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# Feedback from the Heart: emotional learning and memory is controlled by cardiac cycle, interoceptive accuracy and personality

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## Introduction

Feedback processing is critical to trial-and-error learning. Here, we examined whether feedback processing during the learning of emotional face-name pairs was influenced by interoceptive signals concerning the state of cardiovascular arousal (Garfinkel et al., 2014), with subsequent effects on retrieval.

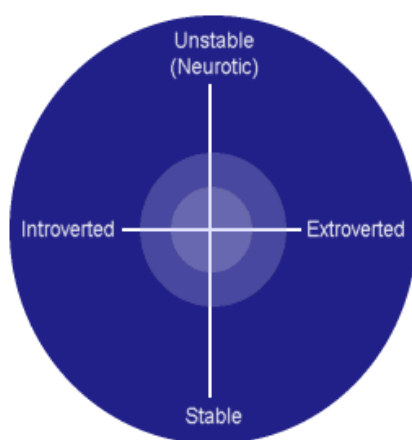
### CARDIOVASCULAR AROUSAL



States of cardiovascular arousal (stronger, faster heartbeats) are signalled to the brain by the activation of arterial baroreceptors (pressure sensors) in the great vessels leaving the heart. When the heart contracts to eject blood (at **systole**), aortic and carotid baroreceptors fire. Baroreceptors are quiet between heartbeats (at **diastole**).

➡ We hypothesised that auditory feedback delivered at systole would lead to better learning and/or retrieval of fearful faces (Garfinkel & Critchley, 2016).

➡ Participants with high interoceptive sensitivity (an ability to detect their own heart beats without manually checking) were expected to show enhanced cardiac timing effects during learning and retrieval (Garfinkel et al., 2013).



### PERSONALITY and AROUSAL

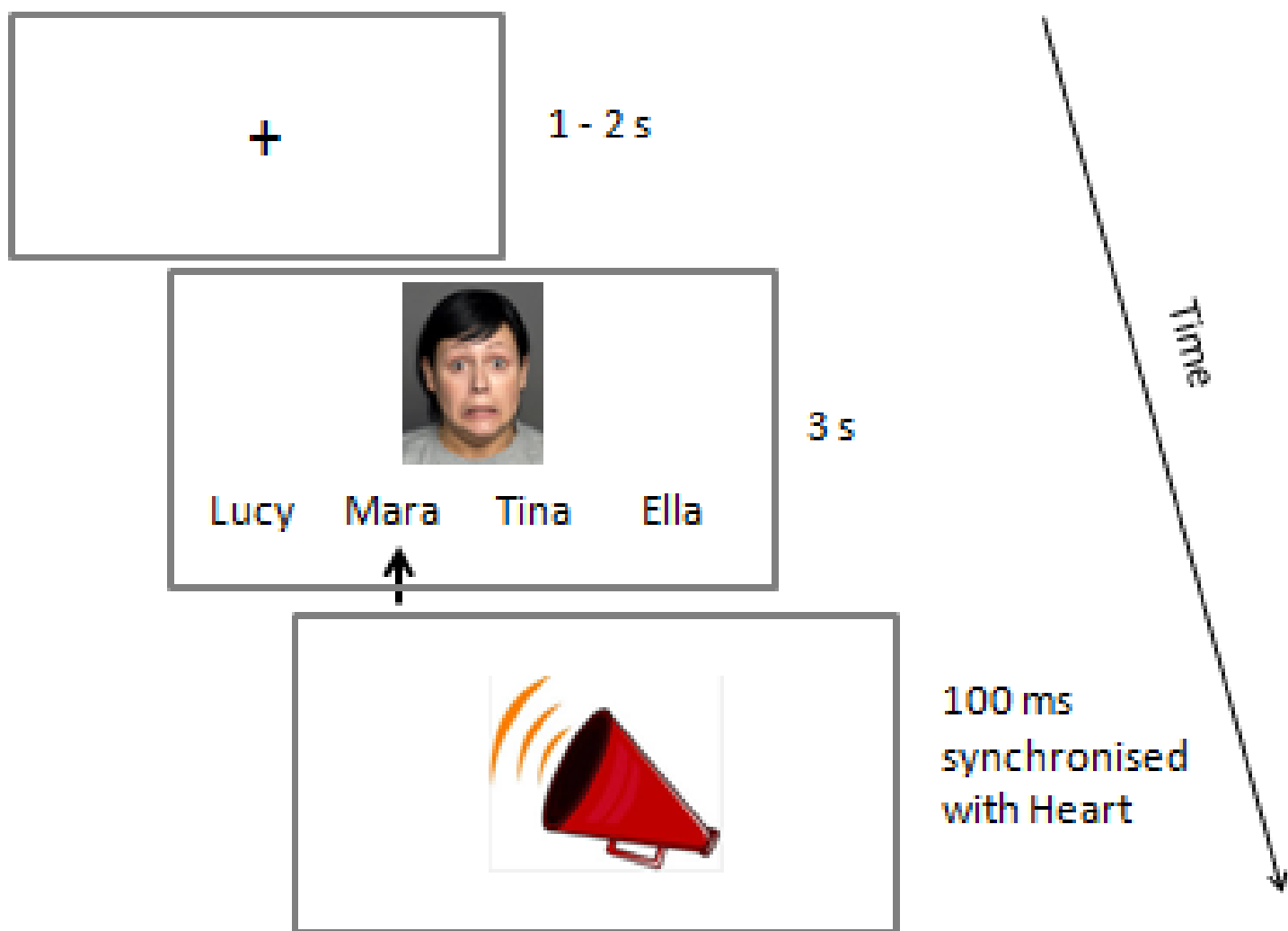
**Extraversion** is characterised by lower levels of cortical arousal at rest than introversion (H.J. Eysenck, 1967; Kumari et al., 2004). **Neuroticism** is linked to heightened autonomic reactivity to emotional stimuli, mediated through heightened activity within the ‘visceral brain’ (Harvey & Hirschmann, 1980; Norris et al., 2007).

