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Good things better? Reappraisal and discrete emotions in Acquired Brain Injury

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Abstract

There has been substantial interest in emotion after acquired brain injury (ABI), but less attention paid to emotion *regulation* (ER). Research has focused primarily on the ER strategy of reappraisal for regulating negative emotions, without distinguishing between classes of emotion, and there has been no attempt at exploring these differences in patients with ABI. The present study explored components of reappraisal, across classes of emotion, and their associated neuropsychological mechanisms. Thirty-five patients with ABI and twenty-two matched healthy control participants (HCs) completed two questionnaires, a battery of cognitive tasks, and an emotion regulation task (the Affective Story Recall Reappraisal task). Results suggest that those with ABI take *longer*, and generate *fewer* reappraisals than HCs across several discrete emotions. Notably, their ability to decrease emotional intensity did not differ significantly to HCs for *negative* emotions, but findings suggest that their reappraisals are less effective when up-regulating *neutral* emotions to *positive*. Working memory was the only significant predictor of the total number of reappraisals generated, and the time taken to produce a first reappraisal. Implications of these findings are discussed in the context of neuropsychological rehabilitation, including the role of the relatives in implementing and reinforcing micro-interventions.

Keywords: emotion regulation, reappraisal, acquired brain injury, discrete emotions, cognitive control

Word count: 6819

Emotional changes have long been recognized as common impairments following acquired brain injury (ABI) (Draper & Ponsford, 2009; Diaz, Schwarzbold, Thais, Hohl, et al., 2012; Gainotti, 1993), and there has been substantial interest in emotion after ABI (Alway, McKay, Ponsford, & Schönberger, 2012; Shields, Ownsworth, O'Donovan, & Fleming, 2016; Williams & Evans, 2003). A number of studies that have investigated the effects of injury on, for example, emotion perception (Bornhofen & McDonald, 2008), recognition (Calder, Keane, Manes, Antoun & Young, 2000) and experience (Calder et al., 2000; de Sousa, McDonald, & Rushby, 2012). Indeed, this is in line with the emergence of a growing field of affective neuropsychology (McDonald, 2017).

One aspect that has received less attention, but is particularly important to consider, is emotion *regulation* (ER) (Bechara, 2004; Beer & Lombardo, 2007). The most extensively used approach to ER is the "Process model", which describes this ability as a range of strategies that influence emotions, their intensity and the way they are experienced and expressed (Gross, 2013, 2014, 2015; Gross & Muñoz, 1995). Impairment in ER is a common consequence of ABI, across various pathologies and brain regions (Bechara, 2004; Beer & Lombardo, 2007), and is a key transdiagnostic element of global distress and mood disorders in this population (Shields et al., 2016).

The "Process model" of ER outlines five classes of strategy that are used to regulate emotions (Gross, 2014). One particular approach, *reappraisal*, is the most frequently investigated (Goldin, McRae, Ramel, & Gross, 2008; Troy, Shallcross, Brunner, Friedman, & Jones, 2018; Zilverstand, Parvaz, & Goldstein, 2017), and involves changing the meaning of a situation, to alter its emotional consequence (Gross, 2002; McRae, Ciesielki, & Gross, 2012b). Reappraisal is well-understood to be an effective method for managing feelings (Sheppes & Meiran, 2007; Troy, Wihelm, Shallcross, & Mauss, 2010). Its use is positively

correlated with well-being and greater psychological health in neurologically healthy individuals (Gross & John, 2003; McRae, Jacobs, Ray, John, & Gross, 2012).

Reappraisal and Cognitive Control

Reappraisal is also known to be dependent on several cognitive control processes (Ochsner & Gross, 2005). This idea is consistent with neuroimaging studies, which have identified activation in areas in the prefrontal cortex (PFC) supporting cognitive control (Buhle, Silvers, Wager, Lopez, et al., 2014; Kalisch, 2009; McRae, Hughes, Chopra, Gabrieli, et al., 2010). Researchers have also tried to identify which neuropsychological functions support this complex process (McRae et al., 2012); for example, in the neurologically healthy, working memory may be a key capacity to keep the first appraisal in mind (Hendricks & Buchanan, 2015; McRae et al., 2012; Schmeichel, Volokhov, & Demaree, 2008). However, research into the neuropsychological mechanisms of reappraisal has produced variable evidence (Hendricks & Buchanan, 2016; McRae et al., 2012; Salas et al., 2014). In part because participants' reappraisals cannot (because of movement artefacts) be verbally produced in an imaging setting (e.g. Buhle et al., 2014). Additionally, these studies are in neurologically normal participants who *retain* this ability.

To address these critical gaps, Salas and colleagues (2014) investigated reappraisal *generation* in patients with brain injury, comprising reappraisal *productivity* (number of reappraisals generated), and *difficulty* (time to generate first reappraisal). This has been a fruitful approach because patients with ABI are often impaired in the manipulation of thought (Gomez Beldarrain, Garcia-Monco, Astigarraga, Gonzalez, & Grafman, 2005; Luria, 1966), and therefore may struggle to *generate* positive re-interpretations (Salas et al., 2014). Brain-injured patients may be especially vulnerable to reappraisal deficits in the presence of time limitations, related to inhibition and verbal ability performance, but not working memory

(Salas et al., 2014). Notably, this is a contrasting finding to the earlier literature in neurotypical participants, who are able to generate reappraisals (e.g. McRae et al., 2012).

Discrete Emotions

Research on ER, and its biological substrate, has focused primarily on reappraisal for *negative* emotions (e.g. Goldin et al., 2008), often not distinguishing *between* discrete negative emotions. Additionally, traditional reappraisal paradigms typically use visual stimuli (from the International Affective picture System, IAPS, Lang, Bradley, & Cuthbert, 1997) which may trigger diverse discrete emotions, but these emotional reactions are only assessed in terms of valence and intensity. This is noteworthy because different classes of emotion contain unique information about the interaction with the environment, and enable adaptive responding (Ekman, 1992; Lazarus & Smith, 1988; Mauss, Levenson, Wilhelm, McCarter, & Gross, 2005). Equally important, these discrete emotions are supported by different neural systems (Celeghin, Diano, Bagnis, Viola, & Tamietto; 2017; Panksepp, 2003; 2004; 2005; 2011, Vytal & Hamann, 2010), with a large neuroimaging literature supporting interacting brain regions associated with the experience, perception and recognition of various categories of emotion (Adolphs 2002; Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012, for a meta-analysis).

The identification of multiple classes of emotion has provided an opportunity to understand how such experiences might vary. Some discrete emotions have been more closely associated with differences in decision-making (Lerner & Keltner, 2001), perception of risk (Lench & Levine, 2005), and behaviour (See Lench, Flores, & Bench, 2011 for a meta-analysis). The majority of research on emotion *regulation* has yet to systematically compare strategies using a discrete emotion framework, instead viewing ER as a global ability across emotions (e.g. Gratz & Roemer, 2004; Gross & John, 2003). There is, however, a modest body of work describing how ER, and specifically reappraisal, varies across

positive and negative emotions (Kim & Hamann, 2007; Mak, Hu, Zhang, Xiao, & Lee, 2009; Nezlek & Kuppens, 2008), suggesting that neurologically healthy individuals find it easier to up-regulate positive emotions through reappraisal, than down-regulating negative emotions (Kim & Hamann, 2007). Some of the most convincing evidence of the relevance of discrete emotions in ER comes from the finding that strategies employed to regulate anger and sadness differ in both their use and effectiveness (Rivers, Brackett, Katulak, & Salovey, 2007). Individuals are more likely to use reappraisal for sadness than anger, and more likely to use situation-based strategies for anger compared to sadness (Rivers et al., 2007). It is, however, less clear how people with brain injury use ER strategies across different emotions.

