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# Maintenance of Positive Affect Following Pain in Younger and Older Adults

Ian Andres Boggero

*University of Kentucky,* iboggero@gmail.com

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MAINTENANCE OF POSITIVE AFFECT FOLLOWING PAIN IN YOUNGER AND
OLDER ADULTS

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DISSERTATION

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A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Arts and Sciences at the University of Kentucky

By

Ian Andres Boggero

Lexington, Kentucky

Director: Dr. Suzanne C. Segerstrom, Professor of Psychology

Lexington, Kentucky

2017

ABSTRACT OF DISSERTATION

MAINTENANCE OF POSITIVE AFFECT FOLLOWING PAIN IN YOUNGER AND
OLDER ADULTS

Socioemotional selectivity theory posits that as people age, they become motivated and successful at maximizing positive emotions and minimizing negative ones. Yet, 70% of older adults report physical pain, which is associated with negative affect. The strategies and resources that older adults use to maintain positive affect in the face of pain remain largely unknown. Specific positivity-enhancing strategies include recalling, recognizing, and responding to positive stimuli and prioritizing close over knowledgeable social partners. Executive functions (EF, i.e., task-switching, working memory, and inhibition) and heart rate variability (HRV) may be important resources for coping with pain. The current project used two studies to test whether older adults used positivity-enhancing strategies and maintained emotional wellbeing following pain more than younger adults; associations with EF and HRV were also investigated. In Study 1, 50 older and 50 younger adults experienced a control and a pain condition, were given the chance to employ positivity-enhancing strategies, and provided EF and HRV data. Study 2 used longitudinal data from community-dwelling older adults (n =150) to test whether task-switching moderated the within-person relationship between pain and wellbeing. In Study 1, after the pain condition, younger adults demonstrated lesser preference toward knowledgeable social partners than older adults ($\gamma$ = -0.15, p = .016). No other age group x pain condition x valence interactions were found. Older and younger adults did not differ in changes in positive or negative affect following pain. Task-switching and HRV were both associated with reduced preference for knowledgeable social partners following pain, but no other significant EF or HRV interactions were found. Study 2 failed to support the hypothesis that task-switching protected against pain-related declines in wellbeing. Future research on strategies that older adults use to maintain emotional wellbeing in the face of pain is needed.

KEYWORDS: Acute Pain, Aging, Emotional Wellbeing, Positivity Effect,
           Socioemotional Selectivity

    Ian Andres Boggero

    04/27/2017

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By

Ian Andres Boggero


<div style="text-align:right">

Dr. Suzanne C. Segerstrom
Director of Thesis

Dr. Mark Fillmore
Director of Graduate Studies

04/27/2017

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**Chapter One: General Introduction**

Positive affect is associated with psychological wellbeing and health in older adults (Diener & Chan, 2011; Pressman & Cohen, 2005). Older adults who report higher positive affect have reduced mortality risk (Carstensen et al., 2011; Chida & Steptoe, 2008), and positive affect predicts reduced inflammation, better immune and cardiovascular functioning, and higher self-rated health (for a review, see Diener & Chan, 2011; Pressman & Cohen, 2005). These findings highlight the importance of positive affect for health in older adults.

Unfortunately, pain can decrease positive affect and increase negative affect (Lumley et al., 2011; Zautra, Smith, Affleck, & Tennen, 2001; Zautra et al., 1995; Zautra, Johnson, & Davis, 2005). The threat is particularly relevant for older adults, as approximately 70% of older adults report experiencing physical pain within the previous month (Catala et al., 2002; Thomas, Peat, Harris, Wilkie, & Croft, 2004). Yet, older adults appear remarkably adept at maintaining positive affect in the face of pain. Relative to younger pain patients, older pain patients report better quality of life, marital and social satisfaction, and mood, along with less pain interference and dysfunction (Boggero, Geiger, Segerstrom, & Carlson, 2015; Cook & Chastain, 2001; Edwards & Fillingim, 2001; Rustøen et al., 2004). Additionally, changes in pain appear unrelated to changes in psychological wellbeing (Phelan & Heidrich, 2007), and older adults who report "extreme" pain have similar levels of satisfaction with life than those who report "no" or "moderate" pain (Lohmann, Heuft, Schneider, & Kruse, 1998). These findings suggest that older adults maintain positive affect following pain at least as well as their younger counterparts, but little is known about *how* older adults maintain positive affect following acute pain, *whether* older adults' affect changes following acute pain, or *what* makes some older adults better able to cope with acute pain than others. The current studies aimed to answer these questions.

**Socioemotional Selectivity and Pain**

One explanation for how older adults maintain emotional wellbeing (maximizing positive affect and minimizing negative affect) following pain comes from socioemotional selectivity theory (SST). SST posits that as people age, they become motivated to achieve the present-oriented goal of maintaining or increasing positive affect (Carstensen, Isaacowitz, & Charles, 1999). Older adults successfully accomplish positive affectivity by exhibiting a positivity bias in attention and memory that enhances positive emotions (e.g., Mather & Carstensen, 2005). Relative to younger adults, older adults strategically attend to positive environmental stimuli to regulate emotions (Charles, Mather, & Carstensen, 2003; Isaacowitz, Toner, Goren, & Wilson, 2008). Older adults also enhance positivity by prioritizing close over novel but knowledgeable social contacts, leading to small but meaningful social networks (e.g., Fung, Carstensen, Lang, 2001). These close social partners, including close friends and family members, provide affective over informational benefits and allow older adults to maximize positive affect. The fact that older adults maintain positive affect following pain equally well as or better than younger adults highlights the possibility that older adults may be using some of these positivity-enhancing strategies to counteract the negative emotional experience of pain, but no research to date has examined whether older adults use positivity strategies differently than younger adults to maintain positive affect after experiencing pain.

**Individual Differences in Pain Regulation**

Some older adults can maintain positive affect following pain better than others (Affleck, Tennen, Urrows, & Higgins, 1992). Individual differences in self-regulatory ability – or the ability to inhibit dominant responses – is instrumental to successfully managing pain (Carlson, Bertrand, Ehrlich, Maxwell, & Burton, 2000; Solberg Nes, Roach, & Segerstrom, 2009). Executive functioning (EF) and heart rate variability (HRV) are two indices of self-regulatory ability that have been shown to be important for successful pain management.

EF refers to a set of interrelated cognitive abilities that allow people to plan and modify their actions (Miyake et al., 2000). EF predicts how effectively people respond to physical indicators of disease, including pain, and may allow people to plan healthy behaviors and implement them in spite of pain-related challenges (Boggero, Eisenlohr-Moul, & Segerstrom, 2016; Karp, Shega, Morone, & Weiner, 2008; Moriarty, McGuire, & Finn, 2011; Solberg Nes et al., 2009). One particular EF that is important in managing pain is task-switching, defined as the cognitive flexibility to shift attention from one task to another (Miyake et al., 2000). Longitudinally, task-switching ability predicted pain at 6 and 12 months following knee or breast cancer surgery (Attal et al., 2014). In lab studies, participants with better task-switching more effectively distracted themselves from painful stimuli (Verhoeven et al., 2011). In a sample of community-dwelling older adults, pain was negatively associated with task-switching and other measures of mental flexibility (Karp et al., 2006). Other indices of EF that influence how people cope and respond to pain include working memory ability, defined as the ability to store and maintain information in short term memory, and inhibition, defined as the ability to refrain from performing a dominant response (e.g., Attridge, Eccleston, Noonan, Wainwright, Keogh, 2017; & Berryman et al., 2013; Berryman et al., 2014; Buhle & Wager, 2010; Dick & Rashiq, 2007; Luerding, Weigand, Bogdahn, & Schmidt-Wilcke, 2008; Oosterman, Dijkerman, Kessels, & Scherder, 2010). These findings cumulatively suggest that EF is important for successfully managing pain.

Like EF, HRV – a measure of parasympathetic nervous system activity – is another important resource for chronic pain management (e.g., Carlson et al., 2000; Demaree, Robinson, Everhart, & Schmeichel, 2004). HRV represents a physiological resource because it reflects a strong or active inhibitory neural axis. Chronic pain patients have lower levels of HRV than healthy controls, and HRV is negatively associated with pain thresholds and tolerance in acute pain studies (for a review, see Koenig, Jarczok, Ellis, Hillecke, & Thayer, 2014). Interventions aimed at increasing HRV effectively reduce depression and pain in chronic pain patients, highlighting the importance of HRV in pain management (Carlson et al., 2000; Hallman, Olsson, Von Schéele, Melin, & Lyskov, 2011; Hassett et al., 2007). Individual differences in either EF or HRV may predict how well people are able to maintain emotional wellbeing following pain.

**Within-Person Differences in Pain Regulation**

Not only are there between-person individual differences in people's ability to cope with pain, there are also within-person differences. Individuals may experience difficulty coping with pain that is higher than usual relative to their own usual levels. However, relatively few studies have examined within-person differences in ability to maintain wellbeing in the face of increased pain. Such within-person analyses could elucidate how individuals respond to changes in pain relative to their own levels. The

current study aims to expand on a recent finding showing that within-person levels of pain and EF predict future health by testing whether they also interact to predict concurrent wellbeing (Boggero et al., 2016).

**The Current Studies**

In summary, older adults will likely experience pain-related threats to positive affect. Little is known about the strategies they use to maintain affective wellbeing following pain. Guided by SST, the current studies tested whether younger and older adults use positivity-enhancing strategies differently to maintain positive affect or reduce increases in negative affect following pain. The studies tested whether differences in EF or HRV allow people to maintain positive affect following pain better than others. Study 1 compared usage of positivity-enhancing strategies (recall, recognition, and response time to differently-valenced pictures and preference for close social contacts) following an experimental pain induction between younger and older adults. HRV and EF were explored as potential moderators of the pain - positive affect relationship. Study 2 used a preexisting longitudinal dataset of community-dwelling older adults to test whether within-person changes in pain interacted with task-switching ability to predict wellbeing.

The following four hypotheses were made for the current study:

Hypothesis 1: Older adults would use more positivity-enhancing strategies following pain than younger adults. Specifically, older adults would recall, recognize, and be quicker to respond to positive over negative pictures than younger adults following pain, and prefer closer versus knowledgeable social partners.

Hypothesis 2: As a result, it was hypothesized that older adults would maintain positive affect and minimize increases in negative affect following pain better than their younger counterparts.

Hypothesis 3: Older and younger adults with better EF and HRV would use more positivity-enhancing strategies and be better at regulating their affect following pain.

Hypothesis 4: Finally, it was hypothesized that within-person increases in pain would decrease wellbeing most strongly for those with lower level of EF.

**Chapter Two: Study 1 Introduction**

In Study 1, older and younger adults who were not experiencing pain in their daily lives were asked to view positive, negative, and neutral pictures after experiencing pain (from submerging their hands in ice water) and not experiencing pain (submerging their hands in room temperature water.) Positivity-enhancing strategy usage, positive and negative affect pre-and post-pain, EF, and HRV data were obtained. Data from Study 1 was used to test Hypotheses 1-3.

## Chapter Three: Study 1 Methods

**Participants**

      An *a priori* power analysis was conducted to determine the necessary sample size. Previous research found medium effect sizes for the effect of pain on positive affect ($d = 0.48$; Connelly et al., 2007). A meta-analysis found medium to large effect sizes for positivity in recognition tasks between younger and older adults ($d = 0.66$; Murphy & Isaacowitz, 2008). No estimates in the literature could be found for the effect of pain on social preferences, so a conservative estimate of small-to-medium effect of $d = 0.4$ was used. With an alpha level set at .05 and a desired power of .80, the power analysis indicated that a total sample size of 94 would be needed to detect the predicted effects. As such, 48 participants were targeted for the younger age group and 48 for the older age group. Additional participants were recruited to safeguard against drop-out and incomplete data affecting the targeted sample size.

      Older adults between ages 65 and 85 were recruited from a research database maintained by the University of Kentucky's Sanders-Brown Center on Aging. A sample of sex- and race-matched younger adults aged 18-30 were recruited from introductory psychology students at the University of Kentucky. Since the average educational level of potential volunteers from the Sanders-Brown database is higher than that of older adults in the community at large, an undergraduate sex- and race-matched sample provided an adequate comparison group. Inclusion criteria for the study included: a) a score of 0-3 to the question of "On a scale from 0-10, with 0 being no pain and 10 being the worse pain imaginable, what is your current level of pain?"; b) absence of disorders that would make pain testing unsafe (e.g., seizure disorders, severe cardiovascular disorder); c) absence of medications that would significantly alter pain processing or HRV, such as psychiatric medications, antidepressants, or pain medication; d) ability to read, write, and understand English, and e) normal or corrected-to-normal vision.

**Design and Procedures**

      The study was conducted in the psychology department at the University of Kentucky. Due to the effects of exercise, caffeine, alcohol, and pain medications on HRV and pain, participants were asked by phone at the time of scheduling to abstain from these activities for 4 hours prior to the start of the study. Upon arriving at the lab, participants provided written consent to participate in the study. The experimenter confirmed compliance with inclusion criteria and to abstention from the four aforementioned activities prior to initiating the study. The experimenter then attached electrocardiogram (ECG) electrodes to the participant's torso in Type II configuration to begin baseline ECG data collection for 7 minutes. During this baseline period, participants provided demographic information, completed questionnaires assessing affect, and were introduced to the social preference task (described below). Blood pressure was taken three times using a blood pressure cuff on the nondominant arm.