➡ We hypothesised that feedback processing at specific cardiac timings would be modulated by personality with effects on learning and retrieval.

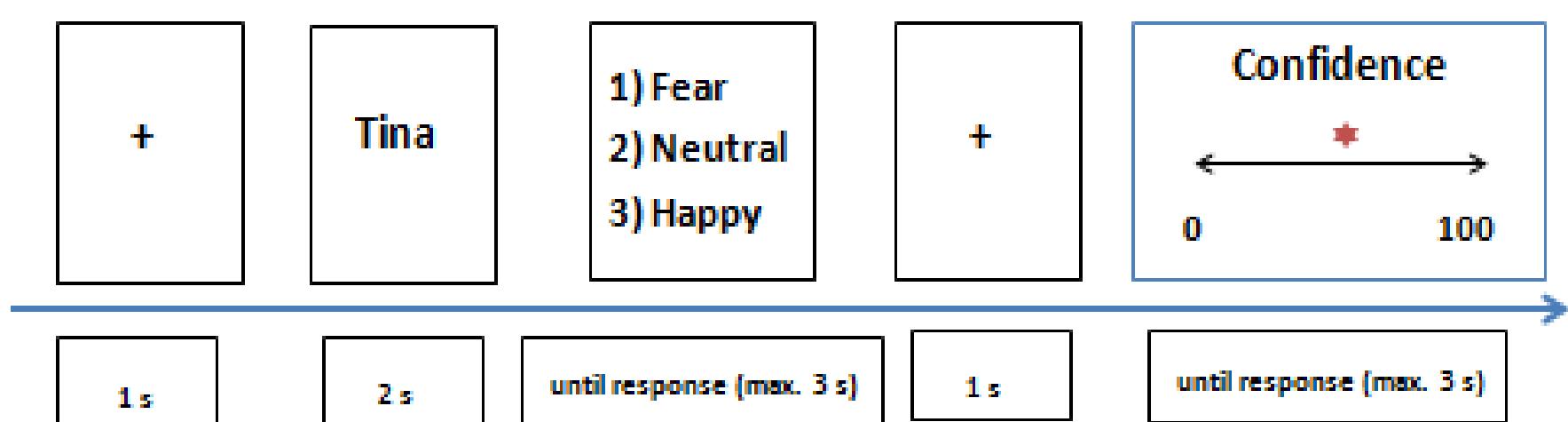
## Methods

Participants (N = 29) engaged in a learning and retrieval task of face-name pairs (fearful, neutral, happy faces).

