AGE-RELATED DIFFERENCES IN ACCURACY OF RETROSPECTIVE PAIN REPORTING

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ABSTRACT

In standard clinical practice, healthcare professionals rely heavily on retrospective self-report methods when assessing and treating pain. Older adults, who are particularly at-risk for a number of painful conditions, may have difficulty accurately reporting pain after a delay for a number of reasons, including declining memory ability. It is therefore of vital importance to understand factors which may influence the accuracy of retrospective pain intensity reports specifically within an older adult population. The purpose of this study was to assess whether age related differences in retrospective pain reporting exist and if so which specific mechanisms drive this effect. In order to do this, an experimentally manipulated heat pain was induced and participants were asked to rate the intensity of this sensation immediately after pain onset and then again one week later. We also assessed depression scores, presence of a pain comparison point, memory ability, specific memory processes, and cognitive status to see how these variables were related to differences in pain-reporting. Results revealed that older adults showed a tendency to over-report pain after a delay, whereas younger adults were more likely to under-report. This finding was not related to memory scores or cognitive status, and instead this effect may be driven by older adults experiencing a higher level of current pain at the time of reporting than young adults. Additionally, both older and young adults with higher depression scores showed a tendency to overestimate pain levels after a delay, most likely due to a mood-congruency recall bias. Beyond this, results also revealed that when both older and young participants rated pain with reference to a framework of previously experienced pain across the lifespan as a comparison point, they were more likely to under-report the specific instance of pain. These results suggest that age-related differences in retrospective pain reporting do exist, and the broader implications of this are discussed.

BIOGRAPHICAL SKETCH

The author, Amber John, was born on May 31st 1993 in Manchester, England. She completed her primary and secondary education at Bolton School, UK. She received a Bachelor of Science Honors in Psychology from the University of Reading in 2014, achieving a First degree classification. Currently, she is completing her Masters in Human Development from Cornell, and will be graduating with a 4.0 GPA.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

One of the most prominent characteristics of the aging process is rapid change and development in a range of different domains, including biological, cognitive, medical and social aspects of life (Craik & Bialystok, 2006; Lang, 2001; Verbrugge & Patrick, 1995). Although there are positive changes which take place during this time such as a growing experience and knowledge of the world, older adults are also at increased risk for a number of negative health issues, including cognitive decline, depression and various medical conditions, such as chronic pain (Nelson et al., 2007). Due to our progressively aging population, these detrimental health risks associated with older adulthood are becoming a major social and healthcare priority (Wallace et al., 1998). It is predicted that by 2050, there will be an increase in the population of adults over the age of 65 years old to 36% (Gavrilov et al., 2003), and for this reason it is relevant to consider how these age associated health outcomes may influence quality of life within this demographic, and how both preventative and interventional medical resources can improve this experience. For the past few years chronic pain in the elderly has become the focus of a growing amount of research, and these investigations have helped to elucidate the debilitating and incapacitating experience of pain within older adults (Peat et al., 2001). There are a number of potential causes of pain within this population, including neuropathic and musculoskeletal disorders (Ferrell et al., 1995), and common causes include joint arthritis, traumatic injury, degenerative disc disease, various types of headache, as well as generalised pain disorders such as fibromyalgia (Breivik et al., 2006). The reported prevalence of pain amongst the elderly fluctuates to a great extent, depending on the specific sample assessed, but there is a general concurrence within the literature that this prevalence is widespread within our society. Studies investigating older adults dwelling in the community generally report a prevalence of approximately 50-73%, but when assessing older adult samples residing in care homes, this statistic appears to increase to 80%, highlighting the pervasive nature of this condition (Allcock et al., 2002; Harstall & Ospina, 2003).

Beyond inhibiting older adults' ability to function effectively and live independently, chronic pain can have a myriad of detrimental outcomes, including reduced mobility (Oerlemans et al., 1999) and heightened levels of disability (Turner et al., 1986). In addition to these physical consequences, persistent pain can have an influential and adverse impact upon the psychological, social, emotional and financial status of the individual, which can subsequently contribute to heightened levels of pain-related burden and distress (Mäkela et al., 1991). Emotional and psychological difficulties associated with pain are also common, and the presence of psychopathology has been well documented in individuals suffering from chronic pain, as compared with a healthy control sample in previous research (Merskey, 1994). There are a number of challenges faced by chronic pain patients, including diminished enjoyment of daily activities, loss of function, social relationship difficulties and role changes (Levenson, 2006). Worry regarding the potential for worsening pain or that pain will not substantially improve are often accompanied by feelings of anxiety, sadness, grief and anger. This strain may act as a precursor and make chronic pain patients more vulnerable to the development of a mental health issue.

In order to improve the experience of pain within older adults, it is of vital importance for accurate assessments of pain intensity to be made by clinicians. In standard clinical practice, healthcare professionals often rely on self-report methods in order to form a diagnosis and prescribe interventions designed to treat pain (Brauer et al., 2003). Such methods generally include delayed self-report, in which the individual is asked to rate pain intensity after a short delay from pain onset (Gedney et al., 2003). One specific example of such an assessment is the Mental Health scale question on pain magnitude in the Medical Outcomes Study, which asks retrospective questions (McHorney et al., 1993). However, despite the clear importance of accurate self-reports of pain, there are numerous factors which may act as barriers to successful pain reporting in patients, including social, cultural, and psychological factors (Chibnall & Tait, 2001). In particular, memory may pose a significant challenge to accurate pain reporting in retrospective self-report techniques. This is especially relevant within older adult populations, for

whom cognitive impairment and memory decline is a major debilitation. Alzheimer's disease is the most common type of dementia within older adults, impacting around 10% of Americans over the age of 71 (Brookmeyer et al., 2002). Additionally approximately 22% of older adults in the US suffer from mild cognitive impairment (MCI), which is characterized by deterioration of cognitive function, particularly in the domain of memory (Grundman et al., 2004). Although individuals with MCI are not considered to be demented, as this decline does not interfere with everyday function, approximately 12% of these individuals transition to Alzheimer's annually (Plassman et al., 2008). Due to the prevalence of declining memory ability as well as the ubiquitous nature of pain within the older generation, it is of critical importance to consider whether memory degeneration may pose as a significant challenge to reporting previously experienced pain after a delay.

Despite the clear theoretical and societal importance of research into memory for pain, there have been relatively few empirical investigations into the manner in which pain is recalled, and the factors which may influence memory for pain (Fienberg et al., 1985; Linton, 1991; Algom & Lubel, 1994; Lefebvre & Keefe, 2002). Previous literature that has focused on this area has been relatively limited with inconsistent and often contradictory findings (Gedney et al., 2003). Early studies, which predominantly examined the degree to which individuals were able to accurately recall painful sensations after a delay, provided contradictory findings. Several researchers have reported that individuals are generally reasonably accurate when recalling pain intensity (Hunter et al., 1979; Roche & Gijsbers, 1986; Babul et al., 1993; Beese & Morley, 1993; Bryant, 1993). However other researchers have provided evidence to suggest that memory for pain does not remain stable after a delay from pain onset (Eich et al., 1985; Kent, 1985; Rofe & Algom, 1985; Lander et al., 1992; Feine et al., 1998). Additionally, of the results which report inaccurate pain recall, it is unclear whether individuals are likely to over or under-report levels of pain intensity after a delay. Cumulatively, these conflicting results suggest that pain recall is variable, and differs across individuals and studies. One particular limitation of this previous

research is that most studies have attempted to assess memory for pain in a general population, without discriminating by age category. Specifically, due to the decline in memory which is characteristic of the aging process, it seems plausible that age-related differences in pain recall may exist. It is therefore of considerable interest to conduct further empirical investigation into this domain.

Previous research into the area has suggested that older adults experiencing higher levels of cognitive impairment seem to report lower levels of pain than healthy older adults and young adults (Schuler et al., 2004). Lucca et al (1994), for example, showed that patients with Alzheimer's disease (AD) were prescribed fewer non-steroidal anti-inflammatory medications than their healthy counterparts. Beyond this, cognitively impaired older adults have been reported to receive fewer analgesics and medications than healthy older adults post-operation, despite demonstrating more behavioral indicators of pain (Bell, 1997). Reynolds et al (2008) found that higher levels of cognitive impairment in older adults was highly related both to lower reports of pain, and lesser treatment of pain than in more cognitively intact nursing home residents. Beyond this, the researchers replicated previous findings (Proctor & Hirdes, 2000) that there appeared to be no significant differences in painful diagnoses of elderly adults based on cognitive status, and for this reason it was concluded that the observed under-treatment of pain was more likely to be associated with difficulties in the recognition of pain in cognitively impaired elderly adults, than due to lower pain rates in such populations. It has been argued that due to the neurological impairments inherent in Alzheimer's and MCI patients, the central nervous system experience of pain could be affected, leading to a decline of awareness of peripheral pain stimuli. However, there has been a vast amount of research demonstrating that these impaired individuals are unlikely to simply be experiencing less pain than those more cognitively intact. For example Kunz et al., (2009) found that cognitively impaired populations experienced pain for a noxious electrical stimulus similarly to healthy older adults and young college student participants based on facial responses and motor reflex in response to the stimulation. This is a fairly commonplace finding

within the literature (Kunz et al., 2007; Lautenbacher et al., 2007). Based on these results, it seems logical to consider that perhaps lower pain reports in older adults, particularly those experiencing deteriorations in cognitive function, may reflect a decline in retrospective retrieval of the sensory pain experience, rather than a decline in the sensory experience of pain in general. It is also possible, however, that cognitively impaired populations may simply be less able to communicate pain than those more cognitively intact, and as such healthcare providers may dismiss their pain to a greater degree (Herr et al., 2006).

