Title
Lessons from Lies: Influences of Age and Neuropeptides on Deception Detection

Author
Castle, Elizabeth C.

Publication Date
2017

UNIVERSITY OF CALIFORNIA

Los Angeles

Lessons from Lies: Influences of Age and Neuropeptides on Deception Detection

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy in Psychology

by

Elizabeth C. Castle

2017

ABSTRACT OF THE DISSERTATION

Lessons from Lies: Influences of Age and Neuropeptides on Deception Detection

by

Elizabeth C. Castle

Doctor of Philosophy in Psychology

University of California, Los Angeles, 2017

Professor Matthew D. Lieberman, Co-Chair

Professor Shelley E. Taylor, Co-Chair

This dissertation aims to contribute to the understanding of how biological signals interact to support complex social communication by presenting three papers examining the neural and behavioral impacts of age and neuropeptide hormones on deception detection accuracy. In Paper 1, published in the *Proceedings of the National Academy of Science* and co-authored by Naomi I. Eisenberger, Teresa E. Seeman, Wesley G. Moons, Ian A. Boggero, Mark S. Grinblatt and Shelley E. Taylor, we use behavioral and neuroimaging methods to identify age differences in judgments of trustworthiness and the neural underpinnings of these patterns. I find that older adults show muted activation of the anterior insula in response to untrustworthy faces, as well as the tendency to rate untrustworthy faces as much more trustworthy than they are, particularly in comparison to younger adults. I discuss the implications of this work for older adults' vulnerability to fraud. In Paper 2, I build on the findings of Paper 1, by testing whether similar age differences are observed in the context of deception detection and whether older adult's tendency towards the positivity might compromise their accuracy. I find partial support for this hypothesis, with positive cues predicting decreased accuracy in older adults but not younger adults. In Paper 3, I explore two hormones, oxytocin and vasopressin, and their impact on deception detection. I find that vasopressin, but not oxytocin, improves deception detection. These findings lead us to a better understanding of how neuropeptides support *human* social regulation.

The dissertation of Elizabeth C. Castle is approved.

Jennifer A. Silvers

Aimee Drolet Rossi

Naomi I. Eisenberger

Shelley E. Taylor, Committee Co-chair

Matthew D. Lieberman, Committee Co-chair

University of California, Los Angeles

2017

DEDICATION

A scientist in her laboratory is not a mere technician: she is also a child confronting natural phenomena that impress her as though they were fairy tales. *~Dr. Marie Curie*

This dissertation is the culmination of not just my graduate efforts, but everything and everyone who has shaped the person that I am now. With this perspective, it felt appropriate to conclude my school journey more or less where it began, with Dr. Marie Curie. The natural curiosity and intellectual creativity that Curie describes are my favorite parts of science and features that I am so grateful my parents, teachers, and friends have helped me cultivate over the past 30 years; this dissertation is for you. I am so very lucky to have so many incredible people as part of my fairy tale, so I'd like to say…

Thank you to my lab mates for making all the banal 'mere technician' moments more fun, and for understanding both how it feels to get swept up in the childlike excitement of an idea and how much it hurts when you realize something as insignificant as a p-value can shatter that dream!

Thank you to my mentors who, through encouragement and example, have reminded me how much I love this fairytale and given me the tools to defeat any fire-breathing-data-dragon.

And finally, thank you to my loved ones for reminding me that there are fairy tales outside of science, and helping me learn to be my own princess charming. But most of all, thank you for still loving me even when I got lost in the story. There are no words to describe what your love and support has meant to me.

ACKNOWLEDGMENTS

In addition to my incredible committee and co-authors, this dissertation was completed with the invaluable assistance of Patrick Rock, Shosuke Suzuki, Philip Rosenbaum, Perri Katzman, Marie Cross, Irene Tung, Nayiri Hovsepian, Josephine Diaz, Yijun Shen, Ethan Wilson, Jessica Alba. I would also like to acknowledge Kate Haltom, Sylvia Morelli, Robert Spunt, Elizabeth Peirce, Ben Tabak, and Ben Inglis for the training, consulting, and support they have provided me over the years.

Paper 1 is a version of a previously published article (Castle, E., Eisenberger, N. I., Seeman, T. E., Moons, W. G., Boggero, I. A., Grinblatt, M. S., & Taylor, S. E. (2012). Neural and behavioral bases of age differences in perceptions of trust. *Proceedings of the National Academy of Sciences*, *109*(51), 20848-20852). I was responsible for analyzing the data, Shelley E. Taylor is the Principle Investigator and she and I wrote the manuscript, Ian Boggero collected the data, and Wesley Moons, Mark Grinblatt, and Teresa Seeman were scientific consultants. Papers 2 and 3 will be submitted for review in the coming months.

I have also been fortunate to be supported by the following graduate fellowship and funding sources: National Defense Science and Engineering Graduate Fellowship from the Department of Defense, and Graduate Research Fellowship from the National Science Foundation. This generous support allowed me the resources and time to complete these and other studies during graduate school.

TABLE OF CONTENTS

VITA

EDUCATION

University of California, Los Angeles
Ph.D. Candidate in Social Psychology **2014-2014**
Minor in Quantitative Psychology
M.A. in Social Psychology **2012**

University of California, Berkeley
B.A. with High Distinction, Psychology **2010**
Research Advisors: Professors Dacher Keltner & Sonia Bishop
Minor in Global Environmental Politics

FELLOWSHIPS AND HONORS

Department of Defense NDSEG fellow: 2012-2014
National Science Foundation GRFP fellow: 2012-2017
National Science Foundation GRFP Honorable Mention: 2011
UCLA Psychology Bertram Raven Award for exceptionally meritorious research paper: 2012
Undergraduate Thesis: *Neurocognitve Mechanisms of Anxiety*; Highest Honors: 2010
UC Berkeley Swan Outstanding Undergraduate Research Award: 2010
Greater Good Science Center Goldberg Fellow: 2009-2010
Member of Phi Beta Kappa Honor Society

PUBLICATIONS AND PRESENTATIONS

Castle, E., Giebl, S., Lieberman, M.D., & Taylor, S.E. (March, 2017) Role of the Amygdala in Deception Detection. Poster presented at the 9th Annual *Social and Affective Neuroscience Society Conference*. Los Angeles, CA.

Tabak, B. A., Meyer, M. L., Dutcher, J. M., Castle, E., Irwin, M. R., Lieberman, M. D., & Eisenberger, N. I. (2016). Oxytocin, but not vasopressin, impairs social cognitive ability among individuals with higher levels of social anxiety: A randomized controlled trial. *Social Cognitive and Affective Neuroscience*.

Tabak, B. A., Meyer, M. L., Castle, E., Dutcher, J. M., Irwin, M. R., Han, J. H., & Eisenberger, N. I. (2015). Vasopressin, but not oxytocin, increases empathic concern among individuals who received higher levels of paternal warmth: A randomized controlled trial. *Psychoneuroendocrinology*, *51*, 253-261.

Forster S., Castle, E., Nunez-Elizalde, A., Bishop S.J. (2014) Moderate threat causes longer lasting disruption to processing in anxious individuals. *Frontiers in Neuroscience*. 8, 626.

Forster, S., Núñez-Elizalde, A., Castle, E., Bishop, S.J. (2013). Unraveling the anxious mind: Anxiety, worry and frontal engagement in sustained attention versus off-task processing. *Cerebral Cortex*. doi:10.1093/cercor/bht248. Epub 2013. Sept. 22.

Castle, E., Eisenberger, N. I., Seeman, T. E., Moons, W. G., Boggero, I. A., Grinblatt, M. S., & Taylor, S. E. (2012). Neural and behavioral bases of age differences in perceptions of trust. *Proceedings of the National Academy of Sciences*, *109*(51), 20848-20852.

Castle, E., Eisenberger, N., Seeman, T., Moons, W., Boggero, I., Grinblatt, M., & Taylor, S. E. *Age differences in BOLD activity related to judgments of trust*. Poster presented at the 5th Annual Meeting of the *Social and Affective Neuroscience Society*, New York, NY (2012, April).

Simon-Thomas, E., Godzik, J., Castle, E., Antonenko, O., Ponz, A., Kogan, A., and Keltner, D. (2012). An fMRI study of caring vs. self-focus during induced compassion and pride. *Journal of Social Cognitive and Affective Neuroscience*.

RESEARCH

Dissertation: *'Lessons from Lies: Influences of Age and Neuropeptides on Deception Detection '*
Masters Thesis: *'Neurocognitive Mechanisms of Misperceptions of Trust in Older Adults'*
Additional Projects: *'Neurocognitive Mechanisms of Learning for Teaching'*
'Social vs. Monetary Reward'

TEACHING

Teaching Assistant	**Organizational Behavior for Executives** *Spring 2017 - Anderson School of Management*
Teaching Assistant	**Persuasion and Influence** *Fall 2016 -Anderson School of Management*
Teaching Assistant	**Social Psychology** *Winter 2016 - Psychology Department, UCLA* *Spring 2012 - Psychology Department, UCLA* *Fall 2011 - Psychology Department, UCLA*
Teaching Assistant	**Social Cognitive Neuroscience** *Spring 2014 - Psychology Department, UCLA*
Teaching Assistant	**Research Methods in Social Psychology** *Winter 2012 - Psychology Department, UCLA*

UNIVERSITY AND COMMUNITY SERVICE

UCLA Underrepresented Graduate Students in Psychology Treasurer: 2014-2017
Suicide Lifeline Counselor and Trainee Mentor at The Trevor Project: October 2012-2017
UCLA Professional Ethics Committee Member: 2010-2013
UCLA Psychology in Action Community Outreach Chair: 2010-2013

Introduction

The highly social nature of human behavior has been well established, with recent work more fully characterizing prosocial processes like social connection, social reward, and even social trust. These processes (and similar others), have been linked to impressive personal benefits such as enhanced emotional wellbeing, more positive health outcomes, and reduced personal stress (Uchino, 2006). Notably however, the success of all three of these important prosocial states, are dependent on a fourth social behavior: social communication.

Social communication can be simply defined as the conscious or nonconscious sharing or receiving of relevant social information with others. However, there is nothing simple about the highly complex way that people are able to represent, share, and understand messages across a wide range of channels including facial expression, vocal pitch, body language, and linguistic content. This impressive range of influence requires that the mechanisms involved operate flexibly across a diverse set of features (e.g. valence, modality, or culture), which suggests that cooperation of multiple different biological signals (e.g. neural and hormonal) might be necessary to achieve such influence. This dissertation explores the biological underpinnings of the receipt of social communication, by examining the impact of age and neuropeptide hormones on perceptions of trustworthiness and evaluations of dishonesty.

The age-related tendency to allocate attentional resources to positive emotional stimuli (known as the positivity effect) has been well documented, (Reed, Chan, & Mikels, 2014) however, it is less clear how this phenomenon interacts with the evaluation of trustworthiness and perception of dishonesty. It has been proposed that older adult’s attentional preference for positivity might result in impoverished processing of salient negative cues, thus leading to an impaired ability to accurately assess trustworthiness or detect deception (Castle et al., 2012). An alternative explanation is that preferential attention towards positivity results in deeper processing of emotional information, which in turn facilitates the identification of less genuine expressions of positivity masking deception. If this is the case, we would expect to see the presence of positivity boost lie detection accuracy in older adults, but if as previously suggested, positivity interferes with the processing of deception cues, we would instead expect to see a reduction in lie detection accuracy and potentially increased (and unwarranted) trust from older adults.

Certain neuropeptide hormones have been shown to support social behavior in non-human animals. For example, oxytocin has been shown to enhance social connection during maternal bonding but it has also been linked to heightened maternal defensive aggression (Baribeau & Anagnostou, 2015; Caldwell & Iii, 2006)(Albers, 2012; Baribeau & Anagnostou, 2015; Caldwell & Iii, 2006). This points to a possible role for oxytocin in enhancing the salience of social signals regardless of valence (Shamay-Tsoory & Abu-Akel, 2016). If oxytocin impacts human social communication similarly, we might expect to see increased deception detection accuracy as a result heightened sensitivity to socially salient cues to deception. Vasopressin has also been shown to support and regulate social processes in nonhuman animals including male-typical competitive aggression, as well as processes of social communication like marking behavior and heightened social perception of certain senses (Albers, 2012). If vasopressin impacts human social communication similarly, we might expect to see increased deception detection accuracy as a result of increased sensitivity to specific modalities of social cues.

This dissertation presents three papers that aim to assess differences in the social cognitive processes thought to underlie perceptions of trustworthiness and evaluations of dishonesty. Specific aims are discussed below.

Paper 1. This is the result published work where I use behavioral and neuroimaging methods to test whether a relationship exists between age and perceptions of trustworthiness. Such that 1) as compared to younger adults, older adults would show increased ratings of trustworthiness when specifically evaluating untrustworthy faces, and 2) that these behavioral effects would be reflected in age-related neural changes showing decreased activation in regions previously implicated in judging trustworthiness. Implications of this work for older adults' vulnerability to fraud are discussed.

Paper2. Here, I build on the findings of Paper 1 by first testing if the behavioral differences observed between older and younger adults when rating trustworthiness extend to age-related differences in deception detection behavior. Since the results of Paper1 implicate age-related attention towards positivity, Paper 2 further examines this potential connection in the context of deception detection. Implications of this work for understanding the mechanism through which older adults' might be vulnerability to fraud are elaborated.

Paper3. Using a sample of both men and women, Paper 3 tests 1) whether the social salience hypothesis is able to account for the effects of OT on behavior in a context where *negative* cues are critical to task success (and therefore preferentially attended), and 2) if AVP confers a social cognitive benefit during competition, in the form of enhanced deception detection accuracy and whether this is impacted by the modality of cues attended.

The presence of deception makes it possible to study the perception of accidental leakage of social communication during deceit (referred to here as 'cues to deception'). By examining the neural and behavioral impacts of age and neuropeptide hormones on deception detection accuracy, this work hopes to shed light on how biological signals interact to support complex social communication.