      Following the blood pressure measurement, participants underwent a control condition in which they submerged their hand in a 71.6°F (room temperature) bath of circulating water for one minute (e.g., Edwards, Fillingim, & Ness, 2003). Every 20 seconds during and immediately after hand submersion, participants provided a pain intensity rating. Immediately following hand submersion, participants were shown a series of 8 positive, 16 neutral, and 8 negative International Affective Picture System (IAPS) pictures in random order, at 2-sec intervals. They were instructed to attend to

these pictures "as if they were watching television" and were not told they would have to memorize the pictures. Next, participants performed a social preference task (described below) which has previously been validated for assessing positivity preferences in older adults (Lang & Carstensen, 2002; Segerstrom, Geiger, Combs, & Boggero, 2016). They were then told to rest for ten minutes while they read magazines or used their phones so that the experimenter could monitor ECG; in reality, the rest period was implemented as a delay period for the memory tasks which were to follow. After the rest period, the experimenter returned to the room and instructed the participants to provide a brief written description of all the pictures they were able to remember (recall). They were then shown a new set of pictures containing half novel and half previously-seen pictures. Participants were instructed to press the "a" key on the computer if they thought the picture was novel, or the "l" key if they thought it was shown in the initial presentation (recognition and response time). The methodology for the recognition task (including the pictures) was based on that used by Charles et al. (2003). After the second recognition task, participants provided ratings of positive and negative affect.

Following the control condition tasks, participants repeated the same procedures in the pain condition. Specifically, participants were asked to place their hand in a 39.2°F bath of circulating ice water for one minute – a temperature which has previously been shown to elicit pain in older adults (Edwards et al., 2003). Participants provided pain intensity ratings every 20 seconds that their hand remained submerged in the water. Participants were then again shown a different set of positive, neutral, and negative pictures following the pain induction task. These pictures were administered in counterbalanced order such that half of the participants were randomly assigned to see one set of pictures first (i.e., following the control condition), and the other half were randomly assigned to see that same set of picture second (i.e., following the pain condition). Following the picture presentation, participants underwent a social preference task, a rest period, and a picture recall and recognition task as described above to test the positivity-enhancing strategies they used following pain. After the recognition task, participants again provided ratings of positive and negative affect.

Following the pain condition tasks, participants completed neuropsychological assessment of working memory, inhibition, and task-switching, in counterbalanced order, as detailed below. These tests were administered last to prevent possible frustration with the tests from influencing affect ratings. After EF testing, participants were detached from the ECG equipment, debriefed, and thanked for their participation. A visual representation of all procedures for the study is presented in Figure 3.1. All procedures were approved by the Institutional Review Board.

Figure 3.1. *Graphical Representation of Study Procedures.*
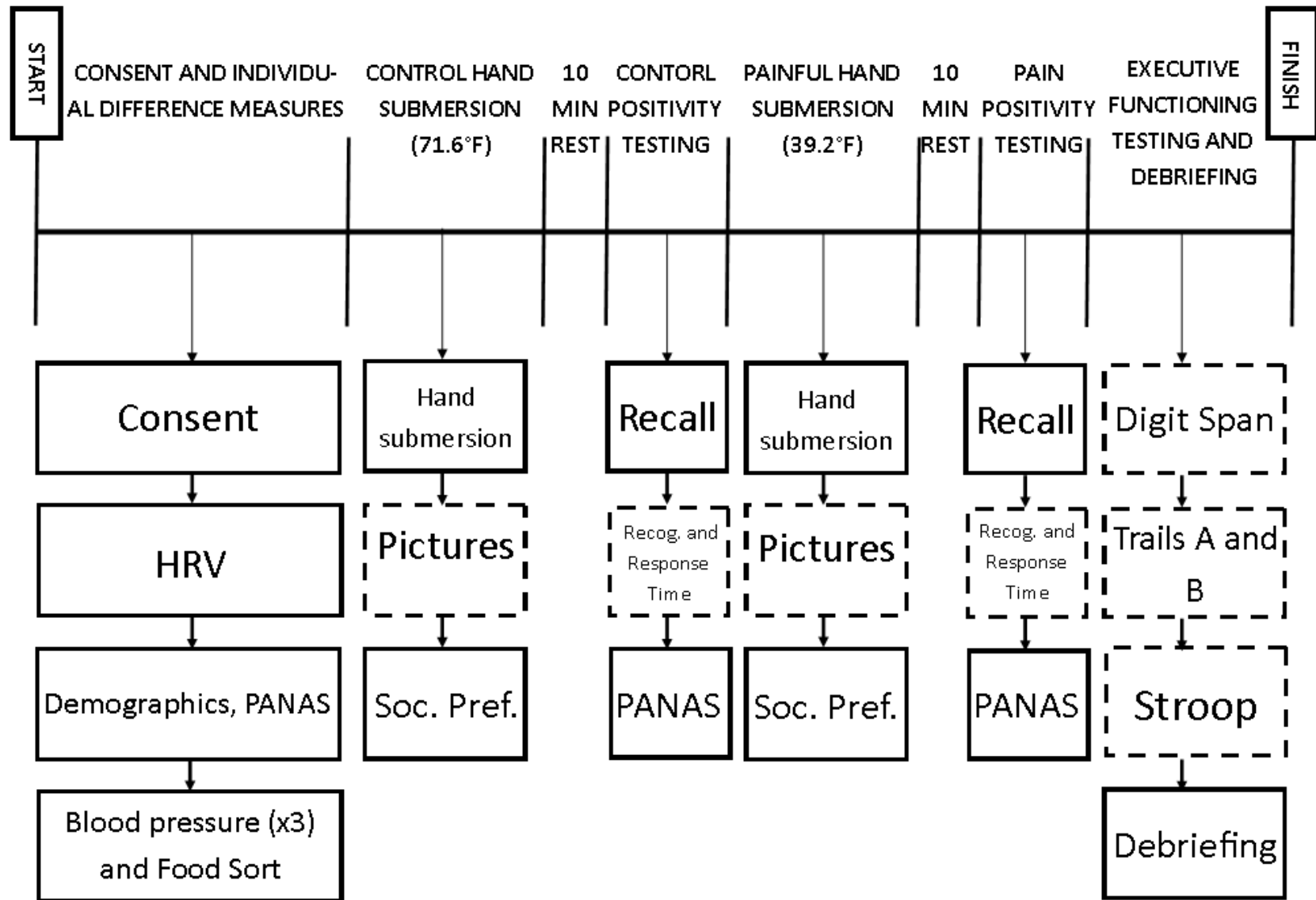
Figure 3.1. *Graphical Representation of Study Procedures* (continued).
*Note*: Participants proceed through all stages of the study in order, moving from left to right across the solid black line. Specific tasks completed at each stage of the study are depicted by the boxes under the corresponding section. Large-dash boxes represent tasks that are counterbalanced between participants; specifically, some participants see Picture Set 1 following the control-submersion and Picture Set 2 following the pain-submersion, whereas others see Picture Set 2 following the control-submersion and Picture Set 1 following the pain-submersion. Small-dash boxes (in the EF section) signify that order of the 3 EF tasks are counterbalanced across participants. Abbreviations: PANAS = positive and negative affect schedule; F = Fahrenheit.

**Materials**

      **Demographics.** Age, sex, education level, relationship status, height, weight, and ethnicity data were collected.

      **Affect.** The positive and negative affect subscales of the Positive and Negative Affect Scale (PANAS; Watson & Clark, 1994) were used to assess positive and negative affect. These subscales have been shown to reliably capture transient pain-related changes in affect (Connelly et al., 2007; Zautra et al., 1995; Zautra et al., 2001). Each subscale contained ten single-word items, and participants reported the way "they felt right now" using a scale of "Very slightly or not at all" (1) to "Extremely" (5). Affect was measured at three points in the study: at the start of the study during the ECG, after the control condition, and after the pain condition (see Figure 3.1). The internal consistencies at these three time points were $\alpha = .89$, $\alpha = .93$, and $\alpha = .94$ for positive affect and $\alpha = .74$, $\alpha = .81$, and $\alpha = .86$ for negative affect, respectively. To assess pain-related changes in positive affect, the post-control value was subtracted from the post-pain value so that scores of zero represented no change in positive affect, negative scores represented pain-related decreases in positive affect, and positive scores represented pain-related increases in positive affect. For negative affect, the post-pain value was subtracted from the post-control value so that scores of zero represented no change in negative affect, negative scores represented pain-related increases in negative affect, and positive scores represented pain-related decreases in negative affect.

      **Pain Intensity.** Participants provided verbal pain intensity ratings every 20 seconds while their hand was submerged in the water using a scale of "No Pain" (0) to "The Worst Pain You Can Imagine" (10). The average of all three ratings was computed so that data from those who withdrew before the minute was up (and therefore had fewer ratings) could still be used. Internal consistency for the pain intensity scale in the control condition was $\alpha = .94$ and in the pain condition, $\alpha = .95$.

      **Positivity-Enhancing Strategy: Recall, Recognition, and Response Time.** Picture recall refers to the number of positive, negative, and neutral pictures participants recalled following the control and pain condition. Recall was operationalized as the sum of correctly identified pictures for each of the three valence categories.

      Recognition for previously-seen pictures was operationalized by calculating a C score for each of the three picture valence categories (positive, neutral, and negative). C is a signal-detection-theory-based estimate of response bias, where values of C above zero indicate a conservative bias (less willing to judge an item as having been previously seen) and values of C below zero indicate a liberal bias (more willing to judge as having been previously seen; Macmillan & Creelman, 1991; Charles et al., 2003).

      Response time was operationalized as the time in milliseconds participants took to respond to each of the previously-seen pictures. Average response times for the three picture valence categories were computed by averaging across all previously-seen stimuli in that category.

      **Positivity-Enhancing Strategy: Social Preference.** Social preferences were assessed using the social preference task from Lang and Carstensen (2002). Participants were first oriented to the task by sorting cards on which 8 foods were printed by preference, with leftmost piles containing the foods they would like to eat the most, and rightmost piles containing the foods they would like to eat the least. Incorrect sorts (e.g., less preferred foods on the left) were corrected until the participant understood the task.

Participants were then given a stack of cards each containing 1 of 18 potential social partners in different categories ranging from close family and friends ("a member of your immediate family") to knowledgeable partners ("an author of a book that you have read"). Participants sorted the cards into piles representing how much they would like to spend half an hour with that person, with leftmost piles containing the people with whom they would most like to spend time, and rightmost piles containing the people with whom they would least like to spend time. Based on previous cluster analysis conducted on a similar sample, two knowledgeable social partners ("author" and "poet") and three close social partners ("close friend," "member of your immediate family," and "sibling") were used for analysis; these two categories were specifically selected because they demonstrated consistent clustering across older and younger adults across different experimental conditions in previous data (Segerstrom et al., 2016). Social preference for each partner was operationalized as pile rank, standardized from 0 (most preferred pile) to 1 (least preferred pile) using the following equation: (pile number – 1)/(number of piles – 1). For example, the values assigned if there were four piles were 0 (most preferred), 1/3, 2/3, and 1 (least preferred).

**EF.** Participants completed three EF tests in counterbalanced order: a task-switching, a working memory, and an inhibition test. To assess task-switching, participants completed the Trail Making Test Parts A and B. In Part A, participants drew lines connecting numbers in sequential order from smallest to largest while being timed by the experimenter. In Part B, participants performed the same task with the added challenge of alternating between numbers and letters. The difference in completion time between Parts A and B produces a valid and reliable measure of task-switching (Sanchez-Cubillo et al., 2009).

To assess working memory, Digit Span Forward, Backward, and Sequencing from the Wechsler Adult Intelligence Scale (4th Edition) task was used. These tests required participants to recite a string of numbers read by the experimenter in the same order, in backward order, and in order from smallest to largest, respectively. A total score was computed by summing the correct number of responses across Forward, Backward, and Sequencing.

A Stroop test was used to measure inhibitory ability (West & Alain, 2000). Participant were shown color congruent words, color-incongruent words, and colored blocks (control) on a computer screen and were asked to identify the color of the font of the word or the block, ignoring the word. Response times of correct responses were measured in millisecond using Inquisit. Inhibition was operationalized as (response time incongruent – response time congruent)/ response time control * (-1) so that higher scores reflected better inhibition ability. An error variable summing the number of errors for congruent, incongruent, and control trials was also computed.

**HRV and Blood Pressure.** The ECG was collected using a Biopac Systems (Goleta, CA) EKG100B amplifier. The ECG was sampled continuously and recorded using Biopac Acqknowledge software. Mindware (Gahanna, OH) HRV software was used to visually inspect and edit data in accordance with the guidelines described by the Task Force of the European Society and Cardiology and the North American Society of Pacing and Electrophysiology (1996). Mindware HRV software provides spectral analysis of the data, yielding log HF HRV (.15-.4 Hz) as a measure of vagally mediated HRV. The mean HF HRV across the last 5 of the 7 minutes' baseline period was used to

assess baseline HRV for each individual (data from the first two minutes were discarded to allow the participant to acclimatize to the testing environment). Following the baseline, three separate blood pressure measurements were taken to include as covariates in HRV analysis. These three measurements were averaged to produce average diastolic blood pressure, systolic blood pressure, and heart rate.

**Data Analysis Plan**

Prior to analysis, all variables were checked for missing data, outliers, and normality. Outliers were identified using a criterion of +/- 4 *SD* from the mean. Next, descriptive statistics and bivariate correlations were computed among all variables. T-tests were used to compare EF and HRV between younger and older adults. A manipulation check tested whether participants rated the cold water as more painful than the room temperature water.

**Hypothesis 1.** The first hypothesis was that older adults would use more positivity-enhancing strategies following pain than younger adults. Specifically, it was predicted that relative to younger adults, after experiencing pain older adults would 1) recall more positive than neutral or negative information in the environment, 2) recognize more positive than neutral or negative information in the environment, 3) respond quicker to positive than neutral or negative pictures, and 4) prefer close (versus knowledgeable) social contacts. To test for recall, recognition, and response time, three separate 2 (younger vs. older, between-person) X 2 (control vs. pain; within-person) X 3 (positive vs neutral vs negative; within-person) mixed model ANOVAs were conducted. To control for multiple comparisons, the Holm-Bonferroni method was used. This method is more precise than the overly-conservative Bonferroni method and is considered the most appropriate method to use when dependent variables are correlated with each other. For details of the Holm-Bonferroni method, see Aickin and Gensler (1996).

