**PROJECT PROTOCOL**

**Project Title**

Emotional Metamemory

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## Abstract

Emotional states, and their physiological components, influence both perception and memory. For example, evidence from our lab and others suggests that arousing stimuli can influence both our perceptual decisions (“what did I see?”) and our confidence in those decisions (“How sure am I?”) (Allen et al., 2016; Hauser et al., 2017). In the context of memory, arousal exerts a well-known effect on the acuity and content of free recall, as for example in the “lightbulb” effect in which memory for traumatic, exciting, or otherwise emotionally arousing events is heightened. Similarly, evidence suggests that negative and positive events (i.e., emotional ‘valence’) exert unique biases on behavior; participants display overconfidence for positive outcomes (i.e., the ‘optimism bias’). However, to our knowledge no experiment has investigated whether arousal and valence also influences *metacognition* for memory (metamemory). This project will adapt a pre-existing task for measuring the sensitivity, bias, and efficiency of metamemory for positive and negative words of variable arousal levels. Further, we will test whether evoked heart-rate changes during cued-recall mediate the influence of decision accuracy on confidence.

**Main Hypotheses**

**Null Hypothesis: *No Effect of Emotion on Meta-Memory***

Under the null hypothesis, we expect to observe no effects of stimulus arousal or valence on confidence or metamemory. This would imply that metacognition is insensitive to emotional inputs, even in the presence of altered accuracy. Statistical support for this hypothesis will be calculated using null Bayes factor analyses. Here, heart rate will have no effect on the confidence-> accuracy correlation.

## Alternative Hypothesis 1A: *Arousal-Mediated Improvements in Memory Signal to Noise Ratio are Independent of Valence*

Under this hypothesis, we expect to see a main effect of stimulus arousal on the recall accuracy and confidence, with no interaction of stimulus valence. This would suggest that arousal serves to sharpen or clarify the stimulus representation in memory, and that metacognition appropriately accounts for this sharpening. Here we would also expect heart rate to mediate the influence of accuracy on confidence, but with no difference between valence conditions.

***Alternative Hypothesis 1B: Valence Bias in Meta-Memory***

Under this hypothesis, we also expect to see a main effect of stimulus arousal on recall accuracy and confidence. However, here we expect this effect to depend on the stimulus valence, such that metamemory will be improved for positive-valence items and reduced for negative-valence items. Under this account, the sharpening effects of arousal on stimulus representation interact with the biasing influence of stimulus valence. Here we would expect heart rate to mediate the influence of accuracy on confidence in a valence-dependent interaction.

**Hypothesis 2: Arousal & Valence-Mediated changes in Heart Rate variability and Respiratory cycles**

As a positive control of our metamemory task we record fluctuations in heart-rate and respiratory cycles to check if there’s a measurable physiological effect of our manipulation.

**Testing Hypothesis**

Our primary analyses will consist of 2x2 Repeated Measures ANOVAs on d’, m-ratio, average confidence, and reaction time. These will be conducted in JASP using frequentist statistical tests, alpha level = 0.95. Additionally, we will split trials into correct vs incorrect trials and estimate a 2 (valence) by 2 (arousal) by 2 (correct/error) ANOVA on average confidence ratings. In the case of any non-significant (i.e., null) effects we will re-run these tests using the equivalent Bayesian test under the default Cauchy prior = 0.707 in order to assess the evidence for the null hypothesis.