However, most of these previous studies have assessed older adults suffering from severe cognitive impairment, and thus it is unclear how healthy older adults differ in their memory for pain from young adults. If these individuals do not report pain accurately after a delay due to declining memory which is often characteristic of the natural aging process (Rioux et al., 1995), it is also of interest to assess whether they are more likely to under-report pain intensity levels or over-report. Previous research proposes that current pain level may influence how a specific instance of previously experienced pain is reported, whereby individuals in a high level of current pain will be more likely to over-report, whereas those in a low level of current pain may be more likely to underestimate the previously experienced sensation (Eich et al., 1985; Smith & Safer., 1993; Smith et al., 1998). This finding could potentially drive age-related differences in memory for pain. As discussed above, older adults are at a greater risk of suffering from painful conditions, and are more likely to experience pain on a day to day basis than young adults (Fox et al., 1999). Therefore if pain level at the time of reporting does indeed influence retrospective reports of a previous instance of pain, then it seems logical that older adults who are likely to be in a higher level of pain than young adults would recall pain intensity differently. Specifically, older adults may be more likely to show an overestimation of pain intensity after a delay, due to higher current pain levels, whereas young adults may tend to under-report the previously experience pain sensation due to lower levels of current pain.

Additionally, there are numerous other factors which may cause older adults to over-report pain levels in comparison to younger adults. Specifically, the presence of depression and depressive symptoms may play an important role in the relationship between memory and pain reporting. Indeed, cognitive theories of depression propose that dysfunctional self-schemas and negative cognitions in this condition bias the processing of information in depressed individuals. There has been a large amount of previous research demonstrating that individuals with depression display a clear memory bias, selectively recalling negative information in favor of positive stimuli (Watkins et al., 1992; Bradley et al., 1995; Ridout et al., 2003). Depression is ubiquitous in aging individuals, and several studies have reported that depression increases in this population (Lehtinen et al., 1990; Blazer et al., 1991; Beekman et al., 1995). If depression incidence grows with age, then older adults may be more likely to rely on these dysfunctional self-schemas and negative cognitions associated with depression when recalling pain intensity, and thus may be biased to retrieve negative information and over-report the level of pain experienced after a delay.

However, in contrast to this, it has also been proposed that an age-related shift may occur in the proportion of positive and negative information recalled (Charles et al., 2003). This is generally discussed in reference to Carstensen's (1995) socio-emotional selectivity theory, a lifespan motivation theory. This theory refers to the human ability to monitor time and the subsequent adjustment of time horizons to consider time limits. As time horizons diminish with age, there is a shift in priorities and more resources are invested into emotionally meaningful goals. Younger adults, by contrast, place higher priority and importance on goals which expand horizons, and which relate to experiencing novelty, rather than goals from which emotional meaning can be derived (Carstensen, 1999). Related to this, in the literature surrounding memory changes through aging, a phenomenon has been observed, whereby older adults seem to show a preference for memory of positive information over negative in terms of items later recalled, whereas younger adults display the opposite effect. In a study conducted by Mather et al

(2004), both young and older adults viewed images of positive and negative content during event-related fMRI. Young adults showed increased amygdala activity to both negative and positively valenced images compared with neutral. Older adults, by contrast, showed increased amygdala activity selectively in response to positive images, suggesting that this positivity effect is present even at encoding, with older adults showing diminished processing of negative information. Applying this positivity effect to memory for pain, this theory posits that older adults may be biased to show biased recall enhancing positive information and suppressing negative information. As a result these individuals may be more likely to recall the previously experienced pain sensation in a positive light, and therefore under-report the experience at a later time.

Current pain influencing recall of previous pain, and the positivity hypothesis appear to predict conflicting findings. Current pain as a predictor of memory for pain suggests that older adults will be more likely to overestimate their pain levels after a delay, whereas younger adults may under-report. By contrast, the positivity effect hypothesis indicates that older adults may be biased to selectively recall positive information, and as a result may under-report pain intensity. It is therefore of interest to assess which of these competing hypotheses has more value in driving age-related differences in memory for pain.

Beyond this, there has up to this point been relatively little consideration of the specific deficits in memory retrieval processes which may at least partially underlie inaccurate pain reports. For this reason we propose to consider this pain literature with reference to Fuzzy Trace Theory (FTT) and dual-retrieval models of recall. Fuzzy Trace Theory posits that memory targets can be recalled through direct access to specific verbatim memory traces, or through a more general reconstruction of memory targets on the basis of partial identifying information, particularly information which is semantic in nature (Brainerd et al., 2010; Brainerd et al., 2012). Direct access retrieval is the most accurate type of recall, as it involves reinstating vivid details of the memory target from earlier presentation in its surface form,

and can therefore be considered as 'errorless' in nature. The non-recollective reconstruction operation involves generating a number of candidate retrieval items on the basis of partial-identifying features, usually semantic. Familiarity checks are carried out on these candidate items as part of a judgment operation, and only memory targets which exceed the decision criterion of familiarity then proceed to output recall. This element of retrieval is generally more sensitive to error, as recall is based on the retrieval of gist traces. Such dual-retrieval models have been applied most frequently to the memory changes that occur through the aging process, and as a method of identifying individuals who may be more at risk of transitioning from being healthy to being cognitively impaired, as well as the transition from mild cognitive impairment (MCI) to dementia (Brainerd et al., 2014). Although these are the most common applications of the model, it may also have value in predicting pain reporting in older adults. More specifically, it is possible that inaccurate reports of pain in older adults may be related to deficits in direct access retrieval of verbatim memory traces, and this effect may be more pronounced in cognitively impaired individuals. It is also possible that inaccurate pain reports in aging populations may be associated with more intact non-recollective reconstruction processes. These hypotheses are based on findings, which seem to indicate that older adults are able to fairly accurately understand the semantic features of pain and localize the site of pain in a similar way to chronic pain patients, but are less accurate in reporting the intensity of pain levels (Schuler et al., 2004). These findings are consistent with evidence that while reconstruction of semantic information regarding the pain remains intact, the direct access retrieval of specific sensory information, relating to the pain intensity is impaired. Similarly a growing body of research has provided evidence to suggest that verbatim memory deteriorates through the aging process, whereas gist retrieval remains relatively preserved, which would explain why this misreporting of pain phenomenon would become apparent through aging (Schacter et al., 1991; Herr et al., 2006; Chibnall & Tait, 2001).

It has also been posited that how an individual recalls a painful event may vary as a function of their previous experiences of pain (Lefebvre & Keefe, 2002). There has, however, been very little research investigating this hypothesis specifically. It is of interest to see whether pain experienced in the past can influence accuracy of reports for a specific instance of pain. It would be interesting to see whether focusing on a framework of painful sensations from across the lifespan can influence specific pain recall. Additionally, if this is the case, it is of value to further our understanding of whether people are more likely to over or underestimate pain levels when reporting with previously experienced pain in mind. We hypothesize that when reporting the intensity of a specific instance of pain with reference to a framework of previously experienced pain, this framework may act as a comparison point from which the pain instance from the previous week would be compared. It seems highly likely that most participants will have experienced more severe pain within their life than that which is administered during the study. As such, we hypothesize that individuals may be more likely to under-report pain when recalling it with reference to more severe pain from the past. If this is the case, older adults may display this pattern to a greater extent than young adults, as they have had a longer lifespan and are more at-risk for experiencing painful conditions, such as arthritis and fibromyalgia (Lawrence et al 2008), and so may be comparing the pain from the study with more severe and consistent pain experiences than young adults. This is one potential mechanism which may have value in manipulating accuracy of pain reporting after a short delay.

It is clear that there are numerous unanswered questions within the previous literature surrounding memory and pain. For this reason, in the current study we aim to elucidate and clarify several of these research questions. We plan primarily to investigate age related differences in memory for pain, specifically within a nominally healthy older adult sample, and to compare competing theories, such as current pain and the positivity effect, which strive to explain such age differences. The current study will also seek to identify whether specific retrieval processes may have value in predicting

accurate pain recall. Specifically, we hypothesize that inaccurate pain recall in older adults may be related to a decline in recollective retrieval (direct access) processes, and additionally we also expect that non-recollective retrieval will remain relatively intact in those with less accurate memory for pain. Beyond this, one further hypothesis in this study is to assess the role of depression in the relationship between memory and pain reporting. Due to findings in the previous literature, we believe that individuals with higher levels of depressive symptoms will show a tendency to over-report pain levels after a delay as compared to individuals with lower depression scores. Finally, we will examine whether reliance upon a framework of previously experienced pain influences later recall of a specific pain instance.

2. METHODS

2.1. Participants

For this experiment, we recruited 75 participants in total, approximately 45 of whom were young adults aged between 18-30 (Mean age: 19.6), and the other 30 were older adults aged over 65 (Mean age: 75.3). Young adults were mainly university students and were recruited through an online SONA system at Cornell University, in which they received course credit in exchange for participation. Older adults were recruited from a database collected of older adults living within the Tompkins County area, and from facilities and institutions for older adults within the local vicinity. In terms of gender, more females took part than males with an approximate ratio of 1:2 males to females. This ratio was the same for both age categories. Additionally, on average the older adults had achieved a slightly higher level of education of approximately 16.3 years on average, whereas younger adults on average had completed 14.4 years of education. Older adults were also taking on average 4.4 prescription medications, whereas young adults on average were taking 0.5 medications. This is relatively unsurprising, given that older adults tend to be a greater risk for numerous physical conditions and co-morbidities than younger adults. Despite this, all participants (older and young adults) reported their overall health as being either good or very good, with only one participant noting a weak immune system. The majority of participants spoke English as their first language, with the exception of eight participants, for whom English was a second language. We did not recruit any participants who may be suffering from cognitive impairment, such as Dementia or MCI. Additionally, we did not include participants with medical conditions which may make them more susceptible to injury, due to decreased sensation. Individuals with known injuries, sensory disorders, or circulatory disorders were therefore excluded. Examples of such conditions include diabetes, lupus/autoimmune disorders, vascular disease and neurologic injury. All participants were blind to the aims of the experiment to avoid the risk of prior knowledge causing changes in behavior and therefore confounding the results.

