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## Research Proposal

* Project title: “Effect of incentive motivation on emotional control”.
* Theoretical framework: Growing evidence suggests that motivation and emotion strongly contribute to goal-oriented cognition and play a fundamental role in cognitive control. A limitation of the prior research is that reward motivation and (positive) emotion have largely been studies independently. Thus, the fact that motivation and emotion actively influence cognitive control is well-known, however, whether motivation has an impact on emotional regulation, a component of cognitive control, has not been addressed previously.
* Aims: To address outstanding questions from previous literature, our study aims to investigate how incentive motivation influences emotional control/regulation by combining an emotion-inducing task with an incentivisation mechanism.
* Hypothesis: the motivational value of incentives improves emotional control on at least one emotional expression level (which is either invert (as measured by physiological techniques) and overt (as measured by experience sampling or behavioural measures).
* Main references:
  + Huys, Q.J.M., Renz, D., 2017. A Formal Valuation Framework for Emotions and Their Control. Biological Psychiatry 82, 413–420. <https://doi.org/10.1016/j.biopsych.2017.07.003>
  + Inzlicht, M., Bartholow, B.D., Hirsh, J.B., 2015. Emotional foundations of cognitive control. Trends in Cognitive Sciences 19, 126–132. <https://doi.org/10.1016/j.tics.2015.01.004>
  + Chiew, K.S., Braver, T.S., 2011. Positive affect versus reward: Emotional and motivational influences on cognitive control. Frontiers in Psychology 2, 1–10. <https://doi.org/10.3389/fpsyg.2011.00279>

### To Look more into

* What kind of incentivisation? Monetary? Then should the incentivisation be **explicit** (understood and acknowledged by the participants) or **implicit** (the participants do not know that they need to control their emotions in order to get the incentive).
* Prior experimental research has suggested influences on cognitive control arising from both emotional manipulations, in which valanced subjective experience is directly induced (e.g., with mood inductions or emotional stimuli; Dreisbach, 2006; Dreisbach & Goschke, 2004;Fredrickson & Branigan, 2005;Gray, 2001; Isen & Daubman, 1984;Isen, Daubman, & Nowicki, 1987; Rowe, Hirsh, & Anderson, 2007; van Wouwe, Band, & Ridderinkhof, 2011), and from motivational manipulations, in which motivational state is altered with rewarding or punishing incentives (Chiew & Braver, 2013; Dambacher, Hübner, & Schlösser, 2011; Engelmann, Damaraju, Padmala, & Pessoa, 2009; Jimura, Locke, & Braver, 2010; Locke & Braver, 2008; Padmala & Pessoa, 2011).
* Limitations: motivation can be defined as an internal state that drives behaviour toward a rewarding goal or end point and away from undesirable or punishing outcomes. According to some theorist, **emotion and motivation cannot be considered separately from one another, with emotion as the readout or output of some motivated potential**. Accordingly, when motivationally relevant goals are at risk of not being met (e.g., during goal conflict), negative affect is produced. More highly valued goals in turn produce more intense motivation, and thus generate more negative affect at the prospect of goal failure.
  + Emotion, in our view, is consequently both an output of motivation and an input to the execution of goal-directed behaviour

## Emotional Control

* The consensus in affective neuroscience recognises an **emotion** as **a subjective conscious state arising from a system-level neural activity in response to a highly significant and relevant stimulus** (Barrett et al., 2007; Phelps, 2009). Compared to an emotion, a **mood** is more **long-lasting and less stimulus-bound** meaning that it can result from the cumulative impact of a variety of different stimuli (Eldar et al., 2016; Morris, 1989; Schwarz et al., 2007). In addition to emotion inducing mood changes, moods can also facilitate the expression of a related emotion by influencing its initiation threshold. For instance, a depressed mood can favour the initiation of sadness or anger (Barrett et al., 2007). Thus, emotion and mood are considered as parallel interacting compounds expressed over different timescales (Eldar et al., 2016).
* “**Emotion regulation** involves the **initiation of new, or the alteration of ongoing, emotional responses through the action of regulatory processes**.
* Several schemes have been proposed for organizing regulatory strategies. One distinction suggested by Gross et al contrasts behavioural (e.g. suppressing expressive behaviour) and cognitive (e.g. attending to or interpreting emotion-eliciting situations in ways that limit emotional responding) regulation. **Behavioural regulation** of negative emotions **might limit expressive action but does not dampen unpleasant experience, worsens memory, and increases sympathetic nervous system activation**. By contrast, **cognitive regulation** **neutralizes negative experience without impairing memory and might decrease physiological arousal**” (Ochsner and Gross, 2005)

