In [1]:

```python
import numpy as np
import gym
from gym import logger as gymlogger
from gym.wrappers import Monitor
import tensorflow as tf
import matplotlib
import matplotlib.pyplot as plt
from tensorflow.contrib.layers import flatten, conv2d, fully_connected
from collections import deque, Counter
import random
from datetime import datetime
import math
import glob
import io
import base64
from IPython.display import HTML
from IPython import display as ipythondisplay
from pyvirtualdisplay import Display

gymlogger.set_level(40) #error only
%matplotlib inline
```

```
/usr/local/lib/python3.6/dist-packages/tensorflow/python/framework/d
types.py:526: FutureWarning: Passing (type, 1) or '1type' as a synon
ym of type is deprecated; in a future version of numpy, it will be u
nderstood as (type, (1,)) / '(1,)type'.
  _np_qint8 = np.dtype([("qint8", np.int8, 1)])
/usr/local/lib/python3.6/dist-packages/tensorflow/python/framework/d
types.py:527: FutureWarning: Passing (type, 1) or '1type' as a synon
ym of type is deprecated; in a future version of numpy, it will be u
nderstood as (type, (1,)) / '(1,)type'.
  _np_quint8 = np.dtype([("quint8", np.uint8, 1)])
/usr/local/lib/python3.6/dist-packages/tensorflow/python/framework/d
types.py:528: FutureWarning: Passing (type, 1) or '1type' as a synon
ym of type is deprecated; in a future version of numpy, it will be u
nderstood as (type, (1,)) / '(1,)type'.
  _np_qint16 = np.dtype([("qint16", np.int16, 1)])
/usr/local/lib/python3.6/dist-packages/tensorflow/python/framework/d
types.py:529: FutureWarning: Passing (type, 1) or '1type' as a synon
ym of type is deprecated; in a future version of numpy, it will be u
nderstood as (type, (1,)) / '(1,)type'.
  _np_quint16 = np.dtype([("quint16", np.uint16, 1)])
/usr/local/lib/python3.6/dist-packages/tensorflow/python/framework/d
types.py:530: FutureWarning: Passing (type, 1) or '1type' as a synon
ym of type is deprecated; in a future version of numpy, it will be u
nderstood as (type, (1,)) / '(1,)type'.
  _np_qint32 = np.dtype([("qint32", np.int32, 1)])
/usr/local/lib/python3.6/dist-packages/tensorflow/python/framework/d
types.py:535: FutureWarning: Passing (type, 1) or '1type' as a synon
ym of type is deprecated; in a future version of numpy, it will be u
nderstood as (type, (1,)) / '(1,)type'.
  np_resource = np.dtype([("resource", np.ubyte, 1)])
```

In [2]:

```python
print(tf.__version__)
```

```
1.13.2
```

Lets define a function that:

- trims the image size beforehand
- converts images into a grayscale 1D tensor
- impoves the contrast for better visibility
- normalizes the image from -1 to +1

The function returns an image the shape of which is (88, 80, 1)

In [3]:

```python
color = np.array([210, 164, 74]).mean()

def reformat_image(capture):
    img = capture[1:176:2, ::2]
    img = img.mean(axis=2)
    img[img==color] = 0
    img = (img - 128) / 128 - 1

    return img.reshape(88,80,1)
```

- The next step is creating the environment and showing examples screen captures from the game.
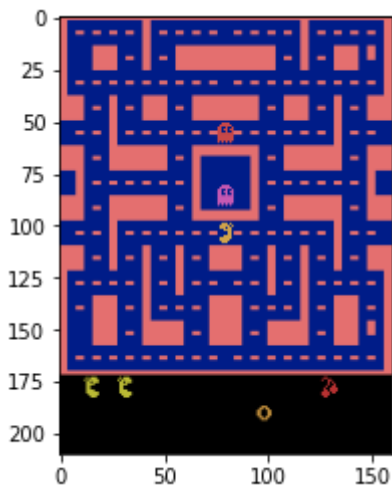- We can also see all the available actions and compare the creen capture from the gym env to our reformated image.

In [4]:

```python
env = gym.make("MsPacman-v0")
actions_count = env.action_space.n
print(actions_count)
print(env.env.get_action_meanings())
screen_capture = env.reset()

plt.imshow(screen_capture)
plt.show()
```
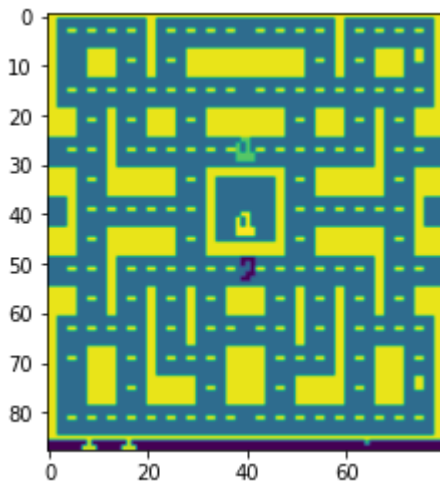
```
9
['NOOP', 'UP', 'RIGHT', 'LEFT', 'DOWN', 'UPRIGHT', 'UPLEFT', 'DOWNRI
GHT', 'DOWNLEFT']
```

In [5]:

```
image = reformat_image(screen_capture).reshape(88,80)
plt.imshow(image)
plt.show()
print(screen_capture.shape)
print(image.shape)
```



```
(210, 160, 3)
(88, 80)
```

Lets define a function that builds our deep Q network:

- initialize three convolutional layers with padding='SAME'
- flatten the output of the last layer
- feed the the flattened output to the fully connected layer
- add final output layer
- the function returns the parameters of the network and the probabilities of taking each action

In [6]:

```python
tf.compat.v1.reset_default_graph()
def dqn(X, name_scope):

    initializer = tf.compat.v1.keras.initializers.VarianceScaling(scale=2.0)
    with tf.compat.v1.variable_scope(name_scope) as scope:

        conv_1 = conv2d(X, num_outputs=32, kernel_size=(8,8), stride=4, padding=
'SAME', weights_initializer=initializer)
        tf.compat.v1.summary.histogram('conv_layer_1',conv_1)

        conv_2 = conv2d(conv_1, num_outputs=64, kernel_size=(4,4), stride=2, pad
ding='SAME', weights_initializer=initializer)
        tf.compat.v1.summary.histogram('conv_layer_2',conv_2)

        conv_3 = conv2d(conv_2, num_outputs=64, kernel_size=(3,3), stride=1, pad
ding='SAME', weights_initializer=initializer)
        tf.compat.v1.summary.histogram('conv_layer_3',conv_3)

        flattened = flatten(conv_3)

        fc = fully_connected(flattened, num_outputs=128, weights_initializer=ini
tializer)
        tf.compat.v1.summary.histogram('fc',fc)

        output = fully_connected(fc, num_outputs=actions_count, activation_fn=No
ne, weights_initializer=initializer)
        tf.compat.v1.summary.histogram('output',output)

        network_parameters = {p.name[len(scope.name):]: p for p in tf.compat.v1.
get_collection(key=tf.compat.v1.GraphKeys.TRAINABLE_VARIABLES, scope=scope.name
)}
        return network_parameters, output
```

In order for the agent to visit every single possible state-action combination, we will get the next action using the epsilon greedy policy. Its idea is that the next action will be random with a probability of [1 - eps] with epsilon decaying over time.

This means that we will either chose the best action or a random one and the probability of choosing the best action will increase over time.

In [7]:

```python
epsilon = 0.5
eps_min = 0.05
eps_max = 1.0
eps_decay_steps = 500000

def greedy_policy(action, step):
    p = np.random.random(1).squeeze()
    epsilon = max(eps_min, eps_max - (eps_max-eps_min) * step/eps_decay_steps)
    if np.random.rand() < epsilon:
        return np.random.randint(actions_count)
    else:
        return action
```

Our gameplay information is built on the SARSA model which stands for: State-Action-Reward-State-Action and we will be storing this information in a buffer of experiences. </br>

We will use this buffer to generate samples in order to genereate y-values and train the network.

In [8]:

```python
buff_size = 20000
experiences = deque(maxlen=buff_size)

def get_experience_batch(batch_size):
    batch = np.random.permutation(len(experiences))[:batch_size]
    sarsa_batch = np.array(experiences)[batch]

    states = sarsa_batch[:,0]
    actions = sarsa_batch[:,1]
    next_states = sarsa_batch[:,2]
    rewards = sarsa_batch[:,3]
    are_terminated = sarsa_batch[:,4]

    return states, actions, next_states, rewards, are_terminated
```

Hyperparameters of the network

In [9]:

```python
num_episodes = 2000
batch_size = 48
input_shape = (None, 88, 80, 1)
learning_rate = 0.001
X_shape = (None, 88, 80, 1)
discount_factor = 0.97

global_step = 0
copy_steps = 100
steps_train = 4
start_steps = 2000
```

In [10]:

```python
tf.compat.v1.reset_default_graph()

X = tf.compat.v1.placeholder(tf.float32, shape=X_shape)
in_training_mode = tf.compat.v1.placeholder(tf.bool)
```

In order to train and generate the data concurently we define two networks using our dqn function.