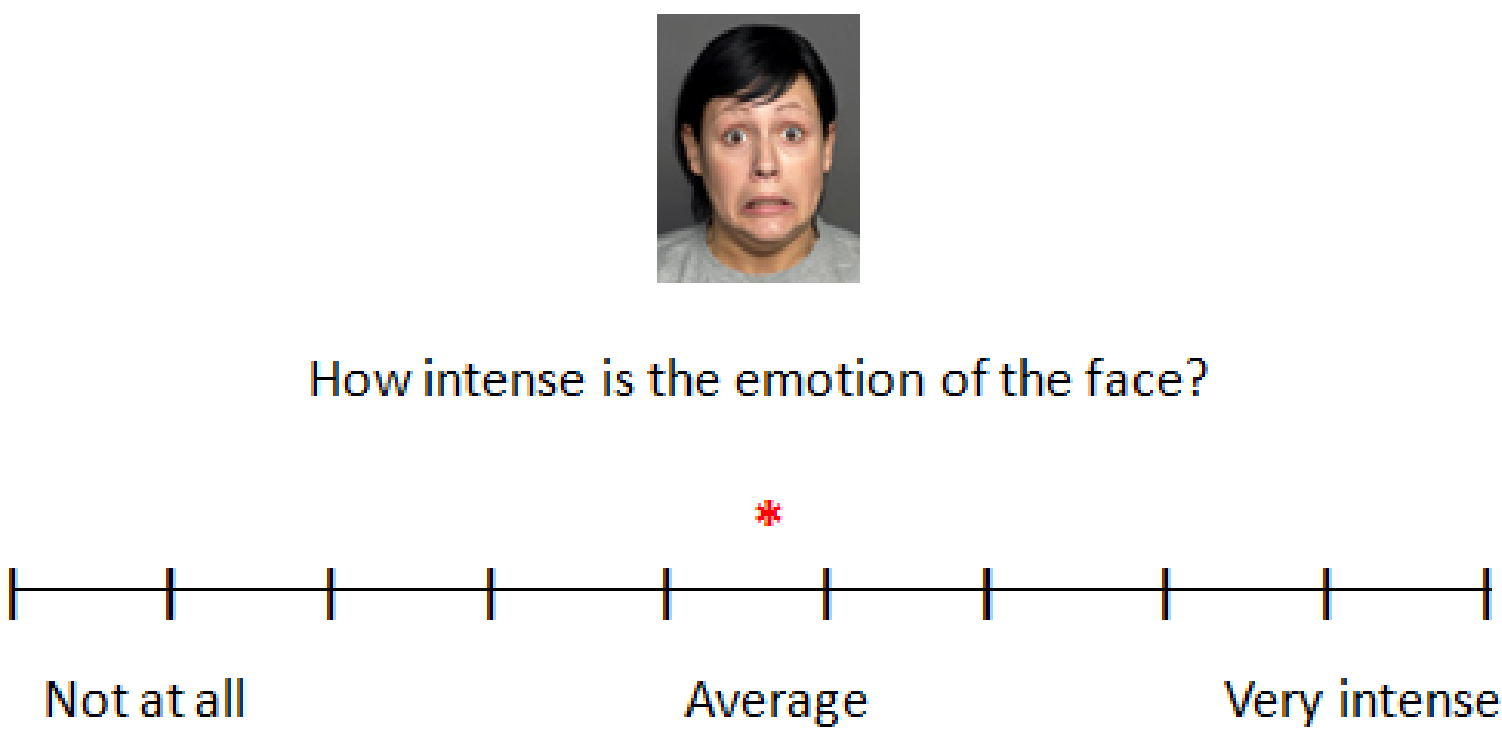
### Associative Learning



### Associative