Discrete Emotions in ABI Research

In ABI, there is a large body of research exploring various aspects of emotional difficulties (e.g. Shields et al., 2016; Williams & Evans, 2003). This includes a prominent theory that the right hemisphere mediates and processes negative emotions, and the left hemisphere positive emotions (the valence hypothesis) (Davidson, 2001; Demaree, Everhart, Youngstrom, & Harrison, 2005). Though studies on the valence hypothesis have provided mixed support (Demaree et al., 2005, for a review), there is substantial evidence of right hemisphere dominance for emotional processing regardless of valence (the right hemisphere hypothesis) (Gainotti, 2005, 2012, for reviews).

Additionally, there are a number of investigations of difficulties with *discrete* negative emotions, in particular anger (Mcdonald, Hunt, Henry, Dimoska, & Bornhofen, 2010; Neumann, Malec, & Hammond, 2015), depression (Kreutzer, Seel, & Gourley, 2001), and a range of emotional disorders (Shields et al., 2016). There are also studies which systematically address emotional processes across various emotion categories, for example the study of emotion recognition across classes of emotions after TBI (Babbage, Zupan, Neumann, Tomita, & Willer, 2011; Croker & McDonald, 2005), the re-experience of discrete

emotions in Korsakoff patients (Stanciu, Rafal, & Turnbull, 2018), and emotional experience in patients with ABI (Salas, Radovic, Castro, & Turnbull, 2015).

The present study

To our knowledge, there has been no attempt at exploring differences in emotion *regulation* (based upon the "Process model") across different classes of emotions, in patients with ABI and healthy controls (HC). This provides an opportunity to understand how a well-researched ER strategy, reappraisal, might differ across emotions following injury. Building on previous research, the present study employed an internal mood induction paradigm (Salas, Radovic, & Turnbull, 2012: Salas et al., 2015) adapted to measure reappraisal. Notably, personally-salient emotion elicitation tasks, such as the Affective Story Recall task (ASR) (Turnbull, Evans, & Owen, 2005), may be more effective at inducing specific discrete emotions, at greater intensities, compared to external emotion elicitation (Salas et al., 2012, 2015).

The present study is the first to investigate reappraisal in ABI patients using an autobiographical recall reappraisal task (c.f. Salas et al., 2015, which focused on emotion elicitation). In addition to reappraisal ability, the present study also examined reappraisal *generation*, by measuring *productivity* (total number of reappraisals generated) and *difficulty* (time taken to reappraise), as based on previous reappraisal research in this patient sample (Salas et al., 2014).

Given that patients with ABI experience difficulties across a range of discrete emotions, the following hypotheses are explored. Firstly, a "discrete emotion hypothesis": that patients with ABI will take longer to generate reappraisals (reappraisal *difficulty*), will produce fewer reappraisals (reappraisal *productivity*), and have less effective reappraisals (reappraisal *ability*) compared to the HC group, differentially across classes of emotions. In addition, a "cognitive control hypothesis": cognitive control abilities (working memory,

inhibition, and verbal ability) will be positively related to reappraisal *productivity* and *ability*, and negatively related to reappraisal *difficulty*.

Methods

Participants

A total of 57 participants were included in the study, comprising an ABI group, and an age and education matched HC group.

Acquired Brain Injury Group

Thirty-five participants with acquired brain injury (ABI) were prospectively referred mainly by clinicians at the North Wales Brain Injury Service (NWBIS), Betsi Cadwaladr University Health Board (BCUHB), a community-based outpatient rehabilitation service (*n* = 25). A small proportion were recruited from a social rehabilitation day service in Manchester (The Headforward Centre) (*n* = 5), and through North Wales branches of the brain injury charity, Headway (*n* = 5). Eligible participants were adults with a confirmed ABI, as per NWBIS referral criteria (Coetzer, Vaughan, Roberts, & Rafal, 2003), duration of 9 months or greater since injury, and sufficient cognitive and language ability to complete the tasks (as judged by clinicians and staff members). Exclusion criteria included the presence of a psychiatric or substance use disorder in need of acute care, a neurodegenerative condition, or learning disability. Participants were also excluded if they did not have the capacity to give informed consent.

The average age of participants was 51 (*SD* = 11.82, range 26 - 74), with an average of 13 years in education (*SD* = 2.24, range 10 - 18). There were 27 males and 7 females, with an average time since injury of 8.7 years (*SD* = 9.86, range 9 months - 32 years). Details of injury characteristics can be found in **Table 1**.

Healthy Control Group

Twenty-two, age and education matched, neurotypical healthy control participants were recruited from the North Wales community. The average age of participants was 54 (*SD* = 8.46, range 35 - 69), with an average of 12.5 years in education (*SD* = 1.79, range 10 - 16). There were 12 males and 10 females.

[*Table 1 here*]

Measures

Emotional assessment

In order to evaluate emotional symptomology and functioning, two self-report questionnaires were employed. Firstly, the Hospital Anxiety and Depression Scale (HADS) (Zigmond & Snaith, 1983) was administered. This consists of anxiety and depression subscales, with 14 items such as 'I feel tense or wound up'. The participant indicates, on a 4 point scale, agreement with each statement. This is a reliable and valid measure of anxiety and depression (Zigmond & Snaith, 1983), and its use has been validated in individuals with brain injury (Schönberger & Ponsford, 2010). Secondly, the Emotion Regulation Questionnaire, adapted for children and adolescents (ERQ-CA) (Gullone & Taffe, 2012), to assess self-report reappraisal in daily life. The adapted version was used because feedback from previous work in our lab (Salas et al., 2014) using the original ERQ (Gross & John, 2003), suggested that several patients struggled to grasp the wording. The ERQ-CA reports sound internal consistency (Gullone & Taffe, 2012).

Cognitive control assessment

A short battery of cognitive control tasks was used to measure working memory, verbal fluency, and inhibition.

a) *Working Memory* was measured using the Digit Span (forward, backwards, and sequence) sub-task from the Wechsler Adult Intelligence Scale (WAIS IV) (Wechsler, 2008). These tasks are informative measures of working memory in brain-injured

participants, and have been used as a marker for cognitive deficits (e.g. Millis, Rosenthal, Novack, Sherer, et al., 2001).

b) *Verbal Ability* was assessed using the Letter Fluency sub-task from the Delis-Kaplan Executive Function system (D-KEFS) (Delis, Kaplan, & Kramer, 2001). Letter fluency has been shown to be more strongly associated to cognitive control than other measures (Henry & Crawford, 2004), and has been used previously to investigate cognitive control and reappraisal in patients with ABI (Salas et al., 2014).

c) *Inhibition* was evaluated using the Hayling sentence completion task from the Hayling and Brixton tests (Burgess & Shallice, 1997). This task was chosen due to its sensitivity (Burgess & Shallice, 1997), and validity in a sample of brain-injured patients (Odhuba, van den Broek, & Johns, 2005).

