PSYC 365 Class 17:
Reward-biased attention

Where we've been

- Recognizing objects from the bottom up
- Recognition through prediction
- Filtering perception through selective attention
- Sustained attention: A neuromarker and ADHD
- Selective attention to emotional relevance
- And now….

Where we're going

- Today: Reward-biased Attention
  - Readings: 2 articles/blogs, Anderson et al.
- March 17th: Last chance to submit a discussion question
- March 18, 11:59pm: Submit groups for final project
- Tuesday March 18: The hippocampus
  - Reading: Passingham Chap 4
  - Fernandez-Velasco & Spiers, 2024: Optional!
  - In-class discussion
- Thursday March 20: Episodic memory; Rehearsing and retrieving memories
  - Readings: Bird et al.; How to see a memory

Learning Objectives: Emotion, Motivation and Attention

- ✓Describe four evolutionarily conserved basic emotional/motivational systems
- Explain ways in which amygdala and mid-brain dopamine systems play a role guiding affectively-biased and *motivated attention*
- Evaluate factors that influence individual differences in vulnerability to anxiety, addiction and depression

[1,2] For this class we are going to focus on reward and mid-brain dopamine systems linked to addiction on the one hand and and depression on the other.

Climate Anxiety

- Not considered a clinical condition but a healthy response
- BUT can negatively affect mental health
- It helps to take action
- Do you know about UBC's climate hub? https://ubcclimatehub.ca/
- A video on climate doomism (the positive effects of thinking negatively) by UBC's Gavin Esdale: https://www.youtube.com/watch?v=3dPKOPGTiG0
- Talk to your neighbor: Does what have been learning about biases in cognitive processes give you insight into how humans respond to the climate emergency? How?
- Based on your insights, do you have thoughts about effective responses?

Q: What is climate anxiety? It's been in the media a lot lately. What do you know about it?

Many many species self-medicate in the wild. Seeking rewarding altered states is a common behaviour, but when we come to require the substance, driving us to it habitually in a way that overrides our other goals, and threatens wellbeing it becomes a problematic addiction. The dopamine tech article points out that drugs like opioids these days are so strong, and involve so much opium release, that it overwhelms the system beyond what evolution prepared us for. These days, the shadow cast by the huge toxic drug crisis lies over any discussion of addiction. There is an increasing urgency to understand how neurochemical (dopamine) and behavioral processes may perpetuate addiction – although in the end a biopsychosocial or ecosocial approach that includes understanding the cultural and economic circumstances under which it takes place is crucial.

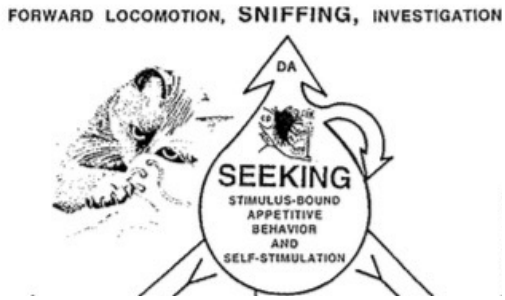
Reward-biased attention

One behaviour that is involved in perpetuating cravings linked to addiction is habitual and involuntary attention to cues that signal the reward the thing we're addicted to brings. Last class we talked about the role of the amygdala in biased attention to emotionally arousing words and we talked about biases to attend to threatening information and how that plays a role in anxiety. Anxiety is focused on threatening things you want to avoid. Now let's turn to biases for things we want to approach and get. These images are cues that are associated with beer and money. I see the picture and I start to feel the thirst! I want the cold texture, the delicious taste and that mellow buzz of wellbeing.

Seeking/Approach & addiction

Emotions

- *Desire*
- *Hope*
- *Anticipation*



As the blogs you read point out, addiction is driven by seeking, and of Panksepp's seeking system is implicated in the seeking component of addiction. The action tendency is approach, it's what Panksepp calls stimulus bound appetitive behaviour –that is, a form of working toward the thing that makes you feel good. Its emotions include desire and anticipation. It harnesses the DA system in search and goal directed behavior to achieve a range of appetitive (think appetite) goals. The media often portrays dopamine as being involved in feeling good when you get a reward. But Dopamine (motivation) is a neurochemical that is all about wanting not about getting.

In addiction, cues associated with reward trigger craving

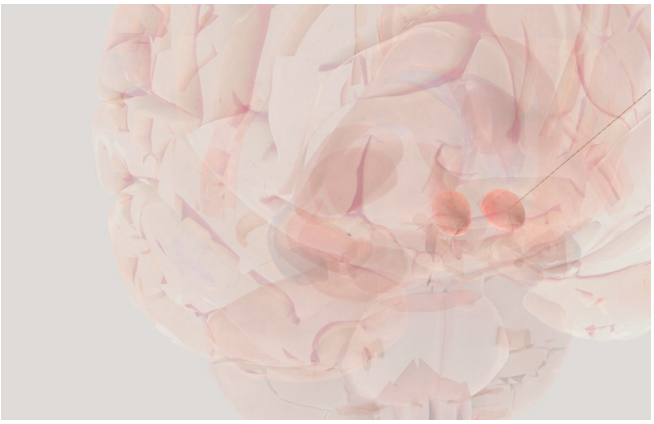
They have *incentive salience*

- Cue
- Craving
- Automatic action

Advertisers have known this for a very long time. Incentive salience means a cue stands out because of its association with reward. We've talked about emotional salience. This is a very similar idea. And the associations with this kind of cue trigger craving. That feeling of craving in turn leads to an automatic response where you reach for your pack of cigarettes, your whisky bottle, your weed stash.

Reward system

Nucleus accumbens

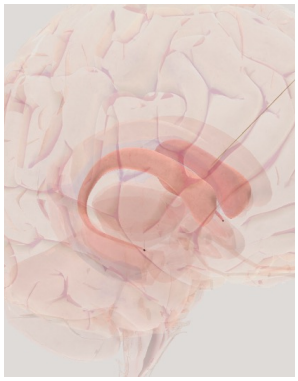


Expecting reward
Encountering unexpected amounts of reward

So just to review, the nucleus accumbens is a region of the ventral striatum (which is in the basal ganglia) that is a key node in the mesolimbic DA system - in the seeking system. It plays a role in motivation and addiction. Dopamine is released onto neurons in the NAc either when you expect a reward or when you encounter an unexpected reward. They "sulk" or reduce firing when you don't get a reward you expected.