retrieval



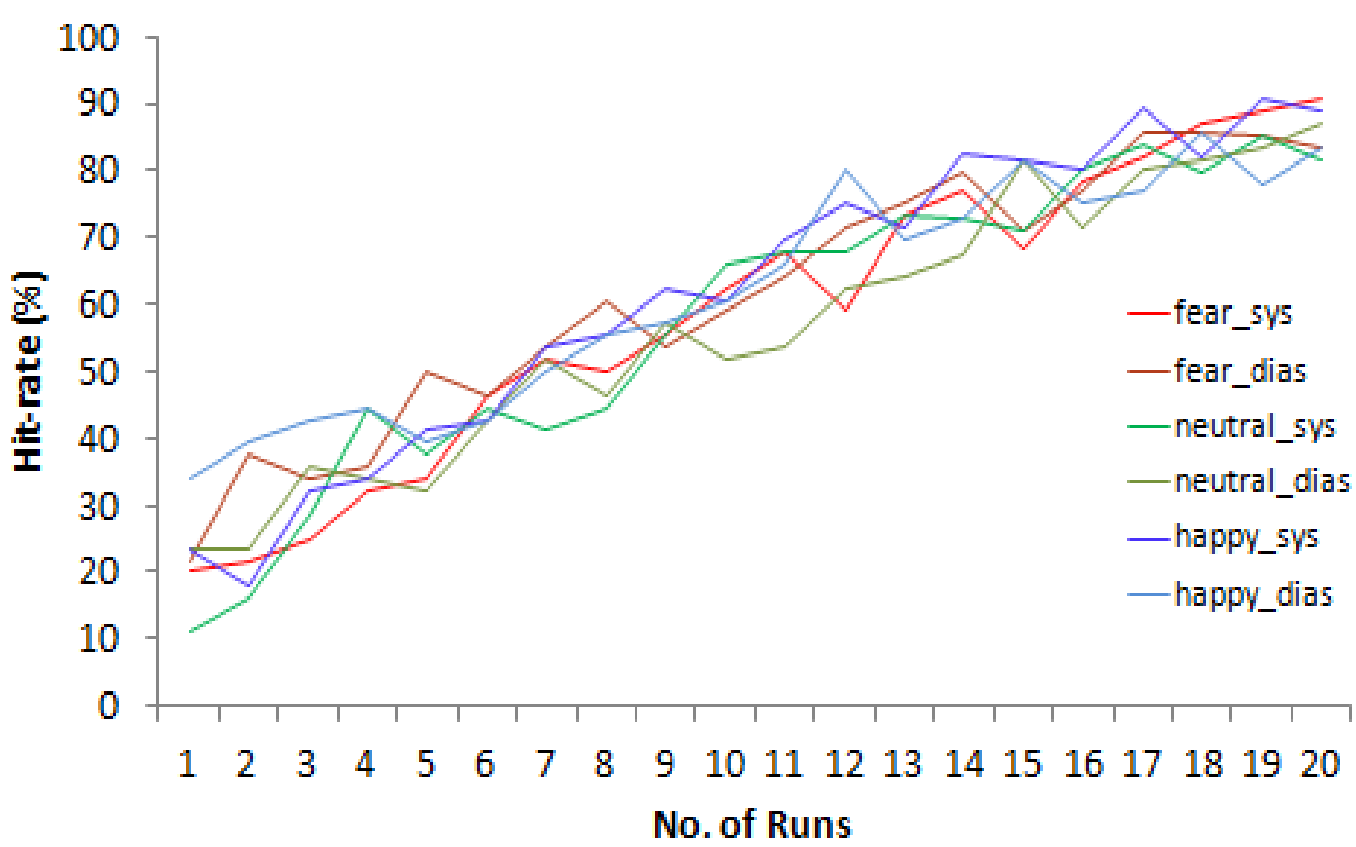
### Intensity Ratings