Paper 1:

Neural and Behavioral Bases of Age Differences in Perceptions of Trust

Elizabeth C. Castle, Naomi I. Eisenberger, Teresa E. Seeman, Wesley G. Moons, Ian A. Boggero, Mark S. Grinblatt & Shelley E. Taylor

Published in the *Proceedings of the National Academy of Science (PNAS)*

Abstract

Older adults are disproportionately vulnerable to fraud, and federal agencies have speculated that excessive trust explains their greater vulnerability. Two studies, one behavioral and one using neuroimaging methodology, identified age differences in trust and their neural underpinnings. Older and younger adults rated faces high in trust cues similarly, but older adults perceived faces with cues to untrustworthiness to be significantly more trustworthy and approachable than younger adults. This age-related pattern was mirrored in neural activation to cues of trustworthiness. Whereas younger adults showed greater anterior insula activation to untrustworthy versus trustworthy faces, older adults showed muted activation of the anterior insula to untrustworthy faces. The insula has been shown to support interoceptive awareness that forms the basis of "gut feelings," which represent expected risk and predict risk-avoidant behavior. Thus, a diminished "gut" response to cues of untrustworthiness may partially underlie older adults' vulnerability to fraud.

Older adults are disproportionately vulnerable to frauds of many kinds. Both the Federal Bureau of Investigation (2001) and the Federal Trade Commission (2007) have conjectured that older adults' excessive positive responses to other people may underlie their vulnerability. Consistent with this idea, a large body of literature indicates that older adults shape their experiences and social networks in ways that lead to positive socioemotional outcomes (Carstensen, Pasupathi, Mayr & Nesselroade, 2000). As such, older adults' judgments of the trustworthiness of others may also be skewed in a positive direction. Affective judgments of trustworthiness implicate processing in limbic regions, including the amygdala and insula (Adolphs, Tranel & Damasio, 1998; Winston, Strange, O'Doherty & Dolan, 2002). Accordingly, age differences in trust may be reflected in altered patterns of activation in these neural regions.

We report the results of two investigations that address how older adults process facial cues indicative of trust differently from younger adults. The first is a behavioral study in which participants rated faces that varied in cues conveying trustworthiness (trustworthy, neutral, untrustworthy) (Adolphs et al., 1998). The second study used functional neuroimaging to identify whether facial cues of trustworthiness are processed differently in the brains of older vs. younger adults. We predicted that older adults would perceive people to be more trustworthy and that this pattern would be reflected in lesser insula and/or amygdala responses to the stimuli.

Study 1

People make many inferences about personal attributes from facial features (Ekman & Friesen, 1975; McArthur & Post, 1977). One fundamental such judgment is whether a person is inherently trustworthy or not (Winston et al., 2002; Todorov, Pakrashi & Oosterhof, 2009). The present study investigated whether there are reliable age differences in how older and younger adults infer trust from facial cues.

Study 1 Methods

Participants were 143 adults (40 men and 103 women). The sample was composed of 119 older adults (aged 55–84, M = 68.76, SD = 6.601) and a comparison group of 24 younger adults (aged 20–42, M = 23.21, SD = 5.090) who completed a study of "perception of personal qualities." The younger adults were students and employees at a large Western university, and the older adults were residents of a retirement community. The education levels of the older adults ranged from some high school to postgraduate degrees, and the younger adults had at least some college; there was no overall difference in education level. All participants provided written informed consent according to the procedures of the UCLA Institutional Review Board.

Participants saw and rated frontal images of faces that encompass a range of cues related to trustworthiness, a task developed by Adolphs et al. (1998). All pictures are gaze-forward images of approximately equal size and equivalent background and picture both genders and an array of ages. For the stimuli in study 1, we chose 10 faces that had been previously been selected to be trustworthy, 10 faces selected to be neutral, and 10 faces selected to be untrustworthy (Adolphs et al., 1998). Participants rated, on 7-point scales, the extent to which each face was "very untrustworthy (−3) to very trustworthy (3)" and the extent to which each face was "very unapproachable (−3) to very approachable (3)."

Following this task, participants completed questionnaires assessing dispositional trust (Yamigashi, Cook & Watabe, 1998), future time perspective (Lang & Carstensen, 2002), and loneliness (Russel, Peplau & Cutrona, 1980). Analyses concerning these measures appear in SI Text.

Study 1 Results

Older and younger adults observed faces that had previously been selected to convey cues regarding trustworthiness (trustworthy, neutral, or untrustworthy) (Adolphs et al., 1998) and rated them on how ratings were subjected to Age group (younger vs. older) by Face Type (trustworthy, neutral, untrustworthy) mixed-model ANOVAs, with the second factor being within participants. Consistent with predictions, there was a significant age by face type interaction [F(2,270) = 7.176, P = 0.001, ${\eta_\rho}^2$= 0.050]: Faces high in trust cues were perceived as equally trustworthy by older [mean (M) = 0.952, SE = 0.075] and younger adults (M = 0.926, SE = 0.167) (F < 1); neutral faces were also perceived as equally trustworthy by older (M=0.451, SE=0.069) and younger adults (M=0.309, SE=0.153) (F < 1); in contrast, untrustworthy faces were perceived as significantly more trustworthy by older adults (M = –0.757, SE = 0.073) than by younger adults (M= −1.404, SE = 0.162) [F(1,135) = 13.267, P < 0.001] (Fig. 1A). Thus, as predicted, older adults perceived faces conveying cues to untrustworthiness to be more trustworthy, compared with younger adults, although they did not differ in their evaluations of faces high or medium in cues related to trust.

Analyses of approachability ratings showed related patterns. A main effect of age group indicated that older adults viewed the photographed people as more approachable (M = 0.577, SE = 0.061) than younger adults (M = 0.078, SE = 0.137) [F(1,137) = 10.985, P = 0.001, ${\eta_\rho}^2$= 0.074]. These main effects were qualified by a significant age group by face trustworthiness interaction [F(2,274) = 13.735, P < 0.001, ${\eta_\rho}^2$= 0.091). Trustworthy faces were perceived as equally approachable by older adults (M= 1.478, SE= 0.075) and younger adults (M = 1.191, SE = 0.162) [F(1,137) = 2.441, P = 0.120]. Similarly, older (M = 0.875, SE = 0.067) and younger adults (M = 0.635, SE = 0.150) perceived neutral faces as equally approachable [F(1,137) =

2.145, P = 0.145]. However, older adults (M = –0.624, SE = 0.072) perceived untrustworthy faces to be significantly more approachable (that is, less unapproachable) than was true for younger adults (M = −1.591, SE = 0.162) (F(1,137) = 29.885, P<0.001). Thus, consistent with the trustworthiness results, older adults regarded the people pictured in the photographs as more approachable than younger adults did, and this was especially true for the faces conveying cues of untrustworthiness.

Study 1 Discussion

Older adults perceive facial cues relating to trust differently than younger adults. Although the two age groups rated faces high or neutral in trust cues similarly, older adults rated untrustworthy faces as significantly more trustworthy and approachable than younger adults did. Thus, older adults' propensity to see people as trustworthy occurs disproportionately at the untrustworthy end of the trust dimension. Essentially, then, older adults regard the faces as more similar than younger adults, who made sharper discriminations based on cues to trust. These findings provide some support for the contention that older adults' vulnerability to fraud may have at least a partial basis in a reduced sensitivity to cues to untrustworthiness. We next examined whether older adults' lack of sensitivity to cues related to trust is reflected in patterns of neural activation.

Study 1 Figures

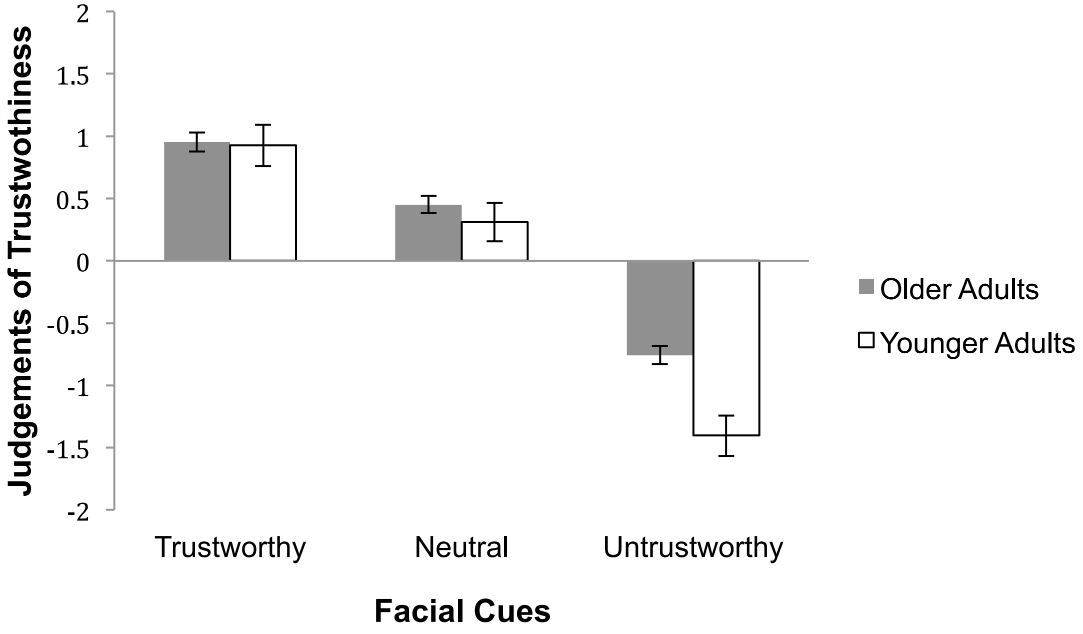


Figure 1A. Older and younger adults' ratings of the trustworthiness of faces varying in trust cues

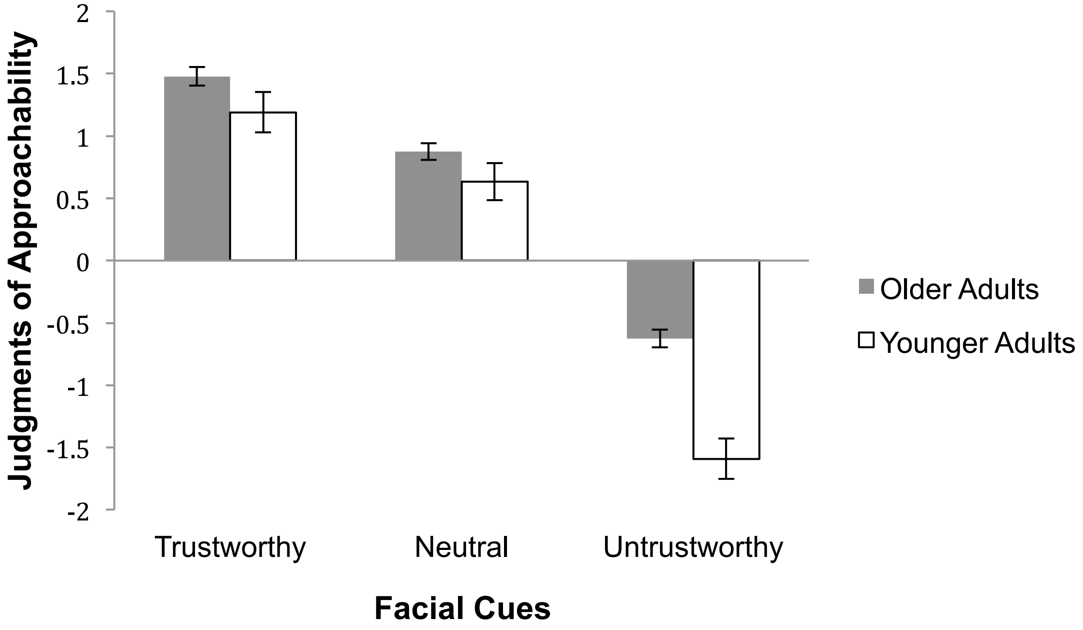


Figure 1B. Older and younger adults' ratings of the trustworthiness of faces varying in trust cues

Study 2

Study 2 examined neurocognitive mechanisms underlying age differences in perceptions of trust. Participants saw pictures of faces pre rated to range in trustworthiness, which came from an expanded continuous set similar to the three discrete types of stimuli used in study 1. To identify neural processes related to explicit trust perception, participants evaluated the trustworthiness of the face by making a binary judgment of each face as either "trustworthy" or "untrustworthy" (trustworthiness judgments). As a comparison task, participants rated the same faces as either "female" or "male" (gender judgments), which involves only passive exposure to facial cues of trustworthiness. For analytic purposes, faces were divided into those perceived to be trustworthy vs. untrustworthy.

Age-related differences in explicit judgments of untrustworthy faces found in study 1 led to hypotheses regarding activation in the anterior insula (AI), a region believed to contribute to decision making by instantiating valenced subjective feeling states (Damasio, 1999). This region has previously been implicated in assessing trustworthiness and responding to breaches in trust (Rilling & Sanfey, 2011). We also examined the amygdala, a region that has been associated with processing facial cues regarding untrustworthiness (Adolphs et al., 1998; Todorov et al., 2008; Winston et al., 2002).

First, we hypothesized an age by task interaction in the AI, such that compared with younger adults, older adults would show reduced activation during explicit judgments of trustworthiness. Critically, we also predicted an age by trustworthiness interaction in the AI and amygdala, such that compared with younger adults, older adults would show a muted response to untrustworthy faces.

Study 2 Methods

Participants. Forty-four healthy right-handed participants screened for health, psychological, and cognitive counter indications participated in a functional magnetic resonance imaging (fMRI) study of trust perception. The sample consisted of 23 older adults (aged 55–80, M = 66.39, SD = 6.11; 12 females), recruited with the help of the Recruitment Core of the University of California, Los Angeles (UCLA) Older Americans Independence Center, from Los Angeles retirement centers and communities. Education level ranged from some high school to postgraduate degree. All participants provided written informed consent according to the procedures of the UCLA Institutional Review Board. The comparison group was 21 younger adults (aged 23–46, M = 33.24, SD = 7.51; eight females) recruited from the broader Los Angeles community who also had an education level ranging from some high school to postgraduate degree. On the day of each participant's appointment, we administered the Mini Mental State Examination (MMSE) and used a cutoff of 23 out of 30. On the basis of this score and responses to the physiological screener (a repeat of the telephone screener used initially), one participant was excluded. Subsequent to completing the fMRI study, five older participants were excluded from analysis, three for movement greater than 3 mm within each run and two for strokes not reported during screening, leaving 39 participants total.