To test for social preferences, multilevel models were conducted in SAS version 9.4 using PROC MIXED with standardized pile rank as the dependent variable. Multilevel models are ideal for handling nested data where social partners are nested within person. The Kenward-Rogers correction was used to calculate degrees of freedom due to the small sample size of the current study. An unstructured covariance structure was used for all models because it is particularly good at handling balanced data, and because results from likelihood ratio tests comparing it to compound symmetry and autoregressive structures revealed that it was a significantly better fit for the current data.

Main effects of age group, pain condition, valence, and their interactions were tested for all models. Main effects models only included the main effect term without any other variables in the model. Interaction models included all main effect and interaction terms entered simultaneously.

**Hypothesis 2.** The second hypothesis was that older adults would maintain positive affect and minimize increases in negative affect following pain better than their younger counterparts. First, a repeated-measure ANOVA was used to determine whether positive and negative affect changed following pain. Next, a mixed-factor ANOVA was conducted with change in positive affect as the dependent variable and age group as the independent variable. These same analyses were repeated for negative affect.

**Hypothesis 3.** The third hypothesis was that older and younger adults with better EF and HRV would use more positivity-enhancing strategies and be better at regulating their affect following pain. Specifically, it was predicted that those higher in EF or HRV

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would 1) be able to recall and recognize more positive pictures following pain, and be able to do so faster. Additionally, it was predicted that those with higher EF and HRV would prefer close (versus knowledgeable) social partners following pain. Finally, it was predicted that those with higher EF or HRV would be better able to maintain positive affect and reduce increases in negative affect following pain.

Because composite scales best capture the universe of EF (Mather & Knight, 2005), a composite EF scale of the Trails, Digit Span, and Stroop scores was attempted. However, scale analysis revealed that these items did not demonstrate sufficient internal consistency to be analyzed as a unitary composite ($\alpha = .32$). As such, all three EF variables were analyzed independently. To test these associations, main effects models where the EF was entered as the unitary predictor of positivity-enhancing strategy or affect were computed using linear regression. Then, an EF/HRV (between subject) X pain condition (control vs. pain; within) X valence (positive vs neutral vs negative; within) interaction was independently tested for each EF/HRV variable with all lower-order main effect and interaction terms included in the model. Linear regression was used to describe between-subject effects. Systolic and diastolic blood pressure were entered as covariates in HRV analysis. All models were run with and without stimuli order entered as a covariate. Inclusion of order, blood pressure, or heart rate did not substantively change results; as such, only models without these covariates are reported below.

For all models, results from linear regression are reported using beta ($\beta$). $\beta$ represents the standardized unit change in the dependent variable that is accounted for by one standardized unit change in the predictor. Interactions are probed using B instead of $\beta$, which represent the unstandardized unit change in the dependent variable that is accounted for by one unstandardized unit change in the predictor. Results from multilevel models (i.e., those of social preference) are reported using gamma ($\gamma$), which can be interpreted as $\beta$ in linear regression. All analyses were conducted using SPSS version 22 software or SAS version 9.4 software.

**Chapter Four: Study 1 Results**
**Missing Data, Outliers, and Normality**

**Affect**. There were no missing data on change in positive or negative affect. One person had a negative affect decrease that was 4.9 *SD* from the mean; this person was considered an outlier, and all analyses of negative affect were conducted with and without this person. Inclusion of this person did not substantively change results, so reported results include this person. Changes in positive and negative affect were normally distributed.

**Pain Intensity**. Pain intensity ratings from one person were removed from analysis because the participant misused the pain scale (i.e., they rated the room temperature water as an "8" and the cold water as a "2" and after the study stated that they did not understand what the numbers meant), leaving a total of 99 available cases for analysis. As expected, the pain intensity ratings for the control condition were significantly negatively skewed, with most participants reporting no or very little pain.

**Recall, Recognition, and Response Time**. Due to an error in administration, one person was not shown the picture stimuli following the control condition. There were no missing data in the pain condition. For recall, variables for all three valence categories (positive, neutral, and negative) were normally distributed in both conditions. An average recall variable within condition was computed by averaging across all three valences for the control and pain condition separately. A total recall variable was computed by averaging these condition-specific averages. Thus, there were 100 cases available for analysis for the total recall variable.

For recognition, an additional person was missing data in the control condition due to a computer failure, leaving 98 cases for analysis. C scores for all valence categories were normally distributed. An average recognition variable within condition was computed by averaging across all three valences for the control and pain condition separately. A total recognition variable was computed by averaging these condition-specific averages. Thus, there were 98 cases available for analysis for the total recognition variable.

For response times, there were also 98 cases available in the control condition and 100 in the pain condition. Outlier analysis revealed that there were several people who had disproportionately long response times using the criteria of > 4 *SD*; after removing these people, there were 97, 97, and 94 cases available for neutral, negative, and positive response times in the control condition, respectively. In the pain condition, there were 100, 99, and 100 cases available for neutral, negative, and positive response times, respectively. After removing outliers, all distributions were normally distributed.

**Social Preferences**. Nine people in the sample did not have siblings and as such could not rate them. In those cases, preference for close social partners was computed by averaging across the other close social partners. Due to an error in administration, one person did not complete the social preference task following the control condition, leaving 99 cases available for analysis.

**EF**. One person did not complete Trails because the experimenter ran out of time. The difference variable was significantly negatively skewed. A square root transformation was conducted to normalize the distribution; as such, models below use the squared Trails difference. The Digit Span Total variable had four missing cases: two who refused to do the task because they found memory tasks distressing and two who

were not administered the task due to the experimenter running out of time. The scores from the 96 remaining cases were normally distributed. Eight people did not complete the Stroop task due to computer failure or the experimenter running out of time. Of the remaining cases, one outlier was identified for the inhibition variable and four outliers for the total error variable using the criteria of $> 4$ *SD*.

**HRV**. HRV ratings from four people could not be obtained due to equipment failure or experimenter error, leaving 96 cases for analysis. The distribution of HRV was positively skewed. To correct for this, a log transformation of the log HF HRV was conducted. Subsequent analyses of HRV therefore use the log of the logged HF HRV variable. Systolic, diastolic, and heart rate variables were normally distributed.

**Manipulation Check**

The average water temperature in the control condition was 72.9°F (*SD* = 4.43) and in the pain condition it was 42.2°F (*SD* = 3.54). In the younger age group, all participants kept their hand submerged for the entire minute in the control condition, and 48 of 50 kept their hand submerged for the entire minute in the pain condition. The average length of hand submersion for the other two participants was 24.95 seconds. As expected, younger adults reported the cold water (i.e., pain condition) as significantly more painful (*M* = 4.46, *SD* = 2.26) than the room temperature water (i.e., control condition, *M* = 0.35, *SD* = 0.75), *t*(49) = -13.28, *p* <.001.

In the older age group, all participants also kept their hand submerged for the entire minute in the control condition, and 39 of 50 kept their hand submerged for the entire minute in the pain condition. The average length of hand submersion for the other eleven participants was 28.46 seconds. Analysis reported below include the full sample, with the last value carried forward for those who did not complete the painful hand submersion task. Older adults also reported the cold water as significantly more painful (*M* = 5.62, *SD* = 2.52) than the room temperature water (i.e., control condition, *M* = 0.49, *SD* = 1.16), *t*(49) = -14.08, *p* <.001.

Older and younger participants did not differ in their ratings of room temperature water (*t*(97) = 0.73, *p* = .47), but older adults rated the cold water as significantly more painful than the younger adults (see means above; *t*(97) = 2.41, *p* = .018).

**Participants**

Demographic characteristics of the sample by age group are presented in Table 4.1. The sample was entirely Caucasian and 62% female. Older adults demonstrated significantly lower EF and HRV than younger adults.

Table 4.1. *Demographic Characteristics of the Sample by Age Group*

| | Younger Adults (n = 50) | Older Adults (n = 50) | *t*(df) | *P* |
|---|---|---|---|---|
| Mean Age (*SD*) | 19.06 (1.81) | 73.44 (4.73) | | |
| Observed Age Range | 18-28 | 65-84 | | |
| Relationship Status | | | | |
|    Single | 96.0% | 6.0% | | |
|    Married/Cohabitating | 4.0% | 62.0% | | |
|    Divorced | 0% | 12.0% | | |
|    Widowed | 0% | 20.0% | | |
| Mean BMI (*SD*) | 23.59 (4.08) | 18.36 (5.11) | -2.23(97) | .028 |
| Mean Years of Education (*SD*) | 12.51 (0.77) | 16.06 (2.57) | -9.26(95) | <.001 |
| Trails A (*SD*) | 24.33 (7.77) | 34.08 (11.59) | -4.93(97) | <.001 |
| Trails B (*SD*) | 53.14 (15.95 | 93.13 (46.22) | -5.77(97) | <.001 |
| Trails A – B (*SD*) | -28.81 (15.63) | -60.11 (40.29) | 5.11 (96) | <.001 |
| Digit Span Total (*SD*) | 26.64 (4.51) | 24.00 (4.68) | 2.81 (94) | .006 |
| Stroop Inhibition (*SD*) | -0.22 (0.18) | -0.14 (0.23) | -1.86 (89) | .067 |
| Stroop Error (*SD*) | 2.79 (2.40) | 2.54 (2.37) | 0.49 (86) | .62 |
| Log HRV (*SD*) | 2.80 (0.36) | 2.03 (0.59) | 7.82 (94) | <.001 |

Note: Sample sizes for EF and HRV are influenced by missing data.

**Descriptive Statistics and Bivariate Correlations Among Variables**

Table 4.2 includes means, standard deviations, and bivariate correlations among study variables, collapsing across age group, pain condition, and picture valence. For ease of interpretation, only data from variables with outliers removed are presented.

Table 4.2. *Bivariate Correlations Among Study Variables.*

| Variable | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Age | - | -.62** | -.50** | -.30** | .20 | -.04 | .10 | .05 | .22* | -.15 | -.34** | .64** |
| 2. Log HRV | | - | .26* | .20 | -.10 | .08 | -.10 | -.12 | -.11 | .04 | .33* | -.36* |
| 3. Trails A – B[1] | | | - | .44 | -.06 | -.14 | -.01 | .01 | -.16 | .24* | .21* | -.50** |
| 4. Digit Span Tot. | | | | - | .00 | -.35** | -.20 | .05 | -.13 | .33** | .18 | -.27** |
| 5. Stroop Inhib.[2] | | | | | - | -.02 | .08 | -.11 | -.07 | .10 | -.15 | .14 |
| 6. Stroop Error | | | | | | - | -.17 | -.12 | .05 | .05 | -.09 | -.08 |
| 7. Δ Pos. Aff. | | | | | | | - | .20* | -.15 | .10 | -.20* | .22* |
| 8. Δ Neg. Aff. | | | | | | | | - | -.13 | .13 | .12 | .16 |
| 9. Pain Intensity | | | | | | | | | - | -.27** | -.10 | .08 |
| 10. Recall[3] | | | | | | | | | | - | -.09 | -.18 |
| 11. Recognition[4] | | | | | | | | | | | - | -.17 |
| 12. Resp. Time[5] | | | | | | | | | | | | - |
| Mean | 46.25 | 2.41 | -44.14 | 25.29 | -0.18 | 2.67 | -0.17 | -.01 | 2.77 | 5.57 | 0.12 | 1223.45 |
| *SD* | 27.56 | 0.62 | 34.02 | 4.76 | 0.21 | 2.34 | 0.41 | 0.17 | 1.46 | 2.23 | 0.29 | 346.43 |

*Note*: Abbreviations: Aff. = affect; HRV = heart rate variability; Neg. = negative; Pos. = positive. Symbols: 1 = higher scores represent better task-switching ability; untransformed variable presented for ease of interpretation; 2 = higher scores represent better inhibition ability;  3 = calculated as average number correct across all three valences and across both conditions- higher scores represent better recall; 4 = calculated as average C score across all three valences and across both conditions- higher scores represent more conservative bias; 5 = calculated as average response time in ms across all three response times and across both conditions- higher scores represent longer response time; * = significant at the .05 level; ** = significant at the .01 level.

**Hypothesis 1: Positivity-Enhancing Strategies Following Pain in Younger and Older Adults**

**Recall**. Participants recalled more pictures following the control condition ($M = 6.42$, $SD = 2.65$) than the pain condition ($M = 4.71$, $SD = 2.65$), $F(1, 97) = 36.23$, $p < .001$ (see Model 1 in Table 4.3). Consistent with the positivity effect, recall was greater for positive pictures ($M = 2.05$, $SD = 1.08$) than for neutral ($M = 1.68$, $SD = 1.08$) or negative pictures ($M = 1.84$, $SD = 0.99$), $F(2, 198) = 4.12$, $p = .017$. This main effect of picture valence was moderated by age group such that older adults remembered significantly fewer negative pictures than did younger adults ($M = 1.54$ vs $2.14$, respectively, $t(98) = 3.18$, $p = .002$), but did not differ from younger adults in recall of positive ($t(98) = -0.73$, $p = .46$) or neutral pictures ($t(98) = 0.46$, $p = .65$) (see Figure 4.1). Contrary to the hypothesis, there was not a significant three-way pain condition by age group by valence interaction in predicting recall, $F(2, 194) = 0.55$, $p = .58$. For results from the full model with main effect and interaction terms entered simultaneously, see Table 4.3. Order effects did not change the interpretation of the results (results not shown).