Other regions of striatum

- Caudate Nucleus

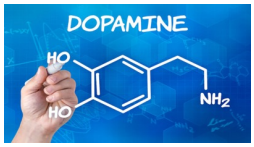


- Putamen

Approaching things to get reward

Dopamine!

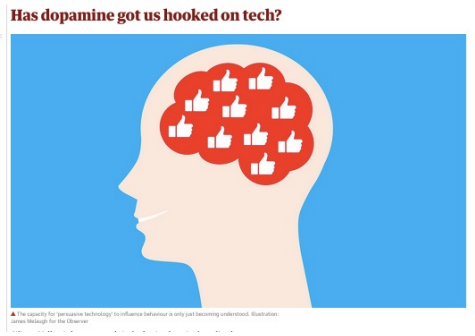
- Produced by DA neurons
  - Substantia Nigra
  - Ventral Tegmental Area
- *Tonic:*
  - Wanting/seeking
- *Phasic*:
  - Prediction error
  - Expectation of reward
- *Incentive salience*
  - When a cue acquires association with reward and triggers a feeling of wanting or craving



For this class,one reading was the blog on the many and grievous Crimes against Dopamine. It's short, sweet, accessible, not wrong and will help you make sense of the rest of this lecture and the next one. There is so much BS out there on the topic of dopamine!!! But it is a neuromodulator that is important for understanding addiction and depression. To summarize key things we know about it: [1]. DA is produced in several brain nuclei, including the *substantia nigra* and *ventral tegmental area* or VTA. As you saw, the VTA is part of the mesolimbic DA pathway [2] Tonic or slow and sustained DA motivates you to get up and out of bed and get out there and work to get reward in general. [3] Influential theories have proposed that phasic, or fast, bursts of dopamine are all about prediction error. This proposal is well supported and focuses on the relationship of your predictions to the outcome. So in this way its similar to predictive coding, but it is much more specifically focused on prediction error coded by DA neurons. Moving beyond the material in the blog, recent evidence ALSO suggests that phasic DA is not just about prediction error. It ALSO signals reward expectation and recent theories suggest it's more complicated than just being about prediction error. [4] DA is involved in incentive salience. This is a term coined by behavioural neuroscientist Kent Berridge, who has been a leader in DA/reward system research. It is when a cue acquires an association with

reward. This in turn triggers wanting or craving and that gets our seeking system going. Importantly, because this module focuses on attention, when a cue has incentive salience, we come to attend to it more in a habitual way. And habit -- including habits of attention -- are a key part of addiction.

Dopamine: the celebrity molecule



Reward expectation: Habit

Prediction error: Learning

Dopamine inspires us to take actions to meet our needs and desires – anything from turning up the heating to satisfying a craving to spin a roulette wheel – by anticipating how we will feel after they're met…

DA release anticipates a reward to an action and, if the reward is met, enables the behaviour to become a habit, or, if there's a discrepancy, to be adapted

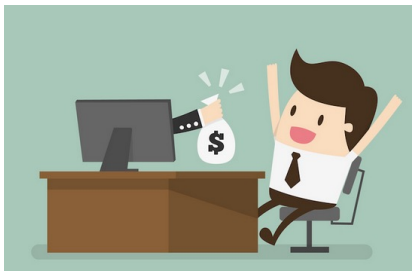
Now there's a lot of hype about Dopamine. Dopamine has been called the the celebrity molecule of silicon valley. This is an article that makes a nice link between DA, it's very adaptive role in learning, and addiction. This article focuses on how tech companies hijack processes that are fundamental to our learning. [1] For example one company has designed a running app where they use machine learning they figure out when you're least likely to be expecting a big reward like a high five or confetti in a running app and time the reward to maximize prediction error. They also manipulate reward expectation to translate desire into habit. [2] If a cue predicts reward it's habit forming. And habit is at the heart of addiction. [3] When expectations are met you have Habit. When they are unexpected you have learning! And if there is prediction error we learn – we adjust our behaviour so we are more likely to experience reward. "Tech companies understand what causes dopamine surges in the brain and they lace their products with 'hijacking techniques' that lure us in and create 'compulsion loops'."

Anderson et al., 2016

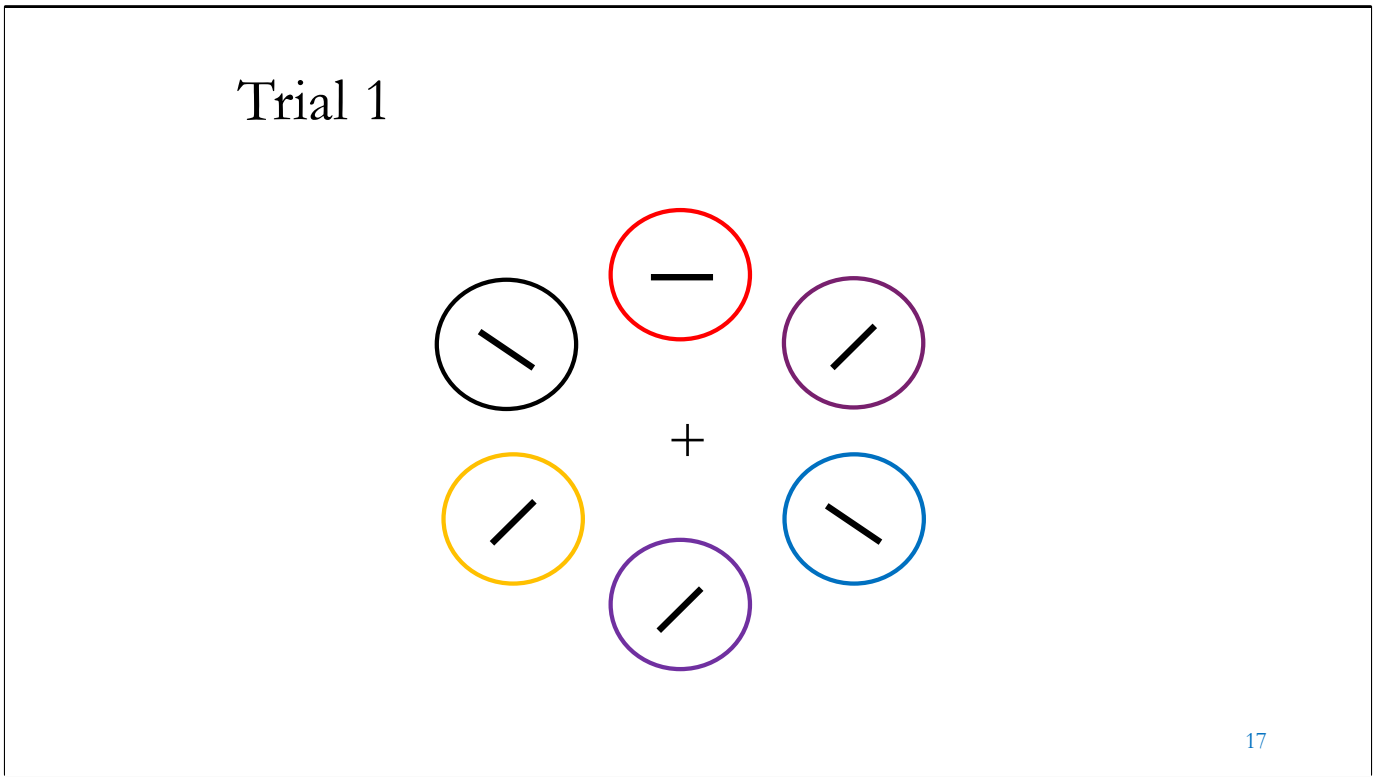
- Big Picture Question
  - What is the role of dopamine in attentional biases to cues signaling reward?
- Background
  - DA is important for learning that certain cues predict reward
  - Cues signaling reward capture attention, even when not relevant to "top-down" goals
- Specific Question
  - What is the role of dopamine in maintaining the attentional salience of reward cues even when they no longer predict reward

