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Assessing Empathy Across the Lifespan: A Functional Near Infrared Spectroscopy Approach

Abi M. Heller
aheller@unomaha.edu

Assessing Empathy Across the Lifespan: A Functional Near Infrared Spectroscopy Approach

University Honors Program Thesis

University of Nebraska at Omaha

Submitted by

Abi Heller

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Dr. Janelle Beadle

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UNIVERSITY OF NEBRASKA AT OMAHA

HONORS THESIS ABSTRACT

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DIRECTOR: LUCY MORRISON

ADDRESS: KH 208

UNIVERSITY OF NEBRASKA AT OMAHA

OMAHA, NE 68182

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ABSTRACT OF THESIS: (LIMIT TO 200 WORDS):

This thesis project aimed to utilize functional near infrared spectroscopy (fNIRS) technology in order to assess empathy in a lifespan sample. fNIRS is a non-invasive brain imaging technique that uses properties of light to infer brain activity. Participants ranged in age from 19-75 and were recruited to participate in an fNIRS experiment to assess empathy. Each participant was asked to assume the mental perspective of players on a computer game, and witnessed the player win, lose or tie the game involving a monetary reward. After the fNIRS recording, participants completed personality trait questionnaires related to empathy and emotional contagion. Results

revealed brain activity during the win condition was positively correlated with trait perspective taking, and brain activity during the lose condition was positively correlated with emotional contagion. Additionally, younger adults had greater activation in both medial pre-frontal and dorsolateral regions compared to older adults in the win condition. These results suggest older and younger adults process information related to empathy differently in the frontal cortex, and that trait personality characteristics may be related to task-based brain activity in empathy-inducing situations. Understanding the way information processing changes in aging is an important aspect of taking care of the growing aging population.

1. Introduction

1.1 Functional Near-Infrared Spectroscopy (fNIRS)

Functional Near-Infrared Spectroscopy (fNIRS) is a cutting-edge brain imaging technique that utilizes the spectroscopic properties of blood to estimate regional brain activity. This technology is non-invasive, lightweight and highly affordable in comparison with functional magnetic resonance imaging (fMRI). Additionally, it is safe to use on a much greater number of people, including infants and older adults with pacemakers or other implanted devices. The use and application of fNIRS is a brand-new area of interest in the neuroscience field; the patent for the technology was filed just 30 years ago (U.S. Patent No. 5,137,355, 1992). fNIRS can be used to assess cognitive, emotional, motor activity during a multitude of tasks (Ferrari & Quaresima, 2012). Recently, fNIRS has also been applied to understand brain connectivity when tasks are not being performed (resting state) (Lu et al, 2010), and adapted to be worn during excessive movement for extended periods of time (Piper et al, 2014). This technology is slowly growing in popularity and usage because it is safe, cost-effective and can be applied to modalities where other imaging techniques cannot, and is considered a technique on the cutting edge of neuroscience.

The fNIRS system was developed upon a unique property of human tissue: transparency to light in the near-infrared range (≈ 650-1000 nm). Light in this range that passes through human tissue and is either absorbed by the tissue or passes through to the other side, scattering on the way out. If a beam of light with known wavelength and intensity is directed at a tissue, the amount of light that is absorbed by the tissue and the amount of light that is reflected through can be measured (U.S. Patent No. 5,137,355, 1992). This measurement of light can then be related to concentration through Beer-Lambert's Law: $A = \varepsilon \cdot c \cdot l$, where A = absorbance, ε = molar extinction coefficient (this value depends on the wavelength of light), c = concentration, and l = pathlength (Baker et al, 2014). Hemoglobin, a protein found in red blood cells, is a primary absorber of near-infrared light when it passes through a tissue. In the brain, hemoglobin can be either oxygenated or deoxygenated, and metabolically active cells require increased amounts of oxygenated hemoglobin. Thus, this technology operates on the assumption that the increased levels of oxygenated hemoglobin, which we can detect concentrations of using near-infrared light and Beer-Lambert's law, is a result of increased functional activity in the region the brain light is being emitted to and detected from (U.S. Patent No. 5,137,355, 1992).