Table 4.3. *Effects of Age Group, Pain Condition, and Picture Valence on Positivity-Enhancing Mechanism Usage.*

| | Model 1: Recall | | | Model 2: Recognition | | | Model 3: Response Time | | |
|---|---|---|---|---|---|---|---|---|---|
| | $F$(df) | $p$ | $\eta^2$ | $F$(df) | $p$ | $\eta^2$ | $F$(df) | $p$ | $\eta^2$ |
| Age Group | 1.53 (1, 97) | .22 | .02 | 13.21 (1, 96) | < .001 | .12 | 50.81 (1, 91) | < .001 | .36 |
| Condition | 36.23 (1, 97) | <.001 | .27 | 1.56 (1, 96) | .22 | .02 | 17.36 (1, 91) | <.001 | .16 |
| Valence | 3.93 (2, 194) | .021 | .04 | 6.56 (2, 192) | .002 | .06 | 2.13 (2, 182) | .12 | .02 |
| Age Group x Condition | 0.17 (1, 97) | .68 | .002 | 0.35 (1, 96) | .56 | .004 | 1.73 (1, 91) | .19 | .02 |
| Age Group x Valence | 4.60 (2, 194) | .011 | .04 | 1.27 (2, 192) | .28 | .01 | 3.88 (2, 182) | .022 | .04 |
| Condition x Valence | 0.62 (2, 194) | .54 | .01 | 3.16 (2, 192) | .032 | .03 | 0.62 (2, 182) | .94 | .001 |
| Age Group x Condition x Valence | 0.55 (2, 194) | .58 | .01 | 2.53 (2, 192) | .083 | .03 | 0.02 (2, 182) | .98 | .000 |

*Note*: Age group: 0 = young, 1 = older; Condition: 0 = control, 1 = pain.

Symbols: $\eta^2$ = partial eta squared.

Figure 4.1. *Graphical Representation of Age Group by Valence Interaction on Picture Recall.*
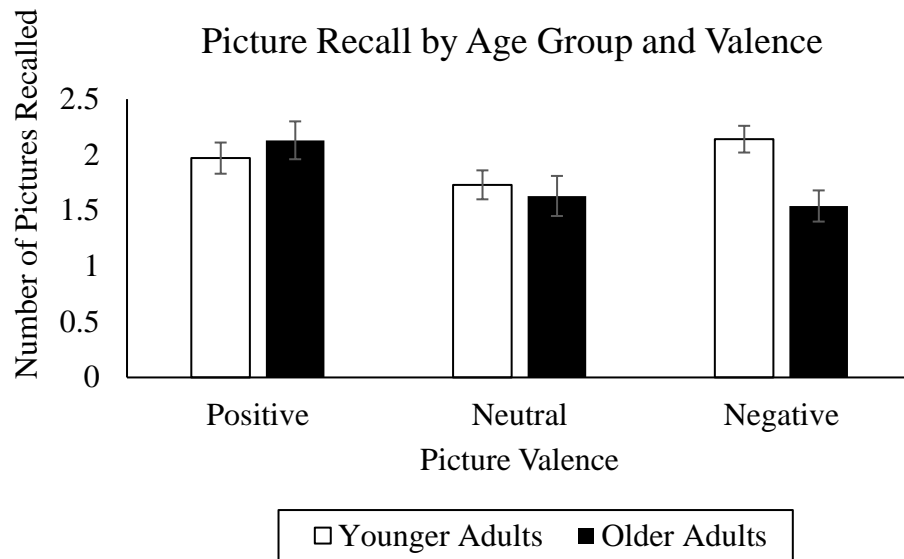
**Recognition**. Younger adults were significantly more conservative (i.e., less willing to judge a picture as previously seen) than older adults (*M* C scores of 0.22 vs. 0.03 for younger and older adults, respectively), $F(1, 96) = 13.21$, $p < .001$ (see Model 2 in Table 4.3).  A main effect of valence was modified by a significant pain condition by valence interaction ($F(2, 192) = 3.16$, $p = .032$). Specifically, after experiencing pain, people were marginally more liberal in recognizing negative pictures (but not positive or neutral pictures) than prior to experiencing pain, $t(97) = 1.79$, $p = .077$ (See Figure 4.2). There was not a main effect of pain condition on picture recognition, nor was there the predicted pain condition by age group by valence three-way interaction, $F(2, 192) = 2.53$, $p = .083$. Order effects did not change the interpretation of the results (results not shown).

Figure 4.2. *Graphical Representation of C-Score by Valence and Pain Condition.*



Picture Recognition by Condition and Valence
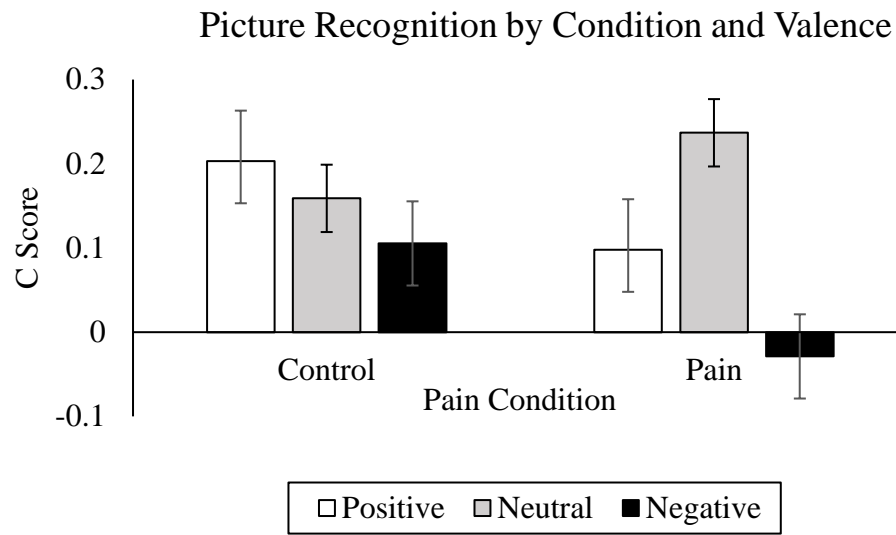
**Response Time**. Participants were quicker to recognize pictures following pain than following the control condition ($M$ = 1146.51 vs 1231.33, respectively, $F(1, 91)$ = 17.36, $p$ <.001 (see Model 3 of Table 4.3). Older adults took significantly longer to identify pictures than younger adults ($M$ = 1435.47 vs 1011.42, respectively, $t(98)$ = -7.72, $p$ <.001. However, this main effect of age group was moderated by valence such that older adults took significantly longer than younger adults to recognize negative pictures ($M$ = 1449.27 vs 996.35, respectively), $t(97)$ = 7.40, $p$ <.001. Contrary to the hypothesis, there were no other significant interactions (all $p$s >.05). Inclusion of outliers or order effects did not substantively change the results (results not shown).

**Social Preferences**. A main effect of target emerged such that participants preferred close versus knowledgeable social partners ($\gamma$ = -0.33, $t(134)$ = -8.88, $p$ <.001; see Table 4.4). There was no main effect of pain condition on social preference ($\gamma$ = 0.02, $t(144)$ = -1.25, $p$ = .21), nor was there a main effect of age group on social preference ($\gamma$ = -0.05, $t(121)$ = -1.55, $p$ = .12). However, there was a significant 3-way interaction between social partner, pain condition, and age group ($\gamma$ = -0.15, $t(125)$ = -2.45, $p$ = .016). In contrast to the control condition, after the pain condition younger adults demonstrated lesser preference for knowledgeable social partners than older adults (see Figure 4.3).

Table 4.4. *Three-Way Interaction of Partner Type, Age Group, and Pain Condition on Social Preference.*

| Variable | Effect | Estimate | *SE* | Df | *p* |
|---|---|---|---|---|---|
| Intercept | | 0.58 | 0.05 | 141 | <.001 |
| Partner Type | Close (ref = knowledge) | -0.54 | 0.05 | 127 | <.001 |
| Age Group | Older (ref = younger) | -0.36 | 0.07 | 141 | <.001 |
| Condition | Control (ref = pain) | -0.14 | 0.04 | 113 | .001 |
| Partner Type*Age Group | Close, Older (ref = knowledge, younger) | 0.36 | 0.08 | 129 | <.001 |
| Partner Type*Condition | Close, Control (ref = knowledge, pain) | 0.14 | 0.04 | 125 | .003 |
| Age Group*Condition | Older, Control (ref = younger, pain) | 0.15 | 0.06 | 113 | .012 |
| Partner Type*Age Group*Condition | Close, Older, Control (ref = knowledge, younger, pain) | -0.15 | 0.06 | 125 | .016 |

Figure 4.3. *Graphical Representation of 3-Way Interaction of Age Group, Partner Type, and Pain Condition in predicting Social Preference (higher = less preferred).*
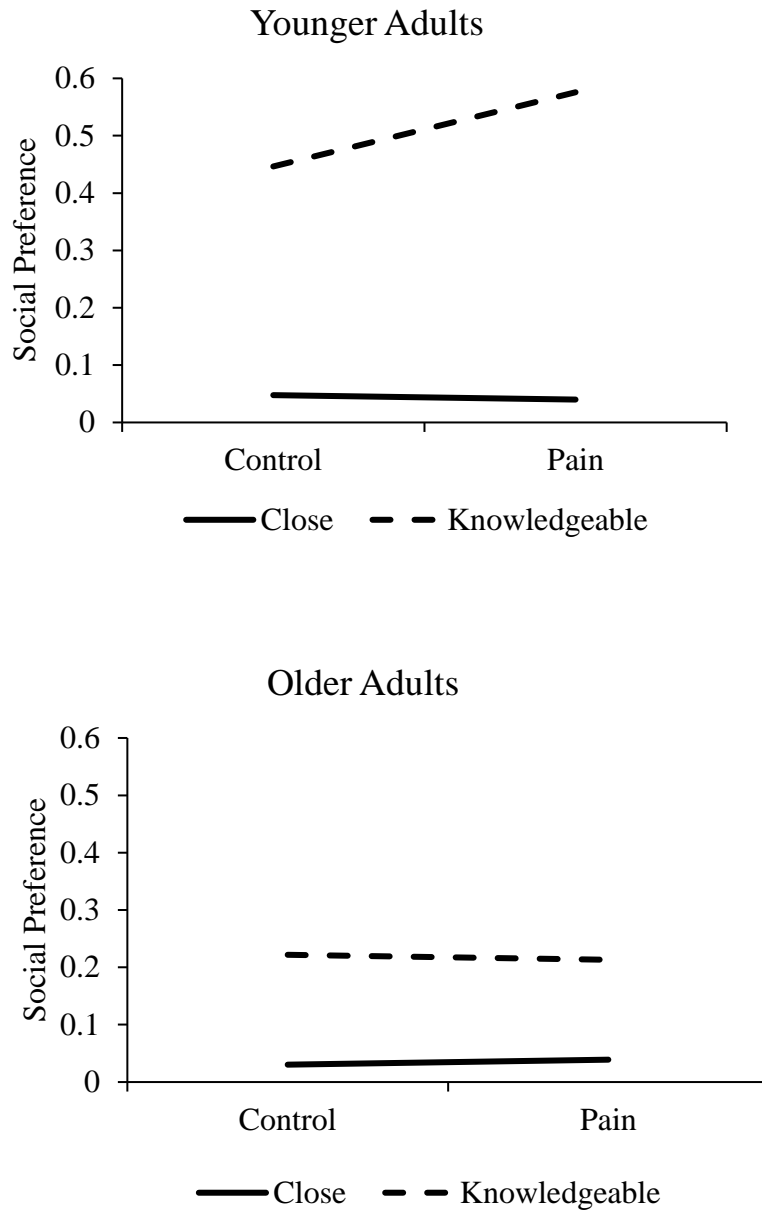
**Hypothesis 2: Changes in Positive and Negative Affect Following Pain in Younger and Older Adults**

**Positive Affect**. A significant main effect of age group revealed that older adults reported greater positive affect ($M = 3.56$, $SD = 0.90$) than younger adults ($M = 2.84$, $SD = 0.72$, $t(98) = 4.47$, $p < .001$). A main effect of condition revealed that positive affect was significantly lower after the pain ($M = 3.11$, $SD = 0.95$) than after the control condition ($M = 3.28$, $SD = 0.86$, $F(1, 99) = 17.77$, $p < .001$). However, there was not a significant age group by pain condition interaction ($F(1, 98) = 0.79$, $p = .38$), suggesting that positive affect change after experiencing pain did not significantly differ between age groups.

**Negative Affect**. Older adults ($M = 1.12$, $SD = 0.16$) and younger adults ($M = 1.16$, $SD = 0.21$) did not differ in levels of negative affect, $t(98) = 1.20$, $p = .23$. There was no main effect of pain condition on negative affect ($F(1, 95) = 0.06$, $p = .81$), nor was there an age group by pain condition interaction ($F(1, 95) = 0.14$, $p = .71$), suggesting that negative affect change after experiencing pain did not significantly differ between groups. See Figure 4.4 for a graphical representation of the results.