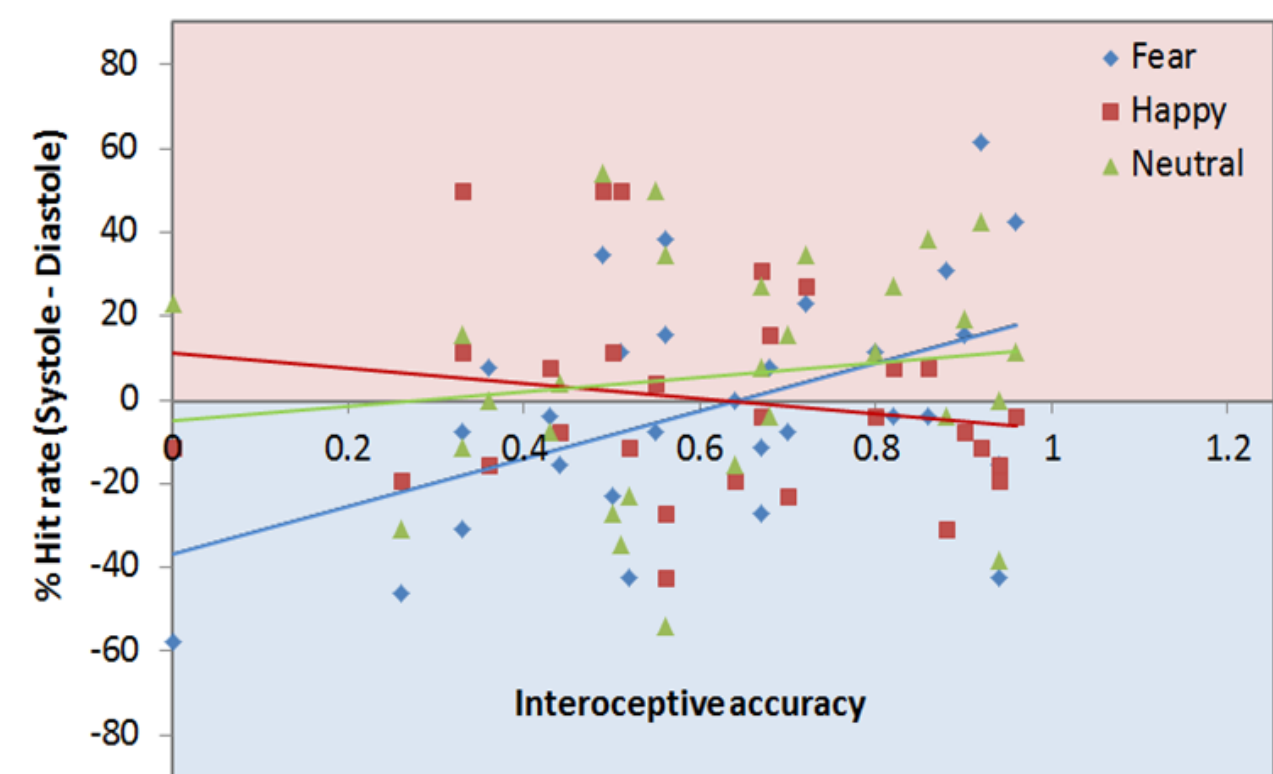
## Results

### ASSOCIATIVE LEARNING

Learning curve (N=29)