1.2 fNIRS, Aging and Empathy

The safety, comfort and portability of the fNIRS makes it an excellent technology to use on populations that are unable to be functionally imaged by other means, such as fMRI. Many other imaging technologies have a long list of exclusionary criteria, including presence of implanted devices, fillings in the teeth, certain allergies, pregnancy and even age restrictions. Based on several of these criteria, older adults are often excluded research studies that involved an fMRI. Many of these individuals that cannot receive an fMRI can, however, participate in a study including an fNIRS due to the minimal risk of near-infrared light. The application of studying the cognitive and emotional process with fNIRS in older adults, however, is an area in the field that has not yet been explored to its full potential. Studies of aging have revealed that changes in the brain occur that affect both a cognitive and emotional domains (Bailey, Henry & Von Hippel, 2008; Ruffman et al, 2008), and the ability to image these processes in real-time may aid in the understanding of how these changes are affecting individual's lives as they age.

Aging and Empathy.

Empathy, the ability to understand thoughts and feelings of another, is a trait we possess that allows us to connect to one another and foster successful social relationships (Batson et al, 1991). Those with low empathy typically have higher levels of loneliness and lower levels of relationship satisfaction and perceived well-being (Beadle et al, 2012; Davis & Oathout, 1987l; Wei et al, 2011). There are two main domains of empathy of interest to this thesis project: cognitive empathy (putting yourself in someone else's shoes) and emotional empathy (tearing up at a sad commercial on TV, feeling compassion for someone) (Smith, 2006). Some evidence suggest cognitive and emotional empathy are represented along slightly different neural networks that recruit both similar and distinct regions in the brain (Decety, 2011). Regions activated when an individual is having an emotional empathic response include regions such as the inferior frontal gyrus (IFG) and the anterior cingulate cortex (ACC), the ventromedial prefrontal cortex (vmPFC), the anterior insula, and the amygdala (Decety, Echols & Correll, 2010; Saarela et al, 2007; Singer et al, 2006; Rizzolatti, Fabbri-Destro & Cattaneo, 2009). Cognitive empathy, on the other hand, activates areas such as the prefrontal-cortex (PFC), temporal pole, dorsomedial prefrontal cortex (dmPCF) and the posterior cingulate cortex (PCC), areas that are thought to be highly involved in Theory of Mind (thinking about what others are thinking) and emotion regulation (Engen & Singer, 2013; Decety, 2010; Decety & Lamm, 2006). All of these regions work together to integrate information about social and emotional stimuli in order to feel empathy in certain situations. Evidence of brain region involvement in empathic processing an also be taken from lesion studies. Patients with damage to the vmPFC seem to have the greatest deficit in emotional and cognitive empathy, as well prosocial behavior related to empathy (Beadle, Paradiso, & Tranel, 2018; Shamay-Tsoory, Aharon-Peretz & Perry, 2009; Shamay-Tsoory et al, 2003). Functional and lesion studies provide evidence that the PFC is extremely important in empathic processes, making it the obvious candidate for exploration in empathy and aging.

As individuals age, it is typical to see a decrease in cognitive empathy, while levels of emotional empathy remain relativity intact (Beadle et al, 2012a; Beadle et al, 2012b; Bailey et al, 2008; Sze, Gyurak, Goodkind & Levenson, 2012). In the aging adult brain, atrophy in the pre-frontal cortex has been demonstrated as one of the regions with some of the most significant decreases in volume during aging (Raz, 2004). Therefore, a decrease in cognitive empathy in aging is possibly related to the degradation of prefrontal regions that occurs during the natural aging process. Overall, however, older adults tend to be more empathetic than their younger counterparts, even with a reduced capacity for cognitive empathy. One theory that explains this phenomenon is known as the socioemotional selectivity theory, which posits that as older adults age and perceive their time to be more limited, they invest more time and put more emphasis on interactions with emotional and social meaning (Carstensen, Isaacowitz & Charles, 1999). Although older adults may be more motived to be empathetic and engage in emotionally meaningful situations, the response and involvement of brain regions such as the prefrontal cortex has been studied in a limited capacity.