The primaryQ updated exactly one state-action value per timestep whereas the targetQ network will be used to compute the loss for every action during training.

But why do we need a second network?

Conceptually it's like saying, "I have an idea of how to play this well, I'm going to try it out for a bit until I find something better" as opposed to saying "I'm going to retrain myself how to play this entire game after every move".

In [11]:

```
primaryQ, primaryQ_outputs = dqn(X, 'primaryQ')
targetQ, targetQ_outputs = dqn(X, 'targetQ')

X_action = tf.compat.v1.placeholder(tf.int32, shape=(None,))
Q_action = tf.reduce_sum(input_tensor=targetQ_outputs * tf.one_hot(X_action, act
ions_count), axis=-1, keepdims=True)
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tenso
rflow/python/framework/op_def_library.py:263: colocate_with (from te
nsorflow.python.framework.ops) is deprecated and will be removed in
a future version.
Instructions for updating:
Colocations handled automatically by placer.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tenso
rflow/contrib/layers/python/layers/layers.py:1624: flatten (from ten
sorflow.python.layers.core) is deprecated and will be removed in a f
uture version.
Instructions for updating:
Use keras.layers.flatten instead.
```

Copy the primary Q network parameters to the target Q network

In [12]:

```
copy_op = [tf.compat.v1.assign(main_name, targetQ[var_name]) for var_name, main_
name in primaryQ.items()]
copy_primary_to_target = tf.group(*copy_op)
```

In [13]:

```
y = tf.compat.v1.placeholder(tf.float32, shape=(None,1))
loss = tf.reduce_mean(input_tensor=tf.square(y - Q_action))

optimizer = tf.compat.v1.train.AdamOptimizer(learning_rate)
training_op = optimizer.minimize(loss)

init = tf.compat.v1.global_variables_initializer()
loss_summary = tf.compat.v1.summary.scalar('LOSS', loss)
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tenso
rflow/python/ops/math_ops.py:3066: to_int32 (from tensorflow.python.
ops.math_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.cast instead.
```

Lets start the tensoflow session. Every episode consists of the following actions:

- Get the screen capture for the current state
- Reformat the screen capture
- Get the best action for the state from the primary network
- Generate next action using the greedy policy
- Perform action and get to the next state
- Get the next screen capture
- Receive reward through the gym env step function
- Store this transition in the experiences buffer
- After a set amount of steps we can train our network with a sample experience batch
- Calculate loss
- At a certain point copy the primary network into the target network