Stimuli. A set of grayscale frontal images, expanded from study 1, of 60 gaze forward male and female faces of varying ages, set to approximately the same size and equivalent background contrast were the stimuli. These images were selected to represent of the full range of trustworthiness (Adolphs et al., 1998).

Psychological task. The scanning session for each participant was divided into two runs, a target task run and a control task run. In the target task, participants made a binary trustworthiness judgment (“Is this person trustworthy or untrustworthy?”), and in the control task, participants made a binary gender judgment (“Is this person male or female?”). All participants viewed the task through fMRI stimulus presentation goggles and responded using their right hand to make a button press. Before the start of each run, participants viewed a screen indicating which judgment to make, “Trust” or “gender.” Both runs were of an event-related design, with 60 faces presented sequentially for 2 s each, with a 3- to 6-s variable interstimulus interval fixation cross displayed between each face. A similar task was previously used by Winston et al. (2002). The same 60 faces were used for both the trust and gender judgment tasks; however, there was a different standardized face order for each task, and the run order was counterbalanced between participants. After scanning, participants were shown the faces again (in a different order) and asked to rate each face for trustworthiness and approachability using a 1–7 Likert scale.

Image Acquisition and Data Analysis. Participants were scanned during task performance using a Siemens 3-tesla Trio MRI scanner with 12-channel head coil at the UCLA Ahmanson-Lovelace Brain Mapping Center. See SI Text for the scanning parameters and preprocessing steps.

An event-related first-level model was specified, in which events were modeled as zero duration and convolved with a canonical hemodynamic response function. Each face condition (trustworthy and untrustworthy) was modeled separately for each task (gender and trust judgments), and appropriate linear contrasts were applied to the design to enable determination of regions active for each condition between the tasks. All first-level contrast images were entered into a two-sample t test random-effects analysis to investigate age differences at the group level. Unless otherwise specified, whole-brain analyses were conducted using a statistical criterion of at least 25 voxels exceeding a voxelwise threshold of $P < 0.001$. This joint voxelwise and cluster-size threshold corresponds to a false-positive discovery rate of 5% across the whole brain, as estimated by a Monte Carlo simulation implemented using AlphaSim in AFNI (Forman et al., 1995). ROI analyses were performed using the Marsbar toolbox (http://marsbar.sourceforge.net) to estimate average percentage signal change across all voxels in each ROI. All anatomical ROIs were defined using the Wake Forest University PickAtlas anatomical toolbox (http://fmri.wfubmc.edu/cms/software#PickAtlas; Maldjian, Laurienti, Kraft & Burdette, 2003). The insula ROI was cut off at 15 in the y direction to restrict analysis to anterior regions.

Study 2 Results

ROI analyses. Based on a priori hypotheses regarding the involvement of the AI and amygdala, we began by examining task related effects using region of interest (ROI) analyses within anatomically defined bilateral AI and amygdala ROIs.

AI ROI. We first focused on our control cohort of younger adults to identify neural activation associated with trust perception and subjected their data to a 2 (face type) Å~ 2 (task) ANOVA. As predicted, there was a main effect of task, reflecting greater bilateral AI activity when making trustworthiness vs. gender judgments [F(1,19) = 27.51, P < 0.001]. There was also a main effect of face type, such that untrustworthy (vs. trustworthy) faces led to greater activity in the bilateral AI [F(1,19) = 4.89, P = 0.02]. There was no task by trustworthiness interaction [F(1,19) = 0.092, P = 0.383]. In contrast, when the same ANOVA was performed for the sample of older adults, they showed no significant effects of task [F(1,17) = 0.272, P = 0.305], trustworthiness [F(1,17) = 0.095, P = 0.381], or task by trustworthiness [F(1,17) = 0.00, P = 0.497]; these findings suggest that, consistent with their lesser sensitivity to trust cues in study 1, older adults do not show differential AI activity in response to untrustworthy vs. trustworthy faces or to making trustworthy (vs. gender) evaluations.

To compare bilateral AI activity for the age groups directly, a 2 (age) x 2 (face type) x 2 (task) ANOVA was performed. Significant main effects for age [F(1,36) = 5.3, P = 0.014], face type [F(1,36) = 3.79, P = 0.03], and task [F(1,36) = 7.77, P = 0.004] were found, such that there was greater AI activity for younger vs. older adults overall, for untrustworthy vs. trustworthy faces, and for the trustworthy vs. gender judgments. More importantly, there was a significant age by task interaction [F(1,36) = 13.16, P < 0.001] and a marginally significant age by trustworthiness interaction [F(1,36) = 2.56, P = 0.059] (Fig. 2), such that younger adults showed more activation of the AI than older adults during the trust-rating task and in response to untrustworthy faces. Because the age by trustworthiness interaction was marginally significant, we explored further and found that it reached significance in the left AI [F(1,36) = 2.905, P = 0.049], but was only marginally significant in the right AI [F(1,36) = 1.925, P = 0.087]. No other interactions were significant.

Amygdala ROI. No significant main effects or interactions were present in the amygdala in either age group when the groups were modeled separately as a 2 (trustworthiness) x 2 (task) ANOVA or when directly compared in a 2 (age) x 2 (trust level) x 2 (task) ANOVA (see SI Text for F statistics).

Whole-brain analyses. To obtain a more detailed picture of neural regions that were differentially activated as a function of age, we next conducted whole-brain analyses. Again, we first focused on the control cohort of younger adults to identify neural activity associated with typical trust perception. The main effect of task ("all trustworthiness judgments" > "all gender judgments") revealed that younger adults show heightened activation in bilateral AI (right: 33, 23, 1; t = 5.51, k = 160; and left:–30, 20 –8; t = 4.65; P = 0.001, k = 57; cluster extent threshold, 25 voxels), when making explicit judgments of trustworthiness, and no other neural regions reached significance. For the main effect of face type (“all untrustworthy faces” > “all trustworthy faces”), younger adults also showed heighted activation in left AI (–39, 23, –2; t= 4.21, k = 66; P = 0.001; cluster extent threshold, 25 voxels) and right inferior frontal gyrus (57, 32, 7; t = 5.4, k = 45; P = 0.001; cluster extent threshold, 25 voxels) when viewing faces with untrustworthy features across both judgment tasks, and no other neural regions reached significance. In contrast, older adults showed no neural regions that were significantly more active when making explicit judgments of trustworthiness vs. gender or when subjects were viewing untrustworthy vs. trustworthy faces. Thus, as in study 1, older adults did not appear to discriminate strongly between trustworthy and untrustworthy faces, whereas younger adults did.

Finally, to directly compare trust-related neural responses in younger and older adults, we conducted whole-brain two-sample *t* tests. To identify a whole-brain age by task interaction, the contrast “all trustworthiness judgments” > “all gender judgments” was compared in younger vs. older adults. This analysis revealed that older adults showed reduced activation in bilateral AI relative to younger adults (right: 36, 23, 1; t = 5.21, k = 75; and left: –30, 20, –2; t = 3.26, k =27, P = 0.001; cluster extent threshold, 25 voxels). To identify a whole-brain age by face type interaction, the contrast “all untrustworthy faces” > “all trustworthy faces” was compared in younger vs. older adults. Effects in this contrast were too subtle to detect at threshold; however, a small left AI cluster was present when the significance threshold was reduced (–45, 32, 13; t = 3.37; P < 0.005, uncorrected).

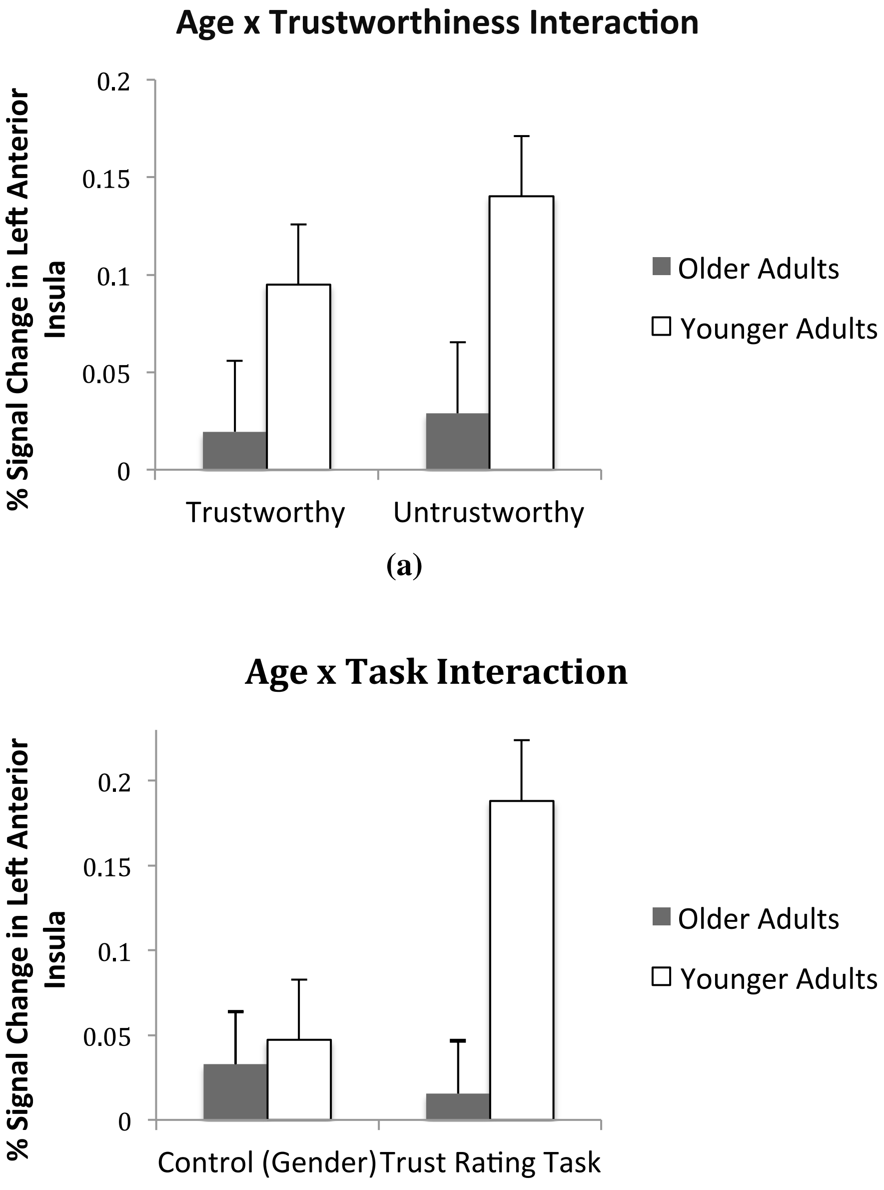
Study 2 Discussion

These results demonstrate that the AI is critical for explicitly judging trustworthiness and is particularly important for perceiving untrustworthy faces, whether or not participants are explicitly assessing trustworthiness. Consistent with predictions, each of these effects interacted with age such that, compared with younger adults, older adults show lesser AI activation when making explicit judgments of trustworthiness and when perceiving untrustworthy faces.

The AI has been implicated in reactions of disgust (Damasio, 1999) and shown to support interoceptive awareness more generally (Critchley, Wiens, Rotshtein, Ohman & Dolan, 2004). Researchers have suggested this mapping of visceral states forms the basis of "gut feelings" that inform decision making (Naqvi, Shiv & Bechara, 2007; Weierich et al., 2011). Previous research has also shown that neural activation in the AI is important for assessing risks (Meyer-Lindenberg, 2008), responding to breaches in trust (Rilling & Sanfey, 2011), representing expected financial risks, and predicting choice of safer outcomes (Knutson & Bossaerts, 2007). Following this interpretation, reduced AI activation seen in older adults may be a neural indicator of a weaker warning signal than is present in younger adults, and as such, may be implicated in older adults' higher perceptions of trustworthiness in the presence of cues to untrustworthiness.

Although we did not expect to see an age by task interaction in the amygdala [because the threat-related amygdala response is thought to be automatic and thus should be present during both explicit and implicit (gender) perceptions of trustworthiness], our hypothesized age by face type interaction was not found. This lack of significant findings for the amygdala is a surprise, given previous research (Adolphs et al., 1998; Todorov et al., 2008) that implicates the amygdala in perceptions of trust. It may be that the amygdala is not engaged in responses to stimuli such as these. Specifically, the stimuli in this study did not explicitly convey emotional states, which reduces the likelihood of seeing a robust amygdala response. Alternatively, prior work (Adolphs et al., 1998; Todorov et al., 2008) has shown several different patterns of amygdala activation in response to trust cues, and so there is currently little basis for predicting exactly how the amygdala may be related to perceptions of trust and how that might be moderated by age.

Study 2 Figures



(a)

(b)

*Figure 2.*Activation of Left Anterior Insula in younger and older adults in response to facial cues (a) and task (b).

General Discussion

Two studies, one behavioral and one using neuroimaging methodology, investigated age differences in perceived trust. Older adults rated faces high and neutral in trust cues the same as younger adults did, but perceived untrustworthy faces to be significantly more trustworthy and approachable than younger adults did. These results are consistent with research on age differences in emotion regulation. Across a variety of experiences and perceptions, older adults show a positivity bias (Carstensen, 2006): They report being happy and satisfied with life (Diener & Diener, 1996), they experience negative emotions after unpleasant interpersonal events less strongly than younger adults (Birditt, Fingerman & Almeida, 2005), they remember positive information better than negative information (Charles, Mather & Carstensen, 2003), they attend more to positive or neutral information than negative information (Mather & Carstensen, 2003), and they recover faster from negative emotions (Carstensen et al., 2000). This general pattern of findings is consistent with socioemotional selectivity theory (Carstesen, 2006), which posits a general pruning by older adults of negative experiences and people in ways that may foster well-being. The present results are consistent with this pattern: Older adults did not discriminate trustworthy from untrustworthy faces as sharply as younger adults did (study 1), instead regarding untrustworthy faces as more trustworthy and approachable; and older adults did not show left AI activation to untrustworthy faces as younger adults did (study 2). Thus, a visceral early warning system that may alert younger adults to be cautious in the presence of cues regarding trust/distrust may not be present to the same degree in older adults.

