**PROJECT PROTOCOL**

**Project Title**

Emotional Metamemory

**Applicant and Contact Person**

Primary Investigator

Sebastian Scott Engen – Bachelor student in Cognitive Science (AU).

E-mail: [201708490@post.au.dk](mailto:201708490@post.au.dk)

Center for Functionally Integrative Neuroscience (CFIN).

Nørrebrogade, 44, building 1A, ground floor, room 35a.

Aarhus University.

Primary Supervisor

Micah Allen (M.A.) PI.

E-mail: [micah@cfin.au.dk](mailto:micah@cfin.au.dk).

Center for Functionally Integrative Neuroscience (CFIN).

Nørrebrogade, 44, building 1A, ground floor, room 38.

Aarhus University.

Contribution

Camile Correa (C.C.) – ECG postdoc at CFIN

E-mail: [correa@cfin.au.dk](mailto:correa@cfin.au.dk)

Center for Functionally Integrative Neuroscience (CFIN).

Nørrebrogade, 44, building 1A, ground floor, room 35a.

Aarhus University.

Contribution

Nicolas le Grand (N.L.)- ECG postdoc at CFIN

E-mail: [nicolas.legrand@cfin.au.dk](mailto:nicolas.legrand@cfin.au.dk)

Center for Functionally Integrative Neuroscience (CFIN).

Nørrebrogade, 44, building 1A, ground floor, room 35a.

Aarhus University.

## 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, heartrate 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 heartrate to mediate the influence of accuracy on confidence, but with no difference between valence conditions.

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

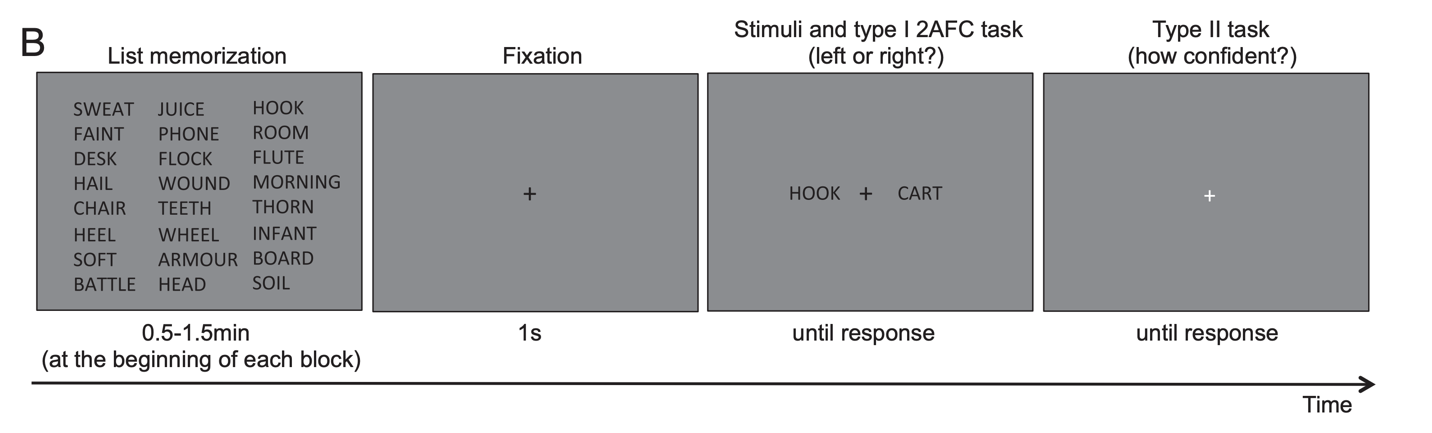
Under this hypothesis, we also expect to see a main effect of stimulus arousal on recall accuracy and confidence. However, here we expect this effect to depend on the stimulus valence, such that metamemory will be improved for positive-valence items and reduced for negative-valence items. Under this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

## Paradigm structure

## 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 heartrate variability and respiratory cycles and subjective arousal ratings by stimulus condition will provide manipulation checks. However, 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).

**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 paid 100 DKK per hour and the estimated total duration of the test session is 1,5 hour (150 DKK).

**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 a 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 stored after termination of the project. All participant’s data will be anonymized. Data is stored in accordance with the stipulations in The Danish Personal Data Protection Act (Persondataloven) and other relevant Danish legislation.

Names and contact details of participants will be assigned to a numerical subject code and will be stored in a password-protected and encrypted file according to CFIN standard procedures. Access to this file is only granted to the authorized personnel. Project staff and experimenters will only have access to the data in an anonymous format.

**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 DKK 100 per hour as compensation for their participation in the experiment. The amount is liable to tax and will therefore be reported to the Danish tax authorities as B-income. The expected duration of the study (preparation included) is 1,5 hours (150 DKK).

**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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