fMRI studies of brain activity and empathy in older adult have shown several regions involved in empathic processes, including the prefrontal cortex, but few studies address how this may change throughout the lifespan. An fMRI study involving empathy for pain found greater activation in younger adults versus older adults in regions such as the anterior insula and cingulate cortex (Chen, Chen, Decety, & Cheng, 2014). Another study investigating aging and empathy found differences in younger and older adults in the prefrontal cortex during cognitive and empathic processes (Moore et al, 2015). Inconsistent findings such as these possibly reflect the usage of different methodologies and different stimuli, however the environment of the fMRI has the exclusive ability to display stimuli on a screen. The studies done to date reveal little about empathic processes across the entire lifespan, especially in aging, which is why further investigation is certainly warranted. Use of the fNIRS to investigate age-related differences in brain activity related to empathy is a sound approach because of its comfort and ability to present stimuli in realistic, face-to-face settings which is the way we normally confront and associate with empathy anyway. Additionally, fNIRS is a technology that can be used on a greater proportion of older adults that would not qualify to be imaged by an fMRI.

Only a small handful of studies in the fNIRS literature have investigated the neural correlates of empathy, and the majority of these studies focus on children and young adults. These studies, however, have aided in identifying feasible regions on interest, stimuli presentations and methodological approaches to data collection and analysis. For example, a study where subjects were asked to perspective take with characters interacting in images on a screen found a greater response in the left PFC during positive perspective taking versus a greater response in the right PFC during the negative perspective taking in a sample of younger adults (mean age = 24.5) (Balconi & Vanutelli, 2017). Another study of similar design found a correlation with oxygenated hemoglobin and the Interpersonal Reactivity Score when subjects viewed stimuli of emotionally negative and positive situations (Vanutelli & Balconi, 2015). A more realistic, empathy inducing situation in the form of an observed economic game found increased activity in the ventrolateral PFC in subjects reporting higher levels of emotional empathy and displaying more prosocial behavior towards the other game players (Himichi & Nomura, 2015). Based on these studies, the measurement of brain activity during an empathic process such as perspective taking yields significantly different activation in the prefrontal cortex, which can be correlated with trait measures of empathy and prosocial behavior.

The current study seeks to monitor brain activity in the prefrontal cortex in a lifespan sample during a realistic empathy inducing situation. In order to accomplish this, an interactive and realistic empathy inducing situation will be used as a stimulus. Both younger and older adults will complete the study in order to examine age differences in response to the stimulus, a novel application of the fNIRS that has not been examined in the context of empathy. Decreases in prefrontal activation seen in aging in response to emotional and cognitive stimuli leads me to hypothesize that older adults will have less activation than younger adults in response to empathy inducing situations. I hypothesize that measures of oxygenated hemoglobin will also correlate with trait-empathy questionnaires, such as the IRI, in both older and younger adults. The design of this study allows for the novel and exploratory use of the fNIRS in older and younger adult populations in order to fill a gap in the literature regarding aging, empathy and related brain activity.

2. Methods

2.1 Subjects

Subjects for this study were recruited from the greater Omaha area through the Aging Brain and Emotion Registry and included 7 younger adults (4M, 3F) and 8 older adults (4M, 4F) (N = 15). In order to qualify for the study, subjects were required to have English language proficiency, between the ages of 19-75 and were considered cognitively healthy. Written consent from participants was obtained and all experiments performed were approved and regulated by the University of Nebraska Medical Center's Institutional Review Board (IRB #144-19-EP). One younger subject was excluded from analysis due to excess movement artifact in fNIRS signal resulting in poor data quality.