On the whole, this pattern of lesser sensitivity to negative cues, such as those that cue untrustworthiness, may be a benign contribution to the well-being of older adults much of the time. However, this propensity may also put older adults at risk for failing to process cues to untrustworthiness that they should attend to. As noted, the Federal Trade Commission (2007) and the Federal Bureau of Investigation (2001) have speculated that one reason older adults are more vulnerable than younger adults to frauds of all kinds, especially financial frauds, may be because they fail to process cues related to untrustworthiness when perceiving others, relative to younger adults.

The behavioral findings are reflected in patterns of neural activation in response to cues of trustworthiness. Younger adults showed preferential activation of the AI both when making ratings of trustworthiness and when viewing untrustworthy faces. The results indicated no significant activation of the AI during older adults' evaluations of trustworthiness or viewing of untrustworthy faces. The AI is critical for creating interoceptive (feeling-based) representations of visceral cues, which can be thought of as "gut feelings" (Craig, 2009; Critchley, Mathias & Dolan, 2001; Damasio, 1999), and people with lower interoceptive awareness experience less arousal in response to negative emotional stimuli (Pllatos, Gramann & Schandry, 2007). Consistent with this analysis, AI activity has been shown to represent expected risk and to predict risk aversion in a monetary game (Knutson & Bossaerts, 2007), suggesting that the heightened negative visceral feelings associated with AI activity might aid in risk aversion. Importantly, interoceptive awareness tends to decline with age (Khalsa, Rudrauf & Tranel, 2009), and compared with younger adults, older adults show muted left AI activation when anticipating monetary loss (Samanez-Larkin et al., 2007), which supports the interpretation of AI activity as a visceral "warning signal." The present study connects these two lines of research by suggesting that a diminished interoceptive "gut response" in older adults contributes to their tendency to be trusting, with the possibility that it affects vulnerability to fraud and poor financial decision making.

An alternative explanation for the results is that people who are older at this particular point in time process cues to untrustworthiness differently than younger adults, both behaviorally and in the brain, i.e., a cohort effect. That is, the current older cohort may simply be a more trusting one. A second alternative explanation is that more positive and trusting people live longer (i.e., selective mortality). Several investigations, however, have shown that the balance of positive to negative experience that changes with age is seen over time and is not particular to one particular cohort. For example, there is a steady improvement in the ratio of positive to negative experience across adulthood. This process becomes evident sufficiently early in adulthood to refute the possibility that enhanced well-being in late life simply reflects the experience of one cohort or selective mortality of more trusting people (Carstensen et al., 2011; Sutin et al., 2013).

The present results are consistent with older adults' general positivity bias in person perception and with their heightened vulnerability to fraud, a vulnerability that has been credited to being overly trusting (Federal Bureau of Investigation, 2001; Federal Trade Commission, 2007). However, studies using economic game-type formats sometimes find that older adults are more cautious in their willingness to invest (e.g., Bellemare & Kröger, 2007; Fehr, Fischbacher, von Rosenbladt, Schupp & Wagner, 2003), although the evidence is mixed (Sutter & Kocher, 2007). This paradigm difference in age-related findings may be due to older adults' unfamiliarity with economic games. Alternatively, certain kinds of cues (faces) may evoke different responses than other kinds of cues (e.g., proposed monetary transfer in an economic game); such instructions may make older adults more cautious, given possible reduced financial circumstances. Older adults do, however, provide larger rewards to people who have invested in them, reflecting a heightened trustworthiness. Studies have also shown that older adults are actually less afraid of being victimized, despite their greater vulnerability to many kinds of crime (Ferraro & LaGrange, 1992).

The consequences of misplaced trust for older adults are severe. A recent study estimates that older adults (over 60) lost at least $2.9 billion in 2010 to financial exploitation, ranging from home repair scams to complex financial swindles (MetLife Mature Market Institute, 2011). This figure represents a 12% increase from 2008. Older adults' reduced sensitivity to cues related to trust may partially underlie this vulnerability.

Conclusion

Older adults perceive faces conveying cues of untrustworthiness as more trustworthy and approachable than younger adults. Differences in activation of the AI observed when evaluating trustworthiness and in response to cues suggestive of untrustworthiness may underlie this age difference. As such, older adults may have a lower visceral warning signal in response to cues of untrustworthiness, which could make deciding whom to trust difficult, and may at least partially underlie their vulnerability to fraud. All participants provided written informed consent according to the procedures of the UCLA Institutional Review Board.

References

Adolphs R, Tranel D, Damasio AR (1998) The human amygdala in social judgment. Nature 393(6684):470–474.

Bellemare C, Kröger S (2007) On representative social capital. Eur Econ Rev 51: 183–202.

Birditt KS, Fingerman KL, Almeida DM (2005) Age differences in exposure and reactions to interpersonal tensions: A daily diary study. Psychol Aging 20(2):330–340.

Carstensen LL (2006) The influence of a sense of time on human development. Science 312(5782):1913–1915.

Carstensen LL, et al. (2011) Emotional experience improves with age: Evidence based on over 10 years of experience sampling. Psychol Aging 26(1):21–33.

Carstensen LL, Pasupathi M, Mayr U, Nesselroade JR (2000) Emotional experience in everyday life across the adult life span. J Pers Soc Psychol 79(4):644–655.

Charles ST, Mather M, Carstensen LL (2003) Aging and emotional memory: The forgettable nature of negative images for older adults. J Exp Psychol Gen 132(2): 310–324.

Craig AD (2009) How do you feel—now? The anterior insula and human awareness. Nat Rev Neurosci 10(1):59–70.

Critchley HD, Mathias CJ, Dolan RJ (2001) Neuroanatomical basis for first- and secondorder representations of bodily states. Nat Neurosci 4(2):207–212.

Critchley HD, Wiens S, Rotshtein P, Ohman A, Dolan RJ (2004) Neural systems supporting interoceptive awareness. Nat Neurosci 7(2):189–195.

Damasio A (1999) The Feeling of What Happens: Body and Emotion in the Making of Consciousness (Harcourt Brace, New York).

Diener E, Diener C (1996) Most people are happy. Psychol Sci 7:181–185.

Ekman P, Friesen WV (1975) Unmasking the Face (Prentice Hall, Englewood Cliffs, NJ).

Federal Bureau of Investigation (2001) Fraud Against the Elderly. Available at www.fbi.gov/congress/congress01/lormel0910.htm. Accessed July 17, 2008.

Federal Trade Commission (2007) Telemarketing Fraud Against Older Americans. Available at www.ftc.gov/reports/Fraud/fraudcon.shtm. Accessed August 28, 2008.

Fehr E, Fischbacher U, von Rosenbladt B, Schupp J, Wagner GG (2003) A nation-wide laboratory: Examining trust and trustworthiness by integrating behavioral experiments into representative surveys. Working Paper 866. Institute for the Study of Labor. Available at http://ssrn.com/abstract=385120. Accessed September 25, 2012.

Ferraro KF, LaGrange RL (1992) Are older people most afraid of crime? Reconsidering age differences in fear of victimization. J Gerontol 47(5):S233–S244.

Forman SD, et al. (1995) Improved assessment of significant activation in functional magnetic resonance imaging (fMRI): Use of a cluster-size threshold. Magn Reson Med 33(5):636–647.

Khalsa SS, Rudrauf D, Tranel D (2009) Interoceptive awareness declines with age. Psychophysiology 46(6):1130–1136.

Knutson B, Bossaerts P (2007) Neural antecedents of financial decisions. J Neurosci 27 (31):8174–8177.

Lang FR, Carstensen LL (2002) Time counts: Future time perspective, goals, and social relationships. Psychol Aging 17(1):125–139.

Maldjian JA, Laurienti PJ, Kraft RA, Burdette JH (2003) An automated method for neuroanatomic and cytoarchitectonic atlas-based interrogation of fMRI data sets. Neuroimage 19(3):1233–1239.

Mather M, Carstensen LL (2003) Aging and attentional biases for emotional faces. Psychol Sci 14(5):409–415.

McArthur LZ, Post DL (1977) Figural emphasis and person perception. J Pers Soc Psychol 13:520–535.

MetLife Mature Market Institute (2011) The MetLife study of elder financial abuse: Crimes of occasion, desperation, and predation against America's elders. Available at www.preventelderabuse.org/documents/mmi-elder-financial-abuse.pdf. Accessed June 18, 2012.

Meyer-Lindenberg A (2008) Psychology. Trust me on this. Science 321(5890):778–780.

Naqvi N, Shiv B, Bechara A (2006) The role of emotion in decision making: A cognitive neuroscience perspective. Curr Dir Psychol Sci 15:260–264.

Pollatos O, Gramann K, Schandry R (2007) Neural systems connecting interoceptive awareness and feelings. Hum Brain Mapp 28(1):9–18.

Rilling JK, Sanfey AG (2011) The neuroscience of social decision-making. Annu Rev Psychol 62:23–48.

Russell D, Peplau LA, Cutrona CE (1980) The revised UCLA Loneliness Scale: Concurrent and discriminant validity evidence. J Pers Soc Psychol 39(3):472–480.

Samanez-Larkin GR, et al. (2007) Anticipation of monetary gain but not loss in healthy older adults. Nat Neurosci 10(6):787–791.

Sutin AR, et al. Cohort effect on well-being: The legacy of economic hard times. Psychol Sci, in press.

Sutter M, Kocher MG (2007) Trust and trustworthiness across different age groups. Games Econ Behav 59:364–382.

Todorov A, Baron SG, Oosterhof NN (2008) Evaluating face trustworthiness: A model based approach. Soc Cogn Affect Neurosci 3(2):119–127.

Todorov A, Pakrashi M, Oosterhof NN (2009) Evaluating faces on trustworthiness after minimal time exposure. Soc Cogn 27:813–833.

Weierich MR, et al. (2011) Older and wiser? An affective science perspective on agerelated challenges in financial decision making. Soc Cogn Affect Neurosci 6(2): 195–206.

Winston JS, Strange BA, O’Doherty J, Dolan RJ (2002) Automatic and intentional brain responses during evaluation of trustworthiness of faces. Nat Neurosci 5(3):277–283.

Yamagishi T, Cook KS, Watabe M (1998) Uncertainty, trust, and commitment formation in the United States and Japan. Am J Sociol 104:165–194.

Supplementary Information

Castle et al. 10.1073/pnas.1218518109

Face Stimuli.

Stimuli were obtained from Adolphs et al. (1998) and prescreened; only those that showed adult male and female faces that appeared to range in age from mid or late 20s through 70s were retained. A few stimuli were deemed inappropriate (a man wearing sunglasses), and these were discarded from the stimulus set before the conduct of the investigations. For study 1, we used the SDs of trust ratings previously obtained by Adolphs et al. (1998), to identify faces that were homogeneously perceived to be trustworthy, homogeneously perceived as neutral, and homogeneously perceived as untrustworthy. The result was three sets of 10 faces each. In study 2, the nature of the study required a larger number of stimuli, and so 60 faces that ranged continuously across the trustworthy/ approachability ratings of Adolphs et al. (1) were used.

Telephone Health Screen

Prospective participants were screened out if they indicated any of the following conditions: brain damage, active coronary artery disease, significant arrhythmia, uncontrolled hypertension, post-traumatic stress disorder, a history of stroke or other neurological disorder, cardiac stents, pregnancy, anxiety disorders, depression or dysthymia, asthma or other respiratory disease, bipolar disorder, or any psychiatric illness such as schizophrenia.

Manipulation Checks: Study 1

A main effect of face trustworthiness on ratings of trustworthiness confirmed pretesting of those faces [$F(2,270) = 286.480$, $P < 0.001$, $\eta_\rho{}^2 = 0.680$]. Trustworthy faces were perceived to be more trustworthy ($M = 0.939$, $SE = 0.092$) than both neutral faces ($M = 0.380$, $SE = 0.084$) [$F(1,135) = 98.506$, $P < 0.001$] and untrustworthy faces ($M=-1.081$, $SE=0.089$) [$F(1,135)=$

343.655, $P < 0.001$]. Neutral faces were seen as more trustworthy than untrustworthy faces [$F(1,135) = 275.788$, $P < 0.001$].

A main effect of face trustworthiness on approach ratings also emerged [$F(2,274) = 539.529$, $P < 0.001$, $\eta_p^2 = 0.797$]. Trustworthy faces were more approachable (M= 1.335, SE = 0.092) than both neutral faces (M=0.755, SE=0.082) [$F(1,37) =102.836$, $P<0.001$] and untrustworthy faces (M = −1.107, SE = 0.089) [$F(1,137) = 659.505$, $P < 0.001$], and neutral faces were more approachable than untrustworthy faces [$F(1,137) = 598.770$, $P < 0.001$].

Individual Differences: Study 1

Participants completed questionnaire assessments of individual difference measures potentially related to judgments of trustworthiness. The General Trust Measure (Yamagishi et al., 1998) is an 11-item scale that assesses how much people are inclined to trust others. Examples of items are “most people are trustworthy” and “in today’s society, if you are not careful, people will use you” (reverse-coded). Participants indicated how much they agree with each item on 5-point scales with labeled endpoints (1 = strongly disagree, 5 = strongly agree).

The Future Time Perspective measure developed by Carstensen and Lang (2002) is a 10-item measure that includes such statements as “many opportunities await me in the future” and “I have the sense that time is running out” (reverse-coded). Participants rate the items on 7-point scales from “very untrue” (1) to “very true” (7).

The UCLA Loneliness Scale is a reliable and well-validated assessment of loneliness (4) that has been used extensively with both younger and older adults (e.g., Russel et al., 1980; Hawkley, Masi, Berry & Caccioppo, 2006). It includes items such as “I feel isolated from others” (reverse-coded), “people are around me but not with me” (reverse-coded), and “there are people I can talk to." Participants rate the extent to which they feel this way on a 4-point scale, where 1 indicates "I have never felt this way" and 4 indicates "I have felt this way often."

