δx = 2*np.pi/100
B = 1
N = 100
  = 0.5
  = 0.5
 _n = 0
 _n = 0.05
ntrials = 5000

# Define sigmoid function
def sigmoid(x):
    return (1 / (1 + np.exp(-x))) -

# Define lateral interaction kernel
def lateral_kernel(i, j):
    return B*(1/(np.sqrt(4*np.pi) *  ) * np.exp(-((i-j)*Δx)**2 / (4* **2)) - C)

# Initialize variables
x = np.zeros(N) # internal state of nodes
tau = np.zeros(N) # integration time constant
for i in range(N//2):
    tau[i] = np.random.normal( 1,  1)
for i in range(N//2, N):
    tau[i] = np.random.normal( 2,  2)
w = np.zeros((N,N)) # synaptic efficacies
for i in range(N):
    for j in range(N):
        w[i,j] = lateral_kernel(i, j)
I_ext = np.zeros(N) # external input
I_ext[18:22] = Ir
I_ext[78:82] = Ip
In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
dt = 1 # time step
tmax = 600 # maximum time to simulate
nt = int(tmax/dt) # number of time steps
x_hist = np.zeros((N, nt)) # history of node activity

# Simulate network
for i in range(nt):
    dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
    x += dxdt * (tau)
    x_hist[:,i] = x

# Plot node activity over time
```

```
fig = plt.figure(figsize=(10,10))
ax = plt.axes(projection='3d')
x = np.arange(N)
y = np.arange(nt)*dt
X, Y = np.meshgrid(x, y)
Z = x_hist.T
ax.scatter(X, Y, Z, c=Z, cmap='viridis')
ax.set_xlabel('Neuron Index')
ax.set_ylabel('Time (ms)')
ax.set_zlabel('Node activity')
ax.set_xlim([0, 100])
ax.set_ylim([0, 600])
ax.set_zlim([0, 2])
ax.invert_xaxis()
plt.show()
```



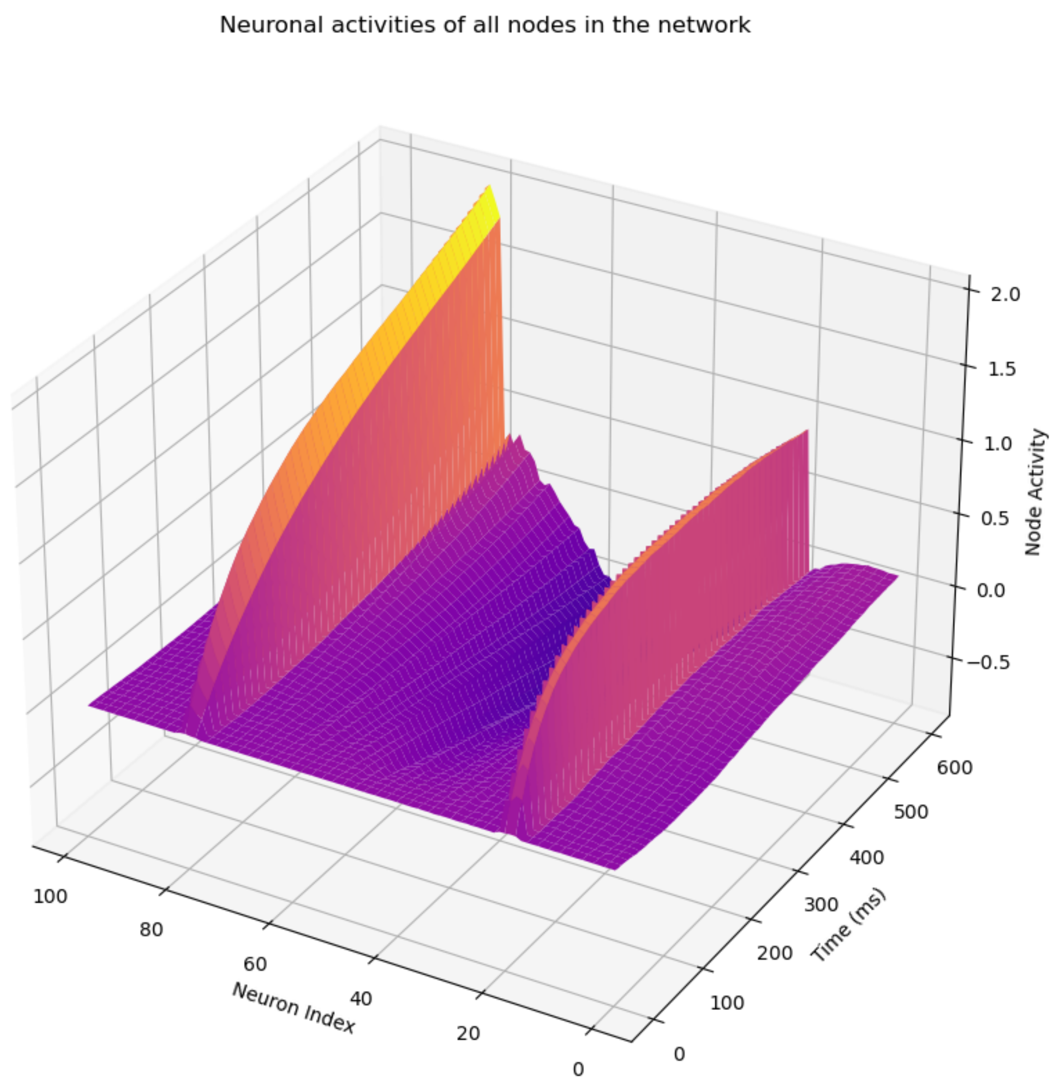
[13]:

```
from mpl_toolkits import mplot3d

# Define parameters
Th = 0.1791
C = 0.35
Ir = 1
Ip = 1.5
 1 = 0.01685
 1 = 0.003
 2 = 0.0065
 2 = 0.0016
T = 50
  = 2*np.pi/10
Δx = 2*np.pi/100
B = 1
N = 100
  = 0.5
  = 0.5
 _n = 0
 _n = 0.05
ntrials = 5000

# Define sigmoid function
def sigmoid(x):
    return (1 / (1 + np.exp(-x))) - 

# Define lateral interaction kernel
def lateral_kernel(i, j):
    return B*(1/(np.sqrt(4*np.pi) *  ) * np.exp(-((i-j)*Δx)**2 / (4* **2)) - C)

# Initialize variables
x = np.zeros(N) # internal state of nodes
tau = np.zeros(N) # integration time constant
for i in range(N//2):
    tau[i] = np.random.normal( 1,  1)
for i in range(N//2, N):
    tau[i] = np.random.normal( 2,  2)
w = np.zeros((N,N)) # synaptic efficacies
for i in range(N):
    for j in range(N):
        w[i,j] = lateral_kernel(i, j)
I_ext = np.zeros(N) # external input
I_ext[18:22] = Ir
I_ext[78:82] = Ip
In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
```

```python
dt = 1 # time step
tmax = 600 # maximum time to simulate
nt = int(tmax / dt) # number of time steps
x_hist = np.zeros((N, nt)) # history of node activity

# Simulate network
for i in range(nt):
    dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
    x += dxdt * (tau)
    x_hist[:,i] = x

# Create 3D plot of node activity over time
fig = plt.figure(figsize=(10,10))
ax = plt.axes(projection='3d')
x_axis = np.arange(N)
y_axis = np.arange(nt) * dt
X, Y = np.meshgrid(x_axis, y_axis)
Z = x_hist[X.astype(int), Y.astype(int)]
ax.plot_surface(X, Y, Z, cmap='plasma')
ax.set_xlabel('Neuron Index')
ax.set_ylabel('Time (ms)')
ax.set_zlabel('Node Activity')
ax.set_title('Neuronal activities of all nodes in the network')
ax.invert_xaxis()
plt.show()
```



[34]:
```
# Control Condition - Correction RT

import numpy as np

# Define parameters
Th = 1.025
C = 0.35
Ir = 1
Ip = 1.5
 1 = 0.01685
 1 = 0.003
 2 = 0.0065
 2 = 0.0016
```

```
T = 50
  = 2*np.pi/10
Δx = 2*np.pi/100
B = 1
N = 100
  = 0.5
  = 0.5
 _n = 0
 _n = 0.05
ntrials = 5000