Figure 4.4. *Positive and Negative Affect Following Pain by Age Group.*

## Positive Affect By Condition and Age Group



## Negative Affect By Condition and Age Group
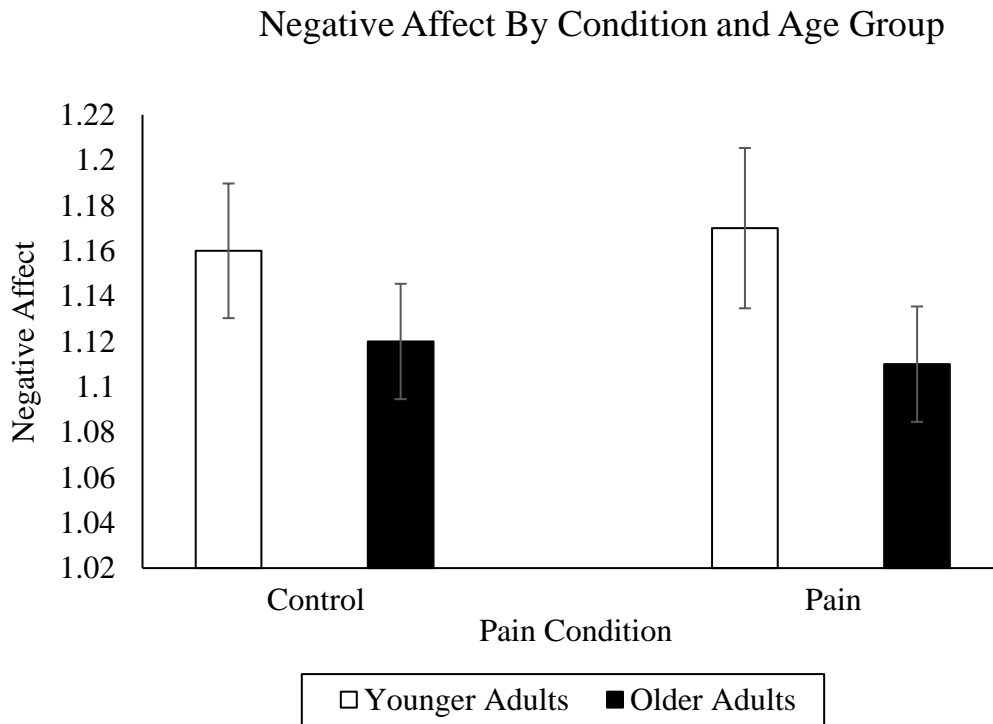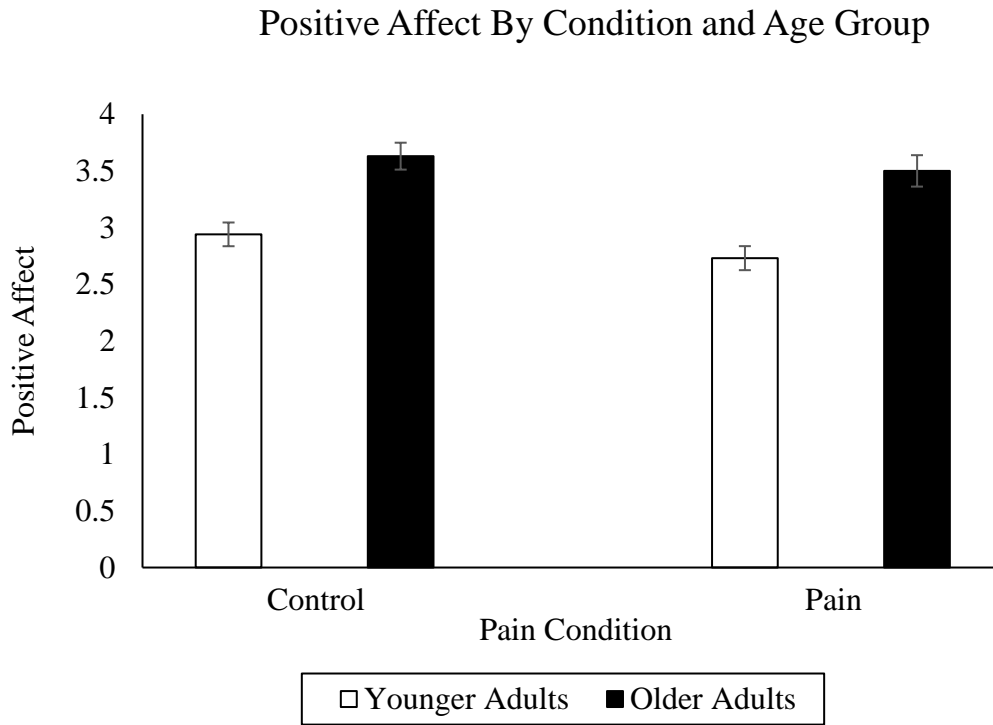
**Hypothesis 3: The Influence of EF and HRV on Positivity-Enhancing Strategies and Affect**

EF. *Task-Switching.* Better task-switching performance was associated with better recall ($\beta = 0.25$, $t(97) = 2.50$, $p = .014$), slightly more conservative bias (i.e., less willing to judge pictures as previously seen, $\beta = 0.22$, $t(97) = 2.25$, $p = .027$), and shorter response times ($\beta = -0.49$, $t(97) = -5.43$, $p = < .001$). Task-switching performance was not associated with social preference ($\gamma = 0.00$, $t(109) = -0.06$, $p = .95$). Table 4.5 reveals that there were no significant two- or three-way interactions between task-switching performance, pain condition, and picture valence on recall or recognition. However, there was a significant three way interaction on response time ($F(2,180) = 3.49$, $p = .033$), such that after the control condition, better task-switching performance was associated with faster response time for neutral pictures ($B = -.026$, $t(90) = -5.66$, $p < .001$) than for positive ($B = -.020$, $t(90) = -4.09$, $p < .001$) or negative pictures ($B = -.02$, $t(90) = -3.23$, $p = .002$), $F(2,89) = 3.77$, $p = .03$. After the pain condition, there were no task-switching performance by valence interactions on response times.

Additionally, there was a three-way interaction of task-switching performance by pain condition by partner type on social preference. After the control condition, better task-switching performance was associated with greater preference for knowledgeable social partners, whereas after the pain condition, better task-switching performance was associated with reduced preference for knowledgeable social partners ($\gamma = 0.00001$, $t(120) = 2.07$, $p = .041$, See Figure 4.5).

Task-switching performance was not significantly related to changes in either positive ($B = 0.00$, $t(96) = -0.58$, $p = .56$) or negative affect following pain ($B = 0.00$, $t(96) = 0.89$, $p = .38$).

Table 4.5. *Effects of Task-Switching on Recall, Recognition, and Response Time.*

| Predictors in Model | Model 1: Recall | | | Model 2: Recognition | | | Model 3: Response Time | | |
|---|---|---|---|---|---|---|---|---|---|
| | $F$(df) | $p$ | $\eta^2$ | $F$(df) | $p$ | $\eta^2$ | $F$(df) | $p$ | $\eta^2$ |
| Task-Switching | 6.13 (1, 95) | .015 | .06 | 5.21 (1, 94) | .025 | .05 | 22.75 (1, 90) | < .001 | .20 |
| Condition | 2.73 (1, 95) | .10 | .03 | 0.96 (1, 94) | .33 | .01 | 8.72 (1, 90) | .004 | .09 |
| Valence | 4.67 (2, 190) | .010 | .05 | 2.81 (2, 188) | .063 | .03 | 2.68 (2, 180) | .072 | .03 |
| Task-Switching x Condition | 0.06 (1, 95) | .81 | .001 | 0.43 (1, 94) | .51 | .005 | 3.53 (1, 90) | .064 | .04 |
| Task-Switching x Valence | 2.97 (2, 190) | .053 | .03 | 0.91 (2, 188) | .40 | .01 | 1.64 (2, 180) | .19 | .02 |
| Condition x Valence | 0.06 (2, 190) | .95 | .001 | 2.69 (2, 188) | .070 | .03 | 3.48 (2, 180) | .033 | .04 |
| Task-Switching x Condition x Valence | 0.21 (2, 190) | .81 | .002 | 2.91 (2, 188) | .057 | .03 | **3.49 (2, 180)** | **.033** | **.04** |

Figure 4.5. *Interaction of Task-Switching, Pain Condition, and Partner Type on Social Preference (higher = less preferred).*
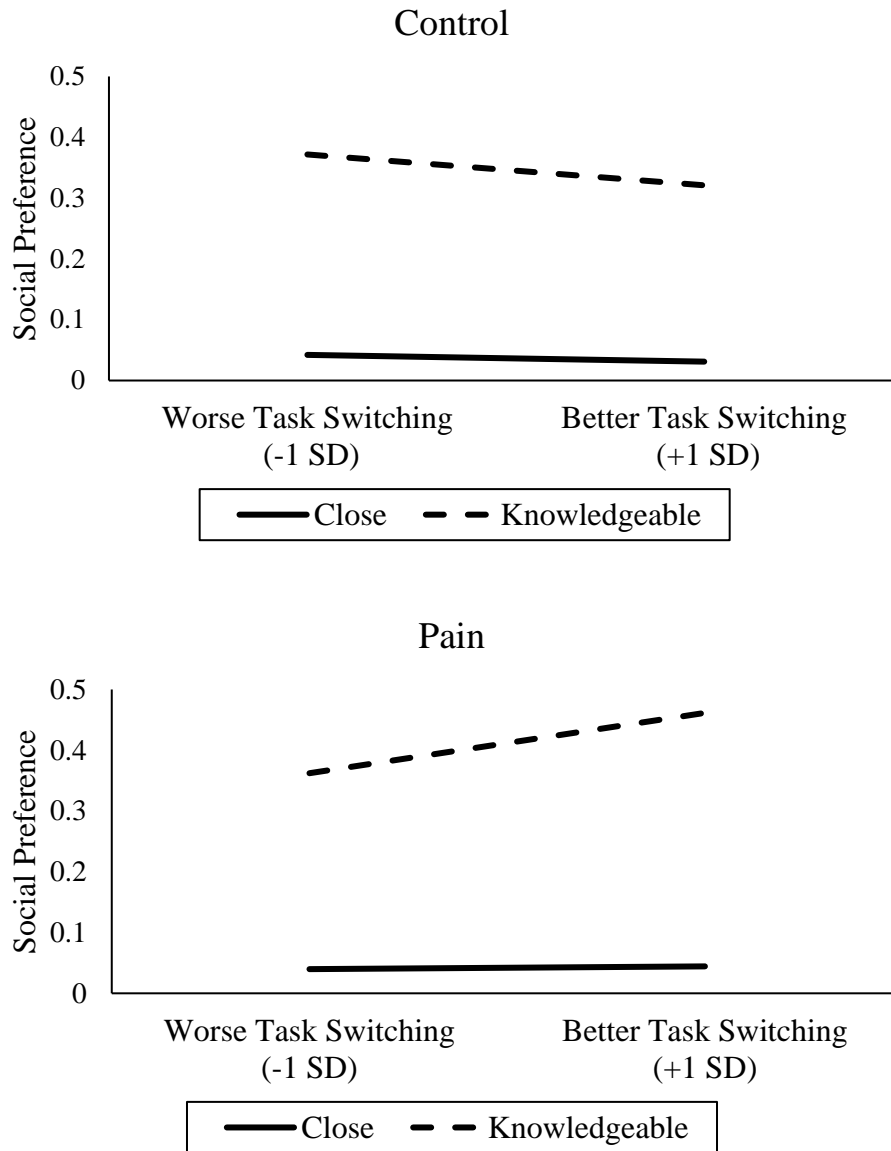
*Working Memory.* Working memory ability was associated with better recall ($\beta$ = 0.33, $t(94)$ = 3.4, $p$ = .001) and shorter response times ($\beta$ = -0.27, t(94) = -2.74, $p$ = .007), but was only marginally related to recognition ($\beta$ = 0.18, $t(94)$ = 1.78, $p$ = .078). Working memory ability was not associated with social preference ($\gamma$ = -0.003, $t(108)$ = -0.69, $p$ = .49). Table 4.6 reveals a significant three-way interaction between working memory, pain condition, and valence such that following the control condition, better working memory significantly predicted more recall of negative ($B$ = 0.09, $t(93)$ = 3.44, $p$ = .001) but not positive ($B$ = 0.02, $t(93)$ = 0.63, $p$ = .53) or neutral pictures ($B$ = 0.05, $t(93)$ = 1.65, $p$ = .10). The opposite was found following the pain condition; namely, working memory did not significantly predict recall of negative pictures ($B$ = 0.01, $t(94)$ = 0.52, $p$ = .60), but marginally predicted more recall of positive pictures ($B$ = 0.06, $t(94)$ = 1.96, $p$ = .053) and significantly predicted more recall of neutral pictures ($B$ = 0.08, $t(94)$ = 2.87, $p$ = .005). There was not a three-way interaction of working memory ability by condition by valence on recognition or response time, nor was there a significant three-way interaction on social preference, (all $p$'s > .05).

Surprisingly, working memory ability was associated with small but significant *decreases* is positive affect following pain ($B$ = -0.02, $t(96)$ = -2.06, $p$ = .042) but was unrelated to changes in negative affect ($B$ = 0.002, $t(96)$ = 0.44, $p$ = .66).

Table 4.6. *Effects of Working Memory on Recall, Recognition, and Response Time.*

| Predictors in Model | Model 1: Recall | | | Model 2: Recognition | | | Model 3: Response Time | | |
|---|---|---|---|---|---|---|---|---|---|
| | $F$(df) | $p$ | $\eta^2$ | $F$(df) | $p$ | $\eta^2$ | $F$(df) | $p$ | $\eta^2$ |
| Working Memory | 11.45 (1, 93) | .001 | .11 | 3.67 (1, 92) | .060 | .04 | 0.91 (1, 87) | .34 | .01 |
| Condition | 1.01 (1, 93) | .32 | .01 | 2.14 (1, 92) | .15 | .02 | 4.95 (1, 87) | .029 | .05 |
| Valence | 1.11 (2, 186) | .33 | .01 | 2.11 (2, 184) | .12 | .02 | 1.75 (2, 174) | .19 | .02 |
| Working Memory x Condition | 0.06 (1, 93) | .95 | .000 | 1.53 (1, 92) | .22 | .02 | 2.49 (1, 87) | .12 | .03 |
| Working Memory x Valence | 0.47 (2, 186) | .62 | .01 | 1.15 (2, 184) | .32 | .01 | 1.23 (2, 174) | .29 | .01 |
| Condition x Valence | 2.84 (2, 186) | .061 | .03 | 1.33 (2, 184) | .27 | .01 | 0.14 (2, 174) | .89 | .002 |
| Working Memory x Condition x Valence | **3.37 (2, 186)** | **.037** | **.04** | 0.88 (2, 184) | .42 | .01 | 0.14 (2, 174) | .87 | .002 |

*Inhibition.* There were no significant associations between inhibitory ability and average recall, response bias, response time, or social preference (all $p$'s > .05). Moreover, there were no significant two- or three-way interactions among inhibitory ability, pain condition, and valence on recall, recognition, or response time (all $p$'s > .05, see Table 4.7). There was also not a three-way interaction of inhibitory ability by pain condition by partner type on social preference, $\gamma = -0.14$, $t(102) = -0.85$, $p = .40$.