Table 1. Demographic Characteristics of Participants

Group	Age Mean (SD)	Sex (M/F)	Education Mean (SD)	Race/Ethnicity (% Caucasian)	Handedness (right/left)
Older N = 8	68.1 (7.6) yrs.	4/4	13.7 (1.0)	100%	7R/0L
Younger N= 7	25.3 (8.1) yrs.	4/3	14.9 (1.2) yrs.	86%	7R/0L

2.2 Empathy Task

This empathy task was modeled after an experiment originally performed by Himichi and Nomura (2015) that was adapted for American subjects and modified to include a condition involving positive empathy. During this task, subjects were told they were going to be observing a card game being played by other participants in the study (these players were actually computer-generated confederates). The instructions for the game began with 2 players taking turns picking a card. One card was the winning card (worth $1.00) and the other was the losing card (worth -$1.00). The players alternate picking one of the two cards each round, with the card the remaining card automatically going to the other player. None of the players knew which card was the winning card and which was the losing, they were just required to pick either card A or card B. Therefore, during each turn, one player won $1.00, while the other lost $1.00, which contributed to their overall totals during the game. After discovering the results of each turn, the players on the screen are shown to make either happy expressions due to winning, or sad and disappointed expressions due to losing. The participant observing this game was told that these subjects are competing to either add or subtract these totals from their overall study compensation. Before beginning to view the game, the participant was given specific instructions on how to view the game. They were asked to focus their attention on the instructed “target” player, and told “to imagine person feels during the game, and to try and imagine how he or she feels as a result of each round.” (Batson et al, 1991). Each round consisted of 8 turns, and the subjects were able to view 3 rounds. Each round had a different outcome, with the target player losing once, winning once, and tying once. Figure 1 illustrates the block-design procedure for the game.

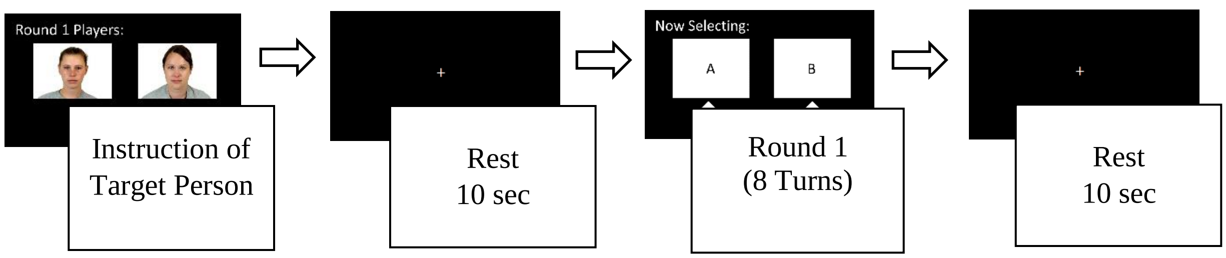

Figure 1. Time course of one round of the game. A 10 second rest period occurred between each round, for a total of 3 rounds in the entire game.

After a fixation cross is presented (1000 ms) the participant begins to view the first round, where they are introduced to the players on an introduction screen. Next, the computer subjects select their cards, and the results of the draw are shown, along with the reactions of the winner/loser in the form of pictures. To confirm that the subjects are paying close attention, they were asked to simply state if their target player won or lost each draw by simply stating “win” or “lose”. In the win condition, the target person won \$4.00, while their opponent lost \$4.00. In the lose condition, the target person lost \$4.00, while their opponent won \$4.00. In the tie condition, neither play won or lost any money. All conditions were randomized for each subject, and the target player was counterbalanced for each game.

Upon arrival, subjects were consented and fitted with the fNIRS cap, and given instructions on the experimental procedure. Before beginning the actual experiment, subjects were trained on a "practice round" of the task described above in order to ensure they understood the instructions and how to recognize a win or a loss for their target player. After the practice round, subjects were given a final set of instructions and given the chance to ask any further questions. During the experiment, the fNIRS cap monitored oxy and deoxy hemoglobin concentrations in the pre-frontal cortex. After the experimental session was completely over, subjects were debriefed and informed the players of the game were actually computer-generated confederates.