# Define sigmoid function
def sigmoid(x):
    return (1 / (1 + np.exp(-x))) -

# Define lateral interaction kernel
def lateral_kernel(i, j):
    return B*(((1/(np.sqrt(4*np.pi) *  )) * np.exp((-((i-j)*Δx)**2) / (4* **2)))␣
  ↪- C))

distances = []

for i in range(500):
    # Initialize variables
    x = np.zeros(N) # internal state of nodes
    tau = np.zeros(N) # integration time constant
    for i in range(N//2):
        tau[i] = np.random.normal( 1,  1)
    for i in range(N//2, N):
        tau[i] = np.random.normal( 2,  2)
    w = np.zeros((N,N)) # synaptic efficacies
    for i in range(N):
        for j in range(N):
            w[i,j] = lateral_kernel(i, j)
    I_ext = np.zeros(N) # external input
    I_ext[18:22] = Ir
    I_ext[78:82] = Ip
    I_ext[20] = 0
    I_ext[80] = 0
    In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
    dt = 1 # time step
    nt = 5000 # number of time steps
    x_hist = np.zeros((N, nt)) # history of node activity
    # Simulate network
    for i in range(5000):
        if i*dt >= 50:
            I_ext[18:22] = Ir
        if i*dt >= 100:
            I_ext[78:82] = Ip
        if i*dt >= 650:
            x[20] = 0
            x[80] = 0
        dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
        x += dxdt * (tau)
        x_hist[:,i] = x * (0.126)

        #if x[79] >= Th and x[19] < Th:
        #    if x_hist[80,i] + 0.05 >= 0.1791 and x_hist[80,i] + 0.05 <= 0.1792:
        #        point = (i*dt + 30) - 100
        #        #print(point)
        #        distances.append(point)
        #        break

        #if x_hist[80,i] + 0.05 >= Th and x_hist[80,i] + 0.05 <= 0.1792 and␣
↪x_hist[20,i] + 0.05 < Th:
        #        point = (i*dt + 30) - 100
        #        print(point)
        #        distances.append(point)
        #        break

        """
        if x_hist[80,i] + 0.05 >= Th and x_hist[20,i] + 0.05 >= Th:
            if np.argmax(x_hist[80,i:]) < np.argmax(x_hist[20,i:]):
                point = (np.argmax(x_hist[80,i:]) + i)*dt - (np.
↪argmax(x_hist[20,i:]) + i)*dt
                distances.append(point)
                break
            else:
                if i*dt + 30 < 100:
                    point = 100 - (i*dt + 30)
                    distances.append(point)
                    print(point)
                    break
                else:
                    point = i*dt + 30 - 100
                    distances.append(point)
                    print(point)
                    break
        """

        if x_hist[80,i] >= Th and x_hist[20,i] < Th:
            point = (i*dt - 100) + 30
            print(point)
            distances.append(point)
            break

        # Check if both node 20 and node 80 have reached the threshold
        #if x_hist[20,i] + 0.05 < Th and x_hist[80,i] + 0.05 >= Th:
        #    point = (i*dt + 30) - 100
        #    print(point)
        #    distances.append(point)
        #    break

        # Check if node 80 reaches threshold Th before node 20 does
        #if x_hist[80,i] + 0.05 >= Th and x_hist[80,i] + 0.05 < 0.1792 and␣
 ↪x_hist[20,i] + 0.05 < Th:
        #    point = (i*dt - 100) + 30
        #    print(i*dt)
        #    print(point)
        #    distances.append(point)
        #    break

median_distance = np.median(distances)
std_distance = np.std(distances)
print('Median distance: ', median_distance)
print(std_distance)
```

```
169
170
173
526
248
160
565
161
179
188
513
170
169
195
191
551
534
159
168
553
505
189
164
162
200
```

```
529
164
190
166
167
294
195
463
227
523
475
163
204
326
489
177
446
125
170
474
519
424
227
155
136
407
159
533
174
408
268
154
212
210
433
550
148
177
181
461
196
461
540
160
568
513
178
141
```

```
209
570
175
160
240
487
129
218
154
498
163
198
414
177
188
181
189
162
171
540
147
570
170
546
535
501
474
151
493
503
427
495
182
435
134
229
184
194
185
178
153
212
506
182
171
210
167
173
```

```
158
173
375
199
156
326
202
381
458
206
500
168
162
168
189
143
231
369
462
200
166
204
392
155
192
211
225
424
192
161
141
152
156
217
158
464
490
162
397
208
526
166
527
173
172
262
145
193
```

```
575
148
565
191
440
280
228
182
519
197
160
192
391
521
182
468
185
183
422
170
190
391
549
182
163
153
426
562
149
195
217
190
181
476
174
191
492
175
191
187
551
155
135
574
195
156
181
437
```

```
516
152
160
163
511
410
528
165
458
477
306
187
187
220
211
309
187
148
175
462
443
200
182
280
169
205
194
182
508
442
167
198
142
209
157
176
169
330
179
349
532
571
186
177
188
196
181
178
```