Consistent with previous research, older adults scored higher on the General Trust Measure ($M = 4.244$) than younger adults ($M = 3.648$) [$t(137) = -4.049$, $P < 0.001$] and lower on the Future Temporal Perspective Scale ($M = 3.798$) compared with younger adults ($M = 5.278$) [$t(137) = 6.106$, $P < 0.001$]. There was no difference in loneliness between older adults ($M = 3.355$) and younger adults ($M = 3.300$) [$t(137) = 0.529$, $P = 0.598$].

Because there were age differences in scores on the General Trust Measure and the Future Temporal Perspective Scale, mediation analyses (Baron & Kenny, 1986) were run to examine whether age differences in each of these measures explained the age differences in perceived trust. For the measure of dispositional trust (General Trust measure), age significantly predicted participants' trust of untrustworthy faces ($\beta = 0.299$, $P < 0.001$) and participants' dispositional trust ($\beta = 0.327$, $P < 0.001$). When simultaneously predicting participants' reported trust of untrustworthy faces, dispositional trust remained a significant predictor ($\beta = 0.235$, $P = 0.006$). Age also remained a significant predictor ($\beta = 0.221$, $P = 0.010$), but the significant drop in predictive power revealed that the effect of age on trust judgments of untrustworthy faces was partially mediated by dispositional differences ($Z = 2.286$, $P = 0.022$) (Fig. S1A). We conducted analogous analyses to examine whether dispositional trust mediated younger and older adults' differential approach of untrustworthy faces (Fig. S1B). Age significantly predicted the perceived approachability of untrustworthy faces ($\beta = 0.423$, $P < 0.001$). When simultaneously predicting participants' reported desire to approach untrustworthy faces, dispositional trust remained a significant predictor ($\beta = 0.284$, $P < 0.001$) as did age group ($\beta = 0.33$, $P < 0.001$), which, however, again significantly dropped in predictive power, indicating partial mediation (Z

= 2.697, P = 0.007). In contrast to the mediation found for dispositional trust, similar mediation analyses showed no support for mediation by participants' score on the Temporal Perspective Scale.

Scanning parameters and processing steps: Study 2

For each participant, we acquired functional T2*-weighted echoplanar image volumes [3.4 Å~ 3.4 in-plane resolution; slice thickness, 4 mm; gap, 1 mm; 33 interleaved slices; repetition time (TR), 2,000 ms; echo time (TE), 30 ms; flip angle, 75°; matrix, 64 Å~ 64; field of view (FOV), 200 mm] divided evenly across two runs. Participants were placed in a light head restraint to reduce artifact associated with head movement, and each run began with two "dummy" volumes to establish a T1 equilibrium for brain signals. Additionally, a high resolution T1-weighted magnetization-prepared rapid acquisition gradient echo (MPRAGE) structural scan (1 Å~ 1 Å~ 1 mm resolution; inversion time, 900 ms; 160 slices; TR, 1900 ms; TE, 3.4 ms; flip angle, 9°; matrix, 256 Å~ 256; FOV, 220 mm) was acquired for each participant.

Functional data were analyzed with Statistical Parametric Mapping (SPM8; Wellcome Department of Cognitive Neurology, London, UK) operating in MATLAB. Within each run, image volumes were realigned to correct for head motion (6-df affine transform using the first echoplanar image in each time series as the template), coregistered to participant space MPRAGE, normalized into Montreal Neurological Institute space (resampled at 3 Å~ 3 Å~ 3 mm) using automated segmentation of gray matter, white matter, and cerebrospinal fluid; and then smoothed with an 8 mm (full-width at half-maximum) Gaussian kernel.

References, Supplemental Information

Adolphs R, Tranel D, Damasio AR (1998) The human amygdala in social judgment. Nature 393(6684):470–474.

Baron RM, Kenny DA (1986) The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. J Pers Soc Psychol 51(6):1173–1182.

Hawkley LC, Masi CM, Berry JD, Cacioppo JT (2006) Loneliness is a unique predictor of age-related differences in systolic blood pressure. Psychol Aging 21(1):152–164.

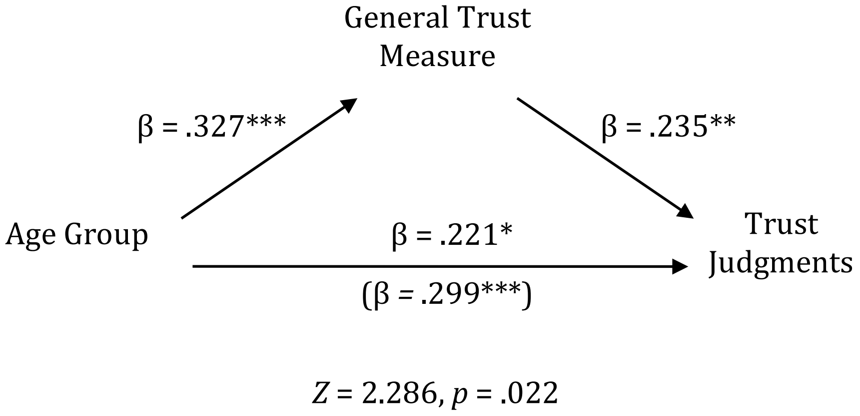
Lang FR, Carstensen LL (2002) Time counts: Future time perspective, goals, and social relationships. Psychol Aging 17(1):125–139.

Russell D, Peplau LA, Cutrona CE (1980) The revised UCLA Loneliness Scale: Concurrent and discriminant validity evidence. J Pers Soc Psychol 39(3):472–480.

Yamagishi T, Cook KS, Watabe M (1998) Uncertainty, trust, and commitment formation in the United States and Japan. Am J Sociol 104:165–194.

Figures, Supplemental Information

(a)



(b)

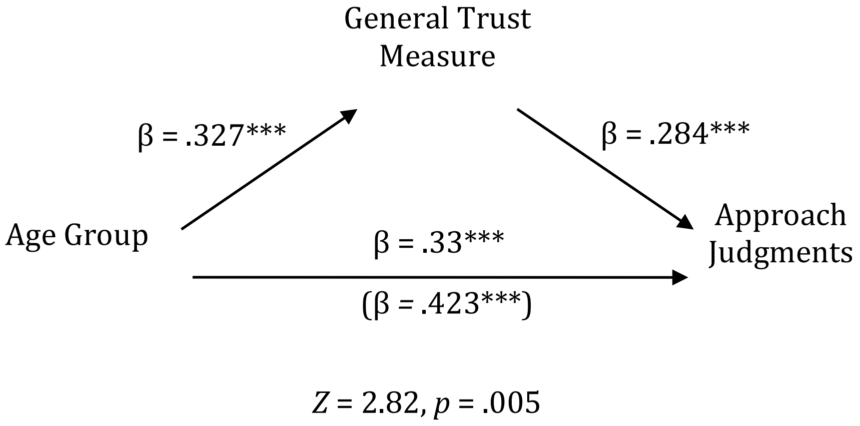


Fig. S1. (A) Mediation of age group effect on trust judgments of untrustworthy faces by participants' scores on the General Trust Measure: study 1. (B) Mediation of age group effect on approachability judgments of untrustworthy faces by participants' scores on the General Trust Measure: study 1.

Table S1

Correlations of individual difference measures with trust and approach judgments for untrustworthy, neutral, and trustworthy faces separately: Study 1

	Trust Judgments			Approach Judgments		
	Untrustworthy Faces	Neutral Faces	Trustworthy Faces	Untrustworthy Faces	Neutral Faces	Trustworthy Faces
General Trust Measure	.308***	.206*	.188*	.392***	.286**	.257**
Temporal Perspective Scale	-.084	.060	-.014	-.191*	-.048	-.106
UCLA Loneliness Scale	.038	.028	-.071	.094	.051	-.019

Note: * $p < .05$; ** $p < .01$; *** $p < .0$

Paper 2:

Deception Detection Across the Lifespan

Elizabeth C. Castle, Saskia Giebl, Naomi I. Eisenberger, Teresa E. Seeman, Mark S. Grinblatt,
Matthew D. Lieberman, and Shelley E. Taylor

Abstract

Previous research has demonstrated that aging can impact the neurocognitive mechanisms that underlie processes of trust and deception, with older adults appearing more willing than younger adults to rate untrustworthy faces as trustworthy. This represents an example of age-related enhanced attentional processing of positive stimuli, and is considered to be a feature of healthy aging. However, some have suggested there may be circumstances (e.g. in the presence of deception) where a consistent positivity focus may result in impoverished processing of important deceptive cues, thus yielding older individuals disproportionately vulnerability to devious exploitation (e.g. financial fraud). To explore these questions, the present study compared deception detection accuracy for older and younger adults during fMRI scanning, while they completed two distinct deception tasks. As predicted, results indicate that younger adults performed significantly better than older adults and this effect was moderated by attention to positive cues, providing support for the hypothesis that overwhelming focus on positivity can have consequences for deception detection accuracy.

"Man is born, grows up, and dies, according to certain laws which have never been properly investigated, either as a whole or in the mode of their mutual reactions." (Quetelet: Sur l'Homme et le developpement de ses Facultes. 1835).

These grave opening remarks introduce the reader to the first text ever published on the psychology of aging (Quetelet, 1835), but more significantly, they also mark the birthplace of the psychological exploration of aging; which is perhaps the source of Quetelet's gravitas (Birren, 1961). Our present day understanding of this field is likely to bear more notable differences than similarities to its historical roots, however, by observing our work in a more modern historical context, it is easier to appreciate the impact of fairly recent shifts in which *'laws'* of human experience are subjected to scientific inquiry. For instance, while many view the study of social and emotional health to be a central pillar of the of the psychology of aging (Lim & Yu, 2015), emotion wasn't even considered as a potential target of empirical inquiry in this context until about 50 years ago. Since that time, several of the most impactful contributions to our understanding of human aging have come from theories and observations regarding changes in emotional processing through the lifespan.

Positivity Effect

A prime example of this is the positivity effect, which refers to age-related changes in the cognitive processing of emotion such that, as compared to younger adults (YA), older adults (OA) show a preference for positive rather than negative information in a variety of contexts ranging from basic visual attention to happy faces, through complex health-related decision making (English & Carstensen, 2015; Löckenhoff & Carstensen, 2007; Mather & Knight, 2005; Reed et al., 2014). While hypotheses have been put forth to explain this pervasive effect, no causal explanatory link has been established (Reed & Carstensen, 2012).

Aging Brain Hypothesis

One preliminary account of the positivity effect comes is the ‘aging brain’ hypothesis. This account suggests that the enhanced positivity seen in OA can be attributed to age-related neural degradation of the amygdala, a subcortical region the brain known to be important for both processing and generating negative emotion states like threat or fear (Cacioppo, Berntson, Bechara, Tranel, & Hawkley, 2011). Despite its diminutive size, the amygdala’s extensive neural connections make it a highly influential relay center, that along with several related structures like the insula and cingulate cortex, comprise a ‘salience network’ capable of modulating attention to specific features of the environment (Adolphs, 2002; Bickart et al., 2014; Critchley, 2009; Grady, 2008; Phelps & LeDoux, 2005; Samanez-Larkin & Knutson, 2015; Singer, Critchley, & Preuschoff, 2009). The aging brain hypothesis suggests that impaired amygdala function results in a reduction of attentional resources allocated to detecting potential threats, consequently biasing older adults neurocognitive processing towards less negative features of the environment. While this account successfully describes how amygdala dysfunction in older adults might manifest (Iidaka et al., 2002; St. Jacques, Dolcos, & Cabeza, 2010), it fails to explain certain key aspects of the positivity effect. For example, the characterization of the effect as ‘less negative’ is consistent with evidence demonstrating a reduced preference for negative stimuli in OA, but overlooks evidence suggesting an *enhanced* preference for positive stimuli. In previous research, OA have shown *increases* in reward-related neural activity to positive stimuli like pictures of happy faces (Keightley, Chiew, Winocur, & Grady, 2007), and anticipation of a monetary gains but not losses (Samanez-Larkin, Hollon, Carstensen, & Knutson, 2008). Since the amygdala plays a role in processes both negative and positive emotion, we would expect amygdalar degeneration to compromise the processing of positive emotion too. Perhaps the most discrepant piece of evidence however, is the fact that the OA who are most likely to display the positivity effect are those who have the most highly preserved cognitive resources (e.g. have the lowest levels of cognitive or neurodegenerative decline)(Kalenzaga, Lamidey, Ergis, Clarys, & Piolino, 2016; St. Jacques et al., 2010). This finding directly opposes the 'aging brain' hypothesis, and instead, supports a competing account known as Socioemotional Selectivity Theory (SST) (Carstensen, 2006).

Socioemotional Selectivity Theory

The healthy aging process has been associated with a heightened awareness of the limited nature of one's own 'future time horizon' (Carstensen, 2006; Demeyer & De Raedt, 2013). In other words, people have a different perspective on their future at 30 years old versus 80 years old, and SST suggests that this results in the motivated pursuit of different types of goals (Reed & Carstensen, 2012). Critically, YA tend to show more emphasis on long term future goals, despite possible short term sacrifices (e.g. parenting), whereas OA are more likely to prioritize immediately salient socioemotional goals related to wellbeing (e.g. being present with loved ones). With this framework in mind, SST suggests that the preferential processing of positive (vs. negative) emotions observed in OA is a desirable emotion regulation strategy that serves to maintain attention on proximal socioemotional goals that may become more important as we age (Reed & Carstensen, 2012).

A considerable amount of evidence has amassed in support of the SST account of positivity in OA. As compared to YA, OA often show an attentional bias towards happy faces, increased attention to positive emotion cues during face processing, and greater memory for positive vs. negative information (Demeyer & De Raedt, 2013; Di Domenico, Palumbo, Mammarella, & Fairfield, 2015; Mather & Carstensen, 2003; Mather & Knight, 2005). As previously mentioned, these types of effects are most readily observed when cognitive resources remain highly intact; conversely, effects can be completely absent in those with dementia or significant cognitive decline (Reed & Carstensen, 2012). The absence of the positivity effect can also be predicted by imposing situational constraints on information processing. For example, engaging in a taxing experimental task that occupies the majority of an individual's cognitive resources has been shown to banish the positivity effect (Löckenhoff & Carstensen, 2007). This collective evidence suggests a role for the cognitive control of attention in directing focus towards positive features of the environment. This notion is also supported by neuroimaging evidence that, when summarizing across studies, has shown a relatively consistent relationship between limbic and prefrontal activation, in what has been presumed to represent an attempt to reduce of negative states (Grady, 2008; Samanez-Larkin & Knutson, 2015).