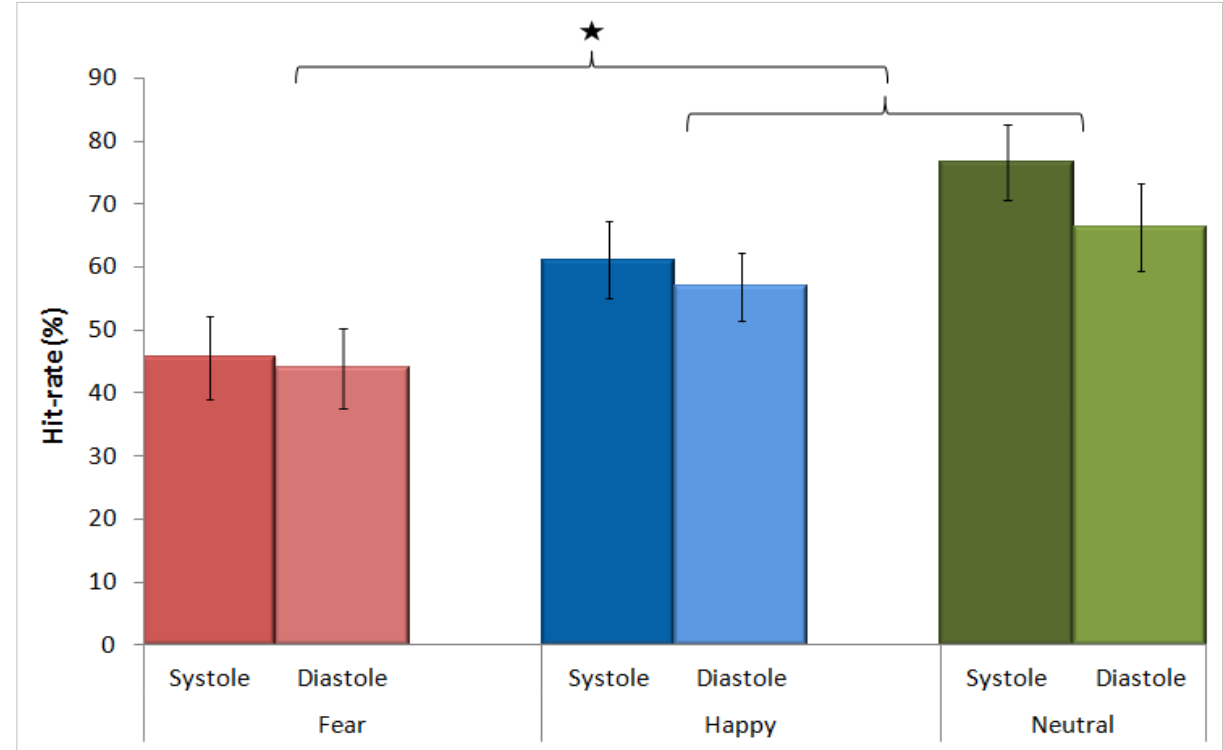
Interoceptive accuracy enhances fear-learning at systole



Three-way interaction between emotion, cardiac cycle and interoceptive accuracy,  $F[2,54] = 5.52$ ,  $p = .007$ .

### ASSOCIATIVE RETRIEVAL

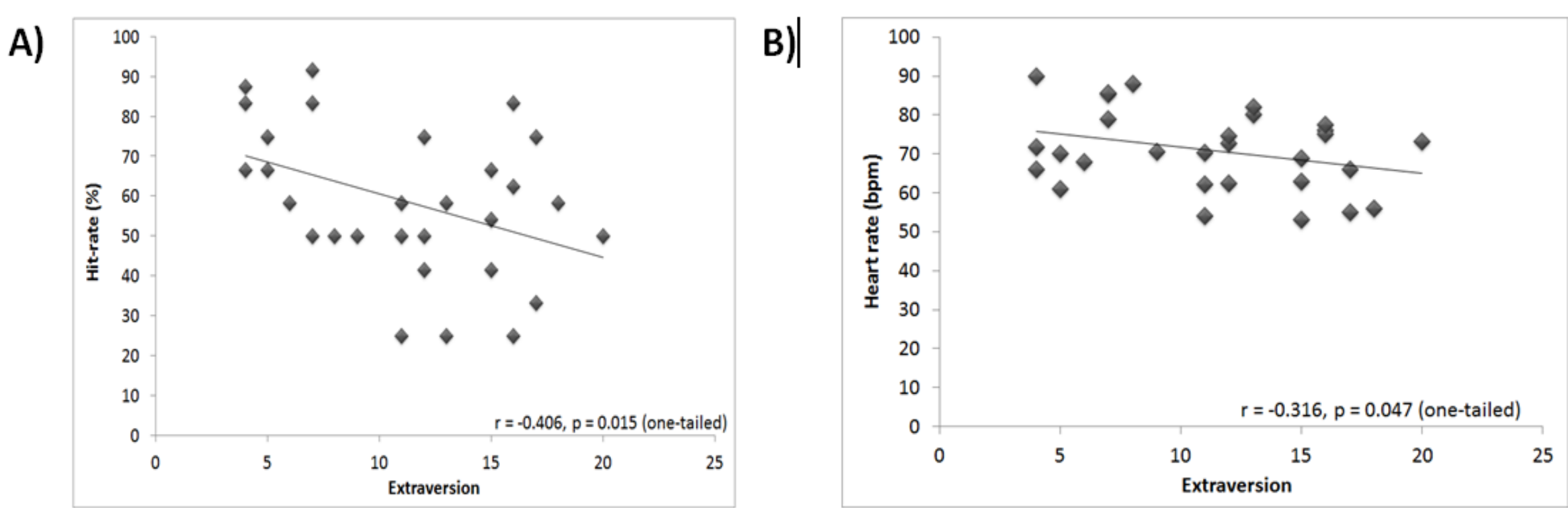
Mean percent Hit-rate for the retrieval of fearful, neutral and happy faces that were initially reinforced at systole and diastole.