Affective Story Recall Reappraisal (ASRR) task

This task has been adapted from previous reappraisal generation tasks that have used stimuli form the IAPS (Salas, Gross, Rafal, Viñas-Guasch, & turnbull, 2013; Salas et al., 2014), and the ASR emotion elicitation task, described in detail elsewhere (Salas et al., 2012; Turnbull et al., 2005). Recalled personal events, as opposed to traditional IAPS stimuli, may elicit discrete target emotions at higher intensities (Chirico, Cipresso, & Gaggioli, 2018) and follow an emerging trend in emotion research of focusing on naturalistic contexts (Siedlecka & Denson, 2018).

The task (See Appendix A for details) was carried out on a 13” laptop screen, providing step-by-step instructions, to avoid any memory bias. Following 2 practice trials, the participant was shown an emotion word (either ‘sad’, ‘scared’, ‘angry’, or ‘neutral’), and described an event which caused them to feel that emotion. Following this they indicated how intense they felt the emotion on a 0 to 10 scale, before generating reappraisals, and associated intensity measurement.

The 3 negative emotions (sadness, fear, and anger) were chosen because of widespread agreement in the literature that these are *basic* emotions (Tracy & Randles, 2011, for a review). The 'neutral' condition involved neutral recollections, to be reappraised *into* positive emotions; chosen to map on to reappraisal in real life settings (e.g. Livingstone & Srivastava, 2012).[1] Each emotion word appeared twice, resulting in 8 total trials. The task was recorded and transcribed *verbatim*, the total number of reappraisals were counted, and the time to generate a first reappraisal noted.

See **Figure 1** for visual representation of one trial ("sad" condition).

[*Figure 1 here*]

Procedure

Ethical approval was granted by Bangor University (2017-16048) and BCUHB (224613). For the ABI group, potential participants were identified prospectively by members of the clinical team at the NWBIS, rehabilitation staff at the Headforward Centre, and the Chairs of Headway branches. One referred participant was not included, due to later concerns of a neurodegenerative condition. Healthy control participants (HC) recruited form the community were invited to take part. Following written informed consent, neuropsychological and emotional tasks were carried out within one session in a quiet room: at Bangor University, NWBIS, Headforward Centre, or participants' own homes. Questionnaires, neuropsychological tasks, and the ASRR task were administered in random order, with a short-break approximately half-way through the session. The ASRR task was transcribed and reappraisals were counted. If needed, a reappraisal coding guide was used in support (McRae et al., 2012b). All measures were administered by the first author, or trained research assistants.

[1] The alternative, making positive emotions *more* positive, would effectively be promoting unrealistic optimism (Fleming & Strong, 1995). It would also be difficult to measure any differences in emotional intensity because of ceiling effects.

Data Analysis

Three measures of reappraisal were produced by the ASRR task, resulting in three variables. Reappraisal *difficulty* was obtained by averaging the time it takes to produce a first reappraisal. Reappraisal *productivity* was calculated by adding the total number of reappraisals produced, and reappraisal *ability* was calculated by averaging the difference value between self-report emotional intensity before, and after, reappraising.

Data was analysed using 'R' Software, with additional packages ('Stats', 'Complmrob', and 'robustbase'). As the data was not normally distributed *the discrete emotion hypothesis* was analysed with several Mann-Whitney U tests, with Bonferroni adjustment for multiple comparisons (new alpha level .013), comparing 1) reappraisal *difficulty*, 2) reappraisal *productivity*, and 3) reappraisal *ability*, between patients with ABI and the HC group across the neutral, sadness, fear, and anger conditions.

The cognitive control hypothesis was explored by carrying out three separate robust multiple linear regression analyses using the 'lmrob' function ('robustbase' package) with bootsrapped coefficients using fast and robust bootsrap via the 'bootscoef' function ('complmrob' package) with 'MM' method (Salibián-Barrera, Aelst, & Willems, 2008). Inhibition (Hayling sentences task scores), working memory (Digit Span WMS IV scores), and verbal ability (Letter fluency DKEFS scores) were entered as predictors, with the outcome variable consisting of reappraisal *difficulty, productivity,* and *ability* across all emotion trials combined (ASRR Total). Bootstrapping techniques were employed for 999 bootstrap samples as a form of model validation (Babyak, 2004; Efron, 2003).

Results

Emotional and Cognitive functioning

Participants' average scores on measures of emotional and cognitive functioning can be seen in **Table 2**. In relation to depression symptomology, participants with ABI scored on

average within the "borderline abnormal" range on the HADS, and were significantly more depressed than the HC group, with 11/35 scoring within the clinical range. On the anxiety subscale, participants with ABI also scored on average within the "borderline abnormal" range and were significantly more anxious than the HC group, with 20/35 in the clinical range. Participants with ABI also reported using reappraisal significantly less frequently to regulate their emotions than the HC group on the ERQ-CA.

On average both ABI and HC group scored within the "moderate average" range on the Hayling sentence task, as an indicator of inhibition. Working memory scores (Digit span, WAIS IV) and verbal ability scores (Letter fluency, DKEFS) for the ABI group were in the "low average" range, and were significantly less than the HC group.

[*Table 2 here*]

The Discrete Emotion Hypothesis

This sought to investigate reappraisal *difficulty, productivity,* and *ability* across 4 classes of emotion.

Reappraisal Difficulty

The average time taken to produce a first reappraisal (reappraisal *difficulty*) was compared between the ABI and HC group, across the emotion classes (neutral, sadness, fear, and anger). See **Table 3** for descriptive statistics.

[*Table 3 here*]

Results of the Mann-Whitney U test demonstrates that the ABI group took significantly more time to produce a reappraisal compared to the HC group for the neutral (U = 150.00, z = -3.86, p < .001, r = .51), sadness (U = 193.50, z = -3.14, p = .001, r = .42), and fear conditions (U = 145.50, z = -3.94, p < .001, r = .52), all demonstrating medium-to-large effect sizes. There was no significant difference between groups for the anger condition, although there was a trend (U = 275.50, z = -1.80, p = .072, r = .24). See **Figure 2**.

[*Figure 2 here*]

Reappraisal Productivity

The total number of reappraisals produced (reappraisal *productivity*) was compared between the ABI and HC group, across the emotion classes. See **Table 4** for descriptive statistics.

[*Table 4 here*]

Results of the Mann-Whitney U test demonstrated that the ABI group produced significantly fewer reappraisals compared to the HC group for the neutral (U = 222.50, z = -2.753, p = .005, r = .36), sadness (U = 232.00, z = -2.55, p = .010, r = .34), and fear conditions (U = 210.00, z = -2.92, p = .003, r = .39), all demonstrating medium effect sizes. The difference between groups for the *anger* condition was marginally significant (with the adjusted alpha level), and demonstrated a medium effect size (U = 243.50, z = -2.26, p = .018, r = .31). See **Figure 3**.

[*Figure 3 here*]

Reappraisal Ability

This analysis was conducted to investigate differences is reappraisal *ability* between the ABI and HC group across classes of emotion. Participants' reappraisal *ability* scores (difference between *initial* self-report arousal and arousal *after* reappraising) were compared across emotions: neutral, sadness, fear, and anger. For descriptive statistics see **Table 5.**

[*Table 5 here*]

The results of the Mann-Whitney U test indicated that the ABI group had significantly lower reappraisal *ability* scores, compared to the HC group, on the neutral condition with a medium effect size (U = 188.00, z = -3.265, p = .001, r = .43). There were no significant differences in reappraisal *ability* across the sadness (U = 284.50, z = -1.65, p = .099, r = .22),

fear (U = 311.50, z = -1.21, p = .230, r = .16), and anger conditions (U = 266.500, z = -1.938, p = .053, r = .26). See **Figure 4**. [2]

[*Figure 4 here*]

The Cognitive Control Hypothesis

This sought to investigate a range of cognitive elements related to the components of reappraisal. A series of robust multiple linear regression analyses were conducted to investigate the relationship between three measures of cognitive control (working memory, verbal ability, and inhibition) and reappraisal components (*difficulty, productivity,* and *ability*) across all emotion trials combined (ASRR Total). For this the ABI group and HC group were combined to increase sample size.