Inhibition was not significantly related to changes in either positive ($B = 0.16$, $t(89) = 0.76$, $p = .50$) or negative affect following pain ($B = -0.10$, $t(89) = -1.07$, $p = .29$).

Table 4.7. *Effects of Inhibition on Recall, Recognition, and Response Time.*

| Predictors in Model | Model 1: Recall | | | Model 2: Recognition | | | Model 3: Response Time | | |
|---|---|---|---|---|---|---|---|---|---|
| | $F$(df) | $p$ | $\eta^2$ | $F$(df) | $p$ | $\eta^2$ | $F$(df) | $p$ | $\eta^2$ |
| Inhibition | 0.89 (1, 89) | .35 | .01 | 1.90 (1, 87) | .16 | .02 | 1.77 (1, 83) | .19 | .02 |
| Condition | 14.29 (1, 89) | < .001 | .14 | 1.62 (1, 87) | .21 | .02 | 7.77 (1, 83) | .007 | .09 |
| Valence | 2.05 (2, 178) | .13 | .02 | 4.03 (2, 174) | .019 | .04 | 0.34 (2, 166) | .72 | .004 |
| Inhibition x Condition | 0.49 (1, 89) | .49 | .01 | 0.15 (1, 87) | .70 | .002 | 0.01 (1, 83) | .92 | < .001 |
| Inhibition x Valence | 0.32 (2, 178) | .72 | .004 | 0.28 (2, 174) | .76 | .003 | 0.11 (2, 166) | .90 | .001 |
| Condition x Valence | 1.52 (2, 178) | .22 | .02 | 1.54 (2, 174) | .22 | .02 | 0.55 (2, 166) | .58 | .01 |
| Inhibition x Condition x Valence | 1.01 (2, 178) | .37 | .01 | 0.59 (2, 174) | .55 | .01 | 0.78 (2, 166) | .46 | .01 |

**HRV**. HRV was not associated with recall ($\beta = 0.04$, $t(94) = 0.34$, $p = .73$), but was associated with a more conservative bias (i.e., less willing to judge pictures as previously seen, $\beta = 0.33$, $t(95) = 3.39$, $p = .001$), shorter response times ($\beta = -0.36$, $t(95) = -3.68$, $p < .001$), and preference for close social partners ($\gamma = 0.06$, $t(108) = 2.24$, $p = .03$). Table 4.8 shows a significant three-way interaction between HRV, condition, and valence such that following the control condition, HRV was not significantly associated with recall of positive, neutral, or negative pictures (all $p$'s $>.05$). Following the pain condition, higher HRV was marginally associated with less recall of neutral pictures ($B = -0.02$, $t(94) = -1.90$, $p = .060$). There was also a significant three-way interaction of HRV by pain condition by partner type on social preference, $\gamma = 0.12$, $t(119) = 2.33$, $p = .022$. Specifically, after the pain condition, HRV more strongly predicted reduced preference for knowledgeable social partners than after the control condition (see Figure 4.6).

HRV was not significantly related to changes in either positive ($B = -0.07$, $t(94) = -1.05$, $p = .30$) or negative affect following pain ($B = -.0.03$, $t(94) = -1.13$, $p = .26$).

Table 4.8. *Effects of HRV on Recall, Recognition, and Response Time.*

| **Predictors in Model** | *Model 1: Recall* | | | *Model 2: Recognition* | | | *Model 3: Response Time* | | |
|---|---|---|---|---|---|---|---|---|---|
| | $F$(**df**) | $p$ | $\eta^2$ | $F$(**df**) | $p$ | $\eta^2$ | $F$(**df**) | $p$ | $\eta^2$ |
| HRV | 0.13 (1, 93) | .72 | .001 | 11.21 (1, 92) | .001 | .11 | 7.40 (1, 88) | .008 | .08 |
| Condition | 1.39 (1, 93) | .24 | .02 | 0.35 (1, 92) | .56 | .004 | 5.72 (1, 88) | .019 | .06 |
| Valence | 0.44 (2, 186) | .65 | .01 | 2.01 (2, 184) | .14 | .02 | 0.05(2, 176) | .95 | .001 |
| HRV x Condition | 0.09 (1, 93) | .77 | .001 | 0.68 (1, 92) | .41 | .007 | 2.14 (1, 88) | .15 | .02 |
| HRV x Valence | 0.13 (2, 186) | .79 | .003 | 1.06 (2, 184) | .35 | .01 | 0.23 (2, 176) | .80 | .003 |
| Condition x Valence | 4.63 (2, 186) | .033 | .04 | 0.01 (2, 184) | .77 | .003 | 2.65 (2, 176) | .073 | .03 |
| HRV x Condition x Valence | **3.38 (2, 186)** | **.036** | **.04** | 0.72 (2, 184) | .49 | .008 | 2.66 (2, 176) | .073 | .03 |

Figure 4.6. *Interaction of HRV, Pain Condition, and Partner Type on Social Preference (higher = less preferred).*



Control
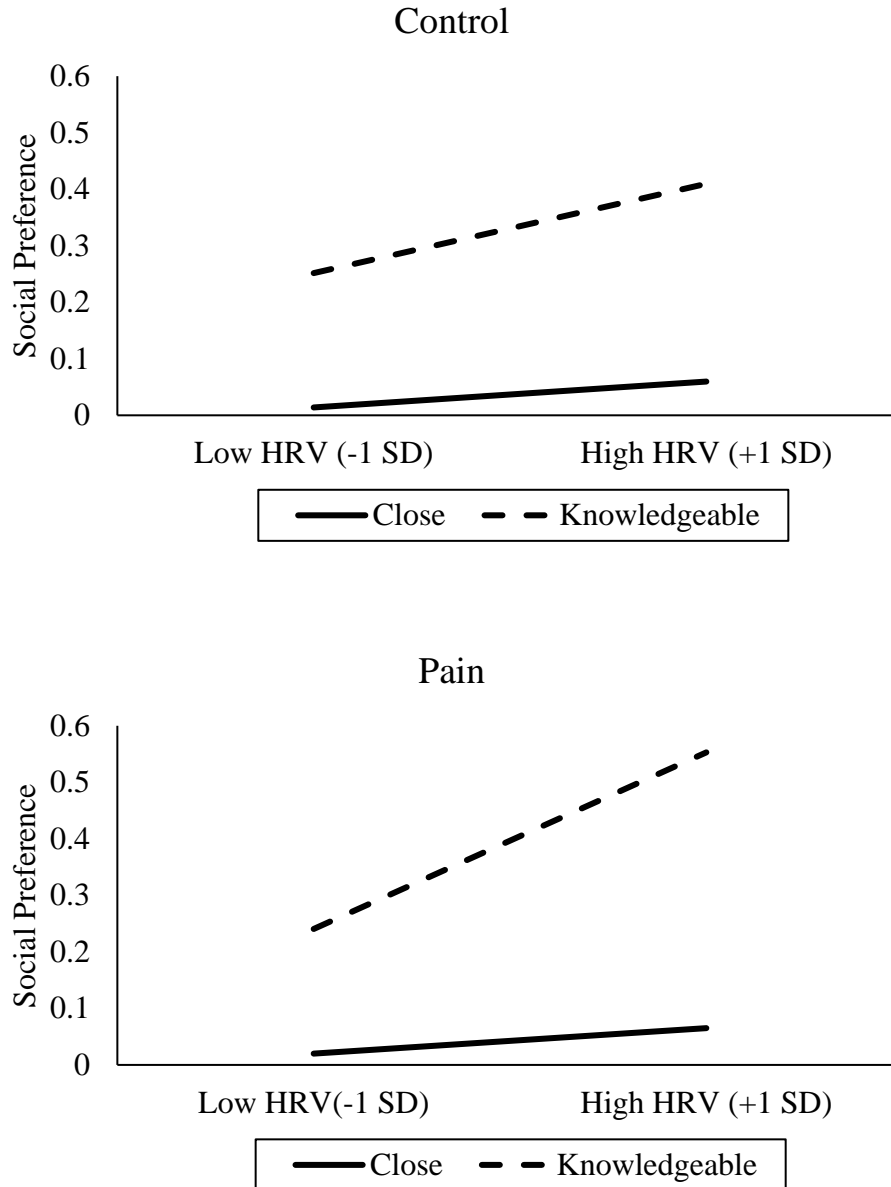


Pain

**Chapter Five: Study 1 Discussion**

The aims of Study 1 were to 1) test whether older adults used greater positivity-enhancing mechanisms than younger adults following pain, 2) test whether older adults were more effective at maintaining positive affect and minimizing increases in negative affect following pain than younger adults, and 3) test whether EF and HRV allowed younger and older adults to use positivity enhancing mechanisms and maintain positive affect following pain.

With regard to the first aim, four separate positivity-enhancing mechanisms were examined: recall of positive pictures, recognition of positive pictures, response time to positive picture, and preference for close over knowledgeable social partners. The hypothesis that older adults would recall more positive pictures following pain than younger adults was not supported. First, people recalled fewer pictures of all valence following the pain than the control condition despite being naïve about having to remember the pictures following the control condition. This is consistent with literature showing that pain demands attention and disrupts cognitive processing (see Bushnell, Ceko, & Low, 2013 for a review). Because participants were shown the pictures immediately following the pain task, it is possible that performance on the recall task reflected problems with encoding instead of recall. Second, positive pictures were better recalled than neutral or negative pictures, but this was not specific to older adults. The only significant age group difference in picture recall was in the negative pictures: older adults recalled significantly fewer negative pictures than younger adults. These effects are consistent with previous work showing that negative pictures are more easily forgotten by older than younger adults (Charles et al., 2003). Hypothesized interactions between age group, pain condition, and picture valence (or partner type) were not found for any of the four positivity-enhancing strategies, suggesting that older and younger adults may be using similar strategies to maintain emotional wellbeing follow pain. Alternatively, it may be that older and younger adults differ in an unmeasured strategy like reappraisal; such possibilities should be explored in future research.

With regard to the second aim, older adults demonstrated higher levels of positive affect and lower levels of negative affect than younger adults, consistent with the positivity and socioemotional selectivity literature. Contrary to the hypothesis, however, there was not a significant pain condition by age group interaction on pain-related changes in positive or negative affect, suggesting that older adults did not maintain positive affect better than younger adults following pain. Because affect was measured after the rest period and positivity tasks, it could be that the lack of pain-related changes in affect were due to affect having already returned to baseline by the time it was measured. Nevertheless, it is important to note that older adults rated the cold water as significantly more painful than younger adults. Whether this age difference in pain ratings reflects differential use of the rating scale by age group or actual differences in the experience and perception of pain in the current study remains unknown. Some evidence suggests that aging is associated with reduced pain inhibition at the neural level (Edwards & Fillingim, 2001; Edwards et al., 2003), but other evidence also suggests that older adults rate pain of the same intensity as slightly more intense (Herr, Spratt, Mobily, & Richardson, 2004). Future work in this area has important implications for the assessment and management of pain in older adults.

With regard to the third aim, there were mixed results that EF or HRV would

predict usage of positivity-enhancing strategies and promote maintenance of positive affect following pain. Effects were specific to EF task and strategy. For example, better task-switching performance was associated with better recall, recognition, and response time but not social preference. Working memory was associated with better recall and response time only. HRV was associated with better overall recognition, response time, and preference toward close social partner. However, there were no significant three-way interactions between EFs/HRV, pain condition, and valence that were consistent across positivity-enhancing strategies, suggesting that there is no ubiquitous resource that uniformly allows people to cope with pain. Instead, specific resources may be better suited for specific strategies. Future work should attempt to replicate the effects of the current study to ensure generalizability of the findings. Moreover, it should be noted that EF and HRV variables were not meaningfully associated with changes in either positive or negative affect following pain. It may be that these resources help people distract away from pain or physiologically inhibit it more than they help people manage pain-related changes in affect.

Study 1 is not without limitations. First, participants always underwent the control condition prior to the pain condition. This was done to ensure that the pain condition did not contaminate the control measurements, but it eliminated the possibility of making conclusive statements about order effects. Practice effects, if present, would have overestimated the performance following the pain condition. Instead, results suggest that participants performed worse on recall and other measures following pain, despite having practiced the task already, minimizing concern about order effects. Another limitation of the study is that EF testing was conducted at the end of the study, following the pain condition. At this point in the protocol, participants may have been tired and may not have exerted maximal effort. Yet another limitation is that the social preference task asked participants to rate their preference for a social partner but did not actually allow them to engage with that partner; thus, there is no reason why performing that task would have increased positive affect. It was merely assessing the willingness to be with a close or knowledgeable social partner, that is, a strategy that might increase or decrease positive affect.