```
137
225
367
175
137
344
162
186
185
203
151
163
156
140
160
543
157
180
180
501
352
153
145
419
211
153
164
477
425
413
158
Median distance:  193.5
145.1432535539558
```

[16]:
```
# Schizophrenia Condition - Correction RT

# This is computing the median distance for node 20 (so from 50 ms to when node␣
↪20 hits the threshold)

# Should be ~258 ms

import numpy as np

# Define parameters
Th = 0.1791
C = 0.35
Ir = 1
```

```
Ip = 1.5
 1 = 0.0135
 1 = 0.005
 2 = 0.004
 2 = 0.002
T = 50
  = 2*np.pi/10
Δx = 2*np.pi/100
B = 1
N = 100
  = 0.5
  = 0.5
 _n = 0
 _n = 0.05
ntrials = 5000

# Define sigmoid function
def sigmoid(x):
    return (1 / (1 + np.exp(-x))) -

# Define lateral interaction kernel
def lateral_kernel(i, j):
    return B*(((1/(np.sqrt(4*np.pi) *  )) * np.exp((-((i-j)*Δx)**2) / (4* **2)))␣
 ↪- C)

distances = []

for i in range(500):
    # Initialize variables
    x = np.zeros(N) # internal state of nodes
    tau = np.zeros(N) # integration time constant
    for i in range(N//2):
        tau[i] = np.random.normal( 1,  1)
    for i in range(N//2, N):
        tau[i] = np.random.normal( 2,  2)
    w = np.zeros((N,N)) # synaptic efficacies
    for i in range(N):
        for j in range(N):
            w[i,j] = lateral_kernel(i, j)
    I_ext = np.zeros(N) # external input
    I_ext[18:22] = Ir
    I_ext[78:82] = Ip
    I_ext[20] = 0
    I_ext[80] = 0
    In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
    dt = 1 # time step
    nt = 5000 # number of time steps
    x_hist = np.zeros((N, nt)) # history of node activity
    # Simulate network
    for i in range(5000):
        if i*dt >= 50:
            I_ext[18:22] = Ir
        if i*dt >= 100:
            I_ext[78:82] = Ip
        if i*dt >= 650:
            x[20] = 0
            x[80] = 0
        dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
        x += dxdt * (tau)
        x_hist[:,i] = x * (0.126)

        if x_hist[20,i] + 0.05 >= Th and x_hist[80,i] + 0.05 < Th:
            point1 = (i*dt)
            break

for i in range(500):
    # Initialize variables
    x = np.zeros(N) # internal state of nodes
    tau = np.zeros(N) # integration time constant
    for i in range(N//2):
        tau[i] = np.random.normal( 1,  1)
    for i in range(N//2, N):
        tau[i] = np.random.normal( 2,  2)
    w = np.zeros((N,N)) # synaptic efficacies
    for i in range(N):
        for j in range(N):
            w[i,j] = lateral_kernel(i, j)
    I_ext = np.zeros(N) # external input
    I_ext[18:22] = Ir
    I_ext[78:82] = Ip
    I_ext[20] = 0
    I_ext[80] = 0
    In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
    dt = 1 # time step
    nt = 5000 # number of time steps
    x_hist = np.zeros((N, nt)) # history of node activity
    # Simulate network
    for i in range(nt):
        if i*dt >= 50:
            I_ext[18:22] = Ir
        if i*dt >= 100:
            I_ext[78:82] = Ip
        if i*dt >= 650:
            x[20] = 0
            x[80] = 0
        dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
        x += dxdt * (tau)
        x_hist[:,i] = x * (0.126)

        # Check if both node 20 and node 80 have reached the threshold
        if x_hist[20,i] + 0.05 >= Th and x_hist[80,i] + 0.05 >= Th:
            # Check if node 80 reached the threshold after node 20
            if np.argmax(x_hist[:,i] + 0.05 == x_hist[20,i] + 0.05) < np.
 ↪argmax(x_hist[:,i] + 0.05 == x_hist[80,i] + 0.05):
                point2  = (i*dt)
                print(abs(point2 - point1))
                distances.append(point2 - point1)
                break

median_distance = np.median(distances)
std_distance = np.std(distances)
print('Median distance: ', median_distance)
print(std_distance)
```

```
C:\Users\micha\AppData\Local\Temp\ipykernel_11788\3950509218.py:31:
RuntimeWarning: overflow encountered in exp
  return (1 / (1 + np.exp(-x))) -
```

```
163
267
331
198
365
386
271
207
399
193
301
286
162
321
176
278
351
283
158
162
184
352
178
185
```