Reappraisal difficulty. The model explained 25% of the variance, and significantly improved prediction of reappraisal *difficulty* (R^2 = .25, $F(3,53)$ = 17.40, p < .001). According to bootstrap for coefficients, the only significant predictor was working memory (Digits WAIS scores) (β = -.22, p = .006), suggesting that a unit increase in working memory ability would result in a decrease of 0.22 seconds in the time taken to generate a first reappraisal.

Reappraisal productivity. The model containing all predictor variables (working memory, verbal fluency, and inhibition) explained 21% of the variance, and significantly improved prediction of reappraisal *productivity* (R^2 = .21, $F(3,53)$ = 18.41, p < .001). Bootstrap for coefficients, demonstrated that the only significant predictor in the model was working memory (Digits WAIS scores), β = .54, p = .001. The coefficients demonstrate that a unit increase in working memory would result in an 0.54 increase in the number of reappraisals produced.

[2] Given the distributed nature of lesion site and underlying pathology of the sample, Mann Whitney U tests were carried out to compare reappraisal *difficulty, productivity,* and *ability* across all emotions; between those with TBI (n = 20) vs CVA (n = 13), and those with frontal brain injury (n = 13) vs non-frontal injury (n = 6). There were no significant differences or obvious trends. A Kruskal-Wallis test was used to compare the components of reappraisal across emotions between those with left lateralised (n = 7), right lateralised (n = 7), and bilateral lesions (n = 9). Again, there were no significant differences or obvious trends.

Reappraisal ability. The model explained only 2% of the variance in reappraisal *ability*, and did not significantly improve predictions ($R^2 = .02$, $F(3,53) = 1.37$, $p = .712$). There were no significant predictors within the model.[3]

Summary of results

These findings suggest that, compared to HC participants, patients with ABI take *longer* to generate a reappraisal, and generate *fewer* reappraisals across all emotion conditions. Concerning reappraisal *ability,* this might vary as a function of the emotion type, with the results suggesting that participants with ABI are comparatively *less* effective at up-regulating neutral to positive emotion, compared to the down-regulation of sadness, fear, and anger. In regards cognitive control hypothesis, the findings suggested that working memory has a role in two subprocesses of reappraisal only: predicting the time taken to produce a reappraisal (reappraisal *difficulty*), and the total number of reappraisals produced (reappraisal *productivity*). There were, however, no predictors of reappraisal *ability,* suggesting that cognitive control may not play a role in regulating emotional experience through reappraisal.

Discussion

There has been no previous attempt to systematically compare components of reappraisal, using a discrete emotion framework, in an ABI sample. This is an important question, in particular in the context of brain-injured patients, where it might inform rehabilitation clinicians. Additionally, the research into the underlying neuropsychological components has not been especially clear (Hendricks & Buchanan, 2016; McRae et al., 2012). The present study aimed to address these gaps, by investigating whether components of reappraisal (*difficulty, productivity,* and *ability*) varied as a function of the emotion in

[3] Due to the differences in reappraisal *ability* between the negative emotions and the neutral emotion, reported in the *discrete emotion hypothesis*, a total score of negative emotions only (excluding neutral) was calculated and the regression run again. The results remained similar, with low explanation of variance (6%) and no significant predictors in the model.

patients with ABI relative to a HC group. A second aim was to investigate the cognitive control capacities related to these three components of reappraisal.

Reappraisal generation across discrete emotions

A key finding of the present study was that patients with brain injury took significantly *longer* to generate a reappraisal (compared to HC participants) for the sadness, fear, and the neutral to positive conditions. They also took longer for the anger condition, though this did not reach significance (perhaps an artefact of the small sample size). This provides further support for Salas and colleagues (2014), who found that patients with ABI may be vulnerable to reappraisal *generation* impairment in the presence of time limitations. Additionally, the present study extends this idea by suggesting that a brain injury compromises the capacity to positively re-interpret events quickly across several discrete emotion categories. In other words, it seems that this impairment is a global difficulty, and not related to any *specific* emotions.

The results also demonstrate that those with ABI generated significantly fewer reappraisals relative to the HC group, across the sadness, fear and the neutral-to-positive conditions, and approached significance for the anger condition. This is a contrasting finding to the only previous group study of reappraisal *generation* in an ABI sample, which demonstrated that participants with brain injury were able to generate a similar number of reappraisals to HCs (Salas et al., 2014). This variation may be a result of tasks used (traditional IAPS paradigm versus a task based on personally salient emotional memories). This is consistent with the idea that reappraisal impairment may be exaggerated in situations that are closer to real life (Salas et al., 2014).

Considered together, it seems that those with an ABI are less able to *generate* reappraisals, across several emotions. If reappraisal is a two-stage process (initial meanings are inhibited, and new meanings generated) (Salas et al., 2014), the findings suggest that the

presence of a brain injury particularly impacts upon this first stage. A possible explanation is that this particular ER strategy relies on the core ability to think flexibly, in order to generate new interpretations of events (Ochsner & Gross, 2004), something that is known to be affected in this patient group (Gomez Beldarrain, et al., 2005). Reappraisal is complex, and dependent upon cognitive control processes (McRae et al., 2012; Ochsner & Gross, 2005), therefore it is not surprising that patients with ABI who are executively impaired find it more difficult to *generate* reappraisals. This idea is consistent with a recent line of evidence in older adults, which suggests that reappraisal may not be the ER strategy of choice for those with age-related cognitive decline (Scheibe, Sheppes, & Staudinger, 2015).

Reappraisal ability across negative emotions

To our knowledge the present study is the first to investigate reappraisal *ability*, defined as the reappraisals' success at reducing (or amplifying) emotional intensity in line with the reappraisals' goals, in a group of patients with brain injury. There were no significant differences in reappraisal *ability* between HCs and patients with ABI when regulating sadness, fear, or anger, although slightly lower for the ABI group. Overall, this suggests that once they are able to *generate* reappraisals, patients with brain injury are equally able to reduce the intensity of *negative* emotions through using this ER strategy. This has important implications for neurorehabilitation (See more below).

The present study suggests that all negative emotions are reappraised similarly for both the ABI and HC group, comparable to that reported elsewhere in the discrete emotion literature in neurologically healthy adults (Mikolajczak, Nelis, Hansenne, & Quoidbach, 2008). The study also extends previous findings in work with children, which demonstrated that reappraisal is an effective strategy for regulating both fear and sadness (Davis, Quiñones-Camacho, & Buss, 2016). It is also similar to the results of a study using a similar autobiographical recall task, again in a neurologically healthy sample (Rivers, Brackett,

Katulak, & Salovey, 2007). These findings suggest that reappraisal is an approach applied commonly to all negative emotions, for both HCs and individuals with brain injury, rather than suggesting that specific emotions have individual regulatory mechanisms.