Despite these limitations, Study 1 also has considerable strengths. The sex- and race- matching of older and younger adults eliminated the possibility of potential gender or race effects in the between-subject comparisons. The inclusion of multiple strategies, EFs, and affective outcomes allowed for the most thorough examination of responses to laboratory pain in older and younger adults to date. The repeated-measures design allowed for participants to serve as their own controls. Finally, stringent inclusion criteria and a controlled laboratory setting provided high internal validity to the study. One potential downside of this high internal validity is that the pain manipulation that was used (i.e., the cold pressor) is one that people are unlikely to encounter in their everyday lives. Thus, Study 1 should be complemented with data that has high external validity and examines the resources people use to cope with pain in their regular lives. Study 2 sought to address this limitation.

**Chapter Six: Study 2 Introduction**

Study 2 used longitudinal daily diary data from community dwelling older adults to examine whether pain and task-switching – a particular EF that has been shown to predict favorable pain outcomes longitudinally (Attal et el., 2014; Boggero et al., 2016) – interacted to predict wellbeing within people. Because pain is a subjective experience, absolute levels of pain may not be as important as whether pain is higher or lower than a person's own usual level. It was hypothesized that within-person increases in pain *would not* decrease wellbeing for older adults with higher levels of task-switching but *would* decrease wellbeing for those with lower level of task-switching (Hypothesis 4).

# Chapter Seven: Study 2 Methods

## Participants

Study 2 used archival data from a longitudinal study of older adults. A post-hoc power analysis was conducted to determine the effect sizes that the study was powered to detect. For multilevel models (MLMs), power is determined by intraclass correlation (ICC), effective sample size (ESS), the number of Level 1 observations (n), and the number of Level 2 observations (N). The ICC of a MLM ranges from 0 (no clustering among observations from the same Level 2 unit) to 1 (perfect clustering among observations from the same Level 2 unit). Snijders and Bosker (1999) provide equations to calculate the ESS based on the ICC, N, and n. The ESS for the present study was estimated to be 772. This ESS was used in GPower to calculate the effect size that could be detected with alpha = .05 (two-tailed) and power = .80. This effect size was $R^2$ = .02. Therefore, Study 2 was powered to detect moderate effect sizes.

Participants were 150 community-dwelling older adults who participated in a study assessing the interrelationships among thoughts, stress, and immunity. Participants were originally recruited for the parent project between 2006 and 2007 using a research registry maintained by the University of Kentucky's Sanders-Brown Center on Aging. Inclusion criteria for the study included: (1) willingness to undergo influenza vaccination and venipuncture; (2) absence of any steroid, opiate, or other immunomodulatory medication; (3) absence of chemotherapy or radiation therapy within the last five years; and (4) absence of more than 2 of the following classes of mediations: psychotropics, antihypertensives, hormone replacement, or thyroid supplements. To avoid violations of independence, only one participant per household was allowed. The sample consisted of 87 females (58%), and mean age at the initial visit was 74.7 ($SD$ = 6.19, observed age range at wave 1 = 60-94). Self-reported ethnicities were white (96%) and African-American (4%).

## Procedures

Participants were interviewed in their homes by trained graduate students every 6 months for up to 5 years, resulting in up to 10 possible waves of data per person. At each wave, participants completed diaries on three consecutive evenings in which they provided daily pain and wellbeing ratings for that day. Participants also completed a task-switching ability task during their home visit at each wave. Only the measures described below were used for the current study. Additional measures from the same project are reported elsewhere (e.g., Boggero et al., 2016; Eisenlohr-Moul & Segerstrom, 2013; Segerstrom 2014; Segerstrom, Eisenlohr-Moul, Evans, & Ram, 2015; Segerstrom, Hardy, Evans, & Greenberg, 2012; Segerstrom, Roach, Evans, Schipper, & Darville, 2010). Participants were paid $20 at each interview. All study materials and procedures were approved by the Institutional Review Board.

## Measures

**Demographics.** At the first wave, participants self-reported their sex, birth date, and ethnicity.

**Pain and Wellbeing.** On three consecutive evenings at each wave prior to their interview, participants completed a health behavior questionnaire assessing pain, wellbeing, and 11 other health behaviors (e.g., smoking, diet, exercise). For the current study, only the pain and wellbeing items from the health behavior questionnaire were investigated.

The pain item asked participants to respond to "How much pain did you experience today?" using a 100 point scale. A score of 50 corresponded to usual level of pain; scores of 51 - 100 corresponded to higher-than-usual levels of pain, and scores of 0 – 49 corresponded to lower-than-usual levels of pain. The within-person variability in pain was calculated at each of three levels: day, wave, and person. At the day level, each person's day pain score was subtracted from their mean score across all three days, all within the same wave ($Pain_{day}$). At the wave level, each person's mean pain score at each wave (averaged across days) was subtracted from their average score across all waves ($Pain_{wave}$). At the person level, each person's mean pain score across all waves was subtracted from the grand mean across all people and waves ($Pain_{pers;}$ Brincks et al., 2016).

The wellbeing item asked participants, "How would you rate your health today (how generally well you felt)?" A score of 50 corresponded to usual level of wellbeing; scores of 51 - 100 corresponded to lower-than-usual levels of wellbeing, and scores of 0 – 49 corresponded to higher-than-usual levels of wellbeing. The variable was reverse-scored so that higher scores indicated more wellbeing.

Although theses measure of pain and wellbeing did not provide overall levels of pain or wellbeing (making them poorly-suited for comparing absolute levels of pain or wellbeing between people), they were ideal for assessing within-person changes in pain and wellbeing because they allowed for the capability to report the same amount of change in either direction regardless of "usual" absolute levels (Boggero et al., 2016).

For both the pain and wellbeing variables, average responses were divided by 10; this transformation was carried out so that a 1-unit change would equal a 10-unit change on the original 0-100 scale. Variables were centered around 0 so that positive scores indicated higher-than-usual pain or wellbeing and negative scores indicated lower-than usual levels of pain or wellbeing.

**Task-Switching.** At each wave, participants completed the Trail Making Test (TMT) as described in Study 1. Task-switching was grand mean centered by taking a person's mean task-switching score across all their waves and subtracting that from the grand mean across all people and waves. Thus, negative grand mean centered scores represent that a person's mean was lower than the grand mean; positive scores represent that a person's mean was higher than the grand mean.

**Data Analysis Plan**

Data were analyzed using multilevel modeling (MLM). MLM is ideal for analyzing longitudinal data where observations are nested within waves which are nested within people because it can (1) account for the fact that observations from the same person and wave are correlated, and (2) accommodate missing data. Descriptive statistics and intraclass correlations (ICCs) were computed by fitting null models (models without predictors) of each variable; the intercept estimates of these models represent an unbiased estimate of the mean. Next, analyses established the functional form over time of the dependent variable (wellbeing). Significant time effects were retained in subsequent models.

The goal of the current study was to test if within-person changes in pain interacted with task-switching to predict wellbeing. To test this, three separate models were constructed. The first model (Model 1) tested if wellbeing was predicted by pain at the person, wave, and day level. To determine whether to model pain as both a fixed and

random effect, a -2 log likelihood ratio test was used. Based on results from the -2 log likelihood ratio test, this model and all subsequent models containing pain as a predictor used random slopes for pain at the wave and day level as well as random intercepts. The second model (Model 2) tested if wellbeing was predicted by task-switching. The third (Model 3) model tested the hypothesis of interest; namely, whether pain and task-switching interacted to predict wellbeing. For all models, between/within degrees of freedom were used, assigning within-person degrees of freedom to variables that changed within people and between-person degrees of freedom to those that remained constant over time.

All models were conducted using PROC MIXED in SAS (version 9.4). An empirical estimation procedure and unstructured error matrix for the random components were specified in all models. Models were rerun in PROC GLIMMIX so that the Kaurmann and Carrol correction for small sample size could be applied. Using the correction did not result in any meaningful changes in inference; as such, only the empirical PROC MIXED models are reported below, as per recommended convention (Gosho, Hirakawa, Noma, Maruo, & Sato, 2015).

# Chapter Eight: Study 2 Results

## Missing Data, Distribution, and Outlier Analysis

Missing data analysis revealed that there were no missing data for age. There were 996 cases available for Trails, 2,856 cases available for pain, and 2,855 cases available for wellbeing. Reasons for missing data are reported in detail in Segerstrom et al. (2014). Prior to data analysis, all variables were checked for normality and outliers. Results revealed that grand-mean centered task-switching ability was negatively skewed. This skew was driven by five people whose mean was more than 3 *SD* below the grand mean. All subsequent analyses containing task-switching were run and are presented with and without these outliers. Pain and wellbeing were normally distributed, and the distributions did not contain any outliers.

## Descriptive Statistics

Means and standard deviations for all variables are provided in Table 8.1. Analysis of the ICCs revealed that approximately 28% of the variance in the pain variable resided at the person level, 30% at the wave level, and 42% at the day level. For wellbeing, approximately 14% of the variance was at the person level, 21% at the wave level, and 65% at the day level. Therefore, most of the variance in pain and wellbeing (72% and 86%, respectively), was in within-person changes across waves and especially across days. This result is expectable given that each person was asked to rate pain and well-being relative to their own usual levels. For task-switching, approximately 42% of the variance was at the person level.

Table 8.1. *Means, Standard Deviations, Range, and Intraclass Correlations of Person-Level Study Variables.*

|  | n | Mean* | SE* | Observed Range | ICC |
|---|---|---|---|---|---|
| Pain | 2,856 | 4.37 | 0.085 | 0 to 10 | .58 |
| Wellbeing | 2,855 | 5.18 | 0.05 | 0 to 10 | .35 |
| Task-Switching Raw Score | 996 | -59.92 | 2.46 | -270.00 to 19.00 | .50 |

Note: *Means were estimated from the intercept and SE of the intercept in null models. With nested data in which individuals contribute differing numbers of observations, the null model intercept is the most valid estimate of sample mean (Singer & Willett, 2003).

**Multilevel Models Predicting Changes in Wellbeing**

Table 8.2 shows results from the three models. Model 1 reveals that a one-unit increase (i.e., a 10 unit increase on the original 0-100 scale) in pain at the person level was associated with a statistically significant 0.37-unit decrease (i.e., a 3.7 unit decrease on the original 0-100 scale) in wellbeing; similarly, one-unit increases at the wave and day level were associated with statistically significant 0.32- and 0.17-unit decreases in wellbeing, respectively. Model 2 reveals that there were no main effects of task-switching on wellbeing. Model 3 reveals a small but statistically significant interaction of person-level pain with task-switching, indicating that at high levels of task-switching performance, day-level pain was associated with *lower* wellbeing (Interaction $\gamma = -0.006$, $SE = 0.002$, $t(791) = -2.66$, $p = .008$).

Table 8.2. *Effects of Pain, Task-Switching, and their Interaction on Wellbeing.*

| | **Model 1: Main Effect of Pain** | | | | **Model 2: Main Effect of Task-Switching with (and Without) Outliers** | | | | **Model 3: Interaction of Pain and Task-Switching with (and Without) Outliers** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\gamma$ | SE | df | p | $\gamma$ | SE | df | p | $\gamma$ | SE | df | p |
| $Pain_{pers}$ | **-0.37** | **0.08** | **1853** | **<.001** | | | | | -0.36 | 0.09 | 138 | <.001 |
| | | | | | | | | | (-0.35) | (0.09) | (133) | (<.001) |
| $Pain_{wave}$ | **-0.32** | **0.05** | **1853** | **<.001** | | | | | -0.26 | 0.07 | 791 | <.001 |
| | | | | | | | | | (-0.26) | (0.07) | (776) | (<.001) |
| $Pain_{day}$ | **-0.17** | **0.03** | **1853** | **<.001** | | | | | -0.16 | 0.06 | 791 | .008 |
| | | | | | | | | | (-0.15) | (0.06) | (776) | (.013) |
| $TS_{gmc}$ | | | | | -0.002 | 0.002 | 807 | .28 | 0.004 | 0.002 | 138 | .010 |
| | | | | | (-.0004) | (.003) | (792) | (.87) | (0.003) | (0.002) | (133) | (.16) |
| $Pain_{pers}$ x $TS_{gmc}$ | | | | | | | | | -0.002 | 0.001 | 138 | .18 |
| | | | | | | | | | (-0.003) | (0.003) | (133) | (.27) |
| $Pain_{wave}$ x $TS_{gmc}$ | | | | | | | | | -0.000 | 0.003 | 791 | .87 |
| | | | | | | | | | (0.000) | (0.003) | (776) | (.88) |
| $Pain_{day}$ x $TS_{gmc}$ | | | | | | | | | **-0.006** | **0.002** | **791** | **.008** |
| | | | | | | | | | **(-0.008)** | **(0.003)** | **(776)** | **(.005)** |

*Note:* GMC = grand mean centered. Values in parenthesis were run with the 5 outliers removed for task-switching. Models with and without outliers were conducted separately.

**Chapter Nine: Study 2 Discussion**

The aim of Study 2 was to supplement the external validity of Study 1 by examining whether task-switching protected against pain-related declines in wellbeing in community-dwelling older adults. Results did not support the hypothesis. In fact, a significant interaction revealed that as day-level pain increased, higher task-switching was associated with reduced (instead of improved) wellbeing. The interaction effect was small ($\gamma = -0.006$) and may not represent a clinically significant finding. Moreover, the direction of the finding is contrary to published findings showing that task-switching is a resources that promotes adaptive psychological and physiological outcomes in the face of pain (e.g., Attal et al., 2014; Boggero et al., 2016). One important difference between Study 2 and these previously-published findings is that the outcome in Study 2 was subjective. It may be that those who are higher in task-switching specifically, and EF generally, are better able to pay attention to, and notice the negative impact of pain. Another important difference is that the current study examined concurrent instead of longitudinal effects. It may be that the protective effects of task-switching manifest over time instead of in the moment. This is especially likely if task-switching allows people to maintain health behaviors like maintaining a workout routine or adhering to medication regimens in the face of pain, as these behaviors have long-term rather than instantaneous effects. Nevertheless, these possibilities are speculative and should be tested in future research.