2.3 Questionnaires

Before beginning the study, the subject completed a basic demographics questionnaire to assess variables such as age, years of education, race and ethnicity. The Interpersonal Reactivity Index (IRI) is a 28-item questionnaire used in this study to measure personality trait level empathy (Davis, 1980). In this questionnaire, subjects are to rate on a 5-point Likert type scale ("Does not describe me well" to "Describes me very well") based on several scenarios where one may feel some type of empathy. Subscales on this questionnaire include perspective taking, empathic concern, fantasy and personal distress. Previous research on fNIRS and empathy has shown that oxygenated and deoxygenated hemoglobin concentrations can be correlated with scores on the IRI (Vanutelli & Balconi, 2015). An additional questionnaire was administered to measure trait emotional contagion, a 15-item Likert-type scale that asks subjects to rate how strongly each scenario or characteristic describes them (Doherty, 1997). These characteristics relate to how individuals might react to certain emotional situations, such as crying at sad movies or feeling warm when a loved one is near. Both of these questionnaires allow for analysis of the various sub-domains of empathy important in social situations which can also be related to the fNIRS brain activity.

2.4 fNIRS Measurements

Changes in oxygenated and deoxygenated hemoglobin were measured in the PFC using a NIRScout System (NIRx Medical Technologies, LLC. Los Angeles, California). The 15 – channel array of optodes allowed for 8 sources and 7 detectors to be placed in the prefrontal region according to Figure 2. Two wavelengths (760 and 850) with an emitter-detector distance of 30 mm was used in the experimental setup. After a 6 minute resting-state baseline was obtained, the NIRStar acquisition software (NIRx Medical Technologies LLC) was used to collect oxy and deoxy hemoglobin data at a sampling rate of 6.25 Hz. Data collected reflect relative change in oxy and deoxy hemoglobin levels was scaled to mM*mm and transformed based on location and wavelength of each channel. Before data analysis, each channel signal was bandpass filtered at 0.01-0.03 Hz using the NIRSLab data analysis software (v2014.05; NIRx Medical Technologies LLC).

(a) (b)

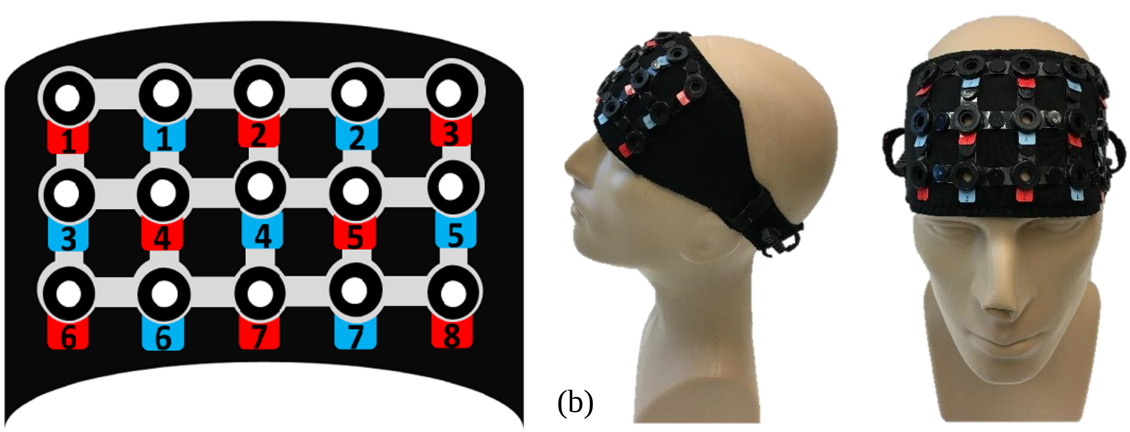

Figure 2. Setup of channel configuration for frontal headband (a) and position of frontal headband over the cortex on subject head (b).