```
196
221
225
279
109
162
397
141
225
367
348
355
271
109
400
363
95
218
210
270
298
271
350
399
294
258
202
376
254
208
349
381
187
215
390
237
187
349
146
95
239
279
362
287
266
229
242
208
```

```
232
210
312
116
244
266
321
400
190
318
388
212
297
208
261
264
174
345
258
306
206
173
327
182
235
341
343
401
249
187
369
176
220
364
151
360
375
354
321
238
121
231
355
310
294
375
130
274
```

```
332
116
327
163
250
362
198
307
234
252
266
340
263
324
191
234
219
258
239
400
309
363
199
192
232
178
225
193
211
329
297
223
373
178
155
108
219
229
167
279
139
263
343
283
164
241
262
315
```

```
142
368
272
340
227
325
323
326
134
294
348
387
223
299
234
224
250
271
175
188
349
257
190
177
166
284
369
349
210
377
135
173
240
202
362
266
232
146
335
304
378
335
165
313
305
131
221
280
```

```
287
325
232
304
187
266
244
355
Median distance:  259.5
77.52665036656717
```

[24]:
```
# Parkinson's Condition Error Rate at Time Point 1

import numpy as np

# Define parameters
Th = 0.1791
C = 0.35
Ir = 1
Ip = 1.5
 1 = 0.0105
 1 = 0.001
 2 = 0.004
 2 = 0.002
T = 50
  = 2*np.pi/10
Δx = 2*np.pi/100
B = 1
N = 100
  = 0.5
  = 0.5
 _n = 0
 _n = 0.005
ntrials = 5000
trials = 500

# Define sigmoid function
def sigmoid(x):
    return (1 / (1 + np.exp(-x))) - 

# Define lateral interaction kernel
def lateral_kernel(i, j):
    return B*(((1/(np.sqrt(4*np.pi) *  )) * np.exp((-((i-j)*Δx)**2) / (4* **2)))␣
 ↪- C)

count = 0  # initialize count
```

```
for i in range(trials):
    # Initialize variables
    x = np.zeros(N) # internal state of nodes
    tau = np.zeros(N) # integration time constant
    for i in range(N//2):
        tau[i] = np.random.normal( 1,  1)
    for i in range(N//2, N):
        tau[i] = np.random.normal( 2,  2)
    w = np.zeros((N,N)) # synaptic efficacies
    for i in range(N):
        for j in range(N):
            w[i,j] = lateral_kernel(i, j)
    I_ext = np.zeros(N) # external input
    I_ext[18:22] = Ir
    I_ext[78:82] = Ip
    I_ext[20] = 0
    I_ext[80] = 0
    In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
    dt = 1 # time step
    nt = 5000 # number of time steps
    x_hist = np.zeros((N, nt)) # history of node activity
    reached_th = np.zeros(N) # to keep track of which nodes have reached␣
 ↪threshold
    # Simulate network
    for i in range(nt):
        if i*dt >= 50:
            I_ext[18:22] = Ir
        if i*dt >= 100:
            I_ext[78:82] = Ip
        if i*dt >= 650:
            x[20] = 0
            x[80] = 0
            reached_th[20] = 0 # reset the threshold flag for node 20
        dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
        x += dxdt * (tau)
        x_hist[:,i] = x * (0.126)

        # Check if node 20 reaches threshold before node 80
        if x_hist[20,i] + 0.05 >= Th and x_hist[80,i] + 0.05 < Th:
            count += 1
            break

        """
        # Check if node 20 or node 80 reaches threshold
        if x_hist[20,i] + 0.05 >= Th or x_hist[80,i] + 0.05 >= Th:
            # Check if both node 20 and node 80 have reached the threshold
            if x_hist[20,i] + 0.05 >= Th and x_hist[80,i] + 0.05 >= Th:
                # Check if node 20 reached the threshold before node 80
                if np.argmax(x_hist[:,i] == x_hist[20,i]) < np.argmax(x_hist[:
 ↪,i] == x_hist[80,i]):
                    count += 1
                    break
            # Check if only node 20 reached the threshold
            elif x_hist[20,i] + 0.05 >= Th and x_hist[80,i] + 0.05 < Th:
                count += 1
                break
        """

print("Schzophrenia Condition") # Forgot to change to Parkinson's
print()
print(f"(Error) Node 20 reached the threshold before node 80 in {count} out of␣
 ↪{trials} trials.")
percentage = float((count/trials)*100)
print("(Error) Node 20 reached the threshold before Node 80 in {:.2f}% of␣
 ↪simulations".format(percentage))
```