Processes of Trust and Deception

Of particular interest to the present investigation, is how social cognitive processes involved in assessing trustworthiness might be affected by positivity. While there have been dozens of studies characterizing the positivity effect and it's various benefits, very few have focused on the potential dangers that might arise as a result of chronic positive focus (Reed & Carstensen, 2012). This dearth of information is surprising given the cultural concern regarding OA vulnerability to financial fraud (Ross, Grossmann, & Schryer, 2014). While the true extent of OA victimization is unclear, one of the first projects to explore this idea showed that OA, as compared to YA, demonstrate compromised accuracy in explicit judgments of trustworthiness (Castle et al., 2012; Zebrowitz, Boshyan, Ward, Gutchess, & Hadjikhani, 2017). Complementary work has demonstrated that OA show enhanced gaze following for trustworthy faces (Petrican et al., 2013), providing a possible mechanism through which these effects might occur (Petrican et al., 2013). This suggests that, at least in certain instances, OA's preference for positive emotional information might result in impoverished processing of salient negative cues; an explanation which also exposes a potential mechanism for OA's disproportionate vulnerability to fraud and exploitation (Lichtenberg & Paulson, 2013; Percy, 1983; Peterson et al., 2014). While further work is needed to empirically evaluate these ideas, this preliminary research has identified a possibly useful context (e.g. judgments of untrustworthiness) for the continued exploration of these poorly understood yet potentially deleterious consequence of pervasive positivity.

Study Aims

The present study aims to test the hypotheses that, compared to YA, OA will show impaired deception detection accuracy, and that age-related positivity will interfere with OA accuracy. To achieve this, we asked older and younger adults to evaluate the veracity of novel video clips in two explicit deception detection tasks. Next, we used linguistic coding to identify naturally occurring, positive cues present in the deception stimuli. Finally, we compared the presence and frequency of these cues to each participant's pattern of accuracy to predict trial-by-trial judgment accuracy; thus yielding critical information about how OA and YA tend to use positive cues to inform their deception judgments.

Methods

Participants

Fifty-five healthy, right-handed participants screened for psychological and cognitive deficits participated in an fMRI study of deception detection. Seven participants were excluded before analysis for movement greater than 3mm within each run and/or technical difficulties resulting in incomplete data. The final sample of forty-eight participants consisted of twentythree older adults (aged 55-79, Mean = 65.73, SD = 7.5; 12 female), recruited with the help of the Recruitment Core of the UCLA Older Americans Independence Center, from Los Angeles retirement centers and communities. Education level ranged from some high school to post-graduate degree. The comparison group was twenty-six younger adults (aged 25-47, Mean 31.56, SD = 5.2; 14 female) recruited from the broader Los Angeles community who also had an education level ranging from some high school to post-graduate degree. All participants were compensated $100, with some earning additional performance-related bonuses up to $40. Informed consent was obtained in accordance with guidelines set by the Office of Protection for Human Subjects at UCLA.

Task Design

Older adults (OA) and younger adults (YA) completed three video-based tasks during fMRI scanning. Two deception detection tasks: the *investment task* and the *opinion task*, as well as one non-social control task: the *food task*. Video stimuli were viewed on MRI-compatible goggles and participants completed one block of each task during each of six fMRI scanning runs. Post-video questions were self-paced for all three tasks resulting in a variable run time of approximately 7 minutes. Task presentation order was randomized (without replacement) within each run, and video stimulus order was randomly selected for each block from three novel video stimulus sets created for this experiment as described in Appendix 1; no video was repeated twice for any subject. All video stimuli and corresponding question-text were jittered with an ISI between .5-6 seconds (mean = 2.5 seconds) (see Figure 1).

Investment Task. During each block of the *investment task,* participants viewed a series of five investment pitch video clips (Mean pitch duration in seconds = 25.30, SD = 5.33). Truthful pitches and deceptive pitches were randomly distributed throughout the task with a mean deception base-rate of 43.16%. Deception base-rate did not differ between age group (*t*(46) = .72, *p* = .48) and was not disclosed to participants. After viewing each investment pitch, participants used a button press to indicate 1) whether they thought the person was telling the truth, 2) their 0-100% confidence rating of that judgment, and 3) whether they would invest their money in the person. If confusion arose regarding the distinction between questions one and three, a distinction was made during pre-scan instructions indicating that for question one, participants were asked to make "an objective assessment" and for question three they were invited to use more "personal or subjective reasoning". To further encourage personal engagement with the task, participants were given a bonus $10 to play this game during the scan. Decisions were made for every video and at the end of the experiment, one of these decisions was selected at random to be implemented. If the subject had made a correct response to this trial they received a $50 bonus.

Opinion Task. During each block of the *opinion task,* participants viewed a series of seven opinion statement video clips (Mean statement duration in seconds = 6.88, SD = 2.47). Truthful opinion statements and deceptive opinion statements were randomly distributed throughout the task with a mean deception base-rate of 50%. Deception base-rate did not differ between age group (*t*(46) = 1.18, *p* = .26) and was not disclosed to participants. After viewing each opinion statement, participants used a button press to indicate whether they thought the person was telling the truth.

Control Tasks. During each block of the *food task,* participants viewed a series of five neutral descriptions of various meals/food items (Mean statement duration in seconds = 18.58, SD = 5.66). After viewing each food video, participants used a button press to indicate whether the previous clip mention 4 or more food items. These videos were meant to control for basic perceptual features associated with complex audiovisual stimuli, non-social decision making processes, attentional engagement, and preparation for motor response. Additionally, we included an additional, backup non-social control task: the *shape-matching task*. In this task, participants decide which of two shapes on the bottom of the screen matches the shape on the top of the screen and make a corresponding button press response. This task was completed in a separate 7 minute scanning run at the start of the experiment. Due to missing data, and the unanticipated stress this task caused to some of the OA participants, this task was not included in analysis.

Measures

dprime. Since most people show some degree of truth bias when performing deception detection tasks (Meissner & Kassin, 2002), deception detection accuracy was assessed here using a measure of pure sensitivity independent of response bias derived from signal detection theory known as d-prime (*d' or discriminability*). *d'* measures how well someone can detect whether or not an event occurred (e.g. signal is present) without undue influence of their bias towards a particular response (Nevin, 1969). In the present study, 'lie' videos where characterized as signal and 'truth' videos were characterized as noise. Discriminability is calculated by comparing the difference between hit-rate (HR) and false alarm rate (FAR) against the standard deviation of the noise distribution; $d' = z(HR) - z(FAR)$ (N. a Macmillan & Creelman, 2005; Stanislaw & Todorov, 1999). Since 'lie' videos represent signal in this case, HR was calculated as: (number of lies identified as lies/total number of lies) and FAR: (number of truths identified as lies/total number of truths) for each participant. Since signal detection theory does not support extreme but realistic HRs/FARs (i.e. 0% or 100%), a correction was applied such that rates of '0' were assigned to '.001' and rates of '1' were assigned to .999 (N. a Macmillan & Creelman, 2005; Sorkin, 1999). Next, the z-score of each rate was then computed using MATLAB's 'NORMINV' function which computes the inverse of the normal cumulative distribution function for a data sample at the value of P (in this case HR or FAR) (MATLAB and Statistics Toolbox Release 2009b, The MathWorks Inc.). Finally, d' was calculated for each participant using the formula: $d' = z(HR) - z(FAR)$.

Criterion. A measure of subject response bias known as the criterion variable (C) was also calculated for each subject. C reflects an individual subject's baseline tendency (all else being equal) to favor 'lie' vs. 'truth' judgments. When C is positive, this indicates that (all else being equal) a subject has higher likelihood of reporting presence of signal (e.g. 'lie'). When C is negative this indicates that (all else being equal) a subject has higher likelihood of reporting the absence of signal (e.g. 'truth'). C was calculated here from the FAR and noise distribution, using the formula; $C = z(FAR) - d'/2$ (Snodgrass & Corwin, 1988).

Positive cues. To test whether OA attend towards positive cues during the detection of deception, we subjected the transcripts of video investment pitches to an automated Linguistic Inquiry and Word Count (LIWC) to identify linguistic features which have been previously associated with discriminating truth from deception (Chung & Pennebaker, 2012). An index of '*positive verbal lie cues'* was created by averaging frequencies of a set of predetermined cues to positive emotion summed with the inverse scored index for negative emotion. This created a single measure representing both presence of positive emotion and relative paucity of negative emotion within each video clip. These methods have been previously validated to produce robust cues (Chung & Pennebaker, 2012; Tausczik & Pennebaker, 2010). The positive cue index was mean centered before incorporation in analyses. It has been firmly established that detectors tend to use some combination of social cues to deception when judging deceit (Hartwig & Bond, 2011), however it is worth noting that cues can vary across context and individuals (C. F. Bond & Depaulo, 2008; Riggio & Friedman, 1983).

Procedure

Participants arrived at the UCLA Ahmanson Lovelace Brain Mapping Center 1.5 hours prior to scanning to complete paperwork (consent form, metal screening, and questionnaire packet) and task training. During training, participants watched an instruction video featuring "Jack" and "Jill" playing the investment game before completing a short practice where they watched and answered questions for two sample videos from each task (*investment, opinion,* and *food tasks*). Finally participants' practiced the shape-matching task. Next, subjects were set up in the 3T scanner where they completed the shape-matching task and three runs of the deception tasks during fMRI scanning. This was followed by a 'mental break' for a structural MPRAGE, and concluded with the three remaining deception task fMRI scanning runs. Scan time was approximately 1.25 hours, and total participation time was approximately 3.75 hours.

MR Image acquisition. All MRI data were collected using a Siemens 3-tesla Trio MRI scanner with a 12-channel head coil at the UCLA Ahmason-Lovelace Brain Mapping Center. Each participant was scanned during task performance while functional T2*-weighted echoplanar image (EPI) volumes were acquired [3.1x3.1x3.0 in-plane resolution; 3mm slice thickness; 33% slice gap; 36 descending slices; 2000ms repetition time (TR), 25ms echo time (TE), 90 degree flip angle, 64x64 matrix; 200mm field of view (FOV)] across seven different run. Each run had approximately 175 3D volumes but since the task was self-paced, the exact number of scans collected in each run varied slightly. Participants were placed in a light head restraint to reduce motion artifact, and each ran began with two 'dummy' volumes to establish a T1 equilibrium for neural signals. A high-resolution T1-weighted magnetization-prepared rapid acquisition gradient echo (MPRAGE) structural scan [1.1x1.1x1.2 mm resolution; 900ms inversion time; 176 sagittal slices; 2300ms TR; 2.93ms TE; 9 degree flip angle; 256x256 matrix; 270mm FOV] was acquired for each participant.

fMRI analysis. Functional data were analyzed with Statistical Parametric Mapping (SPM8; Wellcome Department of Cognitive Neurology, London, UK) operating in MATLAB. Data were subject to standard preprocessing including: spatial realignment of image volumes within each run (6-df affine transform using the first EPI in each time series as the template), coregistration to participant space MPRAGE, normalization into a standard sterotactic space as defined by the Montreal Neurological Institute (resampled at 3x3x3mm) using automated segmentation of gray matter, white matter, and cerebrospinal fluid, and then spatial smoothing using a 6mm (full-width at half-maximum) Gaussian kernel.

The set of videos from each task (investment, opinion, and food) were modeled as blocks at the first level and convolved with a canonical hemodynamic response function. Each video condition (truths vs. lies) was modeled separately for each task (investment, opinion, and food), and appropriate linear contrasts were applied to the design to enable determination of regions active for each condition between the tasks. In addition to the standard set of six movement repressors supplied by SPM, an additional parameter was included in the model to account for particularly impactful ‘bad scans’. All first-level contrast images were entered into a two-sample random-effects t-test to investigate age differences at the group level. Unless otherwise specified, whole-brain analyses were conducted using a statistical criterion of at least 25 voxels exceeding a voxelwise threshold of $P < 0.001$. This joint voxelwise and cluster-size threshold corresponds to a false-positive discovery rate of 5% across the whole brain, as estimated by a Monte Carlo simulation implemented using AlphaSim in AFNI (Forman et al., 1995). ROI analyses were performed using the Marsbar toolbox (http://marsbar.sourceforge.net) to estimate average percentage signal change across all voxels in each ROI. All anatomical ROIs were apriori, anatomically defined. (http://fmri.wfubmc.edu/cms/software#PickAtlas; Maldjian, Laurienti, Kraft & Burdette, 2003). The insula ROI was cut off at 15 in the y direction to restrict analysis to anterior regions.

Results

Deception detection accuracy. *d'*(discriminability) is a sensitivity measure that quantifies how well someone can detect whether or not an event occurred (e.g. 'lie' is present) without undue influence of their bias towards a particular response (Nevin, 1969). A repeated measures ANOVA was conducted to determine whether there were statistically significant differences in deception detection accuracy (*d')* between OA and YA across the two deception detection tasks. Results show a trend for an accuracy differences between tasks, such that accuracy was higher during the opinion task (M = .249, SE = .048) vs. the investment task (M=.054, SE=.081) tasks across age group $F(1,46) = 3.9$, p = .056. As expected, a main effect of age was also observed such that YA (M = .28, SE = .06), were more accurate than OA (M = .024, SE = .065) across both tasks. The interaction between task and age was not significant (p=.8) indicating that OA and YA performed similarly on both tasks.

Criterion Analysis. Response bias was calculated to detect whether there was a relationship between age, task context, and a subject's directional response bias. Practically, this tells us what the baseline odds are that a subject will identify any given video as a 'lie' (when all other factors are held constant). Negative values of *C* indicate a truth bias, whereas positive values of *C* indicate a lie bias. An age x task repeated measures ANOVA was performed with *C* as the dependent variable. The main effect of task showed a statistically significant difference in subject response bias between trials, such that both age groups showed a higher truth bias during the opinion task condition *F*(1,46) = 5.3, *p* = .032. There was also a trend for an interaction between age and task, such that truth bias increased from the investment task to the low-stakes task more for OA than YA *F*(1,46) = 2.12, *p* = .152 (see Figure 2 and 2b). This indicates that the positivity effect impacted OA more in the opinion task than the investment task.