### Cognitive control

* Cognitive control, and the related concepts of self-control and self-regulation, refers to mental processes that allow behaviour to vary adaptively depending on current goals. It is multifaceted, with one of its core functions being to override, restrain, or inhibit unwanted yet dominant response tendencies.
* What are the factors that prompt control and drive it forward? What are its precise mechanics? Inzlicht et al., 2015 propose that cognitive control is initiated when goal conflicts arouse negative affect. This affect, in turn, makes goal conflicts salient and motivates goal-directed behaviour that functions to resolve the conflict and minimize its recurrence.
* Common self-regulatory task: Stroop task, go/no-go task.
* The motivation and willingness to engage control efforts depends on a trade-off between the expected payoff from a controlled process (e.g., Acquiring some desirable reward or avoiding some undesirable punishment) and the perceived cost of engaging control in terms of cognitive effect.

## Inducing Emotional Changes

In addition to the difficulty linked to the conceptualisation of “emotions”, the operationalisation of emotional reactivity is even more challenging. In an ecological environment, intrapersonal mood changes cannot be controlled or monitored. Thus, a relative board spectrum of techniques has been developed to manipulate variables that might induce **“artificial” mood changes** and are known as **Mood Induction Procedures (MIPs**; Kučera and Haviger, 2012).

### Traditional MIPs (Emotion-Arousing Media)

When the field of affective psychology was still at its infancy, most experiments relied on **emotion-arousing media** (Barrett et al., 2007). Indeed, subjects were commonly presented **films, stories or music extracts** that were highly emotionally connotated (e.g. comic vs dramatic films, minor- vs major dominant music). Those early studies showed interesting effects of mood on a diversity of aspects such as interpersonal attraction (Gouaux, 1971) or the steepness of a hill (Proffitt, 2006). It rapidly became the **standard research method** for inducing mood (Westermann et al., 1996).

However, its efficacy is difficult to quantify, and no manipulation of intensity is possible. (For a longer list of difficulties linked to this please see … REF)

* Does not seems to be the way to go. As quite “outdated”.

### Emotional induction through presentation of faces.

“Another class of stimuli commonly used in emotion research consists of faces with emotional expressions. The muscle patterns of the **six basic facial expressions** have been extensively studied and characterized. The presentation of these faces has been shown to **elicit a range of emotional responses in the perceiver**, including those assessed with facial muscle movements (Tassinary and Cacioppo, 1992), subjective judgments (Zajonc, 1984; Adolphs, 2002), and choices (Winkielman et al., 2005). Paul Ekman and colleagues have developed sets of pictures of facial expressions that have been used extensively in studies of emotion <http://www.paulekman.com/>).” Retrieved from (Phelps, 2009).

* Possible to create an experiment in which the participants should be incentivised in a first-time to search for e.g. how many emotionally loaded faces (sad/anger/fear?) are amongst neutral faces and then to be incentivised to look how many neutral amongst emotional faces. Then evaluate the RTs in both conditions.
* Problem: emotion induction is indirect (could address this by using skin conductance, see later).
* Bigger problem: attentional/lower-level processing might lead to an effect because it was found previously that emotionally loaded faces (especially fear) are processed quicker (Look for References).