2.2. Measures

2.2.1. Experimental stimulation of pain

In order to induce an experimental manipulation of pain, we used heat pad equipment. This equipment consists of an electronic benchtop controller, manufactured by Omega Engineering (Model – C5C32.J. Serial Number – 530139040262), which provides a controlled current to a circular heating pad at a prescribed temperature. The participant was asked to place the non-dominant hand on the pad, starting at a baseline temperature of 30 degrees C (which is non-discomforting). The heat was then automatically increased in incremental 1 degree steps until the participant reports mild to moderate pain, which is then taken as their pain tolerance value. This is the standard operating procedure for this specific piece of equipment, and the mean pain tolerance is generally around 45 degrees C. The equipment requires programming of a set-point value beyond which the temperature will cease to increase. In the interest of safety this maximum value was set to 50 degrees. This is a value which has been determined by previous literature and has been identified in such literature as a safe temperature, which will avoid any participants experiencing excessive discomfort. The equipment is programmed to automatically increase temperature at the rate of one degree per second until it reaches this maximum value of 50 degrees.

2.2.2. Outcome measure

The outcome variable of interest for this study was the extent of memory decline for a painful stimulus. In order to assess this, we used the Numerical Rating Scale (NRS), a scale from 1-10, whereby 1 represents no pain at all, and 10 represents the worst possible pain. Participants were asked to report their pain level on this measure immediately after induction of a painful stimulus using heat pad apparatus, and then again one week after onset of pain induction. The discrepancy between these two reported numbers was taken to be the level of change in memory of the intensity of the experimentally stimulated pain.

2.2.3. Predictor Variables

The main predictor variables assessed in this study were age of participant, cognitive status, extent of depression, memory ability, and completion of a judgment task designed to make participants focus on a framework of previous pain experiences. Age of participant was recorded at the beginning of the study on a short form, asking the individual to state their age. Cognitive status was measured using the Telephone Interview for Cognitive Status (TICS) (Brandt at al., 1988). This is an assessment similar to the Mini-Mental State Examination (MMSE), which has been adapted for use over the telephone. This instrument has high sensitivity (82.4%) and specificity (87%) to the diagnosis of cognitive impairment in older adults, and additionally has high test-retest reliability (Cook et al., 2009). Depression levels were assessed using the Beck Depression Inventory (BDI), a measure which has been widely utilized within clinical and research settings. The BDI instrument is a 21 item scale and was first introduced in 1961 (Beck et al., 1961). This measure assesses the presence of various depressive symptoms, including sadness, pessimism, and self-dislike, and all answers are summed to give a total score out of 63. A score over 30 may indicate the presence of depression. We used a version of this task which first provided an initial depression score, and then one week later assessed whether there had been any significant changes in this score from the previous week. The second half of this measure included four questions such as 'Since your last visit, have you felt depressed, sad or blue much of the time?' Memory ability was assessed using Rey Auditory Verbal Learning Task (RAVLT) (Rey, 1964). This task involves eight word lists with 15 items each, which the participant is asked to recall. The first five lists are study trials and are administered immediately one after another. The sixth list is a distractor list of all new words, followed immediately by the seventh list, which includes the initial words in order to assess memory for the initial words after the distractor list. The final list is the initial 15 words again, repeated by the participant after a 30 minute delay. Research has shown that the RAVLT is robust for use in both academic research and clinical assessment of memory decline (Geffen, 1994; Uttl, 2005; Schoenberg et al., 2006). Finally the

judgment task predictor was measured by determining whether or not the participant completed a judgment task, which was designed by the experimenter, adapted from a similar task used in Mills et al (2008). This instrument was designed to assess the level of pain experienced on a day to day basis, as well as the individual's perceptions regarding their likelihood of experiencing chronic pain. This measure included questions such as 'I am likely to experience pain within the next month. (Strongly Agree; Agree; Neutral; Disagree; Strongly Disagree)', and 'What are the chances you are suffering from chronic pain? (Please rate on a scale from 0-100, where 0="no chance at all", and 100="highest possible chance)'.

2.2.4. Other variables of interest

Variables which were not of primary interest in this study but which were nonetheless important to assess were also included. One such variable was pain tolerance. We recorded the peak temperature at which the participant removed their hand from the heat pad and this was taken to be the highest level of pain the individual could tolerate. This allows us to consider whether inherent differences in the objective level of pain which can be tolerated exist between older and young adults. Participants were also asked to complete a questionnaire designed to extract demographic information, including gender, amount of medications the individual is on, number of years in education, and overall health status (excellent, good, average, poor, very poor).

2.3. Procedure

This was a three part experiment. The first and final sessions were both in-person and scheduled to be exactly one week apart. The second session took place over the phone and could be conducted any time in the week between the first and third session. Both in-person sessions were conducted either on Cornell campus, or in participant homes to allow for older adults whose health and/or lack of transportation may not permit them to travel onto campus.

In the first session, participants were first asked to read and sign a consent form to ensure that all individuals were willing and happy to take part. After this approximately half of the participants

completed the judgment task, in which they rate the pain sensation with reference to previously experienced pain from across the lifespan. The other half did not complete this task. Next, heat pain was administered using the heat pad apparatus. This instrument began at 30 degrees Celsius, and increased by 1 degree every second. Participants were asked to place the non-dominant hand on the center of the pad at 30 degrees, and leave it there until the experience was mildly painful, at which point they removed their hand. Participants were then asked to make an immediate report of pain intensity, using the Numerical Rating Scale (NRS). Finally, participants were asked to complete the Beck Depression Inventory to assess presence of depressive symptoms.

The second session took place over the phone. Firstly, participants were asked to answer each question from the demographic questionnaire (gender, age, education etc.) Once this was complete, the researcher administered the Telephone Interview for Cognitive Status to assess extent of cognitive decline. Finally, the participant was reminded about the date and time of their final session.

The third and final session took place in-person, and was scheduled exactly one week after the first session. First, half of the participants (same half as last time) were asked to complete the same judgment task, asking them again to use past life experiences of pain as a comparison point when recalling the experimentally manipulated pain sensation from the study. Next, participants were asked to rate the intensity of the painful sensation experienced in the study the previous week, using the NRS measurement. Once this was complete, participants completed the first six learning trials of the RAVLT to assess memory ability. After this, the second section of the Beck was administered. This assessed changes in depression scores from the previous week based on the responses to four questions. If two or more of the responses to these questions were ‘yes’, then the participant was asked to complete the full 21-item Beck measure again. Next, participants completed the final trial of the RAVLT (trial 7), designed to assess recall ability after a delay. Finally, all participants were fully debriefed about the aims

and purposes of the study, and provided their signature to show that they were happy for their data to be used in this experiment.

All participants in this study were carefully counterbalanced. We were concerned that if the BDI was administered at the beginning of the session, this could then influence participants to report pain in a different, possibly more negative way. Additionally, we were also concerned that if the BDI was completed at the end of the session, the painful experience, which is inherently negative, may influence scores on the BDI. For this reason, we decided to counterbalance participants, so that half completed the BDI at the beginning of the session (1) and the other half at the end (2). Additionally, since we wanted half of the participants to complete the judgment task (J) and the other half to not complete this measure (NJ), this was also counterbalanced. As such, the counterbalancing order was as follows: J1, NJ1, J2, NJ2.

3. RESULTS

3.1. Differences between groups and manipulation checks

In order to examine initial differences between age groups, we ran a number of independent samples t-tests. First we tested to see whether the two conditions differed significantly in the level of education achieved. The analysis that revealed that older adults had spent significantly longer in education than younger adults (Older adult mean = 16.31 years; Young adult mean = 14.42 years), $t(69)=-4.47$, $p=0.001$. A further t-test demonstrated that age groups differed significantly on number of medications taken on a regular basis, with older adults having a higher number of prescription medications than younger adults (Older adult mean = 4.38; Young adult mean = 0.47), $t(67)=-7.72$, $p=0.001$. In terms of proportion of gender, age groups did not differ significantly from one another, suggesting the ratio of males to females was approximately the same in both age categories, $t(69)=-0.37$, $p=0.71$. However, age categories differed significantly in terms of their temperature pain tolerance with this pain tolerance being significantly higher in older adults (Older adult mean = 43.69; Young adult mean = 40.89), $t(69)=-2.18$, $p=0.03$. Finally we used responses to one of the items in the judgment task to assess whether age groups differed significantly in the extent of physical pain experienced on a day-to-day basis. This t-test revealed that older adults were significantly more likely to suffer from pain on a daily basis than young adults (Older adult mean = 51.54% chance of experiencing pain on a daily basis; Young adult mean = 20.69%), $t(69)=-2.94$, $p=0.006$.

3.2. Bivariate Correlations

In order to examine the main correlations between variables, we first ran bivariate correlations. Results of this analysis revealed that immediate-delayed discrepancy scores were significantly correlated with age ($r(68)=0.39$, $p=0.001$), depression scores ($r(68)=0.22$, $p=0.04$), level of education achieved ($r(68)=0.32$, $p=0.08$), number of prescription medications ($r(66)=0.28$, $p=0.02$), pain tolerance ($r(68)=0.24$, $p=0.049$), immediate pain reports ($r(68)=-0.26$, $p=0.03$), and delayed pain reports

(*r*(68)=0.32, *p*=0.007). Immediate pain reports were not significantly correlated with any of the variables except delayed pain reports (*r*(68)=0.77, *p*=0.001). Delayed pain reports were significantly correlated with completion of the judgment task (*r*(69)=-0.25, *p*=0.04), age (*r*(69)=0.33, *p*=0.01), and number of medications (*r*(67)=0.34, *p*=0.01).