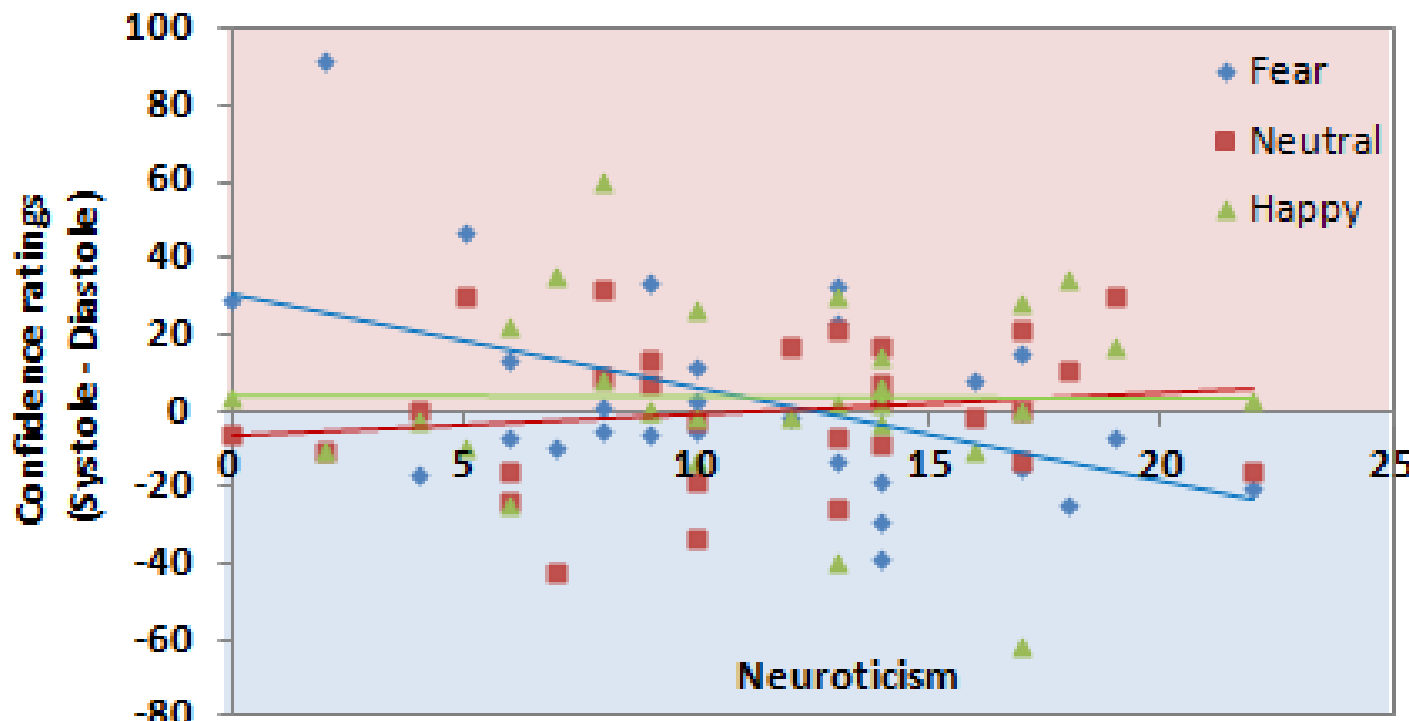
Main effect of emotion showing enhanced recall of neutral relative to fearful faces and happy relative to fearful faces, while the difference in recall between neutral and happy faces was non-significant. Error-bars represent the standard error of the mean.