One of the primary difficulties in using RT as a measure of emotion is that it is non-specific. Reaction-time differences are generally used as measure of mental processing speed that can be indicative of a number of cognitive, behavioural, and emotional processes. For this reason, it is important that**, when using reaction time as a measure of emotion, the task design does not vary additional factors** (e.g., complexity, conflict) along with the emotion variable of interest. In addition, RT does not indicate which component of emotion is linked to any observed difference in processing speed.

* Seemingly not the way to go or need to look for similar alternatives. Personally, I think we will always face some limitations intrinsically linked to face processing.

### Neuro-computational approach: Reward expectations to induce emotional changes

In contrast, monetary outcomes and quantifiable rewards can be controlled and were found to be very effective at affecting mood (Eldar et al., 2016; Shepperd and McNulty, 2002).

Previous physiological and neuroimaging studies outlined well how the brain reacts to rewards (O’Doherty et al., 2006; Pessiglione et al., 2006; Rutledge et al., 2010). Inspired by those dynamic dopamine functions, Rutledge and collaborator (2014) computed a model of happiness in relation to the neural mechanisms underlying responses to rewards based on behavioural data from a **gambling task** (Rutledge et al., 2014). This computational model states that the **RPEs better explain happiness fluctuations than the increased rewards over time.** Complementing this model, happiness also feeds back onto the valuation of rewards and thus influences decisions (Eldar and Niv, 2015). These studies showcase the **two-way interaction between rewards and mood.** We mainly focus on **rewards that are defined as external quantifiable outcomes**, which might elicit **emotional and motivational responses** (Berridge and Robinson, 1998; Rutledge et al., 2014). Even though there is no linear and straightforward relation between happiness (e.g. life and financial satisfaction) and wealth (e.g. annual income; Easterlin et al., 2010; Kahneman and Deaton, 2010), **quantifiable rewards have been proven to be effective at inducing mood fluctuations** (Eldar et al., 2016; Rutledge et al., 2014; Shepperd and McNulty, 2002). Especially, the RPEs play a key determining factor in momentary happiness.

* It is thus possible to use a **probabilistic reward task** to elicit rapid mood changes (Eldar and Niv, 2015; Rutledge et al., 2014).
  + Eldar and Niv used
  + Rutledge used a **gambling task**
  + Used questions
  + In my previous task, we created two conditions (I.e. high win block and low win block), it is instrumental and probabilistic so that one condition results in generally high amounts of rewards and the other in generally low amounts of rewards.
* A possibility is to play with quantifiable rewards in such a way that it induces emotional/mood changes and integrates a monetary incentivisation. Participants would need to control their emotions in order to maximise their earning. There should be different kinds of incentives to make sure that our procedure still induces efficient emotional changes.
* Idea: resulting from thousands of trials and several labs working on this, we now know that rewards expectations induce changes in mood through strong emotional reactivity (and so we do not need a manipulation check). Thus, we could create an incentivisation procedure in which participants would need to control that emotional reactivity. Maybe in

### Opening to newer techniques (VR?)

“Accurate reproduction of sounds from the real world appears to be necessary to fully capture the realism and richness of a mediated environment.

Thus far, the current results replicate previous findings, indicating that (a) presence is linked to spatial sound reproduction and (b) **emotional reactions vary as a function of immersivity** of the sound field. The present results also indicate that the subjective sense of presence and emotional reactions to the music are highly interrelated. Participants who experienced a strong feeling of presence and a sense of being in the sound field also re- ported stronger emotional reactions. The present results, however, do not give any causal explanation. It might be that people respond emotionally because they experience a higher degree of presence and vice versa.