```
C:\Users\micha\AppData\Local\Temp\ipykernel_7820\2534694811.py:28:
RuntimeWarning: overflow encountered in exp
  return (1 / (1 + np.exp(-x))) -

Schizophrenia Condition

(Error) Node 20 reached the threshold before node 80 in 175 out of 500 trials.
(Error) Node 20 reached the threshold before Node 80 in 35.00% of simulations
```

[55]:
```
# Parkinson's Condition - Antisaccade RT at Time Point 1

# This is the mean distance for node 80 (the time from 100 ms to when node 80␣
 ↪reaches the threshold)

# Should be ~430 (+- 30)

import numpy as np

# Define parameters
Th = 0.1791
C = 0.35
Ir = 1
Ip = 1.5
 1 = 0.0105
 1 = 0.001
 2 = 0.004751
 2 = 0.0004
T = 50
  = 2*np.pi/10
```

```
Δx = 2*np.pi/100
B = 1
N = 100
 = 0.5
 = 0.5
_n = 0
_n = 0.05
ntrials = 5000

# Define sigmoid function
def sigmoid(x):
    return (1 / (1 + np.exp(-x))) -

# Define lateral interaction kernel
def lateral_kernel(i, j):
    return B*(((1/(np.sqrt(4*np.pi) *  )) * np.exp((-((i-j)*Δx)**2) / (4* **2)))␣
 ↪- C)

# Initialize variables
distances = []
for i in range(300):
    x = np.zeros(N) # internal state of nodes
    tau = np.zeros(N) # integration time constant
    for i in range(N//2):
        tau[i] = np.random.normal( 1,  1)
    for i in range(N//2, N):
        tau[i] = np.random.normal( 2,  2)
    w = np.zeros((N,N)) # synaptic efficacies
    for i in range(N):
        for j in range(N):
            w[i,j] = lateral_kernel(i, j)
    I_ext = np.zeros(N) # external input
    I_ext[18:22] = Ir
    I_ext[78:82] = Ip
    I_ext[20] = 0
    I_ext[80] = 0
    In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
    dt = 1 # time step
    nt = 5000 # number of time steps
    x_hist = np.zeros((N, nt)) # history of node activity

    # Simulate network
    for i in range(5000):
        if i*dt >= 50:
            I_ext[18:22] = Ir
        if i*dt >= 100:
            I_ext[78:82] = Ip
        if i*dt >= 650:
            x[20] = 0
            x[80] = 0
        dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
        x += dxdt * (tau)
        x_hist[:,i] = x * (0.126)

        if x_hist[80,i] + 0.05 >= Th and x_hist[20,i] + 0.05 < Th:
            point = (i*dt - 100) + 30 # Plus 30 to account for travel time of␣
 ↪neural signal
            print(point)
            distances.append(point)
            break
"""
        if x_hist[80,i] + 0.05 >= Th and x_hist[20,i] + 0.05 >= Th:
            if np.argmax(x_hist[80,i:]) < np.argmax(x_hist[20,i:]):
                point = (np.argmax(x_hist[80,i:]) + i)*dt - (np.
 ↪argmax(x_hist[20,i:]) + i)*dt
                distances.append(point)
                break
            else:
                if i*dt + 30 < 100:
                    point = 100 - (i*dt + 30)
                    distances.append(point)
                    print(point)
                    break
                else:
                    point = i*dt + 30 - 100
                    distances.append(point)
                    print(point)
                    break
"""

mean_distance = np.mean(distances)
std_distance = np.std(distances)
print('Mean distance: ', mean_distance)
print(std_distance)
```

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Mean distance:  430.36333333333334
31.902737430439345
```