2.5 Data Analysis

Questionnaire data was analyzed using independent samples t-tests in order to identify differences between the younger and older individuals and their trait levels of empathy and emotional contagion. Relative concentrations of oxy and deoxy hemoglobin were averaged across channels for each block of the experiment (win, lose, draw) and subtracted from baseline conditions in order to create a Δoxy-Hb variable for each of the 22 channels analyzed. Δoxy-Hb values were compared for each channel across subjects and conditions using t-tests. Differences in oxygenated hemoglobin concentration between younger and older adults was computed via Statistical Parametric Mapping (SPM) t-test maps in order to generate figures for visualizing these differences. Correlation analysis was used to uncover potential relationships between the IRI subscale and EC questionnaire data and brain activity during each condition of the experiment. All analysis were conducted using SPPS statistical software (IBM SPSS Statistics, Version 24) and SPM maps were generated using NirsLab (NIRx Medical Technologies LLC).

3. Results

3.1 Questionnaire Results

Scores on the subscales of the Interpersonal Reactivity Index (Perspective Taking, Fantasy, Empathic Concern, Personal Distress) were not significantly different between younger and older adults. Scores on the Emotion Contagion (EC) scale were also not significantly different between the groups. Analysis of the entire sample revealed correlations between the questionnaire measures and the average Δoxy-Hb in the win and lose conditions. The Perspective Taking (PT) subscale was significantly correlated with the average Δoxy-Hb during the win condition (Table 2, $r = .591$. $p < .05$). The total EC score was significantly correlated with the average Δoxy-Hb during the lose condition (Table 2, r = .537, $p < .05$).

Table 2. Pearson Correlations Among Average Δoxy-Hb and Self-Report Questionnaires

	1	2	3	4
1. IRI-PT Subscale Score	-			
2. EC Total Score	.112	-		
3. Average Δoxy-Hb, win condition	.591*	.147	-	
4. Average Δoxy-Hb, lose condition	.395	.537*	.430	-

* Correlation significant to the .05 level (2-tailed).

3.2 Imaging Results

Independent samples t-tests revealed significant differences in Δoxy-Hb between younger and older adults in the win condition in the mPFC (channel 10: older adults- M = 0.0001, SD = 0.0003, younger adults- M = .0005, SD = .0006; channel 19: older adults- older adults- M = 0.0001, SD = 0.0005, younger adults- M = .0005, SD = .0003) and in the vlPFC (channel 15: older adults- M = .0001, SD = .0002, younger adults- M = .0002, SD = .0002). This data is illustrated in Table 3 and the contrast of [Older-Younger] in the win condition is shown in Figure 3. There were no other significant channel differences between older and younger adults in the lose or draw conditions. Hotter colors on this figure indicate areas where younger adults have greater levels of activation than older adults.

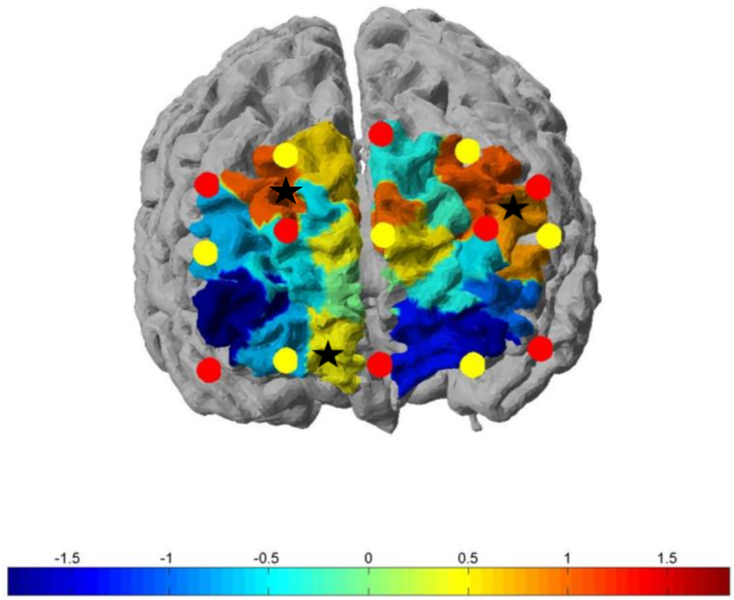

Figure 3. Anatomical SPM t-statistic map of age-related differences in response to the win condition. Warmer colors indicate areas where younger adults had greater activation than older adults in the win condition. Starred channels are locations of significant difference between younger and older adults in the win condition: Channel 10, Channel 15, Channel 19.