The big picture question was [click] As background there is lots of evidence that DA signals that a cue is predictive of reward. And attentional biases are a form of habit that is based on expectation of reward. [click] Once we have learned an association we develop the habit of prioritizing our attention to a cue. [click].. So once an attentional habit is developed cues signaling reward capture attention, even when not relevant to top-down goals. The specific question is really important when you think of relapse. [click]... You can have a cue that triggers a craving for something that used to be rewarding but then wrecked your life and made you feel terrible. And yet when you see it – you get a craving that can lead straight lead to an automatic, habitual action - lighting that cigarette. That's why if you're in in rehab you're not supposed go to old spots you used to spend time in, hang out with old friends... Too much incentive salience in cues that trigger your old craving.

Anderson Task: Training



- What is the orientation of the bar in the red OR green circle?
  - Raise your right hand if horizontal
  - Raise your left hand if vertical



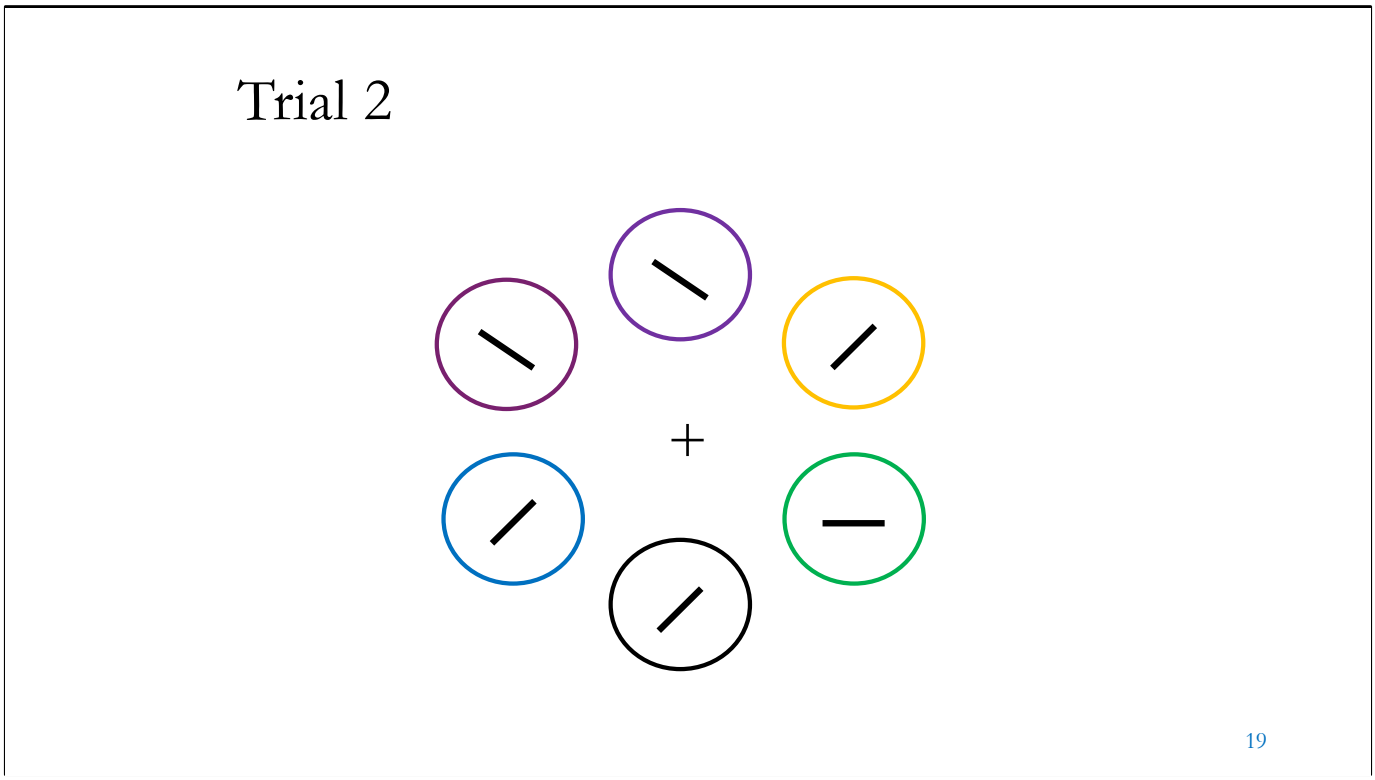
Raise your right hand if the target is horizontal. Raise your left hand if it's vertical