The lack of significant difference between the ABI and HC group, however, is surprising, considering the numerous reports of specific emotional difficulties experienced by those with ABI (*e.g.* Fleminger, Oliver, Williams, & Evans, 2003; Gainotti 1993; Shields et al., 2016). For example, the commonly reported mood disorders such as depression (Bombardier, Fann, Temkin, Esselman, et al., 2010) and anxiety (Mallya, Sutherland, Pongracic, Mainland, & Ornstein, 2015), and difficulties with anger and aggression (Baguley, Cooper, & Felmingham, 2006). There are a number of possibilities for this finding. Firstly, it is likely that emotional distress is a result of emotion dysregulation, which includes *several* strategies (Shields et al., 2016), whereas the present study focused exclusively on reappraisal. Additionally, during the task participants were instructed to reappraise, it does not follow that patients would spontaneously reappraise in real life.

Reappraisal ability for positive emotion

An unexpected finding was that of significantly lower reappraisal *ability* scores when *up*-regulating to positive emotion, suggesting that brain-injured patients find reappraisal comparatively less effective when attempting to increase neutral states. This is in line with the idea that the consequences and success of ER strategies are not always consistent across negative and positive emotions (Gross & John, 2003; Gross & Levenson, 1997; Nezlek & Kuppens, 2008). This finding is especially interesting in the context of previous findings in non-brain-injured individuals, who find it easier to use reappraisal to regulate positive emotions, compared to negative emotions (Kim & Hamann, 2007; Nezlek & Kuppens, 2008; Ochsner, Ray, Cooper, Robertson, et al., 2004). It has been suggested that this may be

because amplifying an emotional reaction is less difficult than decreasing it (Ochsner et al., 2004).

Notably, the opposite was found in the present study. There are a number of possibilities for this. Firstly, it may be related to how the conditions within the task differ. That is, for the down-regulation of negative emotions, participants first described a personal story which elicited a negative emotion. In contrast, the up-regulation of neutral to positive was framed as a neutral baseline, and therefore may require a different skill-set in which the ABI group were more impaired. This is in line with the idea that emotional intensity can affect ER strategy choice (Scheibe et al., 2015; Sheppes, Scheibe, Suri, & Gross, 2011; Sheppes & Gross, 2011).

A second possible explanation relates to reappraisal ability in those with low mood, who show decreased ability to sustain positive emotions when using reappraisal (Heller, Johnstone, Shackman, Light, et al., 2009). If the experience of positive emotion increases reappraisal use (Nezlek & Kuppens, 2008; Fredrickson, 2001), then those who experience less positive affect may struggle to use reappraisal to up-regulate positive emotion. As there are high rates of depression among the ABI group, they may be subject to the same effects. However, re-investigation of our sample does not suggest that patients with lower mood are especially poor in up-regulation, as there was no correlation between their depression scores and reappraisal *ability* for the neutral condition (*Spearman's rho* = .06, p = .736). Future research would benefit from further investigating the effect of low mood in ABI on the up-regulation of positive emotion.

These findings suggest that reappraisal modulates all negative emotions to a similar level (likely due to shared neural mechanisms) regardless of the specific negative emotion. However, for individuals with brain injury, reappraisal seems comparatively less effective when up-regulating neutral to positive emotion.

Cognitive bases of reappraisal

In relation to the cognitive control hypothesis, the main finding was that working memory was the only significant predictor of both the average time taken to produce a reappraisal (reappraisal *difficulty*), and the total number of reappraisals produced (reappraisal *productivity*). This result provides additional support to previous findings in neurologically healthy participants that working memory is an important function for reappraisal (Hendricks & Buchanan, 2015; Jasielska, Kaczmarek, Bronska, Dominiak et al., 2017; McRae et al., 2012; Schmeichel et al., 2008). Additionally, these findings extend a well-established association between working memory and both reappraisal *ability* (e.g. McRae et al., 2012), and *frequency* (e.g. Jasielska et al., 2017). Reappraisal is a complex cognitive process, that may well include several elements (McRae et al., 2012; Ochsner & Gross, 2008). The present study especially supports the role of working memory in maintaining the goal of reappraising, and shielding it from the initial meaning that may otherwise remain in the forefront of attention (Kanske, Heisser, Schönfelder, Bongers & Wessa, 2010; Gross, 2013).

A third finding of note was that none of the measures of cognitive control predicted reappraisal *ability*, the effectiveness of the reappraisal at modifying emotional intensity. This is surprising, because the majority of the literature has focused on this global ability, and the lack of significance might be argued to contradict the large body of neuroimaging studies demonstrating activation in brain areas associated with cognitive control (Buhle et al., 2014, for a review). However, these neuroimaging studies were in neurologically healthy individuals, who are able to reappraise effectively.

It is also possible that the lack of a significant predictor of effectiveness might be related to other components of cognitive control, not measured in the present study. For example, although somewhat unexplored, abstract reasoning may also be related to reappraisal (McRae et al., 2012; Salas et al., 2013). This is likely because reappraisal requires

one to inhibit immediate emotional responses, in order to employ abstract ideas to change the meaning of a situation and its emotional impact (Salas et al., 2013).

Models of Reappraisal

How might these findings relate to existing models of reappraisal (e.g. Kalisch, 2009; Salas et al., 2014)? The present study appears to lend further support to a two-stage process, usually argued to consist of early and late components. The early stages are typically argued to involve choosing and implementing a reappraisal strategy, whereas the late components are concerned with maintaining the strategy in working memory (Kalisch, 2009). Developing this model further, Salas and colleagues (2014) suggested that inhibition and verbal fluency might be important for the early stages, inhibiting the initial meaning and generating a new appraisal, but they found no evidence for the role of working memory in this early phase. The present findings suggest that working memory appears to have a role in distancing from the negative initial appraisal, and producing a contesting mental representation of a positive nature. However, there may be an additional capacity required during the late phase, for example, to translate the reappraisal into a change in emotional intensity. It may also suggest that when it comes to regulating emotional *experience* of a mental representation, it is not so important whether cognitive control skills are average or limited, as long as one is able to *generate* a reappraisal.

Implications for neuropsychological rehabilitation

The present study contributes to our understanding of how brain injury may impact upon reappraisal, across various emotion classes. In particular, by demonstrating that patients with ABI are less able to generate reappraisals, and may find reappraisal less effective when up-regulating positive emotions. This is consistent with the idea that a brain injury increases one’s vulnerability to emotion dysregulation (Salas et al., 2013; 2014), and perhaps especially

for *generating* reappraisals, the experience of sustaining positive emotions, and avoiding instabilities (the 'mood swings' commonly reported by families).

The finding that patients find it difficult to generate reappraisals is particularly relevant for neuropsychological rehabilitation because this skill can be supported and facilitated externally, such as by family members. It has been shown that providing prompts can assist with the process of disengaging from the initial appraisal, and that can improve the capacity to generate alternative interpretations of events (Salas et al., 2013). It may also provide suggestions for treatment, through the development of programmes which include an element of reappraisal generation training.