4. Discussion

Investigation of empathy in aging and the underlying neural correlates is a sparse area of research. There are few studies that have investigated empathy using this new, cutting edge technology. Additionally, this study is the first to utilize fNIRS to investigate empathy in a lifespan sample. Consistent with my hypothesis, I was able to correlate changes in oxygenated hemoglobin with the IRI and EC questionnaires. The IRI-Perspective Taking subscale was positively correlated with concentrations of oxygenated hemoglobin during the win condition of the stimulus (when subjects viewed their target winning money). Perspective Taking is an important aspect of cognitive empathy in both positive and negative situations, however little research has addressed the link between this cognitive process and underlying brain activity with specific regards to positive empathy (Morelli, Lieberman, & Zaki, 2015). This finding demonstrates a possible link between important self-reported cognitive aspects of empathy and brain activity during a task meant to induce empathy. Previous studies have indicated the importance of the PFC in self-referential processes and perspective taking, and this finding could reflect individuals with a greater tendency for perspective taking recruiting pre-frontal regions more heavily during positive empathy situations (D'Argembeau et al., 2007).

Similarly, EC total scores were positively correlated with concentrations of oxygenated hemoglobin during the lose condition (when subjects viewing their target losing money). Emotional contagion is involved in the emotional aspect of empathy. Emotional contagion is the way the various emotions of others may affect our own emotions, or the way they may “spread” between people. In a previous fMRI study assessing negative emotional stimuli and emotional contagion, subjects in the subjective condition were found to have greater brain activity in regions related to the emotional experience of empathy (Nummenmaa, Hirvonen, Parkkola, & Hietanen, 2008). Although studies of positive and negative empathy in relation to emotional contagion are somewhat sparse in fNIRS, the few studies that have been conducted found an increase in Oxy-Hb in response to negative stimuli when subjects are instructed to take a subjective perspective, similar to the way subjects were instructed in the current study (Kreplin & Fairclough, 2015). Based on these results, it is possible that instructing participants to focus on other’s emotions during a negative stimulus induces negative affect in the subject, and the resulting increase in brain activity during the lose condition reflects the influence of outside emotions on the subjects (Hatfield, Cacioppo, & Rapson, 1994). Overall, more research is needed to understand the relationship between trait personality questionnaires and brain activity during related empathy.

The current study demonstrates differential activation in a lifespan sample of younger and older adults when viewing positive, but not negative, empathy inducing stimuli. The tendency for younger adults to show greater activation in positive-empathy inducing situations is consistent with the findings in fMRI studies where younger adults have greater responses to all emotionally valanced stimuli compared to older adults (Chen et al., 2014). Evidence from fMRI studies of empathy and aging suggest that in some cases, the processing that occurs in response to emotional stimuli changes as individuals age, however the exact changes that occur, or how they may specifically affect empathy are still unknown (Chen et al., 2014; Gutchess, Kensinger, & Schacter, 2010). In the negative empathy-inducing situation, no differences between younger and older adults was observed. Based on these results, the emotional valence (positive or negative) of the stimulus causes some variation in the brain activity during the perception of the stimulus. It is possible that the way positive stimuli associated with empathy are processed differently as individuals age compared to negative stimuli.

Results obtained from this study have demonstrated that self-reported measures of empathy and emotional contagion relate to brain activity during positive and negative empathy tasks, and that in positive empathy tasks especially, younger adults recruit greater dlPFC regions as well as some mPFC regions than older adults. The effect of this difference between younger and older adults could possibly be explained by the positivity effect. The positivity effect has been demonstrated in aging in several contexts, including research paradigms related to memory, cognition and emotion (Mather & Carstensen, 2005). The positivity effect in the context of this experiment relates specifically to positive empathy, or the sharing and understanding of other’s positive emotions (Morelli, Lieberman, & Zaki, 2015). Taking on the mental perspective of a person that is winning money in an economic game would likely result in positive empathy towards that individual, whereas in the lose condition, negative empathy would be invoked. While younger adults seem to be recruiting certain regions of the dlPFC during positive empathy situations, older adults may be recruiting other regions not imaged in this study, such as the amygdala, insula, or the anterior mid-cingulate cortex (Chen et al., 2014; Leclerc & Kensinger, 2011; Moore et al., 2015).