Some other related possibilities are that (1) the subjective sense of presence is not a separate con- struct from emotional reaction, but a feeling of presence is actually an emotion, or (2) emotions is an integral part of presence. Another possibility is that emotion is determined by presence. Frijda et al. suggested that “emotions are elicited by events appraised as real, and their intensity corresponds to the degree to which this is the case. What is taken to be real elicits emotions. What does not impress one as true and unavoidable elicits no emotion or a weaker one.” Frijda thus concludes that the appraisal of some- thing as being “real” (also if it is taken to be real when they in fact are not), is a necessary condition and determinant of emotion. The present research cannot determine the exact

relationship between presence and emotions, but the present findings show that auditory presence shares a significant amount of variance with emotional reactions

* Could be very efficient at inducing emotional (or more so mood) changes as it is more ecological valid… Really gives the impression of falling so you feel more fear than in case of sole mental imaging.
* However, would maybe be more challenging to find a good incentive to control their emotions. E.g. if you continue for X minutes (even though you just had the scare of your life), you will get the double of your earnings? However, there is might be a risk-aversion effect (cofound variable that would need to be measured before or after)?
* And might be more difficult to assess the efficacy of this procedure? As skin conductance might be altered by the physical activity (unless it is so strong that it will lead to a peak…? Same for measuring heartbeats. Also, more difficult to use experience sampling.
* Also, needs to be controlled... Every participant should have the same experience.
* One possibility could be to create different conditions in which the impression of falling is variable. For a strong fear of falling (is this ethical though), medium and low impression, then see the rates of choosing the incentive.

## Measure Emotional Changes

### Introspective Methods // Experience Sampling

According to the literature, the most direct way to measure mood is to rely on people’s verbal behaviours (Barrett et al., 2007). Indeed, the golden standard of self-report called “**experience sampling**” consists of repeatedly asking subjects to rate their current subjective emotional state (Bylsma et al., 2011; Csikszentmihalyi and Larsen, 1987; Eldar et al., 2016; Rutledge et al., 2014; Rutledge et al., 2017, 2015). In sum, emotional states in the form of momentary happiness can be precisely induced, manipulated, and characterised using neurocomputational models.

Previous authors have **questioned the method of experience sampling**. They consider that self-reported measure of emotions on a scale can be distorted, inaccurate or resulting from biased introspection (Kučera and Haviger, 2012; Nisbett and Wilson, 1977). However, an increasing consensus considers experience sampling as the golden standard in measuring subjective states (Csikszentmihalyi and Larson, 1987; Killingsworth and Gilbert, 2010; Myin-Germeys et al., 2019). Indeed, serval internal measures such as happiness and confidence ratings are **well captured by computational models** (Fleming and Daw, 2017; Rutledge et al., 2014). Additionally, shifts or patterns in ratings have been linked to several mental illnesses making this technique **representative of the clinical state** of the individual. Mood instability is found in patients with bipolar disorder (Jahng et al., 2008) and a negative shift (i.e. lower happiness and confidence) is observed in individuals displaying depressive symptoms (Bylsma et al., 2011; Rouault et al., 2018; Rutledge et al., 2017).

* Even though individuals show disparities in reporting their internal feelings (Lykken and Tellegen, 1996), experience sampling still adequately represent the individual’s subjective state.

### Physiological clues (Skin Conduction, heart rate, …)

One potential disadvantages of **SCR** is that it takes a few seconds for an SCR in reaction to an event to emerge, so the presentation of stimuli has to be separated by several seconds. In addition, other responses, such a button press, can interfere with the assessment of SCR. SCR is a measure of arousal that does not differentiate positive or negative valence, or more specific categories.

* Thus, it would be impossible to use with the VR and might be biased if the participants need to do an incentivisation task simultaneously.

A physiological measure that can be used to assess more specific emotion categories is **electromyography** (EMG). EMG is primarily used to **assess the response of facial muscles in reaction to emotion-eliciting events**. There are two primary ways EMG is used in the assessment of emotion. Either as an index of the magnitude of the startle reflex or to measure responses of muscles that indicate specific facial expressions.

## Effect of Motivation // Incentivisation on Decision-Making

See how monetary incentives concurrently improve and bias confidence judgements (Lebreton et al., 2018).

## Effect of Motivation // Incentivisation on Emotional Control

## Remaining thoughts

It is a possibility that when the induced mood is too strong, it has the opposite effect? Maybe the induced emotion needs to be moderate in order for the participant to be able to control it regardless of the incentives? How would we know if our procedure has the right emotional induction (Piloting??).