Positivity Cues. To test our primary hypothesis that attention to positive cues impacts older adult's deception detection performance, accuracy for detecting both truths and lies was modeled using a General Estimating Equation (GEE) binary logistic regression (Ghisletta & Spini, 2004; Sweeney & Ceci, 2014). *d'* is an aggregate accuracy measure yielding only one measure per subject, logistic regression however, enables the assessment of the trial-by-trial likelihood that participants identified a video accurately (0 = wrong, 1 = correct) for each task as a function of age and the presence of positivity cues. GEE is a semi-parametric extension of general linear modeling (GLM) that enables processing of correlated within subjects 'clusters.' In the present study, individual subjects are specified as 'clusters' and data are subjected to a simple correction adjusting the standard error to account for the intrasubject correlation between deception judgments (Sweeney & Ceci, 2014). This accounts for the fact that a back-to-back series of subjective social judgments made by a single individual are unlikely to be independent from one another. As an additional control, the proportion of truth video stimuli each participant viewed was also included in the model to address confounds caused by unbalanced data.

For the opinion task, there was a main effect of positivity cues ($\chi^2(1) = 10.96, p <.01$) such that when more positivity is present, subjects are less likely to identify a video accurately than when there is less positivity present (odds ratio = .90, p<.01). There was also a strong trend for a main effect of age ($\chi^2(1) = 2.89, p = .09$) such that as compared to YA, OA are less likely to accurately identify a video as a truth or lie (odds ratio = .15, p=.09). To address our primary hypothesis, understanding of the relationship between the likelihood that OA, as compared to the likelihood that YA, will accurately judge the presence/absence of deception in any given video as a function of the presence of positivity cues is required. The statistical relationship between these two likelihoods is assessed via the p-value of Exp(B) for the OA*positivity cue interaction term (in this case $p = .01$), and the relationship can be described via the product of the odds ratio for the main effect of age for OA (that is, the 'baseline' likelihood that OA will accurately judge the presence/absence of deception in any given video, all else being equal) and the Exp(B) for OA*positive cue interaction term. In this case, [.15*.98 = .147] is the proper odds ratio for the OA*positive cue interaction term. Since the odds ratio is less than one, we can conclude that OA, as compared to YA, are less likely to detect deception accurately, and that this depends on the level of positive cues present, such that when more positive cues are present, OA accuracy decreases (Exp(B) = .147, p=.01). This supports our hypothesis that OA deception detection accuracy would be compromised by positivity. Notably, there was also a trend for a main effect of proportion of truth videos displayed, which was included as a data imbalance control variable in the accuracy regression ($\chi^2(1) = 2.39$, $p = .12$). This indicates that the ratio of truth to lie videos viewed had some impact on accuracy, although it did not reach statistical significance nor does it seem to account for similar variance as the effects of interest are still significant. This is likely due to the slight truth bias typical of most people (and present in this sample); if 'truth' is the more common response then it follows that the chances of being correct would increase if there are more truth videos present. For all parameter estimates and marginal means, see Table 1b and 1c.

To follow up this finding in the opinion task, we tested the hypothesis that the presence of positive cues leads OA to make more trust judgments regardless of the type of video (truth vs. lie). A binary logistic regression was performed to ascertain effects of age and positive cues on the trial-by-trial likelihood that participants identified a video as a truth vs. lie (0 = truth, 1 = lie) for each task, again while accounting for number of video stimuli seen. YA acted as the reference category to which OA likelihoods were compared to determine statistical significance. As expected, the main effect of age was not significant ($\chi^2(1) = 1.35$, $p = .25$), but interestingly, there was a main effect of positive cues ($\chi^2(1) = 7.25$, $p = .01$) such that presence of positive cues tends to make subjects more likely to judge a video as true (odds ratio = 1.08, $p = .02$). Most critically however, there was a significant interaction between positivity cues and age group ($\chi^2(1)= 7.59$, p=.01) such that, as the frequency of positivity cues present in a video increases, the likelihood that OA will judge it as a 'truth' increases compared to YA, regardless of whether or not the video is actually true. In examination of parameter estimates, we calculated the OA*positive cue odds ratio to be 4.13 ($p = .01$). Since this is greater than 1, we can conclude that in the presence of positive cues, OA are drastically more likely to judge a video as true than YA (see Table 2a-c for complete model effects). This suggests that, consistent with our hypotheses, OA do seem disproportionately sensitive to positive cues, with positive cues seeming to increase their willingness to trust, and decrease their deception detection accuracy. There was also a main effect of proportion of truth videos displayed for this regression, ($\chi^2(1) = 6.44$, $p = .01$), with more truth videos leading to higher accuracy odds ratio = 1.08, $p = .02$. As mentioned before, this did not interfere with our hypothesized analysis, is likely due to a slight truth response bias.

The same GEE Binary Logistic Regressions of the effects of age and positive cues on trial-by-trial deception detection accuracy, were applied to the investment task. Although there were some strong trends, no main effects or interactions significantly contributed to either the accuracy model or response (lie/truth) model (.89 >*P*s > .10). This task had less video stimuli so it is likely that it is less robust to unbalanced data because the data imbalance control variables represented the strongest trends. For this reason, we will not be attempting to interpret any of the observed trends but complete parameter estimates can be found in Tables 3 and 4.

Analytical Note. All logistic regressions were completed modeling OA responses as the target and YA responses as the reference, however, since this means we are dealing in below-chance odds which are more controversial to interpret, sometimes the significance is expressed here in terms of YA vs. OA likelihood instead. Where this occurs, statistical tests (using OA as the reference category) were completely just to ensure conclusions were valid. This is consistent with our hypothesis that OA attention to positivity cues may interfere with processing of more informative negative cues to deception; thus leading to decreased accuracy.

ROI analyses. To test whether accuracy differences could be attributed to age-related amygdala degradation, an ROI analysis comparing task-related amygdala activation was performed. Percent signal change was extracted from each subject's first level contrasts (lies > baseline) and (truths > baseline) for both deception detection tasks. We used a contrast of L>T (calculated by simple subtraction after ROI extraction) to perform an age (OA vs. YA) by task (opinion vs. investment) repeated measures ANOVA. Contrary to what the aging brain hypothesis would predict, amygdala activation for OA was not decreased as compared to YA. In fact, there were no significant main or interaction effects (*P*s>.39), suggesting that age-related differences in deception detection could not be due to neurodegeneration of the amygdala in OA.

Whole brain analyses. First, we turned to our younger adult sample to help identify what 'typical' patterns of deception detection neural activation looked like. To achieve this, we performed these whole brain analyses within each group separately, which also served a secondary goal of protecting against invalid group contrasts due to uneven data. While this is not normally such a concern in neuroimaging analyses (Mumford & Nichols, 2006) special care needs to be taken when comparing YA and OA samples, in order to reduce the chance of seeing spurious effects due to missing data or confounds in age-related HRF changes (Samanez-Larkin & D'Esposito, 2008). Also notable, is our use of a two-sample *t* statistic (modeling OA and YA in their respective age groups and computing linear contrasts of group effects versus baseline rather than vs. each other (e.g. [1 0] vs. [1 -1]; this was an attempt to 'scale' the groups to make comparisons meaningful by explicitly accounting for the variance of each group (Seltman, 2014). This does not result in a true 'scaling' of data, but does somewhat reduce the danger of seeing substantially inflated beta values in YA. Regardless, nothing passed our statistical threshold in our tasks of interest.

Individual Differences. As in Study 1, participants completed questionnaire assessments of individual difference measures potentially related to judgments of trustworthiness. The General Trust Measure (Yamagishi et al., 1998) is an 11-item scale that assesses how much people are inclined to trust others. Examples of items are "most people are trustworthy" and "in today's society, if you are not careful, people will use you" (reverse-coded). Participants indicated how much they agree with each item on 5-point scales with labeled endpoints (1 = strongly disagree, 5 = strongly agree). Previous work has shown age differences on this measure, and consistent with that, we see a trend indicating that older adults (M=5.44, SD = .697) rate themselves as slightly more trusting than younger adults (M = 4.15, SD = .727) *t*(42) = -1.87, *p* =

.068. Participants also filled out the Future Time Perspective measure developed by Carstensen and Lang (2002) is a 10-item measure that includes such statements as "many opportunities await me in the future" and "I have the sense that time is running out" (reverse-coded). Participants rate the items on 7-point scales from "very untrue" (1) to "very true" (7). Consistent with previous research, a trend emerged such that OA (M = .887, SD = .646) scored slightly higher than YA measure (M = .6, SD = .63) on this measure (M = .6, SD = .63) $t(42) = -1.48$, $p = .144$.

Sample considerations. Notably, age related-differences have been observed in the hemodynamic response function (from which BOLD signal is measured), so special consideration of any direct between group comparisons is warranted to ensure differences observed in global signal are not misconstrued as condition-specific effects (Dennis & Cabeza, 2008). Since all of the findings discussed in the present study are results of comparative BOLD signal (i.e. use of a control task or other contrast condition as recommended by (Samanez-Larkin & D'Esposito, 2008)), results are unlikely to be attributable to age-related differences in global signal. Additional precaution was taken by focusing primary analyses on a-priori defined regions of interest (ROIs), with beta values scaled for within-subject global signal in Marsbar (http://marsbar.sourceforge.net/). However, these issues are of particular concern for the present data set, because there were more trials (and several subjects) that were dropped from the OA sample before analysis due to data quality concerns; thus resulting in an unintentional, unbalanced design with regard to sample size (difference of n=3) and differences in the proportion of truth vs. lie videos that each participant judged (while this did not impact all subjects to the same degree, on average, YA viewed 2.3 more lie videos than OA). An effort was made to maintain the delicate balance between retaining sufficient data from the group as a whole to ensure reliable parameter estimates, and eliminating unnecessary bias that might be introduced by including subjects with major condition-type discrepancies in valid trials. This was achieved by first dropping the most extreme condition discrepancies from the sample before neuroimaging analysis, and selecting only statistical tests that explicitly account for multi-subject variance and are therefore comparatively more robust to unequal samples (e.g. comparing behavioral data with GEE vs. repeated measures ANOVA and two sample *t* test with single-group linear contrasts vs. one sample *t* test for neuroimaging data analyzed with SPM) (Mumford & Nichols, 2006). To explore the impact of an unequal sample size, statistics were also performed with appropriate compensatory subject weights; however, weighted results did not significantly differ from unweighted results so original data are reported to maintain ease of interpretation. To interrogate the impact of unbalanced presentation of truth vs. lie stimuli, all ANOVA results discussed were also tested against a larger estimated sampling distribution to see if the observed pattern of results would change with the addition of additional, balanced data. Using SPSS's bootstrapping function, parameter estimates were achieved through stratified resampling (with replacement, n samples = 1000) from the original sampling distribution of truth vs. lie trials (Mooney, Duval, & Duvall, 1993). Bootstrapping did not change the outcome of significance testing (i.e. no reported findings crossed the statistical threshold of $p < .05$ in either direction), so original data are reported. These findings indicate the observed findings are valid, however it is still appropriate to handle inferences with caution.

Discussion

As predicted, significant differences in lie detection accuracy were observed such that older adults were significantly less accurate than younger adults during a social deception detection task where participants judged video clips of other's opinions as honest or deceptive. This was particularly true when positive linguistic cues were present, supporting our primary hypothesis that the relative deficit that OA show in judging trustworthiness and identifying deception (compared to YA) may represent a potentially hazardous consequence of the age-related positivity effect.

While the age-related tendency to allocate attentional resources to positive stimuli has been well documented, (Reed et al., 2014) it was less clear what this might look like in a deception detection context. While it has been proposed that OA's preference for positive emotional information might result in impoverished processing of salient negative cues, the tendency to focus on positive information does not necessarily point to a deficit in deception detection. In fact, if this focus resulted in a deeper processing of positive information it might even make it easier to detect 'off' or less genuine expressions of positivity that can mask deception. If this were the case, we would expect to see the presence of positive cues boost lie detection accuracy, but instead, our results link positivity to both reduced accuracy *and* increased (and unwarranted) trust from OA, leading us to conclude that positivity interferes with deception detection in OA.

To further complicate the matter, the results of the few studies that have explored the relationship between age and deception detection accuracy have been mixed. The majority of this work that has demonstrated significant age differences in deception detection accuracy (Ruffman, Murray, Halberstadt, & Vater, 2012; Stanley & Blanchard-Fields, 2008; Sweeney &

Ceci, 2014), but there are two studies that warrant conversation despite failing to observe a significant effect of age on deception detection ability. In the first study, older and younger adults were invited to a local prison where they conducted live, in-person interviews, with actual convicts. Deception was assessed during the interview. (G. D. Bond, Thompson, & Malloy, 2005). Notably, this is the only study we are aware of that has observed OA deception detection accuracy to be higher the YA, and this was driven by the older women in their sample. The second study compared deception detection accuracy between OA and YA, who watched video clips of murder victim's family members making public statements condemning the killer, or making a plea for help in bring them to justice. However, all the family clips (primarily culled from British news archives), were recorded just before the individual themselves became a primary suspect, with approximately half of video senders eventually going on to be convicted of the murder (Shaw & Lyons, 2016). When considered in tandem, it is immediately apparent that each of these studies represents a 'high-stakes' deception detection context (particularly in contrast to the average college samples typically employed for stimuli generation).

Prior research has found that the positivity effect is less reliably observed in high stakes situations, or where personal relevance is obvious (English & Carstensen, 2015). For instance, when OA patients were asked to review a set of health-related decisions (e.g. selecting a new doctor) differences were observed between patients, such that OA in better health demonstrated more extensive evidence of positivity compared to those in poor health. These decisions were contrasted with less critical decisions (e.g. selecting a new car) where evidence of positivity was evident for both patient groups (English & Carstensen, 2015). This has been interpreted as a reallocation of cognitive resources to critical contexts during important decision-making. Complementary evidence has shown that during a visual search task, OA and YA exhibited similar patterns of rapid identification specific to angry faces. This demonstrated OA willingness and capability of confronting negative stimuli when relevant to survival (Mather & Knight, 2006). Taken together, this pattern of results suggests that the stakes associated with a particular decision making context, may play a role in determining the proportion of cognitive resources allocated to processing a decision vs. maintaining positivity.