Another core difficulty may be regulating the experience of *positive* emotions. One way to help promote and acknowledge positive affect is by looking to the field of Positive Psychology (PP) (Seligman, 2000; Seligman, Steen, Park, & Peterson, 2005; See Donaldson, Dollwet, & Rao, 2015 for a review), broadly, study of positive emotion and traits, well-being, and optimal functioning, and has developed a number of small, simple PP interventions (Seligman et al., 2005). Recently, there has been growing interest and appreciation of such interventions in rehabilitation (Bertisch, Rath, Long, Ashman, & Rashid, 2014; Cullen, Pownall, Cummings, Baylan, et al., 2018; Evans, 2011; Karagiorgou, Evans, & Cullen, 2017; Rabinowitz & Arnett, 2018). One particularly influential approach is the "Three Good Things" diary, where one writes down three things that go well each day, for a week, with a short explanation about causality and each event (Seligman et al., 2005). PP has many light touch interventions, for example using signature strengths in a new way, savouring, and letters of gratitude (Boiler, Haverman, Westerhof, Riper, et al., 2013; Evans, 2011; Seligman et al., 2005).

An important point to address, however, is that many patients with ABI have executive impairment, and may find it difficult to implement such activities (Burgess,

Alderman, Evans, Emslie, & Wilson, 1998; Stuss, 2011; Stuss & Alexander, 2007). This highlights the role of *external* regulation of emotion, which can be very effective (Salas 2012b; Salas et al., 2013). For instance, the use of scaffolding or external dialogue from a relative has been shown to compensate for cognitive impairment (Salas et al., 2013). One promising approach would be to reach relatives and care-givers to embed these ideas, so they can be consistently reinforced, and optimize generalisation of therapeutic gains. It might be that micro-interventions by families, such as scaffolding, and supporting patients to reflect on Three Good Things, could help patients acknowledge their positive emotions and stabilise the "mood swings".

Future directions

Calculating reappraisal *ability* in the ASRR task relied on self-report scores of emotional intensity. Though previous work has demonstrated that self-report measures during reappraisal correlate with changes in neural activation and physiology (Ochsner, Bunge, Gross, & Gabrieli, 2002; Troy, Wilhelm, Shallcross, & Mauss, 2010), some have reported dissociations between these measures (Mauss & Robinson, 2009). Nonetheless, the subjective emotional experience is, in itself, an important component of ER processes. Future work may benefit from complementing the ASRR task with a measure peripheral physiology.

A further promising approach is the nature of the ASRR task itself, which has strong ecological validity. This follows an emerging trend in the study of emotion, where processes are observed or elicited in more naturalistic methods (Lench et al., 2011; Rovenpor, Skogsberg, & Isaacowitz, 2013; Salas et al., 2012; 2015). As previously noted, personal events may be particularly effective at inducing higher levels of emotional arousal (Salas et al., 2012; 2015), and are closer to real-life situations, where reappraisal is an important part of daily life (Brockman, Ciarrochi, Parker, & Kashdan, 2017; McRae et al., 2012). The

ASRR allows for the investigation of reappraisal for various target emotions in a more naturalistic setting.

Much of the ER literature has investigated reappraisal, but there is growing interest in other regulatory processes: for example, situation selection (Markovitch, Netzer, & Tamir, 2017; Sands & Isaacowitz, 2017; Webb, Lindquist, Jones, Avishai, & Sheeran, 2018) and attentional deployment (Demeyer, Sanchez, & De Raedt, 2017; Ferri & Hajcak, 2015; Wirth & Kunzmann, 2018). Future work in people with neurological damage would benefit from better investigating these approaches, given that these strategies may be particularly important for those low in cognitive control, such as the elderly (Wirth & Kunzmann, 2018) and people with mood disorders (Webb et al., 2018).

Conclusion

Emotional changes after brain injury have been the focus of a growing literature (Fleminger et al., 2003; Shields et al., 2016; Williams & Evans, 2003). Indeed, with a greater understanding of the relevance of emotion in rehabilitation (Mateer, Sira, & O'connell, 2005), we have seen a recent shift towards an approach which focuses upon socio-emotional adjustment (Bowen, Yeates, & Palmer, 2010). Nonetheless, research on the effects of ABI on emotion *regulation* (based upon the 'process model') has been relatively modest (Salas et al., 2013; 2014). The present study not only demonstrates that an ABI can compromise the capacity to generate reappraisals, and in particular to do this rapidly, but this is the first study to demonstrate that brain-injured patients find reappraisal especially difficult for up-regulating *positive* emotions. Consistent with previous research, the study also provides evidence in support of the role of working memory in reappraisal, which suggests a range of interventions which may be useful for clinicians and patients' families.

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Appendix 1 - Affective Story Recall Reappraisal Task Instructions

Introduction. The task was introduced as follows "Sometimes people try to make themselves feel better by looking on the bright side of things. You will see an emotion word on the screen, it will be either sad, scared, angry, or neutral. When you see each word, try to recall an event in your life that caused you to feel that emotion. Try to be very detailed about the way you *feel*. Following this, you will rate how intensely you feel that emotion *now,* upon describing the event, on a 0 to 10 scale, with 10 being most intense. The next step is to think of as *many* positive sides of that situation as you can, as *quickly* as you can. After thinking of the positive sides, rate how you feel again on the same 0 to 10 scale".

As the "neutral" condition involves the *up*-regulation of emotion from neutral to happy, this was explained in more detail: "With *sad, scared*, and *angry,* low scores on the scale mean less intensely and high scores mean more intense. However, with *neutral,* the more neutral it is, the lower the score, and high scores mean happy. Do you understand the difference?" Before we start we have time to practice".

Practice. Patients were then trained on the task using an "angry", and then a "neutral" practice condition, with examples of two stories: Having an argument for the "angry" condition, and watching television for the "neutral" condition. Following this, participants were shown the 0-10 scale, and the description of the scale was repeated again. They were then required to think of reappraisals when prompted by the written cue "Think of the positive sides. Try to be quick", before examples of possible reappraisals were provided. For the "neutral" condition the example reappraisals were "I was watching television with family, which I am lucky to have and spend time with" and "It was nice to have an evening to relax". The example reappraisals for the "angry" condition were: "We don't argue that often" and "Because of this we've talked about ways we can communicate better in future". The emotion intensity scale was shown and explained again. If the participant did not understand

the task, the practice procedure was repeated, until the participant was satisfied that they understood what was required during the task.

Testing. Participants were informed that they have a maximum of three minutes to describe their stories (as per Salas et al., 2015), but they could use more time if needed. Their responses to the reappraising cue ("Think of the positive sides. Try to be quick") were timed and audio-recorded. These recordings are later transcribed *verbatim*. If participants struggled to think of stories, they were prompted with generic stories, for example "Some people would say they were *sad* when they lost a pet or family member", "Some people would say they were *angry* when they came across someone being rude or disrespectful", "Some would say they were *scared* when they feared for their or their family's safety or well-being", "Some would say they were *neutral* when going for a walk". Previous work using an ASR task, however, shows that brain-injured patients are able to recall emotional events (Salas et al., 2015, Turnbull et al., 2005). In line with this, all patients were able to recall stories, though some required additional prompting during the "neutral" condition, which consisted of asking the participant what they did on the days leading up to the testing session.