Table 1
Bivariate correlations showing the relationship between all variables assessed in the present study.

		TEMP	JUD	BECK	TICS	AGE	NRS	ED	RAVLT	MED	GEN
TEMP	Pearson Correlation	1	.107	.034	-.201	.224	.236*	.261*	-.235*	.122	-.132
	Sig. (2-tailed)		.362	.773	.093	.053	.049	.028	.042	.319	.261
	N	75	75	75	71	75	70	71	75	69	75
JUDGE	Pearson Correlation	.107	1	.182	-.057	-.010	-.185	-.060	.001	.020	.009
	Sig. (2-tailed)	.362		.119	.638	.934	.126	.622	.991	.868	.938
	N	75	75	75	71	75	70	71	75	69	75
BECK	Pearson Correlation	.034	.182	1	.117	-.007	.224	.001	.159	.096	.142
	Sig. (2-tailed)	.773	.119		.330	.953	.042	.992	.174	.432	.225
	N	75	75	75	71	75	70	71	75	69	75
TICS	Pearson Correlation	-.201	-.057	.117	1	-.464**	-.031	-.135	.605**	-.386**	-.001
	Sig. (2-tailed)	.093	.638	.330		.000	.801	.260	.000	.001	.997
	N	71	71	71	71	71	70	71	71	69	71
AGE	Pearson Correlation	.224	-.010	-.007	-.464**	1	.390**	.474**	-.304**	.686**	.079
	Sig. (2-tailed)	.053	.934	.953	.000		.001	.000	.008	.000	.499
	N	75	75	75	71	75	70	71	75	69	75
NRS	Pearson Correlation	.236*	-.185	.224	-.031	.390**	1	.315**	-.133	.278*	-.001
	Sig. (2-tailed)	.049	.126	.042	.801	.001		.008	.272	.022	.993
	N	70	70	70	70	70	70	70	70	68	70

ED	Pearson Correlation	.261*	-.060	.001	-.135	.474**	.315**	1	-.090	.361**	-.058
	Sig. (2-tailed)	.028	.622	.992	.260	.000	.008		.454	.002	.628
	N	71	71	71	71	71	70	71	71	69	71
RAVLT	Pearson Correlation	-.235*	.001	.159	.605**	-.304**	-.133	-.090	1	-.504**	.228*
	Sig. (2-tailed)	.042	.991	.174	.000	.008	.272	.454		.000	.049
	N	75	75	75	71	75	70	71	75	69	75
MED	Pearson Correlation	.122	.020	.096	-.386**	.686**	.278*	.361**	-.504**	1	.053
	Sig. (2-tailed)	.319	.868	.432	.001	.000	.022	.002	.000		.664
	N	69	69	69	69	69	68	69	69	69	69
GENDER	Pearson Correlation	-.132	.009	.142	-.001	.079	-.001	-.058	.228*	.053	1
	Sig. (2-tailed)	.261	.938	.225	.997	.499	.993	.628	.049	.664	
	N	75	75	75	71	75	70	71	75	69	75
D1	Pearson Correlation	-.100	.022	.093	.428**	-.369**	-.023	-.045	.752**	-.305*	.100
	Sig. (2-tailed)	.407	.859	.440	.000	.002	.852	.708	.000	.011	.406
	N	71	71	71	71	71	70	71	71	69	71
D2	Pearson Correlation	-.064	.075	.094	.474**	-.309**	.008	.033	.608**	-.267*	.302*
	Sig. (2-tailed)	.597	.535	.437	.000	.009	.949	.785	.000	.026	.010
	N	71	71	71	71	71	70	71	71	69	71
J1	Pearson Correlation	.010	.090	.181	.107	.050	.042	.093	.032	-.011	.015
	Sig. (2-tailed)	.936	.457	.131	.374	.678	.729	.442	.794	.930	.898
	N	71	71	71	71	71	70	71	71	69	71
J2	Pearson Correlation	-.040	.027	-.004	.045	-.045	-.204	-.091	.110	-.030	-.172
	Sig. (2-tailed)	.739	.821	.977	.709	.712	.090	.451	.360	.808	.151
	N	71	71	71	71	71	70	71	71	69	71
R1	Pearson Correlation	-.046	-.101	-.172	.132	-.260*	-.143	-.140	.286*	-.238*	.042

	Sig. (2-tailed)	.704	.402	.151	.274	.028	.238	.244	.016	.049	.729
	N	71	71	71	71	71	70	71	71	69	71
R2	Pearson Correlation	-.113	-.009	.161	.199	-.145	.019	.047	.159	-.278*	.012
	Sig. (2-tailed)	.350	.944	.179	.096	.229	.875	.698	.185	.021	.919
	N	71	71	71	71	71	70	71	71	69	71
Fd	Pearson Correlation	.032	-.050	.009	-.076	.192	.002	.048	-.256*	.009	.059
	Sig. (2-tailed)	.791	.677	.940	.528	.109	.984	.690	.031	.943	.623
	N	71	71	71	71	71	70	71	71	69	71
Fr	Pearson Correlation	.175	-.040	-.101	-.203	.230	.108	.057	-.275*	.148	-.262*
	Sig. (2-tailed)	.144	.740	.401	.090	.054	.375	.637	.020	.225	.027
	N	71	71	71	71	71	70	71	71	69	71
Immediate	Pearson Correlation	-.172	-.210	-.195	-.083	.084	-.256*	.032	-.197	.178	-.096
	Sig. (2-tailed)	.143	.073	.096	.496	.477	.033	.792	.093	.147	.414
	N	74	74	74	70	74	70	70	74	68	74
Delayed	Pearson Correlation	-.028	-.248*	-.072	-.087	.329**	.320**	.233	-.225	.335**	-.174
	Sig. (2-tailed)	.817	.037	.551	.470	.005	.007	.051	.178	.005	.147
	N	71	71	71	71	71	70	71	71	69	71

Table 2

Bivariate correlations showing the relationship between all variables assessed in the present study continued.

		D1	D2	J1	J2	R1	R2	Fd	Fr	Imm	Delayed
TEMP	Pearson Correlation	-.100	-.064	.010	-.040	-.046	-.113	.032	.175	-.172	-.028
	Sig. (2-tailed)	.407	.597	.936	.739	.704	.350	.791	.144	.143	.817
	N	71	71	71	71	71	71	71	71	74	71
JUDGE	Pearson Correlation	.022	.075	.090	.027	-.101	-.009	-.050	-.040	-.210	-.248*

	Sig. (2-tailed)	.859	.535	.457	.821	.402	.944	.677	.740	.073	.037
	N	71	71	71	71	71	71	71	71	74	71
BECK	Pearson Correlation	.093	.094	.181	-.004	-.172	.161	.009	-.101	-.195	-.072
	Sig. (2-tailed)	.440	.437	.131	.977	.151	.179	.940	.401	.096	.551
	N	71	71	71	71	71	71	71	71	74	71
TICS	Pearson Correlation	.428**	.474**	.107	.045	.132	.199	-.076	-.203	-.083	-.087
	Sig. (2-tailed)	.000	.000	.374	.709	.274	.096	.528	.090	.496	.470
	N	71	71	71	71	71	71	71	71	70	71
AGE	Pearson Correlation	-.369**	-.309**	.050	-.045	-.260*	-.145	.192	.230	.084	.329**
	Sig. (2-tailed)	.002	.009	.678	.712	.028	.229	.109	.054	.477	.005
	N	71	71	71	71	71	71	71	71	74	71
NRS	Pearson Correlation	-.023	.008	.042	-.204	-.143	.019	.002	.108	-.256*	.320**
	Sig. (2-tailed)	.852	.949	.729	.090	.238	.875	.984	.375	.033	.007
	N	70	70	70	70	70	70	70	70	70	70
ED	Pearson Correlation	-.045	.033	.093	-.091	-.140	.047	.048	.057	.032	.233
	Sig. (2-tailed)	.708	.785	.442	.451	.244	.698	.690	.637	.792	.051
	N	71	71	71	71	71	71	71	71	70	71
RAVLT	Pearson Correlation	.752**	.608**	.032	.110	.286*	.159	-.256*	-.275*	-.197	-.225
	Sig. (2-tailed)	.000	.000	.794	.360	.016	.185	.031	.020	.093	.178
	N	71	71	71	71	71	71	71	71	74	71
MED	Pearson Correlation	-.305*	-.267*	-.011	-.030	-.238*	-.278*	.009	.148	.178	.335**
	Sig. (2-tailed)	.011	.026	.930	.808	.049	.021	.943	.225	.147	.005
	N	69	69	69	69	69	69	69	69	68	69
GENDER	Pearson Correlation	.100	.302*	.015	-.172	.042	.012	.059	-.262*	-.096	-.174
	Sig. (2-tailed)	.406	.010	.898	.151	.729	.919	.623	.027	.414	.147
	N	71	71	71	71	71	71	71	71	74	71