## A Formal Valuation Framework for Emotions and Their Control

* Huys, Q.J.M., Renz, D., 2017. A Formal Valuation Framework for Emotions and Their Control. Biological Psychiatry 82, 413–420. <https://doi.org/10.1016/j.biopsych.2017.07.003>

### Using computational psychiatry in the study of Emotions

* Computational psychiatry aims to apply mathematical and computational techniques to help improve psychiatric care (to understand and improve mental health). It is mainly motivated by the **necessity to bring novel statistical and machine-leaning techniques to bear on the rapidly expanding complexity of novel datasets relevant to mental health**.
* Emotions play a crucial role in forging and maintain social relationships, which is a major adaptation of our specially. Emotions are central to mental health, and emotional disorders contribute substantially to the burden of mental illnesses. Thus, as emotions play an important role across many psychiatric disorders, such computational methods must encompass emotions. However, the traditional dichotomisation of emotion and reason might question the feasibility of applying computational techniques to the cores issues of emotion.
* Some have argued to it is imperative for computation psychiatry to address core emotional phenomena which requires the introduction of model-based valuation and meta-reasoning (meta-reasoning considers optimal valuation in the face of resource constraints). Furthermore, there is no single underlying substrate for particular emotions. Rather, each emotional category depends on a distributed network of limbic but also cortical components that reflect the particular neurocognitive processes involved.

### Definition of Emotions

* Key features of human emotions are 1) **correlated physiological psychological and behavioural processes shaped by evolutionarily predefined neural circuitry**; 2) **interpretations or appraisals**; and 3) **conscious verbal self-report about emotion**s.
* Basic emotion theories suggest that there are a limited, relatively fixed, number of universal, evolutionarily shaped, culture-independent, and neurobiologically hard-corded emotional categories including happiness, surprise, sadness, disgust, anger and fear. They represent a set of innately interlinked physiological, behavioural, and psychological processes that are triggered in an inflexible manner by salient stimuli.
* Human emotional responses to stimuli are characterised by substantial within- and between-subject variability. Appraisal theory locates one explanation for this variability in the interpretation (be it conscious or unconscious) of a particular situation or stimulus as being relevant to the individual’s goals (thus the interpretation depends on the goa and the individual’s beliefs).
* The evidence for discrete emotions is controversial. Autonomic responses, electroencephalographic features, and facial expressions **do not permit simple categorisation** and show little evidence of the predicted correlations, though **newer machine learning approaches have shown that categorical information can be extracted from physiological and neural data** (Wager et al., 2015).
  + By using **hierarchical Bayesian modelling** of 2200 participants, Wager et al. found that the **each of the five basic emotions is associated with unique, prototypical patterns of activity across multiple brain systems including the cortex, thalamus, amygdala, and other structures**. Furthermore, the model provides a precise summary of the prototypical patterns for each emotion category and demonstrated that a sufficient characterisation of emotion categories relies on 1) differential patterns of involvement in neocortical systems, and 2) distinctive patterns of cortical-subcortical interactions. They are consistent with componential and constructionist views, which propose that emotions are differentiated by a combination of perceptual, mnemonic, prospective, and motivational elements.
* An alternative view is that the **discreteness of emotions arises from the categorical labelling of internal events for the purpose of intra- and intersubject communication**. The **ventrolateral prefrontal cortex** is involved in categorical labelling of emotional states evolving along the two major axes of valence (from good to bad) and arousal (from high to low). Factor analyses of a variety of measures of emotions including similarity ratings among words, facial expression, and autonomic measures reliably identify these two separate dimensions (Russell, 2003). Neuroimaging has also been used to argue that while the amygdala tracks arousal, the orbitofrontal cortex tracks valence across emotions (Wilson-Mendenhall et al., 2013).