In [14]:

```python
with tf.compat.v1.Session() as sess:
    init.run()

    all_rewards = []
    for i in range(num_episodes):
        terminated = False
        capture = env.reset()
        epoch = 0
        episodic_reward = 0
        actions_counter = Counter()
        episodic_loss = []

        while not terminated:
            capture = reformat_image(capture)

            actions = primaryQ_outputs.eval(feed_dict={X:[capture], in_training_
mode:False})

            action = np.argmax(actions, axis=-1)
            actions_counter[str(action)] += 1

            action = greedy_policy(action, global_step)

            next_capture, reward, terminated, _ = env.step(action)

            experiences.append([capture, action, reformat_image(next_capture), r
eward, terminated])

            if global_step % steps_train == 0 and global_step > start_steps:
                states, actions, next_states, rewards, are_terminated = get_expe
rience_batch(batch_size)
                states = list(states)
                next_states = list(next_states)

                next_actions = primaryQ_outputs.eval(feed_dict={X:next_states, i
n_training_mode:False})

                y_batch = rewards + discount_factor * np.max(next_actions, axis=
-1) * (1-are_terminated)

                train_loss, _ = sess.run([loss, training_op], feed_dict={X:state
s, y:np.expand_dims(y_batch, axis=-1), X_action:actions, in_training_mode:True})
                episodic_loss.append(train_loss)

            if (global_step+1) % copy_steps == 0 and global_step > start_steps:
                copy_primary_to_target.run()

            capture = next_capture
            epoch += 1
            global_step += 1
            episodic_reward += reward

        all_rewards.append(episodic_reward)
        print('Epochs per episode:', epoch, 'Episode Reward:', episodic_reward,
"Episode number:", len(all_rewards))
```

```
Epochs per episode: 651 Episode Reward: 170.0 Episode number: 1
Epochs per episode: 691 Episode Reward: 270.0 Episode number: 2
Epochs per episode: 744 Episode Reward: 250.0 Episode number: 3
Epochs per episode: 696 Episode Reward: 150.0 Episode number: 4
Epochs per episode: 504 Episode Reward: 150.0 Episode number: 5
Epochs per episode: 628 Episode Reward: 170.0 Episode number: 6
Epochs per episode: 641 Episode Reward: 270.0 Episode number: 7
Epochs per episode: 720 Episode Reward: 230.0 Episode number: 8
Epochs per episode: 823 Episode Reward: 290.0 Episode number: 9
Epochs per episode: 607 Episode Reward: 170.0 Episode number: 10
Epochs per episode: 669 Episode Reward: 310.0 Episode number: 11
Epochs per episode: 712 Episode Reward: 300.0 Episode number: 12
Epochs per episode: 554 Episode Reward: 160.0 Episode number: 13
Epochs per episode: 680 Episode Reward: 170.0 Episode number: 14
Epochs per episode: 560 Episode Reward: 130.0 Episode number: 15
Epochs per episode: 602 Episode Reward: 140.0 Episode number: 16
Epochs per episode: 845 Episode Reward: 290.0 Episode number: 17
Epochs per episode: 596 Episode Reward: 160.0 Episode number: 18
Epochs per episode: 593 Episode Reward: 260.0 Episode number: 19
Epochs per episode: 716 Episode Reward: 250.0 Episode number: 20
Epochs per episode: 534 Episode Reward: 150.0 Episode number: 21
Epochs per episode: 572 Episode Reward: 190.0 Episode number: 22
Epochs per episode: 695 Episode Reward: 270.0 Episode number: 23
Epochs per episode: 695 Episode Reward: 290.0 Episode number: 24
Epochs per episode: 627 Episode Reward: 250.0 Episode number: 25
Epochs per episode: 748 Episode Reward: 290.0 Episode number: 26
Epochs per episode: 632 Episode Reward: 200.0 Episode number: 27
Epochs per episode: 584 Episode Reward: 170.0 Episode number: 28
Epochs per episode: 535 Episode Reward: 130.0 Episode number: 29
Epochs per episode: 768 Episode Reward: 270.0 Episode number: 30
Epochs per episode: 911 Episode Reward: 950.0 Episode number: 31
Epochs per episode: 678 Episode Reward: 250.0 Episode number: 32
Epochs per episode: 530 Episode Reward: 170.0 Episode number: 33
Epochs per episode: 574 Episode Reward: 180.0 Episode number: 34
Epochs per episode: 652 Episode Reward: 130.0 Episode number: 35
Epochs per episode: 666 Episode Reward: 260.0 Episode number: 36
Epochs per episode: 602 Episode Reward: 300.0 Episode number: 37
Epochs per episode: 690 Episode Reward: 190.0 Episode number: 38
Epochs per episode: 680 Episode Reward: 160.0 Episode number: 39
Epochs per episode: 657 Episode Reward: 160.0 Episode number: 40
Epochs per episode: 772 Episode Reward: 260.0 Episode number: 41
Epochs per episode: 613 Episode Reward: 220.0 Episode number: 42
Epochs per episode: 640 Episode Reward: 150.0 Episode number: 43
Epochs per episode: 573 Episode Reward: 240.0 Episode number: 44
Epochs per episode: 756 Episode Reward: 300.0 Episode number: 45
Epochs per episode: 556 Episode Reward: 160.0 Episode number: 46
Epochs per episode: 604 Episode Reward: 270.0 Episode number: 47
Epochs per episode: 503 Episode Reward: 230.0 Episode number: 48
Epochs per episode: 512 Episode Reward: 120.0 Episode number: 49
Epochs per episode: 763 Episode Reward: 250.0 Episode number: 50
Epochs per episode: 572 Episode Reward: 200.0 Episode number: 51
Epochs per episode: 608 Episode Reward: 190.0 Episode number: 52
Epochs per episode: 593 Episode Reward: 170.0 Episode number: 53
Epochs per episode: 632 Episode Reward: 310.0 Episode number: 54
Epochs per episode: 633 Episode Reward: 210.0 Episode number: 55
Epochs per episode: 682 Episode Reward: 230.0 Episode number: 56
Epochs per episode: 543 Episode Reward: 140.0 Episode number: 57
Epochs per episode: 863 Episode Reward: 350.0 Episode number: 58
Epochs per episode: 628 Episode Reward: 210.0 Episode number: 59
Epochs per episode: 723 Episode Reward: 250.0 Episode number: 60
Epochs per episode: 469 Episode Reward: 150.0 Episode number: 61
```

```
Epochs per episode: 1070 Episode Reward: 420.0 Episode number: 62
Epochs per episode: 876 Episode Reward: 600.0 Episode number: 63
Epochs per episode: 654 Episode Reward: 150.0 Episode number: 64
Epochs per episode: 663 Episode Reward: 360.0 Episode number: 65
Epochs per episode: 576 Episode Reward: 210.0 Episode number: 66
Epochs per episode: 579 Episode Reward: 240.0 Episode number: 67
Epochs per episode: 631 Episode Reward: 170.0 Episode number: 68
Epochs per episode: 713 Episode Reward: 350.0 Episode number: 69
Epochs per episode: 517 Episode Reward: 210.0 Episode number: 70
Epochs per episode: 659 Episode Reward: 170.0 Episode number: 71
Epochs per episode: 645 Episode Reward: 210.0 Episode number: 72
Epochs per episode: 712 Episode Reward: 300.0 Episode number: 73
Epochs per episode: 719 Episode Reward: 280.0 Episode number: 74
Epochs per episode: 751 Episode Reward: 260.0 Episode number: 75
Epochs per episode: 674 Episode Reward: 250.0 Episode number: 76
Epochs per episode: 705 Episode Reward: 240.0 Episode number: 77
Epochs per episode: 635 Episode Reward: 200.0 Episode number: 78
Epochs per episode: 655 Episode Reward: 200.0 Episode number: 79
Epochs per episode: 665 Episode Reward: 120.0 Episode number: 80
Epochs per episode: 511 Episode Reward: 120.0 Episode number: 81
Epochs per episode: 673 Episode Reward: 280.0 Episode number: 82
Epochs per episode: 983 Episode Reward: 390.0 Episode number: 83
Epochs per episode: 548 Episode Reward: 160.0 Episode number: 84
Epochs per episode: 888 Episode Reward: 1030.0 Episode number: 85
Epochs per episode: 900 Episode Reward: 350.0 Episode number: 86
Epochs per episode: 635 Episode Reward: 300.0 Episode number: 87
Epochs per episode: 551 Episode Reward: 220.0 Episode number: 88
Epochs per episode: 628 Episode Reward: 200.0 Episode number: 89
Epochs per episode: 649 Episode Reward: 140.0 Episode number: 90
Epochs per episode: 599 Episode Reward: 200.0 Episode number: 91
Epochs per episode: 632 Episode Reward: 180.0 Episode number: 92
Epochs per episode: 651 Episode Reward: 200.0 Episode number: 93
Epochs per episode: 572 Episode Reward: 180.0 Episode number: 94
Epochs per episode: 632 Episode Reward: 230.0 Episode number: 95
Epochs per episode: 641 Episode Reward: 160.0 Episode number: 96
Epochs per episode: 572 Episode Reward: 160.0 Episode number: 97
Epochs per episode: 555 Episode Reward: 210.0 Episode number: 98
Epochs per episode: 607 Episode Reward: 260.0 Episode number: 99
Epochs per episode: 727 Episode Reward: 240.0 Episode number: 100
Epochs per episode: 657 Episode Reward: 230.0 Episode number: 101
Epochs per episode: 639 Episode Reward: 280.0 Episode number: 102
Epochs per episode: 703 Episode Reward: 290.0 Episode number: 103
Epochs per episode: 679 Episode Reward: 150.0 Episode number: 104
Epochs per episode: 583 Episode Reward: 200.0 Episode number: 105
Epochs per episode: 727 Episode Reward: 290.0 Episode number: 106
Epochs per episode: 576 Episode Reward: 150.0 Episode number: 107
Epochs per episode: 558 Episode Reward: 190.0 Episode number: 108
Epochs per episode: 610 Episode Reward: 290.0 Episode number: 109
Epochs per episode: 639 Episode Reward: 230.0 Episode number: 110
Epochs per episode: 626 Episode Reward: 320.0 Episode number: 111
Epochs per episode: 744 Episode Reward: 230.0 Episode number: 112
Epochs per episode: 842 Episode Reward: 220.0 Episode number: 113
Epochs per episode: 593 Episode Reward: 210.0 Episode number: 114
Epochs per episode: 805 Episode Reward: 360.0 Episode number: 115
Epochs per episode: 677 Episode Reward: 310.0 Episode number: 116
Epochs per episode: 723 Episode Reward: 220.0 Episode number: 117
Epochs per episode: 613 Episode Reward: 210.0 Episode number: 118
Epochs per episode: 621 Episode Reward: 260.0 Episode number: 119
Epochs per episode: 661 Episode Reward: 200.0 Episode number: 120
Epochs per episode: 550 Episode Reward: 190.0 Episode number: 121
Epochs per episode: 552 Episode Reward: 180.0 Episode number: 122
```

```
Epochs per episode: 882 Episode Reward: 550.0 Episode number: 123
Epochs per episode: 704 Episode Reward: 190.0 Episode number: 124
Epochs per episode: 654 Episode Reward: 260.0 Episode number: 125