Trial 1

+$1.50

$10.50 total

18



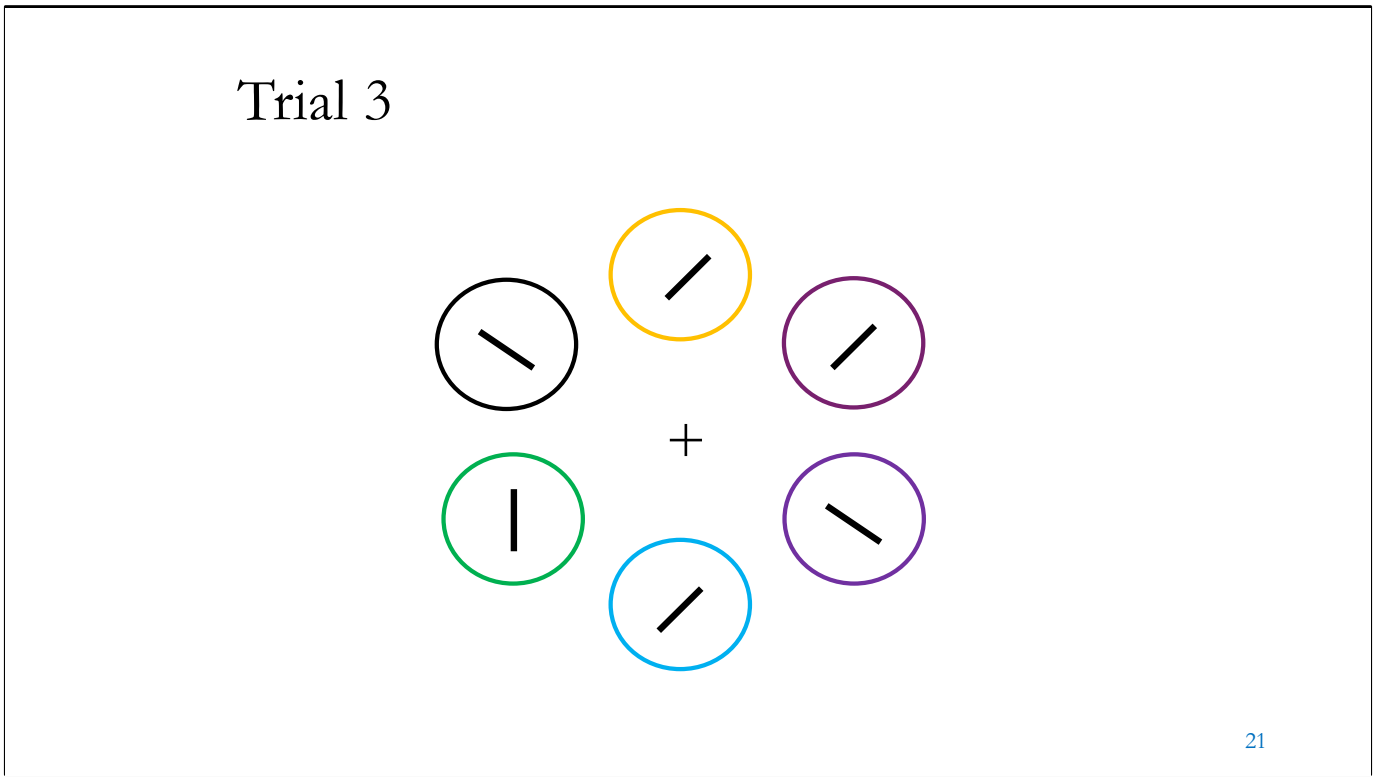
Raise your right hand if the target is horizontal. Raise your left hand if it's vertical.

Trial 2

+.25 cents

$10.75 total

20



Raise your right hand if the target is horizontal. Raise your left hand if it's vertical