### Model-based and Model-Free accounts of emotional expression

* Computationally, inferring adaptive choices involves integrating not only immediate rewards, but also longer-term rewards, and for that reason requires consideration of the future course of events. Specifically, valuation involves summing over an exponentially expanding decision tree of future possibilities. Optimal valuation would search the entire tree, which is rarely feasible. Reinforcement learning is a thriving subfield of machine learning concerned with algorithmic solutions to this problem.
* A substantial body of work has related an algorithmic solution to optimal valuation problem (valuation involves summing over an exponentially expanding decision tree of future possibilities. Optimal valuation would search the entire tree, which is rarely feasible) to how emotional expressions change over time (Bach and Dayan, 2017).
  + In a so-called model-free reinforcement learning, the stability of the world is exploited to replace integration over the future with actual past experience. They used Bayesian decision theory to conceptualise emotions in terms of their relationship to survival-relevant behavioural choices. Decision theory indicates which behaviours are optimal in a given situation. They thus conjecture that the brain uses a range of pre-programmed algorithms that provide approximate solutions. These solutions seem to produce specific behavioural manifestations of emotions and can also be associated with core affective dimensions.

### Meta-reasoning

* Model-based inference is mostly impossible due to the sheer size of most relevant model-based valuation problems. Optimal decision in realistic situations are computationally extremely demanding. The limited resources lead to the meta-reasoning problem, which concerns the optimal deployment of the available computational power. The estimated value of performing a computation is the difference in expected utility between taking a choice without the additional computation, and taking a new alternative choice after having invested in the computation. Stimulations do not actually incur the costs of the real problem, and while taking real poor actions should be avoided to avoid incurring their loos, internally simulating poor actions can be useful.

### Emotions implement approximate meta-reasoning strategies.

* Model-based reasoning is hence faced with two profound challenges, 1) the size of the problem and the even harder task of apportioning limited resources in an adaptive manner. Emotions have been proposed to be able to implement approximate solutions to these challenges. In particular, emotional states 1) come with a strong focus on particular behaviours and 2) induce a strong perceptual and processing focus such that evaluation is concentrated on a narrow set of states. Emotions thereby effectively function as approximate meta-reasoning strategies that prescribe how computational resources are allocated.
* Action tendencies.
  + One of the features of emotions is that they prioritise certain actions. Constraining the action space can substantially simplify the valuation problem because the computational cost is exponential in the size of the action space.
  + Emotions also induce physiological and vegetative changes. A preparatory increase in heart rate to compensate for the anticipated drop in peripheral resistance upon supplying blood to large muscle groups is required when running. As such, these can be seen as a preparation toward a class of behaviours that share physiological requirements
* State observation
  + The complexity of model-based evaluation is also exponential in the range of states considered. There is ample evidence for emotion- or mood- congruent processing biases. By restricting attention to particular states and disregarding others, the problem could again be reduced in size, for instance by pruning searches along branches of the decision tree that result in states outside the attentional focus.
  + By asserting the state, the complexity results from the computational task of valuation because policies for the various possible states can be reduced. Introspection about the state of the body likely plays a particularly important role.