Epochs per episode: 729 Episode Reward: 220.0 Episode number: 126
Epochs per episode: 1052 Episode Reward: 880.0 Episode number: 127
Epochs per episode: 672 Episode Reward: 190.0 Episode number: 128
Epochs per episode: 559 Episode Reward: 170.0 Episode number: 129
Epochs per episode: 603 Episode Reward: 200.0 Episode number: 130
Epochs per episode: 853 Episode Reward: 410.0 Episode number: 131
Epochs per episode: 731 Episode Reward: 280.0 Episode number: 132
Epochs per episode: 642 Episode Reward: 290.0 Episode number: 133
Epochs per episode: 676 Episode Reward: 160.0 Episode number: 134
Epochs per episode: 543 Episode Reward: 110.0 Episode number: 135
Epochs per episode: 631 Episode Reward: 300.0 Episode number: 136
Epochs per episode: 845 Episode Reward: 1010.0 Episode number: 137
Epochs per episode: 670 Episode Reward: 220.0 Episode number: 138
Epochs per episode: 510 Episode Reward: 240.0 Episode number: 139
Epochs per episode: 609 Episode Reward: 190.0 Episode number: 140
Epochs per episode: 681 Episode Reward: 300.0 Episode number: 141
Epochs per episode: 710 Episode Reward: 200.0 Episode number: 142
Epochs per episode: 626 Episode Reward: 260.0 Episode number: 143
Epochs per episode: 673 Episode Reward: 260.0 Episode number: 144
Epochs per episode: 555 Episode Reward: 250.0 Episode number: 145
Epochs per episode: 575 Episode Reward: 150.0 Episode number: 146
Epochs per episode: 777 Episode Reward: 370.0 Episode number: 147
Epochs per episode: 573 Episode Reward: 190.0 Episode number: 148
Epochs per episode: 546 Episode Reward: 210.0 Episode number: 149
Epochs per episode: 725 Episode Reward: 240.0 Episode number: 150
Epochs per episode: 638 Episode Reward: 240.0 Episode number: 151
Epochs per episode: 619 Episode Reward: 150.0 Episode number: 152
Epochs per episode: 704 Episode Reward: 310.0 Episode number: 153
Epochs per episode: 626 Episode Reward: 190.0 Episode number: 154
Epochs per episode: 571 Episode Reward: 200.0 Episode number: 155
Epochs per episode: 534 Episode Reward: 170.0 Episode number: 156
Epochs per episode: 655 Episode Reward: 290.0 Episode number: 157
Epochs per episode: 752 Episode Reward: 250.0 Episode number: 158
Epochs per episode: 591 Episode Reward: 270.0 Episode number: 159
Epochs per episode: 451 Episode Reward: 180.0 Episode number: 160
Epochs per episode: 823 Episode Reward: 290.0 Episode number: 161
Epochs per episode: 466 Episode Reward: 70.0 Episode number: 162
Epochs per episode: 689 Episode Reward: 210.0 Episode number: 163
Epochs per episode: 542 Episode Reward: 200.0 Episode number: 164
Epochs per episode: 547 Episode Reward: 190.0 Episode number: 165
Epochs per episode: 680 Episode Reward: 270.0 Episode number: 166
Epochs per episode: 575 Episode Reward: 190.0 Episode number: 167
Epochs per episode: 561 Episode Reward: 250.0 Episode number: 168
Epochs per episode: 767 Episode Reward: 280.0 Episode number: 169
Epochs per episode: 602 Episode Reward: 250.0 Episode number: 170
Epochs per episode: 549 Episode Reward: 170.0 Episode number: 171
Epochs per episode: 897 Episode Reward: 380.0 Episode number: 172
Epochs per episode: 927 Episode Reward: 1990.0 Episode number: 173
Epochs per episode: 887 Episode Reward: 660.0 Episode number: 174
Epochs per episode: 702 Episode Reward: 180.0 Episode number: 175
Epochs per episode: 663 Episode Reward: 370.0 Episode number: 176
Epochs per episode: 706 Episode Reward: 270.0 Episode number: 177
Epochs per episode: 670 Episode Reward: 190.0 Episode number: 178
Epochs per episode: 821 Episode Reward: 560.0 Episode number: 179
Epochs per episode: 730 Episode Reward: 320.0 Episode number: 180
Epochs per episode: 837 Episode Reward: 370.0 Episode number: 181
Epochs per episode: 538 Episode Reward: 210.0 Episode number: 182
Epochs per episode: 632 Episode Reward: 140.0 Episode number: 183
```

```
Epochs per episode: 786 Episode Reward: 280.0 Episode number: 184
Epochs per episode: 482 Episode Reward: 220.0 Episode number: 185
Epochs per episode: 672 Episode Reward: 430.0 Episode number: 186
Epochs per episode: 678 Episode Reward: 350.0 Episode number: 187
Epochs per episode: 997 Episode Reward: 540.0 Episode number: 188
Epochs per episode: 936 Episode Reward: 550.0 Episode number: 189
Epochs per episode: 639 Episode Reward: 270.0 Episode number: 190
Epochs per episode: 790 Episode Reward: 640.0 Episode number: 191
Epochs per episode: 704 Episode Reward: 320.0 Episode number: 192
Epochs per episode: 815 Episode Reward: 410.0 Episode number: 193
Epochs per episode: 628 Episode Reward: 240.0 Episode number: 194
Epochs per episode: 759 Episode Reward: 410.0 Episode number: 195
Epochs per episode: 690 Episode Reward: 310.0 Episode number: 196
Epochs per episode: 1190 Episode Reward: 1050.0 Episode number: 197
Epochs per episode: 614 Episode Reward: 210.0 Episode number: 198
Epochs per episode: 846 Episode Reward: 510.0 Episode number: 199
Epochs per episode: 585 Episode Reward: 200.0 Episode number: 200
Epochs per episode: 619 Episode Reward: 140.0 Episode number: 201
Epochs per episode: 478 Episode Reward: 150.0 Episode number: 202
Epochs per episode: 517 Episode Reward: 110.0 Episode number: 203
Epochs per episode: 814 Episode Reward: 580.0 Episode number: 204
Epochs per episode: 1160 Episode Reward: 1990.0 Episode number: 205
Epochs per episode: 873 Episode Reward: 500.0 Episode number: 206
Epochs per episode: 568 Episode Reward: 180.0 Episode number: 207
Epochs per episode: 704 Episode Reward: 280.0 Episode number: 208
Epochs per episode: 647 Episode Reward: 230.0 Episode number: 209
Epochs per episode: 627 Episode Reward: 250.0 Episode number: 210
Epochs per episode: 589 Episode Reward: 250.0 Episode number: 211
Epochs per episode: 553 Episode Reward: 230.0 Episode number: 212
Epochs per episode: 1051 Episode Reward: 740.0 Episode number: 213
Epochs per episode: 931 Episode Reward: 600.0 Episode number: 214
Epochs per episode: 1020 Episode Reward: 970.0 Episode number: 215
Epochs per episode: 826 Episode Reward: 260.0 Episode number: 216
Epochs per episode: 564 Episode Reward: 180.0 Episode number: 217
Epochs per episode: 791 Episode Reward: 350.0 Episode number: 218
Epochs per episode: 677 Episode Reward: 340.0 Episode number: 219
Epochs per episode: 809 Episode Reward: 380.0 Episode number: 220
Epochs per episode: 695 Episode Reward: 280.0 Episode number: 221
Epochs per episode: 1044 Episode Reward: 1180.0 Episode number: 222
Epochs per episode: 596 Episode Reward: 220.0 Episode number: 223
Epochs per episode: 720 Episode Reward: 350.0 Episode number: 224
Epochs per episode: 696 Episode Reward: 370.0 Episode number: 225
Epochs per episode: 665 Episode Reward: 250.0 Episode number: 226
Epochs per episode: 694 Episode Reward: 390.0 Episode number: 227
Epochs per episode: 769 Episode Reward: 300.0 Episode number: 228
Epochs per episode: 1081 Episode Reward: 770.0 Episode number: 229
Epochs per episode: 516 Episode Reward: 260.0 Episode number: 230
Epochs per episode: 822 Episode Reward: 650.0 Episode number: 231
Epochs per episode: 819 Episode Reward: 700.0 Episode number: 232
Epochs per episode: 906 Episode Reward: 550.0 Episode number: 233
Epochs per episode: 842 Episode Reward: 460.0 Episode number: 234
Epochs per episode: 784 Episode Reward: 360.0 Episode number: 235
Epochs per episode: 651 Episode Reward: 310.0 Episode number: 236
Epochs per episode: 426 Episode Reward: 140.0 Episode number: 237
Epochs per episode: 454 Episode Reward: 170.0 Episode number: 238
Epochs per episode: 699 Episode Reward: 350.0 Episode number: 239
Epochs per episode: 873 Episode Reward: 460.0 Episode number: 240
Epochs per episode: 921 Episode Reward: 610.0 Episode number: 241
Epochs per episode: 611 Episode Reward: 310.0 Episode number: 242
Epochs per episode: 511 Episode Reward: 200.0 Episode number: 243
Epochs per episode: 794 Episode Reward: 640.0 Episode number: 244
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Epochs per episode: 665 Episode Reward: 240.0 Episode number: 245
Epochs per episode: 958 Episode Reward: 330.0 Episode number: 246
Epochs per episode: 597 Episode Reward: 310.0 Episode number: 247
Epochs per episode: 679 Episode Reward: 290.0 Episode number: 248
Epochs per episode: 540 Episode Reward: 210.0 Episode number: 249
Epochs per episode: 505 Episode Reward: 190.0 Episode number: 250
Epochs per episode: 840 Episode Reward: 700.0 Episode number: 251
Epochs per episode: 1045 Episode Reward: 440.0 Episode number: 252
Epochs per episode: 965 Episode Reward: 1180.0 Episode number: 253
Epochs per episode: 1019 Episode Reward: 900.0 Episode number: 254
Epochs per episode: 758 Episode Reward: 290.0 Episode number: 255
Epochs per episode: 624 Episode Reward: 260.0 Episode number: 256
Epochs per episode: 594 Episode Reward: 330.0 Episode number: 257
Epochs per episode: 658 Episode Reward: 410.0 Episode number: 258
Epochs per episode: 569 Episode Reward: 260.0 Episode number: 259
Epochs per episode: 605 Episode Reward: 240.0 Episode number: 260
Epochs per episode: 974 Episode Reward: 680.0 Episode number: 261
Epochs per episode: 672 Episode Reward: 270.0 Episode number: 262
Epochs per episode: 768 Episode Reward: 720.0 Episode number: 263
Epochs per episode: 627 Episode Reward: 230.0 Episode number: 264
Epochs per episode: 670 Episode Reward: 410.0 Episode number: 265
Epochs per episode: 814 Episode Reward: 360.0 Episode number: 266
Epochs per episode: 1059 Episode Reward: 510.0 Episode number: 267
Epochs per episode: 688 Episode Reward: 430.0 Episode number: 268
Epochs per episode: 473 Episode Reward: 170.0 Episode number: 269
Epochs per episode: 928 Episode Reward: 720.0 Episode number: 270
Epochs per episode: 956 Episode Reward: 470.0 Episode number: 271
Epochs per episode: 648 Episode Reward: 240.0 Episode number: 272
Epochs per episode: 834 Episode Reward: 390.0 Episode number: 273
Epochs per episode: 530 Episode Reward: 250.0 Episode number: 274
Epochs per episode: 681 Episode Reward: 280.0 Episode number: 275
Epochs per episode: 937 Episode Reward: 390.0 Episode number: 276
Epochs per episode: 461 Episode Reward: 180.0 Episode number: 277