Trial 3

+.25 cents

$11.00 total

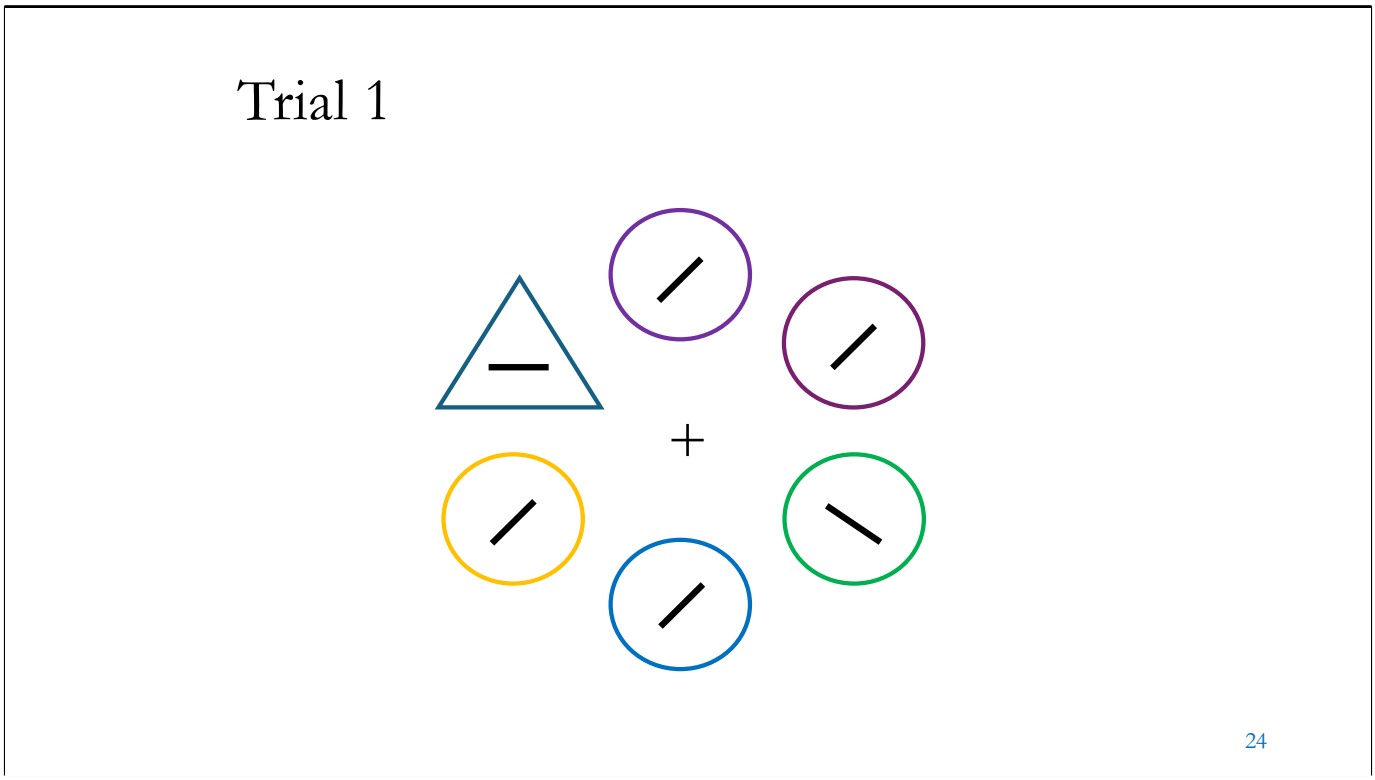
22

Ok. Having fun yet? **Q: What did you learn about the different colours?** That was 3 trials. You will do this for 1200 trials. By the time you're done every cell in your body will know that red predicts high reward and green predicts low reward. Then you will go home, sleep, come back the next day, and have a radioactive tracer injected into your arm. Then the fun really begins!

Test

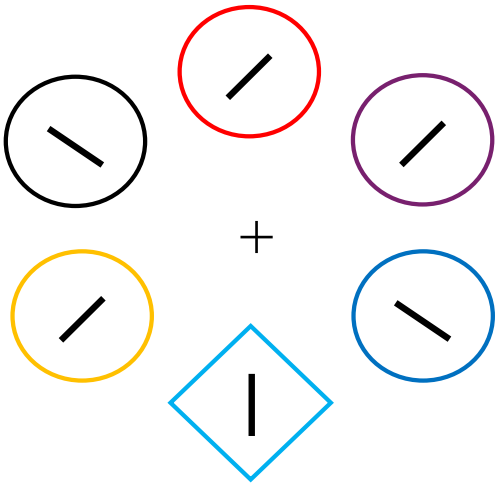
- Scan A:
  - High Reward Distractors (25% trials)
  - Low Reward Distractors (25% trials)
  - No Distractors (50% trials)
- What is the orientation of the bar in the unique shape?
  - Raise your right hand if horizontal
  - Raise your left hand if vertical

Now as you recall there were two different scans, a and b with slightly different versions of the task. This is Scan A and it has a mix of trials with high reward distractors, low reward distractors and no distractors. Now the task is to indicate what is the orientation of the bar in the unique shape – the shape that's different from the others.



Raise your right hand if the target is horizontal. Raise your left hand if it's vertical.
This is a trial with a low reward distractor present

Trial 2



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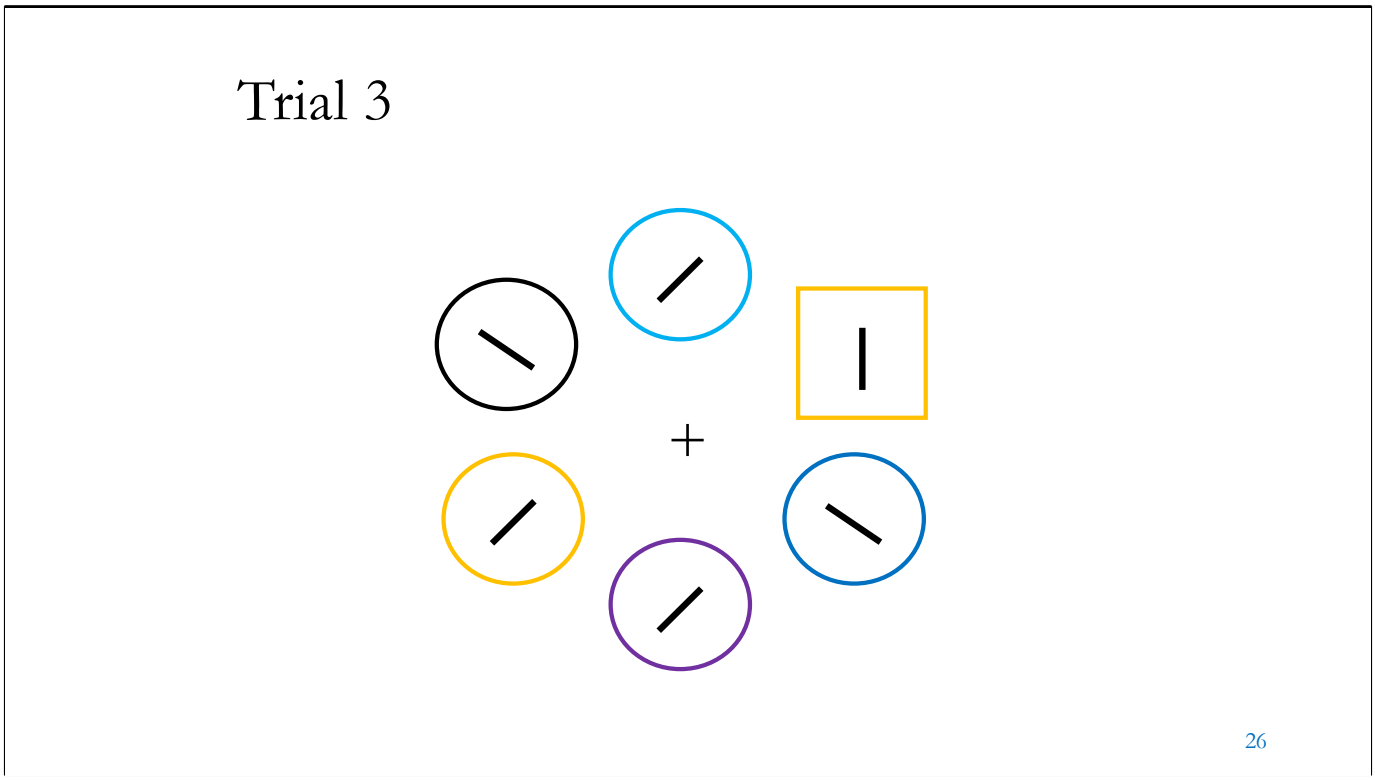
Raise your right hand if the target is horizontal. Raise your left hand if it's vertical . This is a trial with a high reward distractor present



Raise your right hand if the target is horizontal. Raise your left hand if it's vertical This is a No Distractor. This goes on for 1200 trials. When you're finally done, think you can take a break? No there is another scan session to go. If you're thinking of going for lunch don't forget you're attached to an IV.