D1	Pearson Correlation	1	.596**	-.064	-.322**	.043	.073	-.114	-.131	-.125	-.132
	Sig. (2-tailed)		.000	.597	.006	.724	.545	.344	.275	.303	.274
	N	71	71	71	71	71	71	71	71	70	71
D2	Pearson Correlation	.596**	1	-.032	-.366**	.080	-.003	-.114	-.337**	-.282*	-.321**
	Sig. (2-tailed)	.000		.791	.002	.510	.982	.346	.004	.018	.006
	N	71	71	71	71	71	71	71	71	70	71
J1	Pearson Correlation	-.064	-.032	1	.207	-.787**	.464**	.068	-.100	.090	.136
	Sig. (2-tailed)	.597	.791		.083	.000	.000	.576	.406	.457	.258
	N	71	71	71	71	71	71	71	71	70	71
J2	Pearson Correlation	-.322**	-.366**	.207	1	.129	-.179	-.075	.029	.081	-.053
	Sig. (2-tailed)	.006	.002	.083		.284	.135	.532	.811	.504	.658
	N	71	71	71	71	71	71	71	71	70	71
R1	Pearson Correlation	.043	.080	-.787**	.129	1	-.375**	-.084	.028	-.135	-.246*
	Sig. (2-tailed)	.724	.510	.000	.284		.001	.487	.820	.266	.039
	N	71	71	71	71	71	71	71	71	70	71
R2	Pearson Correlation	.073	-.003	.464**	-.179	-.375**	1	-.109	.002	.008	.038
	Sig. (2-tailed)	.545	.982	.000	.135	.001		.366	.986	.950	.754
	N	71	71	71	71	71	71	71	71	70	71
Fd	Pearson Correlation	-.114	-.114	.068	-.075	-.084	-.109	1	-.119	.150	.154
	Sig. (2-tailed)	.344	.346	.576	.532	.487	.366		.324	.216	.199
	N	71	71	71	71	71	71	71	71	70	71
Fr	Pearson Correlation	-.131	-.337**	-.100	.029	.028	.002	-.119	1	.137	.188
	Sig. (2-tailed)	.275	.004	.406	.811	.820	.986	.324		.259	.116
	N	71	71	71	71	71	71	71	71	70	71
Immediate	Pearson Correlation	-.125	-.282*	.090	.081	-.135	.008	.150	.137	1	.777**

	Sig. (2-tailed)	.303	.018	.457	.504	.266	.950	.216	.259		.000
	N	70	70	70	70	70	70	70	70	74	70
Delayed	Pearson Correlation	-.132	-.321**	.136	-.053	-.246*	.038	.154	.188	.777**	1
	Sig. (2-tailed)	.274	.006	.258	.658	.039	.754	.199	.116	.000	
	N	71	71	71	71	71	71	71	71	70	71

3.3. ANOVA

In order to examine the main results of our data, we ran a series of analyses of variances (ANOVAs) to assess the effect of age, completion of judgment task, depression scores, memory ability and cognitive status on the discrepancy pain score (change from immediate to delayed report), using a median split for continuous variables. We also assessed the repeated measure of pain report (immediate vs delayed). Results revealed a significant main effect of age, depression and completion of judgment task on pain reports.

Table 3
Combined ANOVA output for between subjects effects of age, depression, memory ability, cognitive status, and judgment task as main predictor variables, and repeated measure of pain report (immediate vs delayed).

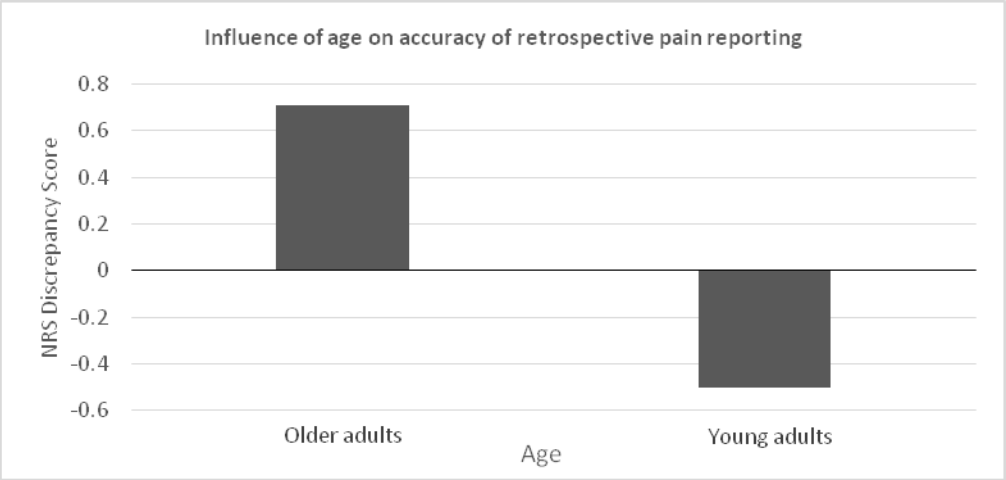
Predictors	*Df*	*F*	*P*
Age	1	6.92	0.02*
Judgment	1	5.58	0.03*
Beck	1	2.39	0.02*
RAVLT	1	0.15	0.7
TICS	1	0.9	0.35
Time	1	0.04	0.84

Note. * = p<0.05

3.3.1. Age

In terms of our primary hypothesis regarding age-related differences in pain reporting, the analysis revealed that age was indeed significantly related to pain reporting discrepancy from immediate to delayed reports, $F(1)=6.92$, $p=0.02$. Older adults were significantly more likely to over-report pain levels after a week delay from pain onset (mean = 0.71), whereas young adults showed a tendency to under-report (mean = -0.5).

Figure 1
A bar chart showing age-related differences in accuracy of retrospective pain reports.



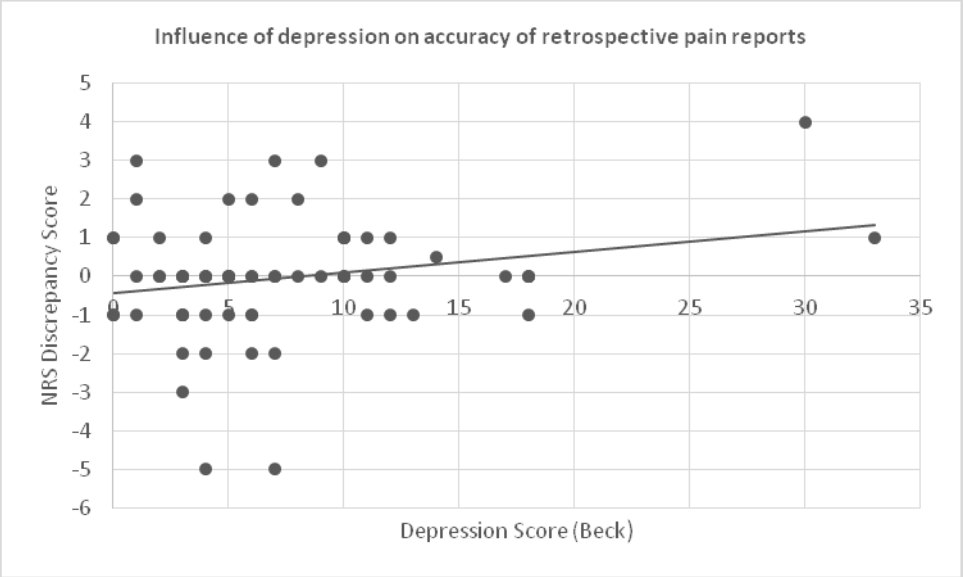
However, although age groups differ in the direction of pain-reports (older adults show positive discrepancy scores, young adults show negative), the magnitude of change from 0 in both groups does not differ significantly, $t(68)=-0.79$, $p=0.43$.

3.3.2. Depression

Additionally, the main effect of depressive symptoms was significantly related to memory for pain, $F(1)=2.39$, $p=0.02$. The findings indicated that individuals with higher depression scores as assessed by the Beck Depression Inventory were significantly more likely to over-report pain levels than those with lower levels of depressive symptomology. However, it seems unlikely that this depression effect is driving the age-related differences in memory for pain, as an independent sample t-test demonstrated that the two age groups did not differ significantly on depression scores (Older adult mean = 7.11, Young

adult mean = 7.3), $t(69)=0.14$, $p=0.89$, and the same pattern appeared to be evident for both age groups.

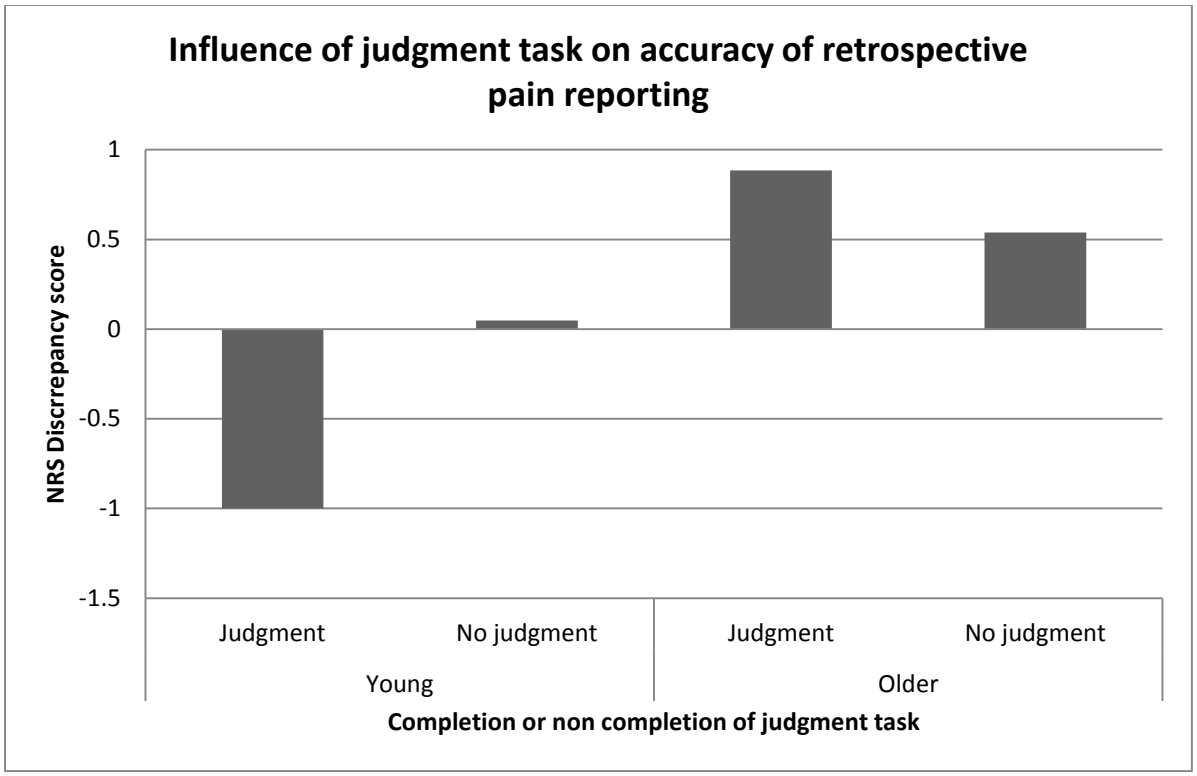
Figure 2
A scatterplot demonstrating the relationship between depression scores and accuracy of retrospective pain reporting.