Tables

Table 1. *ABI participant information and injury characteristics.*

ID	Gender	Age	Years in education	Years since injury	Aetiology	Lesion location & information
1	M	57	17	1	CVA	Left MCA territory. Including left inferior frontal gyrus, white matter tracts in left frontal lobes.
2	M	40	13	21	TBI	Bilateral frontal contusions.
3	M	56	13	13	TBI	--
4	M	42	13	1	TBI	Left fronto-parietal SAH, left intraparenchymal haematoma. Right posterior parietal contusion. Right temporal haematoma. Bilateral frontal extra axial haemorrhage.
5	M	29	13	1	TBI	Bilateral frontal lobe contusion. Right temporal lobe contusion.
6	M	55	16	7	Herpes Simplex Encephalitis	Bilateral asymmetric temporal lobe involvement.
7	F	56	18	1	TBI	Bilateral frontal intraparenchymal haemorrhage, traumatic SAH, left cerebellar haematoma extending to right side.
8	M	57	16	22	TBI	Right temporo-parietal lesion.
9	M	47	10	9 months	CVA	Multiple infarcts (bilateral).
10	F	47	16	1	TBI	Traumatic SAH. Left frontal & parietal contusions.
11	F	63	11	1	CVA	Right MCA occlusion.
12	M	53	13	4	TBI	Left temporo-parietal compound skull fracture with underlying contusion.
13	M	67	13	1	Hypoxic Encephalopathy	--
14	M	55	10	10 months	CVA	Right PCA aneurysm.
15	M	47	13	29	TBI	Left frontal and parietal lesions.

16	M	58	13	3	CVA	Extensive abnormal areas throughout periventricular white matter.
17	M	58	13	5	TBI	Left frontal lobe lesion and possible diffuse axonal injury.
18	M	53	13	9 months	CVA	Left frontal infarct.
19	M	54	11	1	TBI	Fracture of inferior floor of right orbital wall. Presentation highly suggestive of frontal lesion.
20	M	54	16	10	CVA	Right MCA territory infarct.
21	M	50	13	32	TBI	--
22	M	45	16	1	CVA	AcommA Aneurysm.
23	M	40	11	5	CVA	AcommA Aneurysm.
24	F	26	13	8	TBI	Diffuse TBI --
25	M	45	10	1	TBI	Right frontal lesion, left temporal contusion.
HF26	F	32	11	16	Tumour/CVA	Ruptured pituitary gland tumour. No other information available.
HF27	M	70	16	1	CVA	Bilateral multiple infarcts, temporal lobe involvement. No other information available.
HF28	M	46	13	20	TBI	Diffuse TBI, bilateral --
HF29	M	43	13	28	TBI	Diffuse TBI--
HF30	M	59	11	24	TBI	--
HW31	F	61	11	22	TBI	Diffuse TBI--
HW32	M	34	16	1	TBI	Right sided SAH. --
HW33	M	72	10	11	TBI	--
HW34	F	34	16	10	AVM/CVA	Right parieto-occipital lesion.
HW35	M	74	13	8	CVA	Left-sided PCA territory. --

TBI = traumatic brain injury; CVA = cerebrovascular accident; -- = No information available; AVM = arteriovenous malformation; SAH = subarachnoid haemorrhage; MCA = middle cerebral artery; PCA = posterior cerebral artery; ACommA = Anterior communicating artery. Participant IDs beginning with "HF" or "HW" were recruited through Headforward centre and Headway, respectively.

Table 2. Emotional and cognitive functioning of ABI patients and HC participants

	Depression (HADS)	Anxiety (HADS)	ERQ-CA	Working memory (Digit Span, WAIS IV)	Verbal ability (Letter fluency, DKEFS)	Inhibition (Hayling sentences)
M, SD (ABI)	9.26, 4.11	9.89, 4.32	22.77, 6.91	22, 5.79	27.57, 11.24	15.03, 3.88
M, SD (HC)	3.32, 2.40	6.23, 3.32	31.32, 6.74	27.18, 3.40	32.32, 7.89	16.15, 2.90
M, SD Scaled Score (ABI)				7.51, 2.98	7.03, 3.43	4.66, 1.81
M, SD Scaled Score (HC)				10.14, 2.08	8.91, 2.49	5.14, 1.29
Score range for "borderline abnormal/impaired"	8 – 10	8 – 10		6 (scaled)	4 – 6 (scaled)	3 (scaled)
Score range for "clinical/impaired"	11 – 21	11 – 21		1 – 5 (scaled)	1 – 3 (scaled)	1 – 2 (scaled)
Number participants (/35) in the "borderline" range, "clinical/impaired" range (ABI)	11, 11	2, 20		3, 10	12, 4	3, 4
Number participants (/22) in the "borderline" range, "clinical/impaired" range (HC)	1, 0	3, 2		0, 1	1, 0	3, 0
Significant difference (t-test *p* value)	< .001	.001	< .001	< .001	.041	.254

Table 3. Time taken to generate a first reappraisal (reappraisal difficulty)

	Neutral	Sadness	Fear	Anger
ABI Group				
M, SD, Mdn	8.96, 4.38, 8.00	9.96, 3.48, 9.50	7.79, 3.18, 8.50	9.66, 3.90, 8.00
Mean Rank	35.71	34.47	35.84	32.13
HC Group				
M, SD, Mdn	4.68, 2.98, 3.50	6.59, 3.52, 5.25	5.52, 2.91, 5.50	7.32, 3.60, 8.00
Mean Rank	18.32	20.30	18.11	24.02

Table demonstrating descriptive statistics for reappraisal difficulty across all classes of emotion for ABI and HC groups.

Table 4. Total number of reappraisals produced (Reappraisal *productivity*)

	Neutral	Sadness	Fear	Anger
ABI Group				
M, SD, Mdn	3.23, 1.35, 3.00	3.31, 2.06, 3.00	3.40, 1.96, 3.00	3.09, 1.82, 3.00
Mean Rank	24.36	24.63	24.00	24.96
HC Group				
M, SD, Mdn	4.59, 2.11, 4.00	4.73, 2.10, 4.00	4.86, 1.86, 5.00	3.23, 1.35, 3.00
Mean Rank	36.39	35.95	36.95	35.43

Table demonstrating descriptive statistics for reappraisal productivity across all classes of emotion for ABI and HC groups.

Table 5. Reappraisal *ability* scores (the difference in emotional intensity before, and after, reappraising

	Neutral	Sadness	Fear	Anger
ABI Group				
M, SD, Mdn	1.08, 1.18, 0.50	2.26, 2.01, 1.50	2.40, 1.98, 2.50	2.11, 2.21, 1.50
Mean Rank	23.37	26.13	26.90	25.64
HC Group				
M, SD, Mdn	3.21, 2.65, 2.75	3.32, 2.51, 2.75	3.59, 3.09, 2.50	3.46, 2.69, 2.50
Mean Rank	37.95	33.57	32.34	34.34

Table demonstrating descriptive statistics for reappraisal ability across all classes of emotion for ABI and HC groups.

Figures

Figure 1.

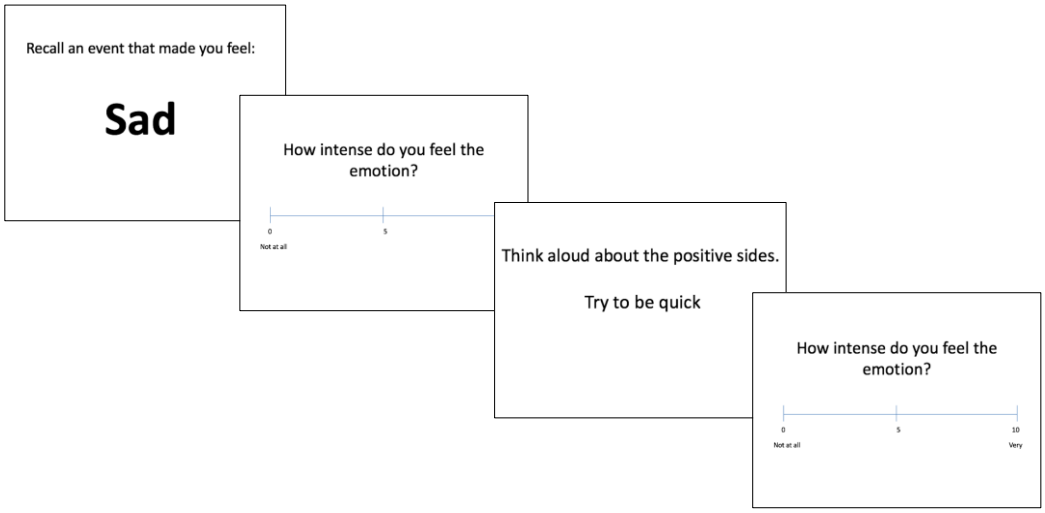

Figure 1. *Figure demonstrating one trial in the ASRR task (sad condition).*

Figure 2.