Test

- Scan B: No distractors
- What is the orientation of the bar in the unique shape?
  - Raise your right hand if horizontal
  - Raise your left hand if vertical

Now as you recall there were two different scans, a and b with slightly different versions of the task. This is Scan A and it has a mix of trials with high reward distractors, low reward distractors and no distractors. Now the task is to indicate what is the orientation of the bar in the unique shape – the shape that's different from the others.

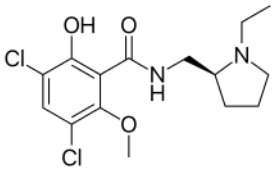
PET (Positron Emission Tomography)

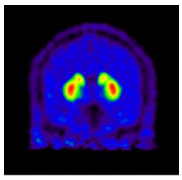
- Radioactive tracers used look at neurotransmitter activity

Questions?

Tracer to measure dopamine (DA) availability

- [^{11}C] Raclopride. A radioactive *tracer* for measuring DA availability
  - 11 Carbon: Radioactive tracer that labels the Raclopride
  - Raclopride: DA *Antagonist:* Binds to DA receptors (D2/D3) & changes availability
  - DV: % Change in Raclopride Concentration:
    - Distractor Present > No Distractor = more DA release in the presence of distractors





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Changes in available DA receptors. This information is also explained in the reading tips. 11 carbon raclopride is a *tracer* used in the PET imaging. [1] 11 carbon is a radioactive isotope that allows you to label the raclopride. [click] Raclopride (without the 11 carbon) is a DA receptor antagonist. Antagonist means it attaches itself to certain types of dopamine receptor (D2 and D3 receptors if you're a DA afficioanado). A receptor is a protein in the membrane of a neuron that is activated by a neurochemical molecule and influences the cell's likelihood of firing. An antagonist blocks a response by binding to the receptor. When you measure raclopride binding twice in two different PET scans, you can interpret the difference in the amount you measure between the scans as a difference in DA release between Scan 1 and Scan 2.

If the index of receptor availability, the nondisplaceable binding potential (BP_{ND}), in the experimental condition is different from the baseline BP_{ND}, then the observed changes in BP_{ND} are attributed to changes in endogenous [DA]. Decreases in BP_{ND} relative to baseline indicate increases in [DA], and increases in BP_{ND} relative to the baseline BP_{ND} indicate decreases in [DA]. **So if there is less binding potential it means more receptors are already taken up with DA. The Raclopride has nowhere to bind to.**

[

Anderson et al.

- Independent Variables
  - Training?
  - Test?
- Dependent Variables

Shout them out! I will leave you to write them down. **Independent variables.** For *Training* the IV was different levels of reward associated with a specific colour. For *Test* Scan: Distractor present and no distractors present. And within distractor present: Rewarding distractor absent, High reward distractor present, low reward distractor present. Region of interest was also an independent variable. They looked at 10, although they focused on Putamen and anterior and posterior caudate. **Dependent variables**: Reaction time in indicating the bar orientation. PET measures of DA availability (raclopride concentrations, or "non-displacable binding potential")

Value-Driven Attentional Capture (VDAC)

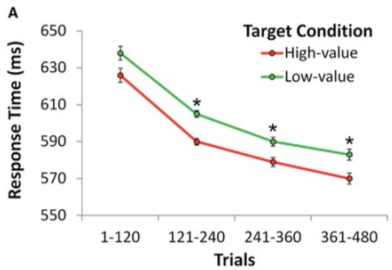
Previously Rewarded Colour (Distractor)

You

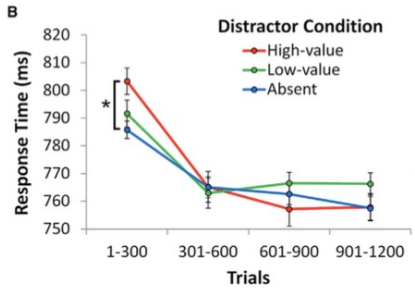
If you're more distracted by the previously rewarded colour, you will be slower to report the orientation of the bar in the target shape

Behavioural Results: Value Driven Attentional Capture (VDAC)

Training



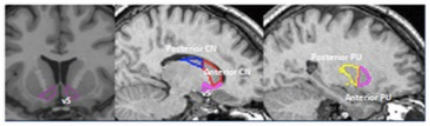
Test

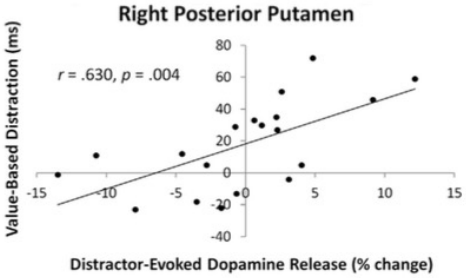


***Training**: Faster RTS for high value targets with learning*
***Test**: High value distractor RT > No distractor RT = VDAC*
***Result**: Greater attentional capture (at first) by high value distractors*

Questions? Let's start by looking at the response time data for the training phase. This happened the evening before. The Y axis is response time. So lower numbers are faster responses The x axis shows blocks of 120 trials. The high value condition is red and the low value condition is green. In training they learned to be faster for high value targets (from 2nd block of trials on) which is an index of appetitive conditioning. In this phase they were directly earning reward, either high or low, when they got it right. [click] In the TEST phase, in the first block of trials, before they learned that there was really no reward related to the distractors (extinction) they were SLOWER to find the target when there was a high value distractor than when there was no distractor (no effect of low value). [click] That meant it captured attention AWAY from the location of what they were supposed to be looking for, just as the image of a cold beer might distract you from studying for a midterm. It acquired INCENTIVE SALIENCE **The difference between high value and distractor absent was the measure of *value-driven attentional capture*.**