Epochs per episode: 752 Episode Reward: 330.0 Episode number: 278
Epochs per episode: 615 Episode Reward: 210.0 Episode number: 279
Epochs per episode: 724 Episode Reward: 360.0 Episode number: 280
Epochs per episode: 847 Episode Reward: 980.0 Episode number: 281
Epochs per episode: 719 Episode Reward: 340.0 Episode number: 282
Epochs per episode: 651 Episode Reward: 190.0 Episode number: 283
Epochs per episode: 850 Episode Reward: 500.0 Episode number: 284
Epochs per episode: 1252 Episode Reward: 980.0 Episode number: 285
Epochs per episode: 581 Episode Reward: 270.0 Episode number: 286
Epochs per episode: 909 Episode Reward: 520.0 Episode number: 287
Epochs per episode: 488 Episode Reward: 150.0 Episode number: 288
Epochs per episode: 614 Episode Reward: 250.0 Episode number: 289
Epochs per episode: 797 Episode Reward: 320.0 Episode number: 290
Epochs per episode: 670 Episode Reward: 280.0 Episode number: 291
Epochs per episode: 705 Episode Reward: 470.0 Episode number: 292
Epochs per episode: 580 Episode Reward: 310.0 Episode number: 293
Epochs per episode: 510 Episode Reward: 180.0 Episode number: 294
Epochs per episode: 734 Episode Reward: 310.0 Episode number: 295
Epochs per episode: 864 Episode Reward: 390.0 Episode number: 296
Epochs per episode: 1029 Episode Reward: 960.0 Episode number: 297
Epochs per episode: 567 Episode Reward: 180.0 Episode number: 298
Epochs per episode: 1174 Episode Reward: 990.0 Episode number: 299
Epochs per episode: 855 Episode Reward: 700.0 Episode number: 300
Epochs per episode: 746 Episode Reward: 360.0 Episode number: 301
Epochs per episode: 718 Episode Reward: 270.0 Episode number: 302
Epochs per episode: 841 Episode Reward: 340.0 Episode number: 303
Epochs per episode: 611 Episode Reward: 350.0 Episode number: 304
Epochs per episode: 448 Episode Reward: 170.0 Episode number: 305
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Epochs per episode: 669 Episode Reward: 300.0 Episode number: 306
Epochs per episode: 448 Episode Reward: 210.0 Episode number: 307
Epochs per episode: 893 Episode Reward: 330.0 Episode number: 308
Epochs per episode: 713 Episode Reward: 250.0 Episode number: 309
Epochs per episode: 896 Episode Reward: 1100.0 Episode number: 310
Epochs per episode: 643 Episode Reward: 210.0 Episode number: 311
Epochs per episode: 586 Episode Reward: 300.0 Episode number: 312
Epochs per episode: 748 Episode Reward: 310.0 Episode number: 313
Epochs per episode: 1056 Episode Reward: 710.0 Episode number: 314
Epochs per episode: 789 Episode Reward: 520.0 Episode number: 315
Epochs per episode: 720 Episode Reward: 190.0 Episode number: 316
Epochs per episode: 624 Episode Reward: 340.0 Episode number: 317
Epochs per episode: 412 Episode Reward: 100.0 Episode number: 318
Epochs per episode: 862 Episode Reward: 520.0 Episode number: 319
Epochs per episode: 572 Episode Reward: 290.0 Episode number: 320
Epochs per episode: 939 Episode Reward: 460.0 Episode number: 321
Epochs per episode: 1293 Episode Reward: 1070.0 Episode number: 322
Epochs per episode: 978 Episode Reward: 550.0 Episode number: 323
Epochs per episode: 671 Episode Reward: 420.0 Episode number: 324
Epochs per episode: 588 Episode Reward: 280.0 Episode number: 325
Epochs per episode: 705 Episode Reward: 690.0 Episode number: 326
Epochs per episode: 634 Episode Reward: 340.0 Episode number: 327
Epochs per episode: 753 Episode Reward: 340.0 Episode number: 328
Epochs per episode: 586 Episode Reward: 250.0 Episode number: 329
Epochs per episode: 714 Episode Reward: 560.0 Episode number: 330
Epochs per episode: 893 Episode Reward: 410.0 Episode number: 331
Epochs per episode: 565 Episode Reward: 240.0 Episode number: 332
Epochs per episode: 540 Episode Reward: 320.0 Episode number: 333
Epochs per episode: 372 Episode Reward: 150.0 Episode number: 334
Epochs per episode: 499 Episode Reward: 270.0 Episode number: 335
Epochs per episode: 811 Episode Reward: 490.0 Episode number: 336
Epochs per episode: 751 Episode Reward: 470.0 Episode number: 337
Epochs per episode: 864 Episode Reward: 450.0 Episode number: 338
Epochs per episode: 1082 Episode Reward: 1020.0 Episode number: 339
Epochs per episode: 648 Episode Reward: 340.0 Episode number: 340
Epochs per episode: 534 Episode Reward: 150.0 Episode number: 341
Epochs per episode: 943 Episode Reward: 510.0 Episode number: 342
Epochs per episode: 621 Episode Reward: 290.0 Episode number: 343
Epochs per episode: 566 Episode Reward: 260.0 Episode number: 344
Epochs per episode: 916 Episode Reward: 770.0 Episode number: 345
Epochs per episode: 775 Episode Reward: 330.0 Episode number: 346
Epochs per episode: 1254 Episode Reward: 1750.0 Episode number: 347
Epochs per episode: 663 Episode Reward: 270.0 Episode number: 348
Epochs per episode: 844 Episode Reward: 620.0 Episode number: 349
Epochs per episode: 901 Episode Reward: 550.0 Episode number: 350
Epochs per episode: 946 Episode Reward: 850.0 Episode number: 351
Epochs per episode: 767 Episode Reward: 330.0 Episode number: 352
Epochs per episode: 879 Episode Reward: 500.0 Episode number: 353
Epochs per episode: 1182 Episode Reward: 1630.0 Episode number: 354
Epochs per episode: 1170 Episode Reward: 550.0 Episode number: 355
Epochs per episode: 475 Episode Reward: 210.0 Episode number: 356
Epochs per episode: 487 Episode Reward: 230.0 Episode number: 357
Epochs per episode: 1077 Episode Reward: 850.0 Episode number: 358
Epochs per episode: 1126 Episode Reward: 690.0 Episode number: 359
Epochs per episode: 1022 Episode Reward: 820.0 Episode number: 360
Epochs per episode: 1200 Episode Reward: 1470.0 Episode number: 361
Epochs per episode: 727 Episode Reward: 320.0 Episode number: 362
Epochs per episode: 819 Episode Reward: 500.0 Episode number: 363
Epochs per episode: 1058 Episode Reward: 1070.0 Episode number: 364
Epochs per episode: 867 Episode Reward: 460.0 Episode number: 365
Epochs per episode: 613 Episode Reward: 300.0 Episode number: 366
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Epochs per episode: 722 Episode Reward: 330.0 Episode number: 367
Epochs per episode: 878 Episode Reward: 430.0 Episode number: 368
Epochs per episode: 1414 Episode Reward: 770.0 Episode number: 369
Epochs per episode: 957 Episode Reward: 530.0 Episode number: 370
Epochs per episode: 1162 Episode Reward: 930.0 Episode number: 371
Epochs per episode: 800 Episode Reward: 590.0 Episode number: 372
Epochs per episode: 870 Episode Reward: 490.0 Episode number: 373
Epochs per episode: 936 Episode Reward: 450.0 Episode number: 374
Epochs per episode: 1238 Episode Reward: 2080.0 Episode number: 375
Epochs per episode: 722 Episode Reward: 340.0 Episode number: 376
Epochs per episode: 687 Episode Reward: 470.0 Episode number: 377
Epochs per episode: 570 Episode Reward: 170.0 Episode number: 378
Epochs per episode: 897 Episode Reward: 540.0 Episode number: 379
Epochs per episode: 545 Episode Reward: 230.0 Episode number: 380
Epochs per episode: 694 Episode Reward: 290.0 Episode number: 381
Epochs per episode: 783 Episode Reward: 720.0 Episode number: 382
Epochs per episode: 667 Episode Reward: 280.0 Episode number: 383
Epochs per episode: 615 Episode Reward: 240.0 Episode number: 384
Epochs per episode: 747 Episode Reward: 290.0 Episode number: 385
Epochs per episode: 828 Episode Reward: 650.0 Episode number: 386
Epochs per episode: 767 Episode Reward: 440.0 Episode number: 387
Epochs per episode: 610 Episode Reward: 510.0 Episode number: 388
Epochs per episode: 683 Episode Reward: 260.0 Episode number: 389
Epochs per episode: 973 Episode Reward: 620.0 Episode number: 390
Epochs per episode: 1237 Episode Reward: 1690.0 Episode number: 391
Epochs per episode: 858 Episode Reward: 600.0 Episode number: 392
Epochs per episode: 503 Episode Reward: 140.0 Episode number: 393
Epochs per episode: 637 Episode Reward: 240.0 Episode number: 394
Epochs per episode: 679 Episode Reward: 270.0 Episode number: 395
Epochs per episode: 490 Episode Reward: 190.0 Episode number: 396
Epochs per episode: 491 Episode Reward: 170.0 Episode number: 397
Epochs per episode: 990 Episode Reward: 810.0 Episode number: 398
Epochs per episode: 665 Episode Reward: 260.0 Episode number: 399
Epochs per episode: 726 Episode Reward: 470.0 Episode number: 400
Epochs per episode: 1031 Episode Reward: 570.0 Episode number: 401
Epochs per episode: 1008 Episode Reward: 300.0 Episode number: 402
Epochs per episode: 823 Episode Reward: 670.0 Episode number: 403
Epochs per episode: 608 Episode Reward: 420.0 Episode number: 404
Epochs per episode: 666 Episode Reward: 280.0 Episode number: 405
Epochs per episode: 463 Episode Reward: 230.0 Episode number: 406
Epochs per episode: 896 Episode Reward: 750.0 Episode number: 407
Epochs per episode: 800 Episode Reward: 370.0 Episode number: 408
Epochs per episode: 596 Episode Reward: 230.0 Episode number: 409
Epochs per episode: 768 Episode Reward: 460.0 Episode number: 410
Epochs per episode: 671 Episode Reward: 240.0 Episode number: 411
Epochs per episode: 942 Episode Reward: 590.0 Episode number: 412
Epochs per episode: 820 Episode Reward: 650.0 Episode number: 413
Epochs per episode: 1096 Episode Reward: 950.0 Episode number: 414
Epochs per episode: 617 Episode Reward: 330.0 Episode number: 415
Epochs per episode: 691 Episode Reward: 480.0 Episode number: 416
Epochs per episode: 652 Episode Reward: 300.0 Episode number: 417
Epochs per episode: 563 Episode Reward: 370.0 Episode number: 418
Epochs per episode: 685 Episode Reward: 380.0 Episode number: 419
Epochs per episode: 1015 Episode Reward: 410.0 Episode number: 420
Epochs per episode: 1041 Episode Reward: 630.0 Episode number: 421
Epochs per episode: 1193 Episode Reward: 1300.0 Episode number: 422
Epochs per episode: 573 Episode Reward: 200.0 Episode number: 423
Epochs per episode: 1148 Episode Reward: 1430.0 Episode number: 424
Epochs per episode: 405 Episode Reward: 170.0 Episode number: 425
Epochs per episode: 528 Episode Reward: 270.0 Episode number: 426
Epochs per episode: 1006 Episode Reward: 730.0 Episode number: 427