### PERSONALITY and AROUSAL

Extraversion was associated with poorer retrieval accuracy (A) and lower heart rate (B).



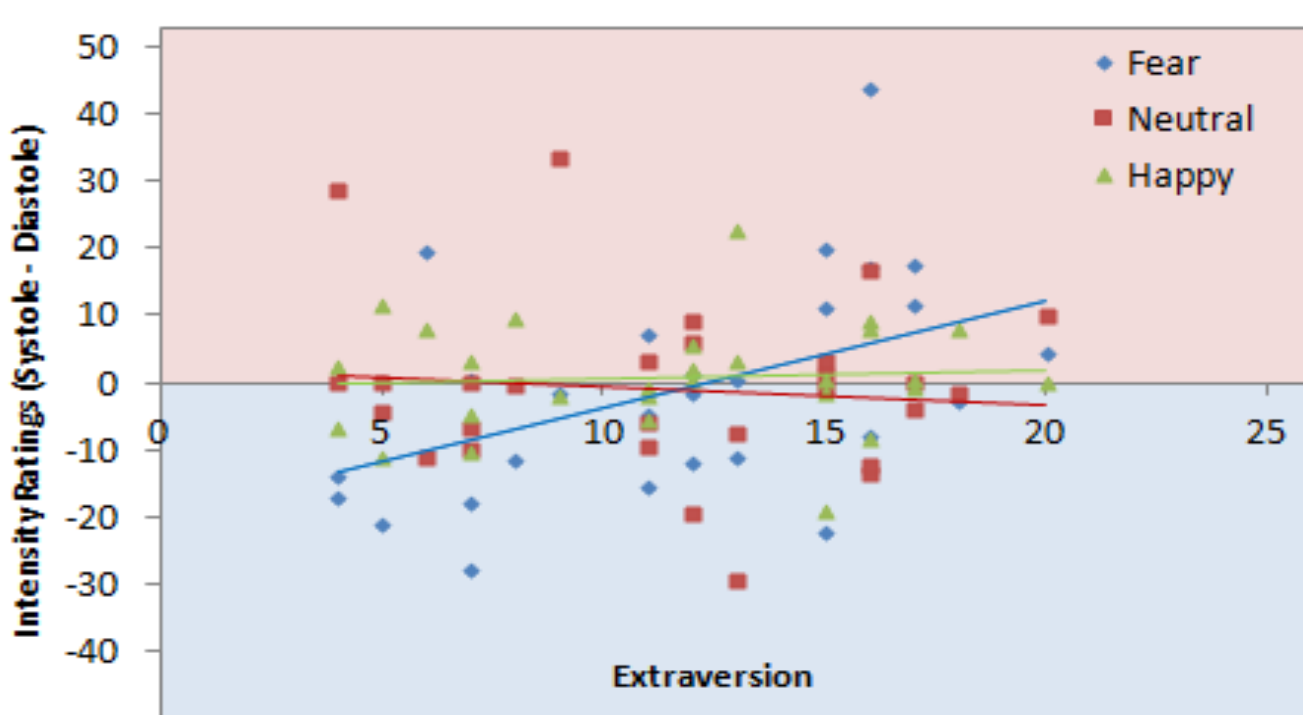
Neuroticism was associated with greater retrieval confidence for fear at diastole.



Three-way Interaction between emotion, cardiac cycle and neuroticism,  $F[2,54] = 4.30$ ,  $p = .018$ .

### INTENSITY RATINGS

Extraversion was associated with enhanced intensity ratings for fearful faces initially learned at systole.



Three-way interaction between emotion, cardiac cycle and extraversion,  $F[2,52] = 3.504$ ,  $p = 0.037$ ,  $\eta_p^2 = 0.119$ .

## Conclusions

We observed combined effects of emotional content and signals of bodily arousal states on learning and memory, in line with constructionist theories of emotion (Feldman-Barrett, 2011). Our results demonstrate that emotional memory is mediated by interoceptive accuracy and personality factors associated with constitutional states of arousal and reactivity.

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