Future research should also continue to focus on exploring other potential moderators of the relationship between pain and wellbeing. The presence of random intercepts and slopes in Study 2 suggests a moderated relationship. One potentially important moderator is fatigue. Fatigue is an important contributor to pain-related disruptions in social and recreational activities (Boggero, Kniffin, de Leeuw, & Carlson, 2014; Boggero, Rojas-Ramirez, & Carlson, 2017; Boggero, Rojas-Ramirez, Carlson, & de Leeuw, 2016), and it may be that when fatigue is higher-than-usual, pain has a more negative impact on wellbeing. Those with low levels of fatigue may be protected against pain-related impact on wellbeing. At the person level, quality of life may be an important moderator. Quality of life is influenced by several factors including social resources, financial resources, psychological resources, and physiological resources, among other (e.g., Sprangers, 2010). When pain is higher-than-usual, those with higher quality of life may be able to maintain feelings of subjective wellbeing by drawing on social or psychological resources, for example. Given the high prevalence of pain, and the fact that pain at the day, wave, and person level all significantly predicted reduced wellbeing in the current study, identifying protective moderators of the pain and wellbeing relationship will be an important component for promoting successful aging.

The intraclass correlations of pain and wellbeing reveal important information about how they change over time. Most of the variance in both variables was at the day level and likely represent transient changes in pain and wellbeing. However, there was still substantial variance at the person level. This person-level variance is surprising given that people were asked to report how their pain and wellbeing were relative to their usual levels (centered at zero). Theoretically, there should not have been person-level variance in these variables because everyone's average across all waves should have been zero. The variability at this level may be due to scale misuse on behalf of the participants. It is also possible that on the particular days of the daily diary people had higher-than-usual

pain, but the likelihood of someone *always* being at higher than usual levels of pain on daily diary days is low. If the observed person-level variance was indeed due to scale misuse, it is possible that the current study is underestimating wave- and day-level effects, and results should be interpreted with that potential caveat in mind.

Study 2 has important limitations. First, the sample consisted entirely of community-dwelling older adults and as such could not compare how younger and older adults differed in their responses to pain. Another limitation is that the sample did not rule out participants with chronic pain, and as such, no distinction could be made between those experiencing acute versus chronic pain. Coping strategies and wellbeing are known to differ as a function of pain chronicity (e.g., Keefe, Crisson, Urban, & Williams, 1990; Lansbury, 2000). A third limitation is that only task-switching was examined in the current study. A more extensive EF battery consisting of working memory, inhibition, and processing speed may have produced more extensive insight into strategies older adults use to cope with pain, as each of these EFs have been linked to pain outcomes (Berryman et al., 2013; Berryman et al., 2014). Despite these limitations, Study 2 has considerable strengths. For one, it was the first to examine how within-person changes in pain and task-switching interacted to predict wellbeing. It was also one of the few studies to specifically focus on community-dwelling adults. Results from the current study highlight important areas for future direction and extend the literature on the strategies that community-dwelling older adults use to cope with increases in pain.

## Chapter Ten: General Discussion

On one hand, older adults experience pain more frequently and intensely than younger adults (e.g., Catala et al., 2002; Edwards et al., 2001; Thomas et al., 2004). On the other, older adults demonstrate greater positive affect, possibly guided by increased motivation to maximize positive emotions and minimize negative ones (Carstensen et al., 1999; Matcher & Carstensen, 2005). Do older adults maintain positive affect following pain better than younger adults, and if so, how?

### Maintenance of Positive Affect and Wellbeing Following Pain

Results from Studies 1 and 2 shed light on this question. Results from Study 1 suggest that both older and younger adults are moderately successful at maintaining emotional wellbeing following acute laboratory pain (i.e., cold-pressor). Although there were pain-related declines in positive affect in both age groups, these changes were minimal ($M = 3.28$ before pain vs $M = 3.11$ after pain). Moreover, pain did not increase levels of negative affect. Even though older and younger adults did not differ in their abilities to maintain emotional wellbeing following pain, older adults reported more intense pain and also demonstrated worse working memory, task-switching, and marginally worse inhibition than the younger adults. The fact that there were no age differences despite older adults having more intense pain and fewer cognitive resources has multiple explanations. Socioemotional selectivity theory would posit that motivational differences account for these effects: older adults have been shown to be motivated and exert greater effort to maintain positive emotions (Carstensen, 1992; Carstensen et al., 2011). Thus, older adults might be motivated to use additional resources or different cognitive strategies like distraction and reframing to cope with pain. Alternatively, older adults have more expertise than younger adults in emotion regulation (Evans et al., in preparation). Previous work has conceptualized pain as an emotion, and techniques that are effective for emotion regulation like reappraisal, suppression, and distraction are also effective for managing acute pain (Craig, 2003; Vogt, 2005). Are older adults using different (unmeasured) strategies, exerting more effort, or relying on emotion regulation experience in lieu of cognitive resources? These questions pave the way for future research into how older adults affectively manage pain.

In contrast to Study 1, Study 2 suggests that older adults may have a difficult time maintaining wellbeing in the face of naturally occurring pain. Main effects of pain revealed that as pain increased within people, wellbeing decreased. The differences in ability to maintain emotional wellbeing between Study 1 and 2 may be a function of three things. First, it may be that older adults respond differently to pain in a laboratory setting than in the real world. In the lab, participants know the pain will end, and they know the cause of the pain. They also know that the pain is safe, as it is administered in a controlled setting. People who agreed to participate in the study were told they could withdraw at any time, giving them control over their pain. In the real world, the duration, cause, safety, threat value and controllability of the pain may be more uncertain, potentially making it harder to manage. A second possible reason for the differences between the two studies is that older adults who agree to come to the lab and participate in a laboratory study may be qualitatively different from those who agree to be followed in their homes for a longitudinal study. The first population is likely higher in openness to experience (i.e., they are willing to drive the lab and participate in a study they know very little about), and may be in better physical health (especially considering the stringent

inclusion criteria for Study 1). A third reason for the differences is the outcome. In Study 1, positive and negative affect was measured with the PANAS, a well-validated instrument for assessing mood. In Study 2, the outcome was wellbeing, which serves only as a proxy for positive and negative affect. Although affect is an important factor in how people assess their wellbeing, it is not the only factor. People may also weigh physical, psychological, and social factors when reporting wellbeing (Spranger, 2010). Thus, the possibility of criterion contamination (using a physical symptom like pain to predict a physically influenced outcome like wellbeing) cannot be excluded and may contribute the main effects of pain in Study 2. It may be that all three of these reasons contribute to the differences between the studies.

**Cognitive Effect of Pain**

Although Study 1 did not find the hypothesized three-way interactions between age group, pain condition, and picture valence (or partner type) on positivity-enhancing strategies, results provided insights into how pain impacts cognition. After experiencing pain, people were marginally more liberal in recognizing negative pictures (but not positive or neutral pictures) than prior to experiencing pain (See Figure 4.2). It may be that pain signals threats and primes people to attend to negative or threatening stimuli. Chronic pain patients selectively attended toward painful faces relative to neutral ones in the dot-probe task (Khatibi, Dehghani, Sharpe, Asmundson, & Pouretemad, 2009). Chronic musculoskeletal pain populations, chronic headache patients, and chronic postoperative pain patients, among others, showed similar attentional bias toward negative pictures, words, and faces (Baum, Schneider, Keogh, & Lautenbacher, 2013; Dehghani, Sharpe, & Nicholas, 2003; Fashler & Katz, 2016; Lautenbacher et al., 2013; Schoth & Liossi, 2010). This is the first study that demonstrates negativity bias following pain in healthy older and younger adults. That these same effects were found after acute pain suggest that it is likely the pain itself instead of pain chronicity that causes this attentional shift. This interpretation is speculative and should be tested in future research.

With regard to social preference, the a priori hypothesis was that after experiencing pain, older adults would demonstrate increased preference for a close versus a knowledgeable social partner. Both younger and older adults demonstrated strong preferences for close social partners both before and after experiencing pain. The age group difference emerged instead in preference for knowledgeable social partners: after experiencing pain, younger adults preferred them less whereas older adults' preferences did not change. Older adults appeared to maintain interest in spending time with knowledgeable social partners following pain. However, it is unclear if maintaining interest in knowledgeable social partners following pain is adaptive or maladaptive. On one hand, it may serve as a sign of reduced pain interference; this is consistent with extant work showing that older adults report less pain-related disruption in social and recreational activities than younger adults at high levels of pain intensity (Boggero et al., 2015). Older adults may be intrinsically motivated to establish, learn from, and maintain social connections, and acute pain may not dissuade them from valuing such opportunities. On the other hand, it may be a sign of resource misallocation. Under conditions of pain, spending time with a knowledgeable social partner probably does not provide as many affective benefits as spending time with a close social partner. In support of this view, those with better task-switching performance and HRV demonstrated reduced preference for knowledgeable social partners (See Figures 4.5 and

4.6) following pain, suggesting that they may have been prioritizing positive affect over obtaining information. Whether these patterns extend beyond the lab and into actual patterns of social network utilization represent an important extension to these findings.

**The Role of Individual Differences in EF and HRV on Affect**

A sizeable body of literature suggests that EF and HRV are important resources for coping with pain (Appelhans & Luecken, 2008; Berryman et al., 2013; Bushnell et al., 2013; Koenig et al., 2014). Yet, most of these studies have looked at pain itself (e.g, Attal et al., 2014) or health (e.g., Boggero et al., 2016) as the outcome. No study to date has examined whether EF or HRV predicts positivity-enhancing strategies or affective wellbeing following pain.

Results from both Studies 1 and 2 fail to support the hypothesis that EF or HRV predict maintenance of affective wellbeing following pain. In Study 1, EFs or HRV were unrelated to pain-related changes in positive or negative affect. In Study 2, higher task-switching was associated with *lower* wellbeing at high levels of pain. This is at odds with other findings emphasizing the importance of EF. It should be noted, however, that the literature is inconsistent, and EF effects are not ubiquitous (Berryman et al., 2013; Berryman et al., 2014; Bushnell et al., 2013). It is likely that the inconsistent results depend on the specific EF and on the outcome. Task-switching appears to be particularly important for maintaining health (Boggero et al., 2016) and reducing post-surgical pain longitudinally (Attal et al., 2014), but may be less important for managing transient increases in pain. Working memory, on the other hand, has been positively correlated with pain thresholds in laboratory studies but does not appear to replicate in naturalistic studies (Berryman et al., 2013; Berryman et al., 2014). The factors that determine why some EF are effective for some outcomes and not others remains an important question.

**Limitations, Strengths, and Conclusion**

A limitation of both Studies 1 and 2 is that the sample was not ethnically diverse. Given well-established racial differences in the experience and responses to pain, results cannot generalize to other populations (Edwards, Fillingim, & Keefe, 2001). Moreover, there are alternate explanations for why older adults might maintain affective wellbeing following pain that were not tested. Older adults may have more experience with pain, may use cognitive reframing to interpret pain differently, or may use emotion regulation strategies to cope with pain. Although the current study used a socioemotional selectivity framework to generate specific hypothesis, by no means are the examined positivity-enhancing strategies inclusive of all possible strategies. Likewise, EF and HRV are two of many possible resources that may contribute to emotional wellbeing following pain.

Despite these limitations, the current study has significant strengths. For one, it is one of the few strategies to examine how older and younger adults differ in their use of coping strategies following acute pain. There is a relative dearth of research examining affective and wellbeing outcomes in acute pain, even though it is more common than chronic pain. The current study also is the first to use a socioemotional selectivity framework to make predictions and test specific pain-related outcomes in older adults. Finally, and perhaps most importantly, the current study guides future work by describing specific ideas for future research and by contributing to the literature on maintenance of positive affect following pain. Maintaining positive affect is an important health goal for many older adults, and learning how older adults do it effectively following pain has the potential to elucidate strategies that promote healthy aging.

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**Vita**

Name: Ian Andres Boggero

Place of Birth: Torrance, CA

Degrees Awarded:
      Associates of Arts in Psychology, El Camino College (2007)
      Bachelors of Arts in Psychology, University of California, Los Angeles (2009)
      Masters of Science in Psychology, University of Kentucky (2013)

Scholastic Honors:
      Eastern Kentucky University (EKU) Creative and Critical Thinking Teacher of
           the Year, EKU
      Hispanic Scholar, Hispanic Scholarship Fund
      Graduate School Travel Award, University of Kentucky (UK)
      Department of Psychology Travel Award, UK
      Award for Excellent Clinical Performance, UK
      Douglas Marshall 'Making a Difference' Award, UK
      Stat Camp Minority Fellowship, Society of Multivariate Experimental
           Psychology
      Minority Initiative Award, American Psychosomatic Society
      Building Bridges Award, National Institute of Dental and Craniofacial Research
      Poster Competition (1st Place, Co-author), American Academy of Orofacial Pain
      Hager Graduate Research Award (2nd Place), Kentucky Psychological
           Association
      Graduate School International Travel Award, UK
      Lyman T. Johnson Academic Fellowship, UK
      Summa Cum Laude, University of California, Los Angeles (UCLA)
      Member, Golden Key International Honour Society
      Member, Phi Chi International Honor Society in Psychology
      UCLA Scholarship Recognition Award, UCLA

Publications:
      Russell, M. E. B., Scott, A. B., **Boggero, I. A.,** & Carlson, C. R. (in press).
           Inclusion of a rest period in diaphragmatic breathing increases high
           frequency heart rate variability: Implications for behavioral therapy.
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      **Boggero, I. A.**, Rojas Ramirez, M. V., & Carlson, C. R. (2017). All fatigue is not
           created equal: The association of fatigue and its subtypes on pain
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*Ian Boggero*

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