Individual differences in DA release





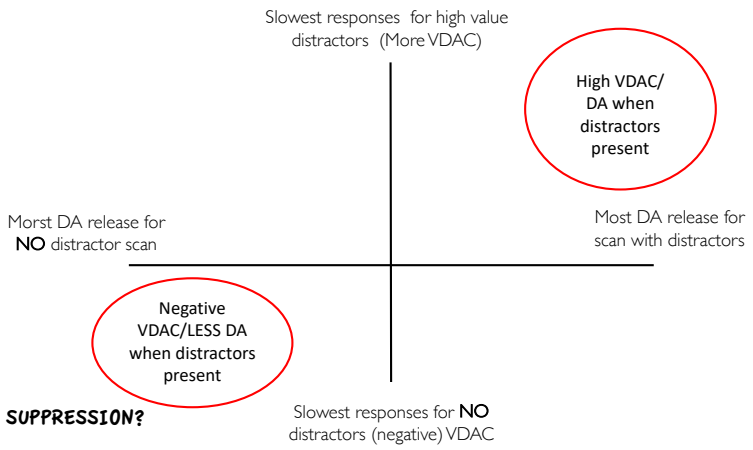
- Group 1: More VDAC & more DA release in scan with distractors,
- Group 2: No or negative VDAC & less DA release in scan with distractors

NOTE. This should be taken with=the caveats of a too-small sample size for correlations. But these patterns are very consistent and they worked hard to control for chance findings (used non-parametric randomization test in which the probability of each correlation was estimated by randomly shuffling the xy pairings 10,000 times. So it is unlikely they are spurious. **Questions?**

They report a similar pattern of results in 3 regions of the striatum, so let's start with the right posterior putamen. **Y axis: Difference in RT between high value distractors and no distractors.** So if it's positive it means that they were slower for the trials with the distractors that had acquired incentive salience. If it's negative it means they were slower for the trials with no distractors. Here most of the negative numbers are close to 0 so it looks more like no attentional capture. **X axis**. This is also a difference or subtraction. **Percent more dopamine release in the distractor present vs no distractor scan**. So larger numbers mean more dopamine release when high value distractors are present, and negative numbers mean there was more dopamine when there were no

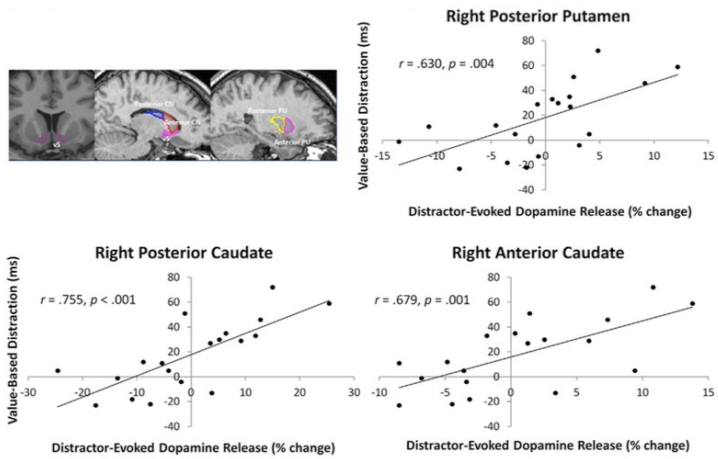
distractors. The more dopamine increased when there were distractors, the more you showed the value-based distraction in that first part of the test phase. Note that for some people it looks like there is more DA release on the distractor absent relative to the distractor present scan. They examined this finding by splitting ps into 2 groups. [click] In the high bias group they showed more dopamine release for distractors and more attentional capture, or RT slowing, in the presence of distractors. [click] In the low-bias group, which showed no evidence of attentional capture, dopamine release was *lower* on distractor-present scans. This suggests a dissociation between groups: Strong value-driven attentional capture is associated with significantly elevated levels of dopamine, whereas the ability to *ignore* previously reward-associated stimuli is associated with less of dopamine release in these same regions.
They also made sure that dopamine release wasn't correlated with individual differences in reaction time in general to make sure the results weren't just reflecting differences in processing speed.

Simplified plot



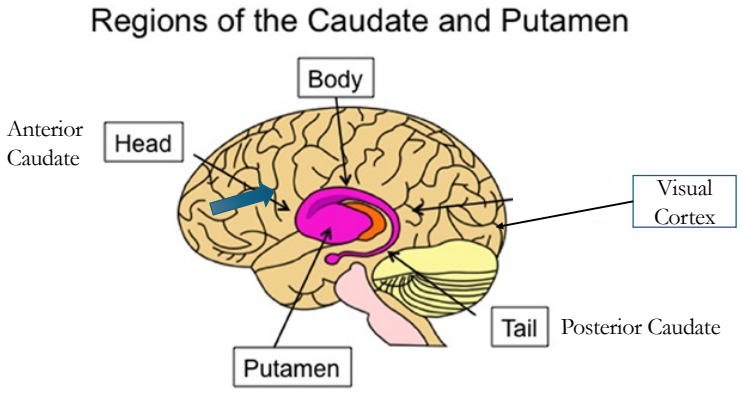
Questions?

Individual Differences in DA release



Questions? AND this pattern was seen in 3 regions in the right posterior caudate and right anterior caudate: **Q : BNS STUDENTS: This is dorsal not ventral striatum. Is this surprising?** These regions are less about prediction error than the ventral nucleus accumbens and more about voluntary motor behavior, habits (learning and using) and motivation related to getting good things.

Caudate & Value-Driven Attentional Capture



Caudate: Role in shifting covert attention, modulation of visual cortex, and **habit**

Questions? The caudate, has been implicated in the shifting of covert attention. More specifically, neural responses in the tail of the caudate have been shown to be sensitive to learned value and play an important role in value-based attentional capture. And the tail communicates with visual cortex. "Given the involvement of this structure in the representation of value and its close connections to the visual system through the caudate tail is well situated to integrate these two sources of information into a value-modulated attentional priority signal " So now we've seen the DAN modulate visual cortex for things that are task relevant (in this task actually looking for the proper target), the amygdala modulate it for emotionally relevant things, and now the caudate for rewardI think the key is HABIT. Anderson suggests – and I agree– that affectively and motivationally biased attention is a habit.