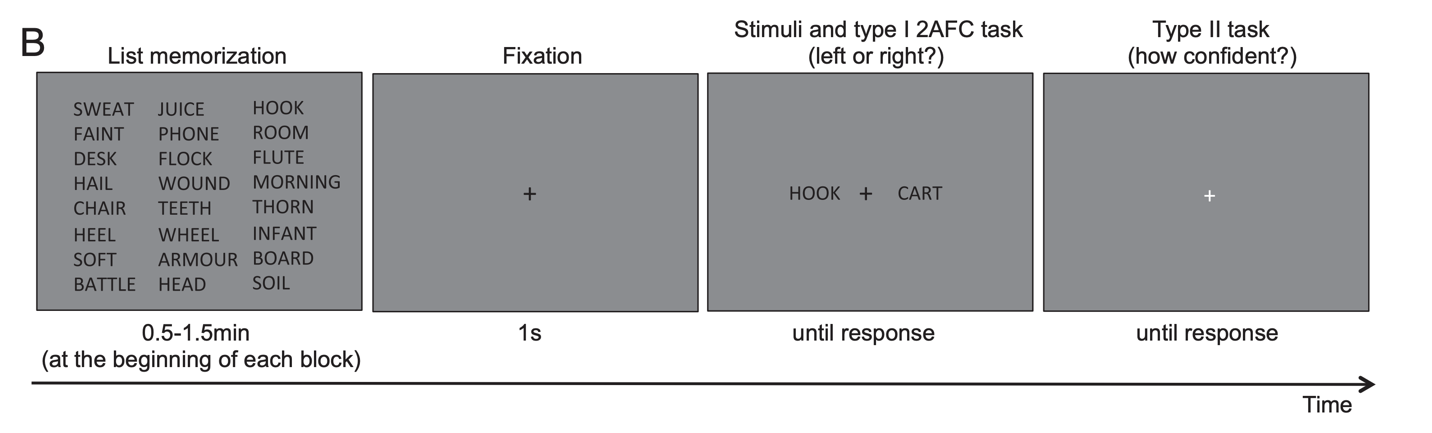
**Choice and motivation for priors**

The choice and motivation for priors used in the BFA are based on the default prior settings recommended by the authors of JASP and the underlying statistical packages in R (e.g., E.J. Wagenmakers and Richard Morey). These are justified as delivering an optimal tradeoff between type 1 and type 2 errors; in particular in exploratory studies such as ours in which there is no available prior information about effect sizes. These tests will thus deliver a conservative estimate of the evidence for the null, relative to the alternative model specified by our design.

For references, please see here <https://link.springer.com/article/10.3758/PBR.16.2.225> and here <https://psyarxiv.com/yqxfr>

## Paradigm structure: memory task + rating questionnaire

## The experiment takes place in two components. In the first component (45 minutes), the metamemory task, participants complete 12 blocks of the cued-recall task with short breaks in between each block. In the second component (15 minutes), participants complete a short subject visual analog scale rating of the valence, arousal, and ‘embodiment’ of all of the previously shown words. For the meta-memory task, we will adapt a commonly used measure of meta-memory, see e.g., https://www.jneurosci.org/content/33/5/1897 as a key reference (Baird, Smallwood, Gorgolewski, & Margulies, 2013; McCurdy et al., 2013; Rouault, McWilliams, Allen, & Fleming, 2018). Participants will make a two alternative forced-choice judgement for item pairs, to discriminate which of the two stimuli have been seen previously in a memorized list. We will adapt this task so that each block will alternate pseudo-randomly between each level of our 2 by 2 factorial design, with factors Valence (Positive vs Negative) and Arousal (High vs Low). The block order will be pseudorandomized and counterbalanced across participants to ensure no block to block repetition of arousal condition.

Behavioral tasks. Participants p -AFC tasks. ***A***, Visual task. Participants viewed two circular stimuli that were presented

y to the left and right of fixation; one stimulus contained only visual noise, and the other

At the beginning of each block of 50 trials, participants study a list of words arranged in 10 rows and 5 columns (an 8 row × 3 column is shown here for ease of display). In each trial, participants viewed two words presented simultaneously to the left and right of fixation; one word had been presented on the study list and the other hand not. Participants performed a 2-AFC judgment, indicating which word (left or right) was on the previously studied list. Subsequently, participants rated how confident they were that their 2-AFC judgment was correct using a 6-point Likert scale (not shown on the screen). Both responses have to be provided within 5 s.

Stimuli will be the top 600 most and least arousing words, divided equally by positive and negative valence, all derived from the “[Affective Norms for English Words](https://www.uvm.edu/pdodds/teaching/courses/2009-08UVM-300/docs/others/everything/bradley1999a.pdf)” database. Because a full-blown double translation and revalidation in Danish is not possible for this study, all participants will be selected for having a high level of English fluency, and measures of heart rate variability and respiratory cycles and subjective arousal ratings by stimulus condition will provide manipulation checks. ANEW has been normed in Dutch and Italian populations, showing good overall consistency in European samples (Montefinese, Ambrosini, Fairfield, & Mammarella, 2014; Moors et al., 2013). In order to better assess the word ratings from our sample, we will ask participants to rate valence and arousal of the tested words with an internet-based questionnaire taken at home after the primary experiment. Therefore, we aim to revalidate ANEW words’ rating with the original procedures and will further check whether stimuli successfully induced a change in heart rate acceleration of our subjects.

**Participants**

Participants (n=35) will be recruited through advertisements via Sona system (CFIN) from Aarhus University and also via social media (Facebook). Participants must be at least 18 years old, give written consent, be normal or corrected to normal vision and fluent in English. Participants will be compensated with 200 DKK for their participation. The estimated total duration of the test session is 1,5 hours and they will also be required to answer the internet-based rating questionnaire at home requiring up to 30 minutes time to complete.

**Data Acquisition**

We will record behavioral data together with participants’ heartbeat during the memory task. For this we will use a pulse oximeter, a noninvasive device for monitoring a person's peripheral oxygen saturation. This is a safe, painless procedure. We do the recording of signals for the purpose of heart rate variability calculations. Participants will then carry out the memory task (practice and detailed instructions will be shown at the computer screen), and should, at the end of the experiment, complete some ratings about the words seen. As the pulse oximeter only provides beat-to-beat intervals, rather than complete QRS waves, the device cannot be used for any medical diagnosis. This will be made clear to participants in their information sheets.