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Epochs per episode: 538 Episode Reward: 210.0 Episode number: 428
Epochs per episode: 634 Episode Reward: 300.0 Episode number: 429
Epochs per episode: 1046 Episode Reward: 1350.0 Episode number: 430
Epochs per episode: 720 Episode Reward: 300.0 Episode number: 431
Epochs per episode: 475 Episode Reward: 180.0 Episode number: 432
Epochs per episode: 563 Episode Reward: 190.0 Episode number: 433
Epochs per episode: 801 Episode Reward: 600.0 Episode number: 434
Epochs per episode: 720 Episode Reward: 510.0 Episode number: 435
Epochs per episode: 591 Episode Reward: 390.0 Episode number: 436
Epochs per episode: 593 Episode Reward: 400.0 Episode number: 437
Epochs per episode: 1038 Episode Reward: 750.0 Episode number: 438
Epochs per episode: 859 Episode Reward: 1070.0 Episode number: 439
Epochs per episode: 753 Episode Reward: 1070.0 Episode number: 440
Epochs per episode: 550 Episode Reward: 280.0 Episode number: 441
Epochs per episode: 627 Episode Reward: 460.0 Episode number: 442
Epochs per episode: 1162 Episode Reward: 780.0 Episode number: 443
Epochs per episode: 695 Episode Reward: 580.0 Episode number: 444
Epochs per episode: 800 Episode Reward: 280.0 Episode number: 445
Epochs per episode: 954 Episode Reward: 1250.0 Episode number: 446
Epochs per episode: 980 Episode Reward: 1060.0 Episode number: 447
Epochs per episode: 472 Episode Reward: 180.0 Episode number: 448
Epochs per episode: 794 Episode Reward: 960.0 Episode number: 449
Epochs per episode: 664 Episode Reward: 300.0 Episode number: 450
Epochs per episode: 879 Episode Reward: 620.0 Episode number: 451
Epochs per episode: 697 Episode Reward: 460.0 Episode number: 452
Epochs per episode: 549 Episode Reward: 240.0 Episode number: 453
Epochs per episode: 784 Episode Reward: 530.0 Episode number: 454
Epochs per episode: 589 Episode Reward: 360.0 Episode number: 455
Epochs per episode: 901 Episode Reward: 790.0 Episode number: 456
Epochs per episode: 770 Episode Reward: 730.0 Episode number: 457
Epochs per episode: 951 Episode Reward: 770.0 Episode number: 458
Epochs per episode: 553 Episode Reward: 280.0 Episode number: 459
Epochs per episode: 890 Episode Reward: 520.0 Episode number: 460
Epochs per episode: 845 Episode Reward: 600.0 Episode number: 461
Epochs per episode: 723 Episode Reward: 500.0 Episode number: 462
Epochs per episode: 761 Episode Reward: 590.0 Episode number: 463
Epochs per episode: 798 Episode Reward: 630.0 Episode number: 464
Epochs per episode: 565 Episode Reward: 290.0 Episode number: 465
Epochs per episode: 703 Episode Reward: 220.0 Episode number: 466
Epochs per episode: 727 Episode Reward: 470.0 Episode number: 467
Epochs per episode: 525 Episode Reward: 310.0 Episode number: 468
Epochs per episode: 838 Episode Reward: 660.0 Episode number: 469
Epochs per episode: 1180 Episode Reward: 1280.0 Episode number: 470
Epochs per episode: 936 Episode Reward: 670.0 Episode number: 471
Epochs per episode: 1186 Episode Reward: 1350.0 Episode number: 472
Epochs per episode: 723 Episode Reward: 430.0 Episode number: 473
Epochs per episode: 1111 Episode Reward: 1480.0 Episode number: 474
Epochs per episode: 576 Episode Reward: 350.0 Episode number: 475
Epochs per episode: 1363 Episode Reward: 1530.0 Episode number: 476
Epochs per episode: 665 Episode Reward: 280.0 Episode number: 477
Epochs per episode: 732 Episode Reward: 440.0 Episode number: 478
Epochs per episode: 632 Episode Reward: 300.0 Episode number: 479
Epochs per episode: 882 Episode Reward: 960.0 Episode number: 480
Epochs per episode: 887 Episode Reward: 720.0 Episode number: 481
Epochs per episode: 969 Episode Reward: 1230.0 Episode number: 482
Epochs per episode: 639 Episode Reward: 370.0 Episode number: 483
Epochs per episode: 507 Episode Reward: 340.0 Episode number: 484
Epochs per episode: 973 Episode Reward: 430.0 Episode number: 485
Epochs per episode: 765 Episode Reward: 380.0 Episode number: 486
Epochs per episode: 903 Episode Reward: 680.0 Episode number: 487
Epochs per episode: 762 Episode Reward: 580.0 Episode number: 488
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Epochs per episode: 1629 Episode Reward: 2070.0 Episode number: 489
Epochs per episode: 746 Episode Reward: 560.0 Episode number: 490
Epochs per episode: 709 Episode Reward: 630.0 Episode number: 491
Epochs per episode: 668 Episode Reward: 490.0 Episode number: 492
Epochs per episode: 491 Episode Reward: 260.0 Episode number: 493
Epochs per episode: 835 Episode Reward: 400.0 Episode number: 494
Epochs per episode: 797 Episode Reward: 470.0 Episode number: 495
Epochs per episode: 486 Episode Reward: 200.0 Episode number: 496
Epochs per episode: 1121 Episode Reward: 1430.0 Episode number: 497
Epochs per episode: 889 Episode Reward: 500.0 Episode number: 498
Epochs per episode: 806 Episode Reward: 320.0 Episode number: 499
Epochs per episode: 493 Episode Reward: 230.0 Episode number: 500
Epochs per episode: 986 Episode Reward: 790.0 Episode number: 501
Epochs per episode: 427 Episode Reward: 130.0 Episode number: 502
Epochs per episode: 845 Episode Reward: 600.0 Episode number: 503
Epochs per episode: 1115 Episode Reward: 850.0 Episode number: 504
Epochs per episode: 809 Episode Reward: 490.0 Episode number: 505
Epochs per episode: 520 Episode Reward: 300.0 Episode number: 506
Epochs per episode: 640 Episode Reward: 330.0 Episode number: 507
Epochs per episode: 548 Episode Reward: 280.0 Episode number: 508
Epochs per episode: 776 Episode Reward: 1040.0 Episode number: 509
Epochs per episode: 838 Episode Reward: 550.0 Episode number: 510
Epochs per episode: 401 Episode Reward: 190.0 Episode number: 511
Epochs per episode: 869 Episode Reward: 670.0 Episode number: 512
Epochs per episode: 820 Episode Reward: 1100.0 Episode number: 513
Epochs per episode: 1295 Episode Reward: 1360.0 Episode number: 514
Epochs per episode: 950 Episode Reward: 440.0 Episode number: 515
Epochs per episode: 575 Episode Reward: 350.0 Episode number: 516
Epochs per episode: 520 Episode Reward: 370.0 Episode number: 517
Epochs per episode: 963 Episode Reward: 290.0 Episode number: 518
Epochs per episode: 853 Episode Reward: 440.0 Episode number: 519
Epochs per episode: 396 Episode Reward: 140.0 Episode number: 520
Epochs per episode: 1188 Episode Reward: 1480.0 Episode number: 521
Epochs per episode: 640 Episode Reward: 390.0 Episode number: 522
Epochs per episode: 951 Episode Reward: 710.0 Episode number: 523
Epochs per episode: 754 Episode Reward: 400.0 Episode number: 524
Epochs per episode: 1102 Episode Reward: 1100.0 Episode number: 525
Epochs per episode: 734 Episode Reward: 610.0 Episode number: 526
Epochs per episode: 936 Episode Reward: 540.0 Episode number: 527
Epochs per episode: 676 Episode Reward: 340.0 Episode number: 528
Epochs per episode: 937 Episode Reward: 890.0 Episode number: 529
Epochs per episode: 375 Episode Reward: 160.0 Episode number: 530
Epochs per episode: 747 Episode Reward: 510.0 Episode number: 531
Epochs per episode: 557 Episode Reward: 320.0 Episode number: 532
Epochs per episode: 486 Episode Reward: 150.0 Episode number: 533
Epochs per episode: 1087 Episode Reward: 760.0 Episode number: 534
Epochs per episode: 1005 Episode Reward: 420.0 Episode number: 535
Epochs per episode: 1107 Episode Reward: 780.0 Episode number: 536
Epochs per episode: 671 Episode Reward: 290.0 Episode number: 537
Epochs per episode: 820 Episode Reward: 600.0 Episode number: 538
Epochs per episode: 462 Episode Reward: 190.0 Episode number: 539
Epochs per episode: 1219 Episode Reward: 1550.0 Episode number: 540
Epochs per episode: 912 Episode Reward: 700.0 Episode number: 541
Epochs per episode: 1290 Episode Reward: 1490.0 Episode number: 542
Epochs per episode: 1030 Episode Reward: 870.0 Episode number: 543
Epochs per episode: 588 Episode Reward: 410.0 Episode number: 544
Epochs per episode: 844 Episode Reward: 1040.0 Episode number: 545
Epochs per episode: 1205 Episode Reward: 1130.0 Episode number: 546
Epochs per episode: 975 Episode Reward: 860.0 Episode number: 547
Epochs per episode: 539 Episode Reward: 270.0 Episode number: 548
Epochs per episode: 708 Episode Reward: 440.0 Episode number: 549
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Epochs per episode: 521 Episode Reward: 320.0 Episode number: 550
Epochs per episode: 813 Episode Reward: 380.0 Episode number: 551
Epochs per episode: 956 Episode Reward: 1260.0 Episode number: 552
Epochs per episode: 420 Episode Reward: 200.0 Episode number: 553
Epochs per episode: 735 Episode Reward: 740.0 Episode number: 554
Epochs per episode: 879 Episode Reward: 710.0 Episode number: 555
Epochs per episode: 791 Episode Reward: 520.0 Episode number: 556
Epochs per episode: 1034 Episode Reward: 820.0 Episode number: 557
Epochs per episode: 453 Episode Reward: 320.0 Episode number: 558
Epochs per episode: 945 Episode Reward: 970.0 Episode number: 559
Epochs per episode: 551 Episode Reward: 500.0 Episode number: 560
Epochs per episode: 1344 Episode Reward: 1090.0 Episode number: 561
Epochs per episode: 1455 Episode Reward: 820.0 Episode number: 562
Epochs per episode: 743 Episode Reward: 550.0 Episode number: 563
Epochs per episode: 778 Episode Reward: 890.0 Episode number: 564
Epochs per episode: 802 Episode Reward: 1780.0 Episode number: 565
Epochs per episode: 596 Episode Reward: 270.0 Episode number: 566
Epochs per episode: 662 Episode Reward: 370.0 Episode number: 567
Epochs per episode: 677 Episode Reward: 410.0 Episode number: 568
Epochs per episode: 1211 Episode Reward: 880.0 Episode number: 569
Epochs per episode: 842 Episode Reward: 1410.0 Episode number: 570
Epochs per episode: 891 Episode Reward: 400.0 Episode number: 571
Epochs per episode: 563 Episode Reward: 340.0 Episode number: 572
Epochs per episode: 1378 Episode Reward: 1340.0 Episode number: 573
Epochs per episode: 946 Episode Reward: 670.0 Episode number: 574
Epochs per episode: 935 Episode Reward: 1010.0 Episode number: 575
Epochs per episode: 990 Episode Reward: 1090.0 Episode number: 576
Epochs per episode: 673 Episode Reward: 380.0 Episode number: 577