Building a bias

- Crucially: This is the first study linking individual differences in behaviour to differences in changes of DA with learning that builds attentional biases in the first place.

Anderson Summary

- Attention is captured by objects that previously predicted reward, even when they no longer do
- People who are more captured by cues of past reward show more dopamine in the dorsal striatum in the presence of reward cues
- Those who are not captured *show less* DA in the presence of reward cues: Maybe they suppress?
- *Habit:* DA signaling in dorsal striatum is important for involuntary motivated attention linked to addictive behaviour.

Q motivated attention: Is this the same as feature based bottom up attention? If so how? If not what is different?

Learning Objectives: Motivated Attention

- ✓Describe four evolutionarily conserved basic emotional/motivational systems
- ✓Explain ways in which amygdala and mid-brain dopamine systems play a role guiding *motivated attention*
- Evaluate factors that influence individual differences in vulnerability to anxiety, addiction and depression

Depression

- Talk to your neighbor
- What do you think addiction and depression have in common?

Talk to your neighbor for a moment first?

VDAC & Depression

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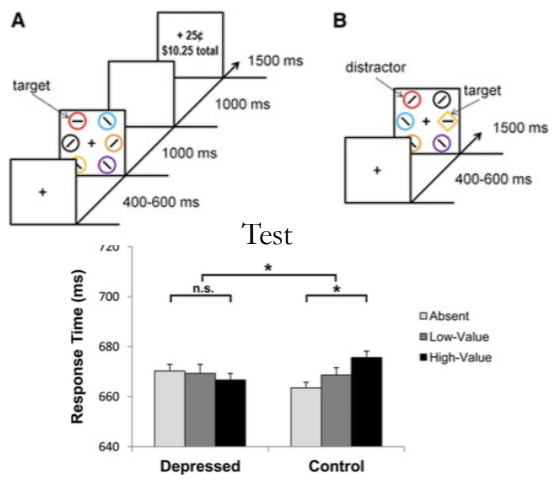
We've been talking about how the promise of reward pulls us towards attending and acting on what we think will give pleasure, sometimes against our interests. But what about when the promise of reward doesn't pull us enough? Now we're going to briefly talk about the other end of the spectrum. Alongside anxiety, depression is extremely common among young people/university students. [1] If DA-driven systems are about seeking and predicting reward, depression is characterized by lack of motivation to seek reward. [2] All of the seekiness and anticipation and hope of the reward system is exactly what has gone missing. You don't expect things that used to give you pleasure to give you pleasure so you don't go out and looking for them. In another study, Brian Anderson and colleagues decided to use the same experimental design as in the PET study to examine whether depression was related to differences in value driven attentional capture. To do so, he gave a version of the task we saw in the PET study task tp a group of participants with diagnoses of clinical depression and a group of non-depressed controls.

No reward bias in depression



- Depressed group
  - No VDAC
  - Not due to inability to learn associations between shape colour and reward

Once again there was a training task where participants had to identify the orientation of a bar in a red or green circle. And again there was a test phase where the the goal was to identify the orientation of a bar in a unique shape. As we saw before, in the test phase, somewhere else on the screen would be a either a circle of the colour that predicted high value rewards, or one that had predicted low value reward, or there was no distractor at all. [1] Here are the results. On the left is the response time data for the depressed group on the right is for the controls.. High value distractors are black, low value dark grey, and distractor absent light gray. Response time is on the y axis. Basically, there is no difference in RT in the presence of a high value distractor in the depressed group. They showed no VDAC. So the authors conclude that it is attentional capture that is blunted during depression **Q:How do you think the depressed group looks in comparison to the suppressors in the last study?** *Suppressors* also showed very little difference between high reward and no reward trials?

Q: But what might be an alternative explanation and how could they have looked at it in this experiment? A. It could be that the depressed participants just don't learn the associations between cues and reward. They examine this by looking at whether they learned to be faster or more accurate for high reward

stim during learning. As it turns out they learned just as well as controls so depression was really linked to lack of VDAC, not to a problem with reward learning. This is important because information you pay attention is is then available for higher-order cognitive processes such as memory and decision-making. Just as attention to threatening information can ramp up negative thoughts and memories and emotions and evaluations, attention to rewarding information can increase positive memories, associations and evaluations. Therefore, in order to promote well-being, it is important that attention be able to select stimuli associated with reward – with good things happening to you.

Take-home

- DA circuitry is important for acquiring incentive salience leading to attentional biases for reward
- Individual differences in DA availability are related to differences in reward-biased attention
- Reward-biased attention is a marker of both addictive behaviour (more) and depression (none)

So bottom line – you can't say is it good or bad to show reward-based attentional capture. It's a normal outcome of learning and it's healthiness depends on the degree to which you see it and situation in which you see it.

Learning Objectives: Motivated Attention

- ✓Describe four evolutionarily conserved basic emotional/motivational systems
- ✓Explain ways in which amygdala and mid-brain dopamine systems play a role guiding *motivated attention*
- ✓Evaluate factors that influence individual differences in vulnerability to anxiety, addiction and depression

A reminder of the learning objectives for this series of three classes, 16-17. We've covered the first of these and are working on the second and third. For this class we are going to focus on reward and mid-brain dopamine systems.

Wrap-up: Attention Classes

- There are many kinds of attention and many brain systems that can guide it. We looked at a few.
- Sustained attention:
  - Multiple processes
  - Brain wide patterns of functional connectivity underlie individual differences

Ok. We've spent the last five classes looking at attention. What are some big picture take-homes?

Wrap-up: Attention

- Selective attention
  - Classic models: Top-down and Bottom-up
  - DAN and VAN *modulate* activity in sensory cortices
  - Motivated attention: Emotional relevance and expectation of reward (DA) also guide attention via amygdala and basal ganglia modulation of sensory cortices
    - Distinct patterns of *attentional bias* are linked to anxiety, depression, and addictive behaviours
- There is still a lot to learn about how all these systems compete with each other to see which one will win out to guide attention in different real-world situations

Next up we will move on to the hippocampus and memory systems.

Next: the Hippocampus, Navigation, and Memory