There are mixed findings about the ways that the positivity effect is reflected through behavior, personality questionnaires and brain imaging data. Some evidence suggests that in older adults, significant changes in processing of positive information in the brain is either exclusively or more specifically seen when using pictures or images as stimuli versus words (Leclerc & Kensinger, 2011; Kensinger & Schacter, 2008; Ze, Thoma & Suchan, 2014). Because the stimulus in this study utilized both images and words, interpreting this criticism of the positivity effect to explain variation in brain activity during a positive-empathy situation is difficult. Combining the picture stimuli with the word stimuli in this experiment appears to have had a similar effect as using picture stimuli alone (Leclerc & Kensinger, 2011). Separating the images from the words and replicating the experiment would address the disparity and clarify the apparent bias older adults have for picture versus word stimuli.

This study is not without limitations, and there are several areas to focus and improve upon in the continuation of this research. The sample size of this study is relatively small compared to the industry standard for neuroimaging studies; typically, fNIRS studies include 30 or more subjects. Increasing the sample size of this study would not only increase the power in the analysis, but would also likely lead to the emergence of more effects typically seen in aging, such as the decrease in cognitive empathy on the IRI (Beadle et al, 2012a; Beadle et al, 2012b; Bailey et al, 2008; Sze, Gyurak, Goodkind & Levenson, 2012), Adding to the racial and ethnic diversity of the sample will also increase the generalizability of the results. Recruiting individuals in the middle age range (35-55) would also aid in the aim of studying a lifespan sample as the study continues to recruit participants. Other analysis methods, such as the utilization of the Homer2 software will also be utilized in future analysis of this data in order to refine the current data and explore different contrasts within and between subjects and experimental conditions.

The current studies and data available on the underlying neural mechanism of empathy in aging is sparse. More research is needed in order to aid in the understanding of this research area. One future direction this project will be headed in is the addition of a prosocial measure or behavioral paradigm, especially in relation to positive empathy. There is a currently a large gap in the research area relating positive empathy, prosocial behavior and brain imaging that can be addressed with fNIRS (Telle & Pfister, 2016). Positive empathy, I argue, is just as an important part of the human experience as negative empathy. We don't just feel and empathize during failures and hard times, but during successes and celebrations too. Positive emotions can improve mental well-being and health, making positive empathy an important area to study when considering the way our emotions and empathy change during aging (Fredrickson, 2000). The technology used in the current study is best suited to address this gap because behaviors, such as the literal act of donating money, or giving someone a hug, can be imaged while using fNIRS, while these activities would be impossible in monitor in an fMRI. Behavioral paradigms related to realistic, face-to-face interaction can be developed and imaged using fNIRS, making this cutting-edge technology an excellent candidate to study empathy, aging and prosocial behavior in the future.

Development of the field of empathy, aging and brain functioning is becoming extremely critical for us to understand more about. As the global population continues to age, specifically the Baby-Boomer population here in the United States, gaining emotional and cognitive profiles of this aging population is extremely important. If we are better able to understand how the way adults process information and make decisions, we will be better equipped to care for them in older adulthood. This thesis project was aimed at exploring the underlying brain activity during an empathy task in a lifespan sample in order to understand mechanisms of change in the brain in hopes to eventually applying this knowledge in real-world situations to benefit both the aging population as well as their caregivers. The development of the fNIRS technology that we now have access to and an understanding of here at UNO opens up the potential for more exploration and scientific inquiry into this area that is in desperate need of more research. The original aims of this project, to develop an understanding of this technology as well as complete a research projected aimed at addressing the aging and empathy research gap were successfully filled in this project.

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