1. PUBLISHABLE SUMMARY

Brain imaging studies have identified a network of areas in the prefrontal cortex (PFC) underlying the voluntary regulation of negative information, including the dorsolateral and dorsomedial pre-frontal cortex. The objective of this study was to investigate the neural substrates underlying the effects of positive or negative framing of verbal cues following the presentation of negative images, and to determine the extent to which the ability of individuals to respond may change across the lifespan. It was predicted that positive framing would engage lateral and ventromedial PFC and decrease subcortical brain regions involved in emotion responses, including the insula and amygdala, whilst negative framing would show the opposite effect, increasing the activation in the subcortical limbic structures. As older adults have more effective emotion regulatory processes engaging sections of the medial PFC, it was further predicted that when negative images were framed positively, age would be negatively associated with activation in the lateral PFC and positively associated with brain activation in the medial PFC.

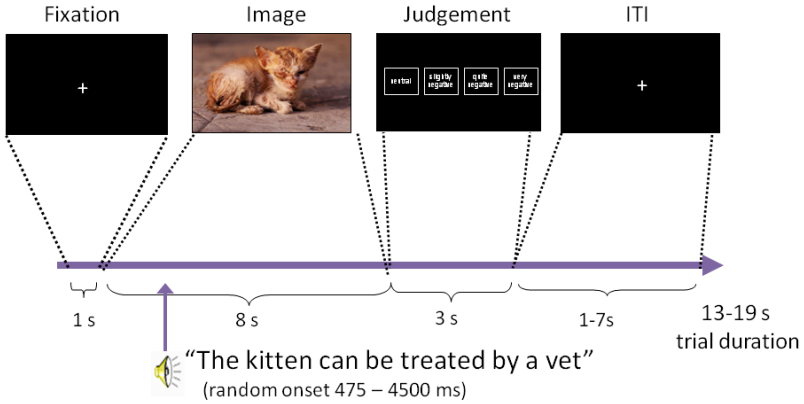

Figure. 1. Trial schema of the FMRI task. A negative (or neutral) picture was presented for 8 seconds. A random period after picture onset, auditory cues were presented emphasising a positive or negative outcome, or factually describing the scenes.

An FMRI study tested the paradigm on 17 University of Reading students. For 8 seconds participants were presented with emotional images, selected from the International Affective Picture System (IAPS, Bradley and Lang, 2005; Fig 1), which were either negative or neutral. Whilst the images were shown the participants heard a short commentary which could be positively framed, emphasising a positive outcome, or negatively framed, emphasising a negative outcome. A control condition was also presented in which the auditory cue described the scene factually. The soundtracks were matched for duration and word count across all conditions. At the end of each trial participants were asked to rate how negative or neutral they found the picture on a four-point scale, ranging from neutral to strongly negative.

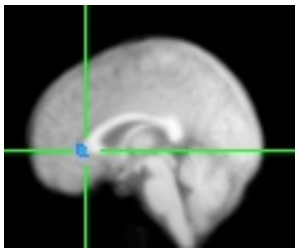

Figure 2:. Location of the ventromedial PFC cluster demonstrating an inverse correlation with the proportion of negative images rated as negative (vs neutral) when accompanied by positive reappraisal commentary

Consistent with prior FMRI studies on voluntary emotion regulation, clusters were found in the medial and lateral PFC, with positive cues associated with a higher response than the control condition. Behavioural data was collected during and after the task which indicated that positive cues significantly dampened the impact of the negative pictures, relative to the control condition, with subjective ratings positively associated with responses in the ventromedial PFC (Fig 2). These data highlighted that directed positive reappraisal of negative information involves the overlap with those underlying participant-generated regulatory strategies.

The second FMRI study recruited 44 participants aged 25 to 75 years, of whom 38 completed the MRI session. All participants were tested for cognitive function using a battery of standard neuropsychological and cognitive tasks, selected on the basis that they correlated with the lateral prefrontal regions involved in emotion regulation. In addition, using self-report based questionnaires, well-being was assessed. Brain images were acquired using a 3-Tesla Siemens Trio MRI scanner whilst participants were presented with pictures accompanied by auditory cues as for the first FMRI study (see Fig. 1). Pupil size of the participants was also measured to ascertain that the framing conditions engaged a similar level of task engagement. The pupil dilation was found to increase after the presentation of the verbal cue, reflecting task engagement, but the framing conditions had no differential impact on pupil size ($p>.05$).

Ratings collected during the task indicated that the impact of negatively valanced pictures was significantly enhanced by negative relative to both positive cues and the control condition (both $p < .01$). The FMRI results were in part consistent with those of the prior study and in part confirm our predictions: Clusters were found in the lateral and (superior) medial PFC, with positively framed cues associated with higher activation than the control condition and lower activation in bilateral insula. No significant differences were found in the amygdala. Contrary to expectations, there was lower activation in the ventromedial PFC with positive cues. Furthermore, age did not significantly correlate with activation in any of the PFC areas, nor did we find significant effects of age on grey matter probability in our sample.

The cognitive data was analysed to assess whether the older-aged participants showed a decline in cognitive control relative to their younger counterparts. Age was positively correlated with phoenemic fluency ($r(41) = .436$, $p = .004$), but negatively associated with semantic fluency ($r(41) = -306$, $p = .049$). Performance on inhibitory control tasks was mixed: Age was positively correlated with slower responding ($r(41)= -.308$, $p = .047$) to the incongruent condition in the Simon task, but we found no effect of age in the Stroop task ($p > .05$), nor in the proactive interference task ($p > .05$). These data, overall, suggest that the older adults in our sample were relatively high performing on cognitive control tasks. This suggests that age per se is not associated with changes in emotional function, and that age-related cognitive decline should be taken into consideration in future studies.

A separate behavioural study was performed to assess whether age is associated with recovery from positive and negative emotion-eliciting information in 28 older (55-84 years) and 30 younger adults (19-35 years). The results showed age-independent task disruption by emotional information, both shortly (250ms to 1000ms) and at a substantial delay (3000ms to 4000ms) after picture offset. After positive images, older relative to younger adults showed maintenance of response, whilst younger adults showed slower recovery from negative images. The results of this task suggest that picture-elicited affect persists for a substantial time after event offset, disrupting subsequent cognitive performance. Importantly, these findings suggest that the impact of positive and negative information is modulated by age.

The research performed for this project is expected to have an impact at the academic and societal level. At the academic level, the research provides evidence of the role of ageing in adaptive responding to negative emotion, its relation to cognitive function, and brain atrophy and the effect of age on emotional functioning, a question that has mostly been assessed using self-reports of emotion regulation and health. These results will improve our understanding of interactions between cumulative effects of resilience to emotion and well-being. At a societal level, we anticipate that this research contributes to the development of strategies for improving health span and well-being during ageing and thus reducing the need for medical and social care in older age.