Epochs per episode: 910 Episode Reward: 810.0 Episode number: 578
Epochs per episode: 700 Episode Reward: 330.0 Episode number: 579
Epochs per episode: 850 Episode Reward: 530.0 Episode number: 580
Epochs per episode: 822 Episode Reward: 530.0 Episode number: 581
Epochs per episode: 1226 Episode Reward: 860.0 Episode number: 582
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Epochs per episode: 1194 Episode Reward: 2280.0 Episode number: 584
Epochs per episode: 766 Episode Reward: 670.0 Episode number: 585
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Epochs per episode: 799 Episode Reward: 530.0 Episode number: 594
Epochs per episode: 563 Episode Reward: 200.0 Episode number: 595
Epochs per episode: 745 Episode Reward: 640.0 Episode number: 596
Epochs per episode: 950 Episode Reward: 800.0 Episode number: 597
Epochs per episode: 482 Episode Reward: 310.0 Episode number: 598
Epochs per episode: 1026 Episode Reward: 710.0 Episode number: 599
Epochs per episode: 695 Episode Reward: 430.0 Episode number: 600
Epochs per episode: 1150 Episode Reward: 760.0 Episode number: 601
Epochs per episode: 1092 Episode Reward: 4170.0 Episode number: 602
Epochs per episode: 833 Episode Reward: 440.0 Episode number: 603
Epochs per episode: 942 Episode Reward: 840.0 Episode number: 604
Epochs per episode: 968 Episode Reward: 500.0 Episode number: 605
Epochs per episode: 954 Episode Reward: 570.0 Episode number: 606
Epochs per episode: 810 Episode Reward: 660.0 Episode number: 607
Epochs per episode: 645 Episode Reward: 530.0 Episode number: 608
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Epochs per episode: 746 Episode Reward: 320.0 Episode number: 611
Epochs per episode: 838 Episode Reward: 470.0 Episode number: 612
Epochs per episode: 770 Episode Reward: 600.0 Episode number: 613
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Epochs per episode: 848 Episode Reward: 500.0 Episode number: 615
Epochs per episode: 720 Episode Reward: 340.0 Episode number: 616
Epochs per episode: 770 Episode Reward: 230.0 Episode number: 617
Epochs per episode: 870 Episode Reward: 470.0 Episode number: 618
Epochs per episode: 726 Episode Reward: 590.0 Episode number: 619
Epochs per episode: 850 Episode Reward: 430.0 Episode number: 620
Epochs per episode: 647 Episode Reward: 370.0 Episode number: 621
Epochs per episode: 900 Episode Reward: 730.0 Episode number: 622
Epochs per episode: 497 Episode Reward: 360.0 Episode number: 623
Epochs per episode: 887 Episode Reward: 1040.0 Episode number: 624
Epochs per episode: 797 Episode Reward: 1040.0 Episode number: 625
Epochs per episode: 983 Episode Reward: 560.0 Episode number: 626
Epochs per episode: 930 Episode Reward: 690.0 Episode number: 627
Epochs per episode: 616 Episode Reward: 220.0 Episode number: 628
Epochs per episode: 641 Episode Reward: 400.0 Episode number: 629
Epochs per episode: 731 Episode Reward: 310.0 Episode number: 630
Epochs per episode: 1156 Episode Reward: 180.0 Episode number: 631
Epochs per episode: 1374 Episode Reward: 880.0 Episode number: 632
Epochs per episode: 994 Episode Reward: 390.0 Episode number: 633
Epochs per episode: 1187 Episode Reward: 1310.0 Episode number: 634
Epochs per episode: 1124 Episode Reward: 1120.0 Episode number: 635
Epochs per episode: 1081 Episode Reward: 910.0 Episode number: 636
Epochs per episode: 906 Episode Reward: 420.0 Episode number: 637
Epochs per episode: 965 Episode Reward: 920.0 Episode number: 638
Epochs per episode: 1080 Episode Reward: 710.0 Episode number: 639
Epochs per episode: 1371 Episode Reward: 1160.0 Episode number: 640
Epochs per episode: 1048 Episode Reward: 710.0 Episode number: 641
Epochs per episode: 820 Episode Reward: 480.0 Episode number: 642
Epochs per episode: 599 Episode Reward: 480.0 Episode number: 643
Epochs per episode: 521 Episode Reward: 350.0 Episode number: 644
Epochs per episode: 1163 Episode Reward: 850.0 Episode number: 645
Epochs per episode: 1030 Episode Reward: 520.0 Episode number: 646
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Epochs per episode: 624 Episode Reward: 410.0 Episode number: 648
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Epochs per episode: 569 Episode Reward: 380.0 Episode number: 651
Epochs per episode: 1261 Episode Reward: 510.0 Episode number: 652
Epochs per episode: 696 Episode Reward: 530.0 Episode number: 653
Epochs per episode: 813 Episode Reward: 690.0 Episode number: 654
Epochs per episode: 840 Episode Reward: 420.0 Episode number: 655
Epochs per episode: 884 Episode Reward: 790.0 Episode number: 656
Epochs per episode: 1141 Episode Reward: 250.0 Episode number: 657
Epochs per episode: 848 Episode Reward: 310.0 Episode number: 658
Epochs per episode: 1216 Episode Reward: 1010.0 Episode number: 659
Epochs per episode: 934 Episode Reward: 370.0 Episode number: 660
Epochs per episode: 851 Episode Reward: 350.0 Episode number: 661
Epochs per episode: 1161 Episode Reward: 1030.0 Episode number: 662
Epochs per episode: 866 Episode Reward: 550.0 Episode number: 663
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Epochs per episode: 1210 Episode Reward: 900.0 Episode number: 665
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Epochs per episode: 782 Episode Reward: 1150.0 Episode number: 667
Epochs per episode: 537 Episode Reward: 270.0 Episode number: 668
Epochs per episode: 1425 Episode Reward: 420.0 Episode number: 669
Epochs per episode: 915 Episode Reward: 580.0 Episode number: 670
Epochs per episode: 589 Episode Reward: 330.0 Episode number: 671
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Epochs per episode: 546 Episode Reward: 230.0 Episode number: 672
Epochs per episode: 784 Episode Reward: 300.0 Episode number: 673
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Epochs per episode: 712 Episode Reward: 370.0 Episode number: 675
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Epochs per episode: 880 Episode Reward: 550.0 Episode number: 685
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Epochs per episode: 830 Episode Reward: 300.0 Episode number: 693
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Epochs per episode: 1004 Episode Reward: 850.0 Episode number: 780
Epochs per episode: 701 Episode Reward: 340.0 Episode number: 781
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Epochs per episode: 672 Episode Reward: 390.0 Episode number: 808
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Epochs per episode: 813 Episode Reward: 480.0 Episode number: 811
Epochs per episode: 533 Episode Reward: 300.0 Episode number: 812
Epochs per episode: 558 Episode Reward: 320.0 Episode number: 813
```

```
------------------------------------------------------------------
-------
KeyboardInterrupt                                Traceback (most recent cal
l last)
<ipython-input-14-61e0be39fbb2> in <module>()
     14              capture = reformat_image(capture)
     15
---> 16              actions = primaryQ_outputs.eval(feed_dict={X:[ca
pture], in_training_mode:False})
     17
     18              action = np.argmax(actions, axis=-1)

/usr/local/lib/python3.6/dist-packages/tensorflow/python/framework/o
ps.py in eval(self, feed_dict, session)
    693
    694        """
--> 695        return _eval_using_default_session(self, feed_dict, self
.graph, session)
    696
    697

/usr/local/lib/python3.6/dist-packages/tensorflow/python/framework/o
ps.py in _eval_using_default_session(tensors, feed_dict, graph, sess
ion)
   5179                      "the tensor's graph is different from
the session's "
   5180                      "graph.")
-> 5181    return session.run(tensors, feed_dict)
   5182
   5183

/usr/local/lib/python3.6/dist-packages/tensorflow/python/client/sess
ion.py in run(self, fetches, feed_dict, options, run_metadata)
    927      try:
    928        result = self._run(None, fetches, feed_dict, options_p
tr,
--> 929                           run_metadata_ptr)
    930        if run_metadata:
    931          proto_data = tf_session.TF_GetBuffer(run_metadata_pt
r)

/usr/local/lib/python3.6/dist-packages/tensorflow/python/client/sess
ion.py in _run(self, handle, fetches, feed_dict, options, run_metada
ta)
   1150      if final_fetches or final_targets or (handle and feed_di
ct_tensor):
   1151        results = self._do_run(handle, final_targets, final_fe
tches,
-> 1152                               feed_dict_tensor, options, run_
metadata)
   1153      else:
   1154        results = []

/usr/local/lib/python3.6/dist-packages/tensorflow/python/client/sess
ion.py in _do_run(self, handle, target_list, fetch_list, feed_dict,
 options, run_metadata)
   1326      if handle is None:
   1327        return self._do_call(_run_fn, feeds, fetches, targets,
options,
-> 1328                             run_metadata)
   1329      else:
```

```
  1330          return self._do_call(_prun_fn, handle, feeds, fetches)


/usr/local/lib/python3.6/dist-packages/tensorflow/python/client/sess
ion.py in _do_call(self, fn, *args)
  1332    def _do_call(self, fn, *args):
  1333      try:
-> 1334        return fn(*args)
  1335      except errors.OpError as e:
  1336        message = compat.as_text(e.message)


/usr/local/lib/python3.6/dist-packages/tensorflow/python/client/sess
ion.py in _run_fn(feed_dict, fetch_list, target_list, options, run_m
etadata)
  1317          self._extend_graph()
  1318          return self._call_tf_sessionrun(
-> 1319              options, feed_dict, fetch_list, target_list, run_m
etadata)
  1320
  1321      def _prun_fn(handle, feed_dict, fetch_list):


/usr/local/lib/python3.6/dist-packages/tensorflow/python/client/sess
ion.py in _call_tf_sessionrun(self, options, feed_dict, fetch_list,
 target_list, run_metadata)
  1405        return tf_session.TF_SessionRun_wrapper(
  1406            self._session, options, feed_dict, fetch_list, targe
t_list,
-> 1407            run_metadata)
  1408
  1409    def _call_tf_sessionprun(self, handle, feed_dict, fetch_li
st):


KeyboardInterrupt:
```
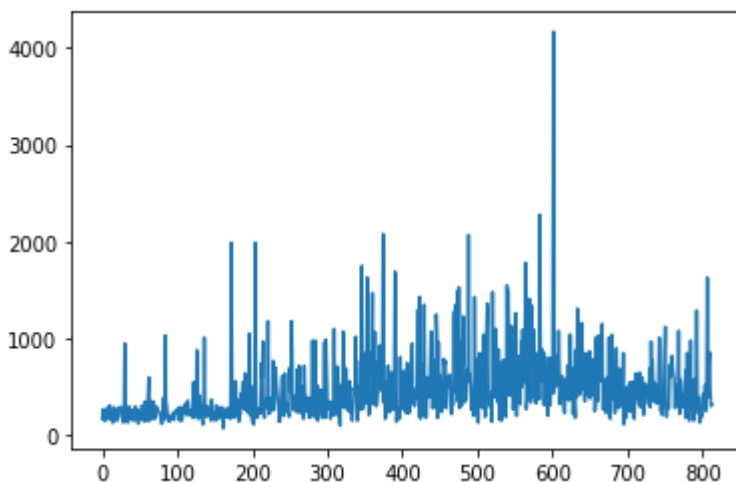
In [16]:

```
plt.plot(all_rewards)
plt.show()
```