3.3.3. Judgment task

Completion of the judgment task was also significantly related to accuracy of pain reporting, $F(1)=5.58$, $p=0.03$. Individuals who reported pain with reference to previously experienced pain over the lifespan in the judgment task were more likely to under-report the intensity of the painful sensation after a week (mean = -0.32), whereas individuals who did not complete this task showed a tendency to over-report (mean = 0.24). However it appears that this effect was being driven primarily by the young adult group, $F(1)=9.99$, $p=0.01$, whereas this effect was not significant within the older adult sample, $F(1)=0.55$, $p=0.49$.

Figure 3
A bar chart showing how completion of the judgment task described above impacted accuracy of retrospective pain reporting in participants.



3.3.4. Cognitive status/memory (TICS and RAVLT score)

When examining the influence of cognitive status, as assessed by the score on the TICS measurement, on memory for pain, the ANOVA revealed that this effect was non-significant, $F(1)=0.9$, $p=0.35$. Cognitive status was also unable to predict pain reporting when run separately for older, $F(1)=0.62$ p=0.44 and young adults, $F(1)=2.87$, $p=0.1$. This indicates that contrary to expectations, cognitive status does not seem to predict pain reporting accuracy in either groups. Beyond this, the analysis also demonstrated that memory scores from the RAVLT similarly did not have a significant effect on accuracy of pain reports, $F(1)=0.15$, $p=0.7$. This demonstrates that, surprisingly, memory function of the individual did not influence their ability to report pain accurately after a delay from pain onset. Memory scores do appear to be significantly higher in young adults than older adults (Older adult mean = 58.38; Young adult mean = 73.94; $t(73)=2.73$, $p=0.01$), and additionally younger adults seem to show a tendency to under-report pain levels while older participants over-report. In this sense, there does appear to be some kind of relationship between memory and retrospective pain reporting. In order

to examine whether this memory result interacts with age in more detail, we assessed the influence of RAVLT performance on pain reporting separately within age categories. Results from this revealed that RAVLT memory scores were not able to predict significant changes in pain reporting in young adults, $F(1)=0.33$ $p=0.57$ or in older adults, $F(1)=1.87$ $p=0.19$.

Table 4
Influence of memory and cognitive status on retrospective pain reporting separated by age category.

Main Effects					
	Mean	SD	Df	F	p-value
Older Adults					
Memory	58.38	19.25	1	1.87	0.19
Cognitive Status	36.35	4.38	1	0.62	0.44
	Mean	SD	Df	F	p-value
Young Adults					
Memory	73.94	25.4	1	0.33	0.57
Cognitive Status	40.38	3.37	1	2.87	0.1

3.4. Model analyses

Although the total RAVLT scores did not significantly predict accuracy of pain reporting, for exploratory reasons we decided that it is still of value to look at how different retrieval processes relate to pain recall. In order to do this, we used dual retrieval models (Brainerd et al., 2009). This involves the application of two-stage Markov models which quantify specific recollective (direct access D) and non-recollective (familiarity J, and reconstruction R) retrieval processes by analyzing sequences of errors and successes on the RAVLT for each participant.

First, frequencies were obtained for all learning trials on the RAVLT (trial 1-5) using an Excel macro. Once this was computed, it was determined that the best fitting model for this data was the error version of the basic model, and this model was then fit to the RAVLT data to extract values for each of the model parameters (D1, D2, J1, J2, R1, R2, Fd, Fr – See table for further explanation) for each participant. We looked at the G squared value to ensure that the error model was a good fit. The G squared statistic was below critical value for both the learning and forgetting data (G squared for

learning data = 1.25; G squared for forgetting data = 2.53), and so this model was determined to be a good fit of the data. Once parameter estimates had been obtained for each participant, significance tests could be run. We used an analysis of variance (ANOVA) design with these retrieval processes as predictors and pain recall as the outcome variable, in order to see whether these model statistics were able to predict differences in accuracy of pain reports. This was run for the pooled data of both age groups. This analysis revealed that none of the model parameters for the learning data (trial 1-5) were able to significantly predict accuracy of pain after a week delay, D1: $F(1)=0.22$, $p=0.64$; D2: $F(1)=0.02$, $p=0.89$; J1: $F(1)=0.001$, $p=0.97$; J2 $F(1)=0.01$, $p=0.93$; R1: $F(1)=0.01$, $p=0.94$; R2: $F(1)=0.32$, $p=0.58$. In order to look at this more closely, the ANOVA was also run separately for young and older participants. This revealed that none of the model statistics for the learning data were able to significantly explain retrospective pain reporting in older adults (D1: $F(1)=0.001$, $p=0.99$; D2: $F(1)=0.03$, $p=0.87$; J1: $F(1)=0.28$, $p=0.61$; J2: $F(1)=0.29$, $p=0.6$; R1: $F(1)=0.09$, $p=0.77$; R2: $F(1)=0.08$, $p=0.78$), or in younger adults (D1: $F(1)=0.001$, $p=0.99$; D2: $F(1)=0.07$, $p=0.79$; J1: $F(1)=0.04$, $p=0.84$; J2: $F(1)=0.06$, $p=0.81$; R1: $F(1)=0.06$, $p=0.81$; R2: $F(1)=0.01$, $p=0.94$). Next we ran an ANOVA to assess forgetting data, to investigate whether the parameters in this model were able to predict retrospective pain reporting accuracy. Results revealed that the model statistics did not significantly predict delayed pain reporting, Fd: $F(1)=0.71$, $p=0.4$; Fr: $F(1)=0.84$, $p=0.36$. Additionally when separated by age category, the model parameters for the forgetting data could not explain variance in pain reporting in young adults (Fd: $F(1)=0.001$, $p=0.98$; Fr: $F(1)=0.85$, $p=0.36$) or in older adults (Fd: $F(1)=6.19$, $p=0.02$; Fr: $F(1)=2.08$, $p=0.16$). Given that the total RAVLT scores were not significant predictors of pain recall, it is relatively unsurprising that specific retrieval processes extracted from the RAVLT were also non-significant.

Table 5
Influence of memory retrieval processes on accuracy of retrospective pain reporting.

Main Effects				
	Mean	Df	F	p-value

Older Adults Learning				
D1	0.18	1	0.001	0.99
D2	0.15	1	0.03	0.87
J1	0.75	1	0.28	0.61
J2	0.5	1	0.29	0.6
R1	0.47	1	0.09	0.77
R2	0.4	1	0.08	0.78
Older Adults Forgetting				
Fd	0.17	1	6.19	0.02
Fr	0.13	1	2.08	0.16
	Mean	Df	F	p-value
Young Adults Learning				
D1	0.32	1	0.001	0.99
D2	0.26	1	0.07	0.79
J1	0.72	1	0.04	0.84
J2	0.51	1	0.06	0.81
R1	0.6	1	0.06	0.81
R2	0.5	1	0.01	0.94
Young Adults Forgetting				
Fd	0.08	1	0.001	0.98
Fr	0.05	1	0.85	0.36

For exploratory reasons, in addition to running the analysis for the dependent variable of change in pain report from immediate to delayed, ANOVAs were also run for the TICS and Beck score. Results revealed that none of the model statistics were significantly related to cognitive status score (D1: $F(1)=1.47$ $p=0.23$, D2: $F(1)=1.33$ $p=0.26$, J1: $F(1)=0.51$ $p=0.48$, J2: $F(1)=1.21$ $p=0.28$, R1: $F(1)=0.03$ $p=0.86$, R2: $F(1)=0.99$ $p=0.33$, Fd: $F(1)=0.68$ $p=0.41$, Fr: $F(1)=2.94$ $p=0.09$). When this was separated by age category, the significance levels remained consistent for both older and young adults. This analysis also revealed that none of the model statistics were significantly related to depression scores, D1: $F(1)=0.33$ $p=0.57$, D2: $F(1)=0.97$ $p=0.33$, J1: $F(1)=0.31$ $p=0.58$, J2: $F(1)=0.83$ $p=0.37$, R1: $F(1)=0.01$ $p=0.91$, R2: $F(1)=0.2$ $p=0.66$, Fd: $F(1)=0.16$ $p=0.69$, Fr: $F(1)=2.41$ $p=0.13$. This was the case both for the pooled data for both age levels, and also for when the analysis was run separately for young and older age categories.