[64]:
```
# Parkinson's Condition - Antisaccade RT at Time Point 2

# This is the mean distance for node 80 (the time from 100 ms to when node 80␣
 ↪reaches the threshold)

# Should be ~407 (+- 27)

import numpy as np

# Define parameters
Th = 0.1791
C = 0.35
Ir = 1
Ip = 1.5
 1 = 0.0105
 1 = 0.001
 2 = 0.004
 2 = 0.002
T = 50
  = 2*np.pi/10
Δx = 2*np.pi/100
B = 1
N = 100
  = 0.5
  = 0.5
 _n = 0
 _n = 0.05
ntrials = 5000

# Define sigmoid function
def sigmoid(x):
    return (1 / (1 + np.exp(-x))) - 

# Define lateral interaction kernel
def lateral_kernel(i, j):
    return B*(((1/(np.sqrt(4*np.pi) *  )) * np.exp((-((i-j)*Δx)**2) / (4* **2)))␣
 ↪- C)

# Initialize variables
distances = []
for i in range(300):
    x = np.zeros(N) # internal state of nodes
    tau = np.zeros(N) # integration time constant
    for i in range(N//2):
        tau[i] = np.random.normal( 1,  1)
    for i in range(N//2, N):
        tau[i] = np.random.normal( 2,  2)
    w = np.zeros((N,N)) # synaptic efficacies
    for i in range(N):
        for j in range(N):
            w[i,j] = lateral_kernel(i, j)
    I_ext = np.zeros(N) # external input
    I_ext[18:22] = Ir
    I_ext[78:82] = Ip
    I_ext[20] = 0
    I_ext[80] = 0
    In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
    dt = 1 # time step
    nt = 5000 # number of time steps
    x_hist = np.zeros((N, nt)) # history of node activity

    # Simulate network
    for i in range(5000):
        if i*dt >= 50:
            I_ext[18:22] = Ir
        if i*dt >= 100:
            I_ext[78:82] = Ip
        if i*dt >= 650:
            x[20] = 0
            x[80] = 0
        dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
        x += dxdt * (tau)
        x_hist[:,i] = x * (0.126)

        if x_hist[80,i] + 0.05 >= Th and x_hist[20,i] + 0.05 < Th:
            point = (i*dt - 100) + 30 # Plus 30 to account for travel time of␣
 ↪neural signal
            print(point)
            distances.append(point)
            break
"""
        if x_hist[80,i] + 0.05 >= Th and x_hist[20,i] + 0.05 >= Th:
            if np.argmax(x_hist[80,i:]) < np.argmax(x_hist[20,i:]):
                point = (np.argmax(x_hist[80,i:]) + i)*dt - (np.
 ↪argmax(x_hist[20,i:]) + i)*dt
                distances.append(point)
                break
            else:
                if i*dt + 30 < 100:
                    point = 100 - (i*dt + 30)
                    distances.append(point)
                    print(point)
                    break
                else:
                    point = i*dt + 30 - 100
                    distances.append(point)
                    print(point)
                    break
"""

mean_distance = np.mean(distances)
std_distance = np.std(distances)
print('Mean distance: ', mean_distance)
print(std_distance)
```

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Mean distance:  408.73333333333335
27.65240596323502
```

[77]:

```
# MSA Condition - Antisaccade RT at Time Point 1

# This is the mean distance for node 80 (the time from 100 ms to when node 80␣
 ↪reaches the threshold)

# Should be ~445 (+- 38)

import numpy as np

# Define parameters
Th = 0.1791
C = 0.35
Ir = 1
Ip = 1.5
 1 = 0.0105
 1 = 0.001
 2 = 0.00461
 2 = 0.00046
T = 50
  = 2*np.pi/10
Δx = 2*np.pi/100
B = 1
N = 100
  = 0.5
  = 0.5
 _n = 0
 _n = 0.05
ntrials = 5000

# Define sigmoid function
def sigmoid(x):
    return (1 / (1 + np.exp(-x))) -

# Define lateral interaction kernel
def lateral_kernel(i, j):
    return B*(((1/(np.sqrt(4*np.pi) *  )) * np.exp((-((i-j)*Δx)**2) / (4* **2)))␣
 ↪- C)

# Initialize variables
distances = []
for i in range(300):
    x = np.zeros(N) # internal state of nodes
    tau = np.zeros(N) # integration time constant
    for i in range(N//2):
        tau[i] = np.random.normal( 1,  1)
    for i in range(N//2, N):
        tau[i] = np.random.normal( 2,  2)
    w = np.zeros((N,N)) # synaptic efficacies
    for i in range(N):
        for j in range(N):
            w[i,j] = lateral_kernel(i, j)
    I_ext = np.zeros(N) # external input
    I_ext[18:22] = Ir
    I_ext[78:82] = Ip
    I_ext[20] = 0
    I_ext[80] = 0
    In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
    dt = 1 # time step
    nt = 5000 # number of time steps
    x_hist = np.zeros((N, nt)) # history of node activity