In [17]:

```python
display = Display(visible=0, size=(1400, 900))
display.start()
```

Out[17]:

```
<pyvirtualdisplay.display.Display at 0x7fae52248e10>
```

In [18]:

```python
"""
Utility functions to enable video recording of gym environment and displaying it
To enable video, just do "env = wrap_env(env)"""
"""

def show_video():
  mp4list = glob.glob('video/*.mp4')
  if len(mp4list) > 0:
    mp4 = mp4list[0]
    video = io.open(mp4, 'r+b').read()
    encoded = base64.b64encode(video)
    ipythondisplay.display(HTML(data='''<video alt="test" autoplay
                loop controls style="height: 400px;">
                <source src="data:video/mp4;base64,{0}" type="video/mp4" />
            </video>'''.format(encoded.decode('ascii'))))
  else:
    print("Could not find video")


def wrap_env(env):
  env = Monitor(env, './video', force=True)
  return env
```

In [19]:

```python
#Evaluate model on openAi GYM
env = wrap_env(gym.make('MsPacman-v0'))
screen_capture = env.reset()
new_screen_capture = screen_capture

prev_input = None
terminated = False

with tf.compat.v1.Session() as sess:
    init.run()
    while True:
      if True:
         image = reformat_image(screen_capture)
         actions = primaryQ_outputs.eval(feed_dict={X:[image], in_training_mode:False})

         action = np.argmax(actions, axis=-1)
         actions_counter[str(action)] += 1

         action = greedy_policy(action, global_step)
         env.render()
         screen_capture = new_screen_capture
         new_screen_capture, reward, terminated, _ = env.step(action)

         if terminated:
           break

    env.close()
    show_video()
```

0:00 / 0:27