Table 6
A table describing the memory retrieval processes which were assessed in the current study.

Process	Explanation
Learning:	
Direct access (recollection): *D1 and D2*	Probability that verbatim trace of an item which was presented on a study trial can be accessed on a following recall test.
Reconstruction: *R1 and R2*	For items whose verbatim trace can't be accessed on a recall test, the probability that it can be reconstructed on this recall test.
Familiarity judgement: *J1 and J2*	For items which are reconstructed on a recall test, the probability that this reconstruction is judged to be familiar enough to proceed to output.
Forgetting:	
Direct access (recollection): *Fd*	On a forgetting task, the probability that the direct access process fails for an item which could be directly accessed in the previous study cycle.
Reconstruction: *Fr*	On a forgetting task, the probability that the reconstruction process fails for an item which could be reconstructed in the previous study cycle.

3.5. ANOVAs with covariates

Next we ran a number of follow up ANOVAs controlling separately for each of the variables measured which were hypothesised to have an influence on the results. The covariate variables we assessed were pain tolerance level, gender, education and medication.

3.5.1. Pain tolerance

Using pain tolerance (the temperature at which the participant removed hand from the heat pad – peak point of pain experienced) as a covariate did not result in any major changes in our main effects. Age, judgment and depression all remained significant, age: $F(1)=5.6$, $p=0.03$; Judgement: $F(1)=5.55$, $p=0.03$; Beck: $F(1)=2.25$, $p=0.03$. Similarly memory and cognitive status remained non-

significant when pain tolerance was controlled for, memory: $F(1)=0.53$, $p=0.47$; cognitive status: $F(1)=1.04$, $p=0.31$.

3.5.2. Gender

Next we assessed whether our results differed when gender was controlled for. Our analysis revealed that this was not the case, and using gender as a covariate did not influence the significance of our results. Age, judgment and depression remained significant, age: $F(1)=6.31$, $p=0.02$; judgment: $F(1)=5.33$, $p=0.03$; Beck: $F(1)=2.29$, $p=0.03$. Memory and cognitive status remained non-significant once gender was controlled for, memory: $F(1)=0.15$, $p=0.7$; cognitive status: $F(1)=0.88$, $p=0.35$.

3.5.3. Medications

Using number of prescription medications as a covariate variable resulted in several changes in our main effect results. Specifically the predictor variable of age was no longer significant when medications were controlled for, $F(1)=0.001$, p-0.98. Additionally depression level was also no longer significant, although it appears to be approaching significance, $F(1)=1.99$, $p=0.06$. Completion of the judgment task continued to be significantly related to pain reporting, even when medications were controlled for, $F(1)=4.39$, $p=0.04$. Memory and cognitive status also remained stable and continued to be non-significant when medications were included as a covariate variable, memory: $F(1)=1.11$, $p=0.29$; cognitive status: $F(1)=0.47$, $p=0.49$.

3.5.4. Education

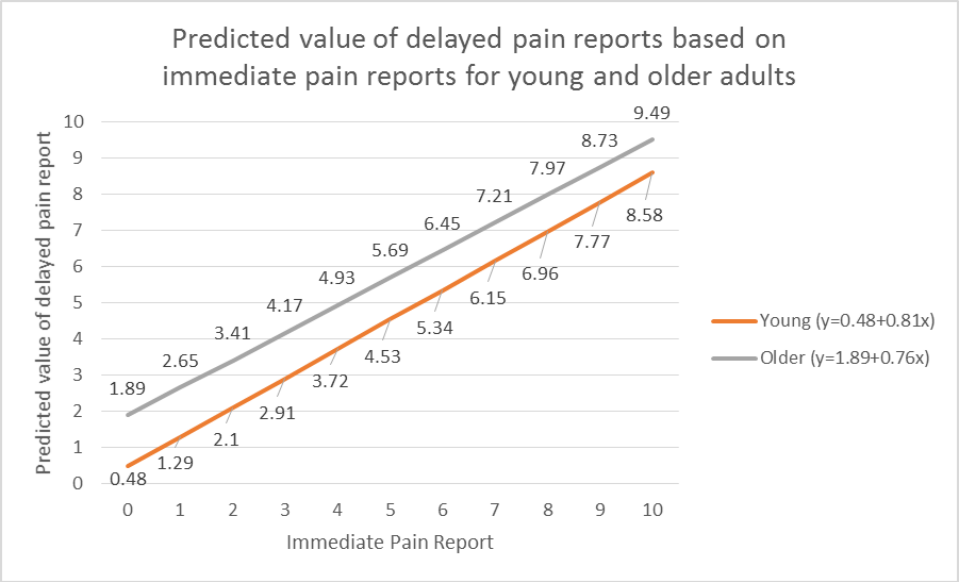
Finally, we included level of education as a covariate in our analysis, which only resulted in slight change. The main predictor of depression was no longer significantly related to pain reporting, $F(1)=1.97$, $p=0.06$. However, it is important to note that this value does appear to be approaching significance. Our other variables did not change when education was controlled for. Age and judgment remained significant, age: $F(1)=5.69$, $p=0.03$; judgment: $F(1)=5.66$, $p=0.03$. Additionally, memory and

cognitive status continued to be not significantly related to pain reporting, memory: $F(1)=0.15$, $p=0.7$; cognitive status: $F(1)=0.54$, $p=0.47$.

3.6. Regression

Beyond this, we also ran a regression to relate immediate pain ratings to delayed pain ratings separately for older and young participants. This is of interest because using the regression equation provided, we can make predictions of how an individual in a certain age category (older or young) will report pain levels after a week, based on how they reported it immediately after pain onset. In older adults, the regression was significant, $\beta = 0.76$, $t(43) = 6.86$, $p=0.001$, with an $\mathbf{r}^2$ of 0.66. The regression equation is therefore as follows: delayed pain report = 1.89 + 0.76x, where x is the immediate pain report (0-10). The constant is 1.89, suggesting that when the immediate pain report=0, the expected mean value of the delayed pain report is approximately 1.89 within older adults. The slope is 0.76, meaning that for every unit increase in immediate pain reports, an increase of 0.76 is predicted in delayed pain report in older adults. Additionally, in young adults the regression was also significant, $\beta = 0.81$, $t(43) = 8.004$, $p = 0.001$, with an $\mathbf{r}^2$ of 0.6. The regression equation is therefore as follows: delayed pain report = 0.48 + 0.81x, where x is the immediate pain report (0-10). The intercept is 0.48, meaning that when immediate pain report=0, delayed pain report is approximately 0.48. The slope coefficient is 0.81, meaning that for each incremental unit change in immediate pain report, a change of approximately 0.81 is predicted in delayed pain reports.

Figure 4
A scatterplot which uses the regression equations for older and young adults to plot predicted values of delayed pain reports based on the score of the immediate pain report.



Note: Using the regression equations for older and young adults we can predict how a painful experience will be reported after a delay based on immediate reports of pain. This graph shows what we expect a delayed report to equal based on immediate reports given.

4. DISCUSSION

Our primary research question was regarding age related differences in retrospective pain reporting. Previous research suggested that older adults may be less accurate in reporting pain after a delay from pain onset than younger adults, but it was unclear whether healthy older adults would be more likely to over or under-report pain levels. Our results suggest that neither older nor young adults are particularly accurate in recalling pain, but age-related differences in this ability do exist. More specifically, older adults show a tendency to overestimate pain levels after a week from pain onset, whereas young adults seem to display the opposite pattern, underestimating pain intensity. This seems to contradict the positivity effect hypothesis, which predicts that older adults would focus on positive information when recalling pain levels, and as a result may be more likely to under-report pain (Mather & Carstensen, 2005). We also considered the possibility that current pain level at the time of reporting may influence how a specific previous instance of pain is recalled (Smith & Safer, 1993) and this may drive age-related differences in pain reporting. Specifically, this theory proposes that individuals with a higher current pain level are more likely to over-report pain, whereas those in a lower level of current pain may under-report. In the current study, results from the judgment task demonstrate that older adults are in higher level of pain day-to-day than young adults. Our results seem to support this, as older adults, who are experiencing higher levels of pain at the time of reporting showed a clear tendency to overestimate pain, and younger adults with a generally much lower level of current pain showed a tendency to retrospectively underestimate a pain experience from the previous week. However, it is important to note that age category did not seem to influence retrospective pain reporting to such a degree when the participant's prescription medications were controlled for. Unsurprisingly, older adults tend to be prescribed a greater number of medications than young adults. Based on our results, it seems plausible that the presence of more medications may be one factor which influences the relationship between age and retrospective pain reports.

We also hypothesized that depression may play a role in the relationship between age and memory for pain. Specifically, we suggested that depression may drive age-related differences in pain reporting. Older adults tend to show a higher incidence of depression than younger adults, and so if the presence of depressive symptoms has an impact on pain recall, this may result in differential memory for pain between older and young participants. However, our results demonstrated that depression levels were approximately equal in both age groups, and so it is unlikely that this is driving the observed age differences in pain recall. However, our results showed that higher depression scores in both young and older adults were related to an overestimation of pain intensity after a week. This is highly consistent with the previous literature into depression. Many researchers have demonstrated that depressed individuals show a pattern of negative cognitive bias, where both older and young adults with depressive symptoms show an enhanced recall of negative information, as compared with a healthy control sample (Mogg et al., 1995; Watkins et al., 1996). This has previously been described as a mood-congruency memory bias, whereby an individual shows a tendency to recall information and stimuli which is conceptually congruent with their mood (Watkins, 2002). This phenomenon is considered to be robust and has been widely replicated in depression literature, and is considered to be an important maintenance mechanism in this condition (Teasdale, 1983). In fact, this finding has been replicated in both explicit (Ruiz-Caballero & Gonzilez, 1994) and implicit (Bradley et al., 1996) memory tasks, and has been shown to occur in recall of various stimuli, including valenced words (Denny & Hunt, 1992), emotional faces (Gotlib et al., 2004) and previous life events (Williams & Scott, 1988). This study has extended this finding to include memory for perceptual information such as pain. Specifically, depressed individuals may be more likely to retrieve negative information when providing retrospective reports of pain, due to dysfunctional self-schemas and mood-congruent recall, and as such may show a tendency to over-report pain intensity levels. Our results, however, also show that when level of education or prescription medications are controlled for, depression is no longer a significant predictor of change in

pain reports, although this was still approaching significance in both cases. This suggests that there are a number of factors, including medication and education, which may influence the relationship between depression and retrospective pain reporting. Further research is required to elucidate our understanding of this area further.