### Controlling Meta-reasoning Strategies

* If there are multiple approximate metareasoning strategies, then there must be some control over which is deployed when.
  + The first source of control is likely evolutionary. Species-specific responses provide a bias toward evaluating particular actions.
  + The second source of control could be model-free. Etkin et al. have recently argued for a model-free component in serial adaptations in the emotional conflict task (Etkin et al., 2015). Model-free learning has been argued to account for learning in strategy selection: with repeated experience, individuals can slowly increase their frequency of using adaptive strategies for solving problems.
  + The third evaluative process for emotions allows for knowledge to be incorporated in the form of heuristics. Individuals can access approximate measures of how adaptive a particular cognitive strategy is, and use this to guide their choice. In the affective domain, misguided beliefs or schemas about the adaptiveness of strategies relate to a number of pathological emotion regulation phenomena. People who dislike emotion regulation are more likely to respond with anger to provocation (Etkin et al., 2015). Depressed persons are not impaired at emotion regulation strategies such as positive imagery to iprove their mood, but they have a reduced tendency to employ them (Ehring et al., 2010).
  + The fourth evaluative process could be model-based, where the precise consequences of particular emotions are examined and evaluated. Psychotherapy allows patients to learn to consciously and explicitly assess whether a particular emotion is appropriate and helpful in a given situation, and to adapt it by using reappraisal and other emotion regulation strategies if necessary.
    - * Emotions may have a potentially important role in facilitating model-based decisions by functioning as internal strategies to allocate computational resources. But also, different processes can lead to adaptive or maladaptive deployment of emotion strategies.
      * This computational framework of emotions contrasts with the view of basic emotions as relatively fixed behavioural and physiological action packages by reflecting the lack of identifiably discrete physiological or behavioural patterns of single neurobiological cause. Rather, it emphasizes the importance of emotional processes in more complex decision-making settings.
      * The complexity of the model-based valuation required for the ability to account for appraisal and contextual effects, led to the notion of approximate metareasoning strategies. These approximate strategies are necessarily often suboptimal and may capture the prototypical adverse influences of emotion on cognition. The focus on valuation is compatible with models emphasizing predictions must be about long-term utility, and that emotions play a key role in facilitating such predictions, albeit approximately.
      * Situations with a higher estimated value of computation should recruit neural resources more extensively, and hence be more likely to involve the brain-wide states postulated as representing the global workspace. It had also been suggested that the component processes in verbal self-report involve an introspective component followed by a classification process.

## Paradigms Used

* LOCKE, H.S., BRAVER, T.S., 2008. Motivational influences on cognitive control: Behavior, brain activation, and individual differences. Cognitive, Affective, & Behavioral Neuroscience 8, 99–112. <https://doi.org/10.3758/CABN.8.1.99>
  + While undergoing fMRI scanning, participants engaged in a continuous performance task, the AX-CPT, which was specifically de- signed to measure cognitive control in terms of the ability to utilize and maintain contextual cue information to bias attention and action.
  + Target AX trials occur with high frequency (70%), creating specific expectancies and response tendencies that can be examined, such as on AY trials (10%) that feature the usually reliable cue A but not the X probe, and on BX trials (10%) that have the X probe without the necessary A cue.
  + The AX-CPT task was performed in three conditions: baseline, reward, and penalty. Participants performed a total of 120 trials in each condition. The baseline condition had standard frequencies of each trial type (AX = 70%, 84 trials; AY, BX, BY= 10%, 12 trials each). In the reward and penalty blocks, 80% of the trials were as above, with approximately the same frequency rates as in the base- line condition (60 AX trials, plus 12 each of the AY, BX, and BY). The remaining 20% of trials (24 total) were no-go trials, indicated by an underlined probe letter, which required participants to withhold their response. These no-go trials were included for the purposes of the penalty incentive condition, described below, and were not predicted to have a strong impact on AX-CPT performance, other than by slowing overall RT. Moreover, any RT slowing caused by the inclusion of no-go trials in the reward condition relative to baseline should have reduced any tendency to observe any reward-related improvements in task performance.
  + Participants performed the baseline condition first, without any instruction that future blocks would be performed with financial incentives. The next two conditions were the reward and penalty blocks, which were performed in counterbalanced order across participants. During reward blocks, 25 cents was offered for each trial faster than the participant’s median RT in the baseline blocks. The default reward rate if performance remained unchanged would be 50%, so there was room for significant improvement. During penalty blocks, participants were told that $3 would be subtracted from their payment for each no-go trial on which they failed to withhold their response. Feedback regarding reward or punishment was given following each trial
* Dreisbach, G., 2006. How positive affect modulates cognitive control: The costs and benefits of reduced maintenance capability. Brain and Cognition 60, 11–19. <https://doi.org/10.1016/j.bandc.2005.08.003>
  + Each trial started with the presentation of a picture for 400ms followed by a blank screen for 100ms. The cue appeared for 300ms, followed by a short (250ms) or long (1250ms) cue target interval (CTI). After that the probe was presented and remained on the screen until a response was given.

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