    # Simulate network
    for i in range(5000):
        if i*dt >= 50:
            I_ext[18:22] = Ir
        if i*dt >= 100:
            I_ext[78:82] = Ip
        if i*dt >= 650:
            x[20] = 0
            x[80] = 0
        dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
        x += dxdt * (tau)
        x_hist[:,i] = x * (0.126)

        if x_hist[80,i] + 0.05 >= Th and x_hist[20,i] + 0.05 < Th:
            point = (i*dt - 100) + 30 # Plus 30 to account for travel time of␣
 ↪neural signal
            print(point)
            distances.append(point)
            break
"""
        if x_hist[80,i] + 0.05 >= Th and x_hist[20,i] + 0.05 >= Th:
            if np.argmax(x_hist[80,i:]) < np.argmax(x_hist[20,i:]):
                point = (np.argmax(x_hist[80,i:]) + i)*dt - (np.
 ↪argmax(x_hist[20,i:]) + i)*dt
                distances.append(point)
                break
            else:
                if i*dt + 30 < 100:
                    point = 100 - (i*dt + 30)
                    distances.append(point)
                    print(point)
                    break
                else:
                    point = i*dt + 30 - 100
                    distances.append(point)
                    print(point)
                    break
"""

mean_distance = np.mean(distances)
std_distance = np.std(distances)
print('Mean distance: ', mean_distance)
print(std_distance)
```

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Mean distance:  445.72240802675583
36.32600254763851
```

[88]:
```
# MSA Condition - Antisaccade RT at Time Point 2

# This is the mean distance for node 80 (the time from 100 ms to when node 80␣
↪reaches the threshold)

# Should be ~440 (+- 33)

import numpy as np

# Define parameters
Th = 0.1791
C = 0.35
Ir = 1
Ip = 1.5
 1 = 0.0105
 1 = 0.001
 2 = 0.00462
 2 = 0.00038
T = 50
  = 2*np.pi/10
Δx = 2*np.pi/100
B = 1
N = 100
  = 0.5
  = 0.5
 _n = 0
 _n = 0.05
ntrials = 5000

# Define sigmoid function
def sigmoid(x):
    return (1 / (1 + np.exp(-x))) -

# Define lateral interaction kernel
def lateral_kernel(i, j):
    return B*(((1/(np.sqrt(4*np.pi) *  )) * np.exp((-((i-j)*Δx)**2) / (4* **2)))␣
↪- C)
```

```
# Initialize variables
distances = []
for i in range(300):
    x = np.zeros(N) # internal state of nodes
    tau = np.zeros(N) # integration time constant
    for i in range(N//2):
        tau[i] = np.random.normal( 1,  1)
    for i in range(N//2, N):
        tau[i] = np.random.normal( 2,  2)
    w = np.zeros((N,N)) # synaptic efficacies
    for i in range(N):
        for j in range(N):
            w[i,j] = lateral_kernel(i, j)
    I_ext = np.zeros(N) # external input
    I_ext[18:22] = Ir
    I_ext[78:82] = Ip
    I_ext[20] = 0
    I_ext[80] = 0
    In = np.random.normal( _n,  _n, (N, ntrials)) # background noise
    dt = 1 # time step
    nt = 5000 # number of time steps
    x_hist = np.zeros((N, nt)) # history of node activity

    # Simulate network
    for i in range(5000):
        if i*dt >= 50:
            I_ext[18:22] = Ir
        if i*dt >= 100:
            I_ext[78:82] = Ip
        if i*dt >= 650:
            x[20] = 0
            x[80] = 0
        dxdt = -x + np.dot(w, (sigmoid( *x))) + I_ext + In[:,i]
        x += dxdt * (tau)
        x_hist[:,i] = x * (0.126)

        if x_hist[80,i] + 0.05 >= Th and x_hist[20,i] + 0.05 < Th:
            point = (i*dt - 100) + 30 # Plus 30 to account for travel time of␣
 ↪neural signal
            print(point)
            distances.append(point)
            break
"""
        if x_hist[80,i] + 0.05 >= Th and x_hist[20,i] + 0.05 >= Th:
            if np.argmax(x_hist[80,i:]) < np.argmax(x_hist[20,i:]):
                point = (np.argmax(x_hist[80,i:]) + i)*dt - (np.
 ↪argmax(x_hist[20,i:]) + i)*dt
                distances.append(point)
                break
            else:
                if i*dt + 30 < 100:
                    point = 100 - (i*dt + 30)
                    distances.append(point)
                    print(point)
                    break
                else:
                    point = i*dt + 30 - 100
                    distances.append(point)
                    print(point)
                    break
"""

mean_distance = np.mean(distances)
std_distance = np.std(distances)
print('Mean distance: ', mean_distance)
print(std_distance)
```

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Mean distance:  440.49666666666667
32.55513255318669
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