Previously we hypothesized that decline in memory and cognitive status with age may be able to account for differences between older and young adults in pain recall. Contrary to these prior expectations, our results indicate that cognitive function does not influence accuracy of pain reporting. Older adults obtained significantly lower scores on the TICS assessment than young adults, but nonetheless scores on this measure were not able to predict any differences in pain recall. In addition to this, although older adults performed significantly worse on the memory task than young adults, this memory decline was also not able to account for differences in pain reporting accuracy after a delay. This is a surprising finding, as previous literature investigating accuracy of pain reporting after a delay often posit that deteriorations in memory and cognitive skill are the primary mechanisms through which inaccurate retrospective pain reports may be derived (Kalso, 1997; Erskine & Morley, 1990). However, our results contradict this, instead suggesting that inaccurate pain reporting after a delay is not attributable to either memory ability or cognitive function. Beyond this, none of the specific memory retrieval processes assessed in this study, recollective nor non-recollective, had any significant association with more accurate pain reporting. This provides tentative evidence that successful retrospective pain reporting does not necessarily rely upon superior memory ability. Despite these findings, it seems unlikely that cognitive decline and memory loss do not distort delayed reporting of pain when it comes to treatment of pain in older adults. It is important to note that our study only assessed reporting of pain after a one week delay from pain onset. Previous research has suggested that memory for pain becomes worse after longer periods of time (Gedney et al., 2003). Perhaps, one explanation for the lack of correlation between memory and pain reporting in the present study is

simply that the delay period was not long enough. It is very possible that memory decline may influence retrospective pain reporting to a greater extent when the period between pain onset and delayed reporting is longer than the one week used for this study (Gedney et al., 2003). Further research is therefore required to elucidate exactly how memory decline relates to pain reporting after a delay. Beyond this, our results also demonstrated that the objective level of pain experienced (in this case, the temperature at which the individual removed their hand from the heat pad) was not able to predict how this sensation is later recalled.

Interestingly, our results seem to suggest that older and young adults differ in the direction of their pain reports, but not the magnitude of change. Specifically, older adults show a tendency to increase reports of pain after a delay, whereas young adults seem to decrease. However, despite displaying results in opposite directions, age groups did not differ in the extent of change after one week. This seems to suggest that although age groups do show opposite patterns of results, neither group is more 'accurate' in how they report pain after a delay. If our initial hypothesis that poorer memory function would lead to an impaired ability to report pain after a delay were true, then we would expect to see higher levels of discrepancy between immediate and delayed reports in older adults with poorer memory than young adults. However, our results did not support this, suggesting that perhaps memory decline with age is not driving age differences in retrospective pain reporting. Additionally, previous research discussed earlier which suggests that older adults with poorer memory and cognitive function report less pain than their healthy counterparts, seem to rely upon cross-sectional design comparing pain reported at one period in time. They did not use the comparison of immediate to delayed pain reporting as we did in the present study. For future research, it would therefore be interesting to use a similar design as in the present study, assessing reports of pain across various time periods from pain onset, but also include participants with cognitive decline, to see how the pattern of results for this population differs from the healthy older adult sample.

We were also interested in seeing how reliance upon a framework of previously experienced painful experiences across the lifespan would influence the reporting of a specific instance of pain. Our results demonstrate that participants who completed a task designed to force them to rely upon such a framework, were more likely to under-report the specific instance of pain experienced one week prior. By contrast, those who did not complete the task showed a slight tendency to overestimate pain levels. This pattern was driven by young adults and did not apply to older adults. This is not entirely surprising, as it is likely that most participants will have experienced more severe pain in the past than that which was administered during the study. Therefore, when participants report the intensity of the mildly painful experience from the previous week, they may be more likely to under-report it when they compare the intensity of the sensation from this study to more severe pain experienced previously. By contrast, our results suggest that individuals who recalled the painful sensation without any reference to such a framework of pain experiences across the lifespan were more likely to under-report it. This is perhaps because these participants did not compare the pain induced from this study with more severe painful experiences from the past. Our study therefore demonstrates that it is possible to manipulate accuracy of retrospective pain reporting in young adults by altering pain comparison points.

However, despite the promising findings from this study, it is important to consider that there are certain limitations. For example, we compared delayed reports of pain with initial reports immediately after pain onset. Due to the subjective nature of how pain is reported, we cannot know that the immediate report after onset of pain is an accurate representation of the objective level of pain experienced. Therefore, when comparing the delayed pain measure with the immediate pain measure, we are simply assessing the level of change in how the pain sensation is perceived after a one week delay. As such, when we refer to over and under reporting of painful sensations after a delay, we refer to a tendency to either increase or decrease the pain rating after one week as compared with the score provided immediately after pain onset. We cannot necessarily know that either immediate or delayed

pain reports are 'accurate'. Instead it is more appropriate to say that there appears to be a discrepancy between how a painful sensation is reported initially and after a delay, without making reference to which report is more accurate.

This study focused on only a few factors which may impact accuracy of retrospective pain reports, but it is clear that there are a myriad of physical, behavioral, and emotional influences which may affect this. For example Lefebvre and Keefe (2002) demonstrated that catastrophizing was strongly related to accuracy of pain recall. Specifically, individuals who scored higher on catastrophizing demonstrated a significantly improved ability to recall pain intensity, as well as changes in pain levels. This was attributed to increased somatic awareness, pain-related rumination and hypervigilance which is associated with greater levels of catastrophizing. As a result, such pain sensations were considered to be more salient in individuals with high catastrophizing scores. Additionally, Jamison et al (1989a) proposed that low activity levels, a sedentary lifestyle, high psychological distress, and familial disharmony were all associated with less accurate retrospective reports of pain. Linton (1991) has posited that perceived helplessness also influences pain recall accuracy, whereby individual with higher levels of helplessness are more accurate in reporting the intensity of a previously experienced pain sensation than those with low levels of helplessness. Cumulatively this results suggest that there are a large number of psychosocial, demographic, and environmental factors which influence pain recall. Our study was only able to assess a small number of these, and as such further research is required to identify these factors and to further our understanding of the mechanisms which underpin pain recall.

An additional limitation of this study is that individuals were only asked to report the experimentally manipulated pain sensation after a one week delay. Research has suggested that the duration of time between pain onset and pain report may considerably influence accuracy (Gedney et al., 2003). McGorry et al., (1999), for example, provided findings suggesting that retrospective pain reports were accurate after one month, but not after 6 months from pain onset. Additionally, Everts et

al (1999) demonstrated that pain recall 6 months after the painful sensation is worse than other studies with a shorter duration between induction of pain and reporting. The present study looked only at pain reports after one week, and did not consider how accuracy of pain recall may fluctuate over longer delay periods. Our results suggest that even after one week, reports of pain are relatively inaccurate in both young and older adults. Based on previous research, it seems reasonable to believe that these reports would become even less accurate after longer periods of time, but further research is required to propose this with certainty.

Thinking more broadly, it is clear that this research has important clinical and societal applications. Assessment and treatment of pain often relies almost entirely on retrospective reports of pain intensity, through various self-report methods. These self-report methods are considered gold-standard assessment for evaluating pain (Herr et al., 2006). For example, a healthcare provider may ask the question 'How did you feel over the past several weeks/months?', which relies strongly upon retrospective reports. Accurate pain recall is essential in delivering an appropriate and well-matched intervention, and additionally is vital for assessing the efficacy of a prescribed treatment. However, it is clear that depending on the age of the individual, and various other factors including depression, accuracy of retrospective pain reports may fluctuate to a great extent. It is therefore of great importance to conduct further research into possible mechanisms which influence pain recall. Additionally, clinicians should be mindful of such factors when assessing pain and prescribing medication and treatment.

5. CONCLUSION

Several important conclusions can be drawn from this study. Age-related differences in pain reporting do exist, whereby older adults are more likely to over-report pain intensity after a delay, whereas young adults show the reverse pattern, underestimating pain levels. Contrary to our expectations, this effect does not seem to be driven by differences in memory or cognitive status. Instead, it seems likely that current pain may be a mechanism which causes differences in age groups. Specifically older adults, who are generally in a high level of current pain at the time of reporting are more likely to overestimate pain, and young adults show a tendency to under-report pain, due to lower levels of current pain. Beyond this, higher depression scores appear to result in an overestimation of pain intensity after one week in both young and older adults. This is likely to be due to a mood-congruency recall bias. Additionally young participants who report pain with reference to a framework of previously experienced pain across the lifespan seem to show a tendency to under-report a specific instance of pain. This suggests that pain intensity ratings can be manipulated by asking participants to use previously experienced pain from their lives as a comparison point. Further research into the mechanisms which underpin accurate retrospective pain reports is necessary, in order to further our understanding of this subject area.

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