**Data Analysis**

For the Metacognitive aspect of the experiment, we’ll be measuring the d-prime (sensitivity) for recall accuracy, and the m-ratio for metacognitive efficiency, as estimated by a signal theoretic model of metacognition (Fleming & Lau, 2014). Furthermore, we will fit an exploratory hierarchical linear model (mixed effects) describing how the influence of trial-by-trial accuracy on participants’ confidence ratings are mediated by fluctuations in heart-rate.

**Perspectives**

Consistent with the COBIDAS guidelines for reproducibility in neuroimaging and psychological research, all core analyses, hypotheses, and associated power calculations will be pre-registered prior to data collection using the OSF template at our associated project page (<https://osf.io/pefnr/>), which will be made public at the time of preregistration. Additionally, all stimuli, code, task materials, and fully anonymized behavioral data will be made available on the OSF project website. Furthermore, the results will be written up and preprinted at an appropriate repository regardless of the results, safeguarding against a ‘file drawer’ effect.

The study of emotional metamemory will allow us to provide a behavioral insight into the role of cognitive and emotional processing in memory and metamemory. It will help us to better understand how people monitor their own decisions, which in the future may inform psychiatric studies in patient populations who we know have pervasive deficits in such type of task. The study may also have implications for legal policy, i.e. understanding the source of biases in eye-witness testimony.

This project will be conducted at the CFIN, at Aarhus University Hospital, by Sebastian Scott Engen, under the main supervision of Micah Allen. In addition, postdocs Camile Correa and Nicolas Legrand will be collaborators supervising the coding of all tasks and data analysis.

**Risks**

There are no risks associated with the experiment.

**Biological Material**

No biological material will be used.

**Personal data**

Data will be anonymized and stored safely after the termination of the project, in accordance with the stipulations in the General Data Protection Regulations and other relevant Danish legislation.

**Economical support**

This project is supported by a Lundbeckfonden Fellowship (R272-2017-4345), and a grant from the AIAS-COFUND II fellowship programme that is supported by the Marie Skłodowska-Curie actions under the European Union’s Horizon 2020 (Grant agreement no 754513), and the Aarhus University Research Foundation. These funders have no role in the design, analysis, or publication of any results from this project. The project group has no affiliation with private companies, foundations, or other potential conflicts of interest. There are no plans for sponsorship of commercial interest.

**Benefits for participants**

Participants will receive 150 DKK as compensation for their participation in the experiment plus 50 DKK when answering an internet-based questionnaire, to be completed at home. The total amount (200 DKK) is liable to tax and will therefore be reported to the Danish tax authorities as B-income. The expected duration of the memory study is 1,5 hours, plus the variable time to reply to the internet-based questionnaire.

**Recruitment procedure and informed consent**

*Recruitment procedure*

* The volunteer participants will be recruited through advertisements at Aarhus University and Aarhus University Hospital. The advertisement may be published in the local press and Facebook.
* The announcement will inform potential participants about the project (brief description), the inclusion criteria, and the amount of compensation for participation. People who show interest in the announcement can contact, by phone or mail, the main investigator to make an appointment at CFIN to receive oral and written information.
* Written information about the participant’s rights in the study will be sent by e-mail and also given in paper form at an information meeting. The person responsible for the project, will provide them with further details about the experiment. During this session, it will be emphasized that participation is voluntary and that the potential participant can withdraw at any time from the study.
* The conversation takes place in a quiet place where it is possible to have an undisturbed conversation.
* Participants are informed that they can bring a bystander at any time.
* Participants are given ample time to make a decision to participate (National Scientific Committee recommends 24 hours).
* Written informed consent will be collected before the investigation begins. No part of the study is commenced without the written information consent.

*Oral Information and for Obtaining Informed Consent*

When a potential participant contacts the responsible of the project, the following should be stated:

* That it is a request to participate in a scientific research project.
* That participation is voluntary, and the subject can withdraw from the project at any time.
* That the potential subject has time to consider his/her participation before giving consent to participate in the project and that the potential subject is welcome to bring a family member or a friend to the information meeting. The potential volunteer will receive a leaflet which includes information on confidentiality, right of access to documents and right to complain.
* That the participant Information will be forwarded by mail/e-mail to the potential subject in order for him/her to know more about the project before experiment.
* Finally, time for the experiment is arranged.

**Publication of Results**

Authors will acknowledge that the study was funded by the Lundbeck fellowship and AIAS (Micah Allen). Authorship will be determined in accordance with the ICMJE guidelines and other contributors will be acknowledged. Positive, negative and inconclusive results arising from the project will be published in international scientific journals, in accordance with the guidelines specified in the “Danish Code of Conduct for Research Integrity” (2014).

**Ethical considerations**

The study is conducted according to the Helsinki Declaration II, and will only commence after approval by the Institutional Review Board of the Danish Neuroscience Center. The study has no side effects, risks or benefits to subjects. All subjects are volunteers and will formally agree (written information consent) with the methods carried out in the experiment as explained in the Participant Information. Participants can retract their consent at any time and are allowed to leave the study without having to justify this choice and will not be subject to any form of mental / physical pressure to complete the study. Additional information about the project can be provided to the participants before, during, and after the completion of the experiment.

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