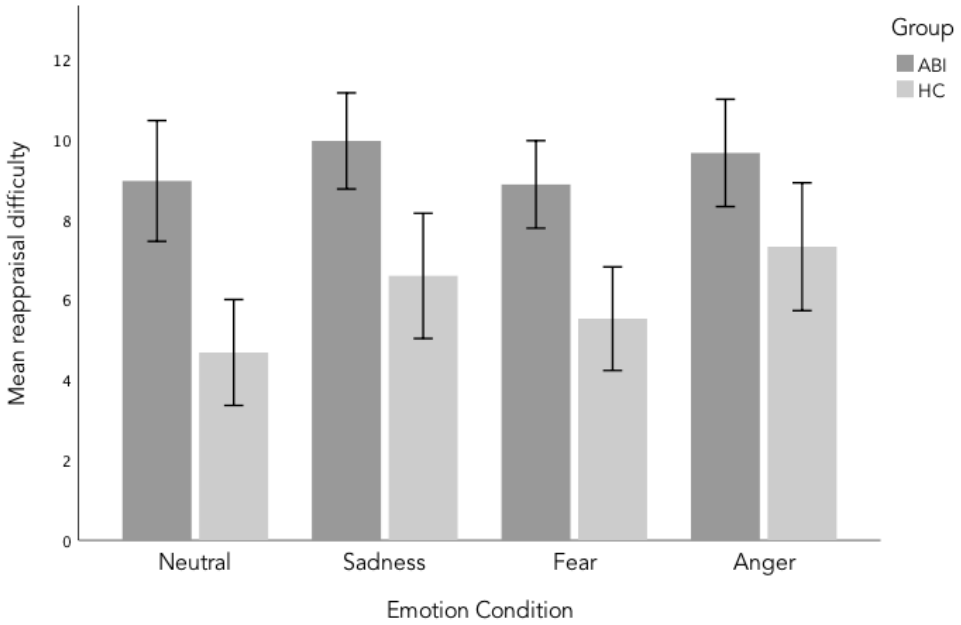

Figure 2. *Bar chart representing the average time taken (seconds) (reappraisal difficulty) to generate a first reappraisal across all emotion conditions for both the ABI and HC group.*

Figure 3.

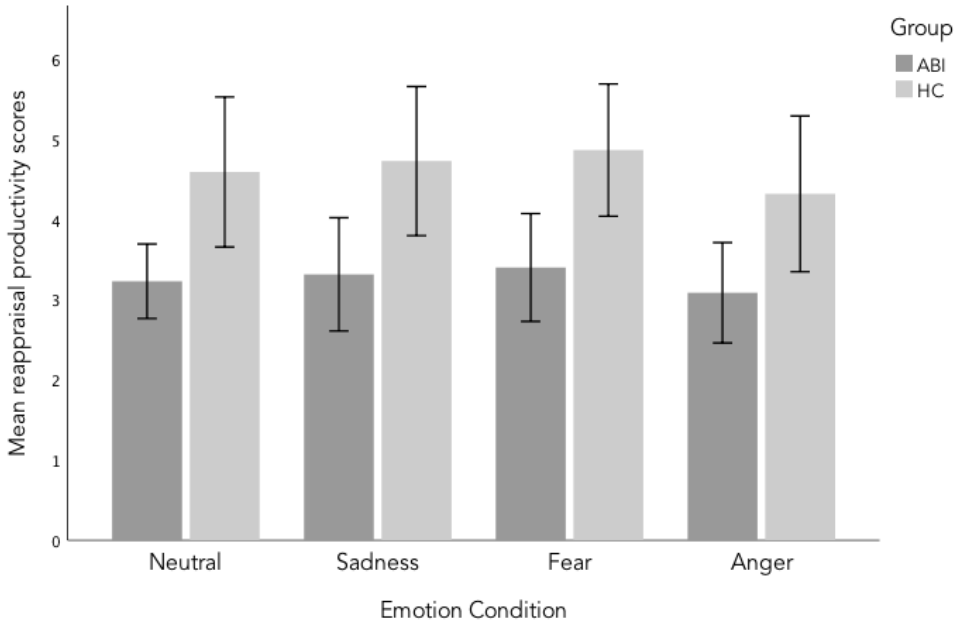

Figure 3. *Bar chart representing the average number of reappraisals produced (reappraisal productivity) across all emotion conditions for both the ABI and HC group.*

Figure 4.

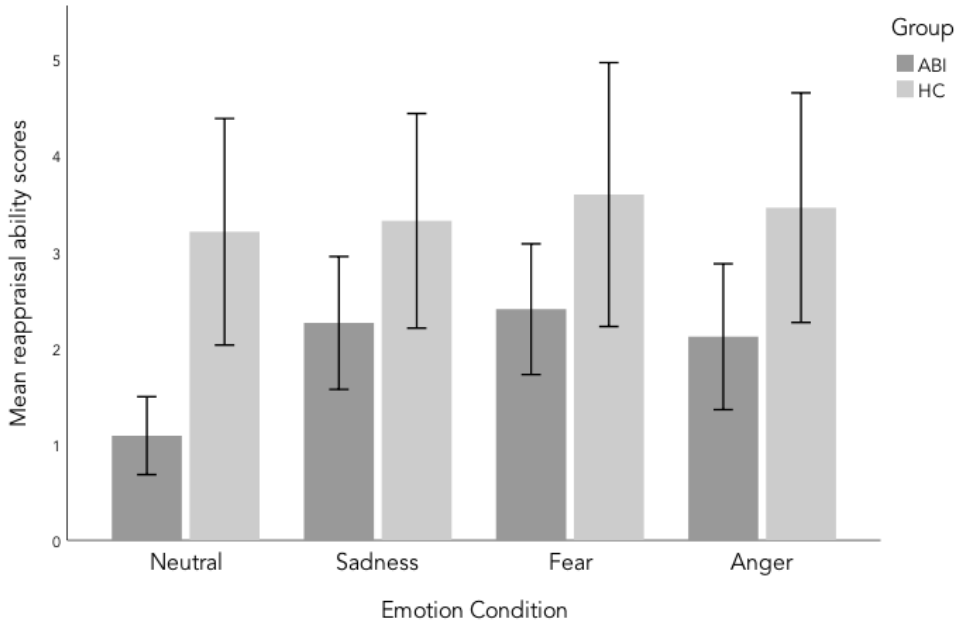

Figure 4. *Bar chart representing the average difference in emotional intensity after reappraising (reappraisal ability) across all emotion conditions for both the ABI and HC group.*