Based on this evidence, it is possible that older adults may only demonstrate muted deception detection in low-stakes situations (due to positivity-related accuracy interference), but not in high stakes situations when there would be less cognitive resources to allocate towards increasing positivity because people would be focused on the task. While no previous work has examined how OA might respond to deception in a high-stakes vs. low-stakes comparison, we believe the summary of evidence presented here creates a compelling case to suspect that stakes could represent an important predictor of lie detection accuracy.

In fact, turning this lens on the divergent task results found in the present study, sheds new light on these observed null group findings. While the opinion task simply asked people to watch videos and make judgments with no interaction or reward, the investment task required subject's play along with the game, making personally relevant investment decisions regarding a real $50 bonus on every trial. It is possible that this added layer of engagement and task complexity was sufficient to require the redirection of enough cognitive resources to interrupt the pursuit of positivity, and increase accuracy as a result. In sum, it is possible that lie detection accuracy was less impaired during the investment task because it is higher stakes relative to the opinion task and the observed accuracy differences might reflect titration of performance as a function of contextual salience.

While on average, the socioemotional regulatory benefits of the positivity effect are likely to outweigh the seemingly modest impairments in lie detection accuracy, the consequences of some scams have proven to be catastrophic for OA who experience financial loss later in life when they might have less time, energy, or resources to start over (Lichtenberg & Paulson, 2013; Spreng, Karlawish, & Marson, 2016; Percy, 1983). This work is important because it exposes a potential mechanism for OA vulnerability to exploitation, and has potential implications for developing protective interventions down the road. Helping to protect older members of our community is both an explicit cultural value, and government aim, especially as the OA population in the United States continues to rapidly expand.

In sum, this work has corroborated previous findings as well as extended our present understanding of how the positivity bias might operate when judging deception, thus achieving the aim of this study to enhance understanding of how neurocognitive processes that inform judgments of honesty and deception might change over the lifespan.

Table 1a: Opinion Task Model Effects Predicting Accuracy from Age and Presence of Positive Cues

Parameter	Wald Chi-Square	df	Sig.
Age Group	2.89	1	0.09
Positive Cues	10.96	1	0.00
Stimuli Imbalance	2.39	1	0.12
Positive Cues * Stimuli Imbalance	11.62	1	0.00
Age Group * Stimuli Imbalance	2.57	1	0.11
Age Group * Positive Cues	7.25	1	0.01

Note: Binary Logistic Regression Model using Generalized Estimating Equations. Model includes Intercept, Age Group, Positive Cues, Stimuli Imbalance, Positive Cues * Stimuli Imbalance, Age Group * Stimuli Imbalance, Age Group * Positive Cues. Accuracy is the dependent variable (0 = wrong, 1 = correct), with wrong responses modeled as the reference category; redundant parameters have been omitted.

Table 1b: Opinion Task Parameter Estimates Predicting Accuracy from Age and Presence of Positive Cues

Parameter	B	Std. Error	Wald Chi-Square	df	Sig.	Exp(B)	95% CI Lower	Upper
(Intercept)	1.98	1.11	3.19	1	0.07	7.24	0.82	63.59
OA	-1.92	1.13	2.89	1	0.09	0.15	0.02	1.34
Positive Cues	-0.10	0.03	9.65	1	0.00	0.90	0.85	0.96
Stimuli Imbalance	-1.72	1.08	2.54	1	0.11	0.18	0.02	1.49
Positive Cues * Stimuli Imbalance	0.11	0.03	11.62	1	0.00	1.12	1.05	1.19
OA * Stimuli Imbalance	1.76	1.10	2.57	1	0.11	5.79	0.68	49.57
OA * Positive Cues	-0.02	0.01	7.25	1	0.01	0.98	0.97	1.00

Note: Binary Logistic Regression Model using Generalized Estimating Equations. Model includes Intercept, Age Group, Positive Cues, Stimuli Imbalance, Positive Cues * Stimuli Imbalance, Age Group * Stimuli Imbalance, Age Group * Positive Cues. Accuracy is the dependent variable (0 = wrong, 1 = correct), with wrong responses modeled as the reference category; redundant parameters have been omitted. Exponentiated beta represents odds ratio.

Table 1c: Opinion Task Marginal Means Predicting Accuracy from Age and Presence of Positive Cues

Age Group	Mean	Std. Error	95% CI Lower	Upper
OA	.52	.023	.48	.57
YA	.56	.119	.33	.77

Note: Covariates appearing in the model are fixed at the following values: Positive Cues = 1.99;
Stimuli Imbalance = 1.02.

Table 2a: Opinion Task Model Effects Predicting Subject Response from Age and Presence of Positive Cues

Parameter	Wald Chi-Square	df	Sig.
Age Group	1.35	1	0.25
Positive Cues	7.25	1	0.01
Stimuli Imbalance	6.44	1	0.01
Positive Cues * Stimuli Imbalance	6.75	1	0.01
Age Group * Stimuli Imbalance	1.37	1	0.24
Age Group * Positive Cues	7.59	1	0.01

Note: Binary Logistic Regression Model using Generalized Estimating Equations. Model includes Intercept, Age Group, Positive Cues, Stimuli Imbalance, Positive Cues * Stimuli Imbalance, Age Group * Stimuli Imbalance, Age Group * Positive Cues. Subject Response is the dependent variable (0 = truth, 1 = lie), with truth responses modeled as the reference category; redundant parameters have been omitted.

Table 2b: Opinion Task Parameter Estimates Predicting Subject Response from Age and Presence of Positive Cues

Parameter	B	Std. Error	Wald Chi-Square	df	Sig.	Exp(B)	95% CI Lower	Upper
(Intercept)	-1.74	1.10	2.51	1	0.11	0.18	0.02	1.51
OA	1.40	1.20	1.35	1	0.25	4.05	0.38	42.83
Positive Cues	0.08	0.03	5.96	1	0.02	1.08	1.02	1.16
Stimuli Imbalance	2.18	1.05	4.28	1	0.04	8.87	1.12	70.11
Positive Cues * Stimuli Imbalance	-0.08	0.03	6.75	1	0.01	0.92	0.86	0.98
OA * Stimuli Imbalance	-1.34	1.14	1.37	1	0.24	0.26	0.03	2.46
OA * Positive Cues	0.02	0.01	7.59	1	0.01	1.02	1.01	1.04

Note: Binary Logistic Regression Model using Generalized Estimating Equations. Model includes Intercept, Age Group, Positive Cues, Stimuli Imbalance, Positive Cues * Stimuli Imbalance, Age Group * Stimuli Imbalance, Age Group * Positive Cues. Subject Response is the dependent variable (0 = truth, 1 = lie), with truth responses modeled as the reference category; redundant parameters have been omitted. Exponentiated beta represents odds ratio.

Table 2c: Opinion Task Marginal Means Predicting Subject Response from Age and Presence of Positive Cues

Age Group	Mean	Std. Error	95% CI Lower	Upper
OA	.63	.04	.56	.70
YA	.63	.14	.34	.83

Note: Covariates appearing in the model are fixed at the following values: Positive Cues = 1.99; Stimuli Imbalance = 1.02.

Table 3a: Investment Task Model Effects Predicting Accuracy from Age and Presence of Positive Cues

Parameter	Wald Chi-Square	df	Sig.
Age Group	2.47	1	0.12
Positive Cues	1.75	1	0.19
Stimuli Imbalance	0.14	1	0.71
Positive Cues * Stimuli Imbalance	2.16	1	0.14
Age Group * Stimuli Imbalance	2.65	1	0.10
Age Group * Positive Cues	0.71	1	0.40

Note: Binary Logistic Regression Model using Generalized Estimating Equations. Model includes Intercept, Age Group, Positive Cues, Stimuli Imbalance, Positive Cues * Stimuli Imbalance, Age Group * Stimuli Imbalance, Age Group * Positive Cues. Accuracy is the dependent variable (0 = wrong, 1 = correct), with wrong responses modeled as the reference category; redundant parameters have been omitted.

Table 3b: Investment Task Parameter Estimates Predicting Accuracy from Age and Presence of Positive Cues

Parameter	B	Std. Error	Wald Chi-Square	df	Sig.	Exp(B)	95% CI	
							Lower	Upper
(Intercept)	-0.50	0.87	0.33	1	0.57	0.61	0.11	3.34
OA	1.45	0.92	2.47	1	0.12	4.25	0.70	25.76
Positive Cues	-0.24	0.20	1.36	1	0.24	0.79	0.53	1.17
Stimuli Imbalance	0.40	0.66	0.37	1	0.54	1.50	0.41	5.51
Positive Cues * Stimuli Imbalance	0.22	0.15	2.16	1	0.14	1.24	0.93	1.65
OA * Stimuli Imbalance	-1.14	0.70	2.65	1	0.10	0.32	0.08	1.26
OA * Positive Cues	-0.05	0.06	0.71	1	0.40	0.95	0.84	1.07

Note: Binary Logistic Regression Model using Generalized Estimating Equations. Model includes Intercept, Age Group, Positive Cues, Stimuli Imbalance, Positive Cues * Stimuli Imbalance, Age Group * Stimuli Imbalance, Age Group * Positive Cues. Accuracy is the dependent variable (0 = wrong, 1 = correct), with wrong responses modeled as the reference category; redundant parameters have been omitted. Exponentiated beta represents odds ratio.

Table 3c: Investment Task Marginal Means Predicting Accuracy from Age and Presence of Positive Cues

Age Group	Mean	Std. Error	95% CI Lower	Upper
OA	.49	.06	.37	.61
YA	.51	.09	.35	.72

Note: Covariates appearing in the model are fixed at the following values: Positive Cues = 2.35;
Stimuli Imbalance = 1.33.

Table 4a: Investment Task Model Effects Predicting Subject Response from Age and Presence of Positive Cues

Parameter	Wald Chi-Square	df	Sig.
Age Group	0.20	1	0.65
Positive Cues	0.47	1	0.50
Stimuli Imbalance	0.50	1	0.48
Positive Cues * Stimuli Imbalance	0.49	1	0.49
Age Group * Stimuli Imbalance	0.27	1	0.60
Age Group * Positive Cues	0.02	1	0.89

Note: Binary Logistic Regression Model using Generalized Estimating Equations. Model includes Intercept, Age Group, Positive Cues, Stimuli Imbalance, Positive Cues * Stimuli Imbalance, Age Group * Stimuli Imbalance, Age Group * Positive Cues. Subject Response is the dependent variable (0 = truth, 1 = lie), with truth responses modeled as the reference category; redundant parameters have been omitted.

Table 4b: Investment Task Parameter Estimates Predicting Subject Response from Age and Presence of Positive Cues

Parameter	B	Std. Error	Wald Chi-Square	df	Sig.	Exp(B)	95% CI Lower	Upper
(Intercept)	-0.77	1.20	0.41	1	0.52	0.46	0.04	4.86
OA	0.72	1.62	0.20	1	0.65	2.06	0.09	49.17
Positive Cues	0.18	0.26	0.47	1	0.49	1.19	0.72	1.97
Stimuli Imbalance	0.81	0.94	0.75	1	0.39	2.25	0.36	14.08
Positive Cues * Stimuli Imbalance	-0.13	0.19	0.49	1	0.49	0.88	0.60	1.27
OA * Stimuli Imbalance	-0.62	1.18	0.27	1	0.60	0.54	0.05	5.44
OA * Positive Cues	-0.01	0.06	0.02	1	0.89	0.99	0.88	1.12

Note: Binary Logistic Regression Model using Generalized Estimating Equations. Model includes Intercept, Age Group, Positive Cues, Stimuli Imbalance, Positive Cues * Stimuli Imbalance, Age Group * Stimuli Imbalance, Age Group * Positive Cues. Subject Response is the dependent variable (0 = truth, 1 = lie), with truth responses modeled as the reference category; redundant parameters have been omitted. Exponentiated beta represents odds ratio.

Table 4c: Investment Task Marginal Means Predicting Subject Response from Age and Presence of Positive Cues

Age Group	Mean	Std. Error	95% CI Lower	Upper
OA	0.55	0.08	0.39	0.70
YA	0.58	0.18	0.24	0.85

Note: Covariates appearing in the model are fixed at the following values: Positive Cues = 2.35;
Stimuli Imbalance = 1.33.

Table 5: Accuracy Summary Table: Opinion Task

Age	M/SD	Hit Rate	False Alarm Rate	Proportion of Trust Judgments	Proportion of Lie Judgments	d'	C
YA	M	45.63%	32.43%	84.87%	54.42%	0.36	-0.30
	SD	15.23%	11.92%	16.40%	16.70%	0.38	0.35
OA	M	38.30%	33.89%	89.26%	50.29%	0.14	-0.46
	SD	12.63%	14.91%	18.36%	18.18%	0.30	0.66

Note: 50% represents chance accuracy. *C* and *d'* do not have easily interpretable units, however they do have interpretable signs. For *d'* positive values indicate higher than chance accuracy, negative values represent lower than chance accuracy, zero represents chance accuracy. For *C* positive values represent a 'lie bias' such that, all else being equal, the predicted response would be 'lie.' Negative values of *C* represent a 'truth bias' such that, all else being equal, the predicted response would be 'truth.' A zero value of *C* represents no response bias.

Table 6: Accuracy Summary Table: Investment Task

Age	M/SD	Hit Rate	False Alarm Rate	Proportion of Trust Judgments	Proportion of Lie Judgments	d'	C
YA	M	45.75%	40.62%	57.31%	42.69%	0.19	-0.22
	SD	16.49%	13.63%	11.65%	11.65%	0.59	0.48
OA	M	42.17%	45.52%	55.82%	44.18%	-0.09	-0.09
	SD	23.30%	19.42%	18.81%	18.81%	0.54	0.81

Note: 50% represents chance accuracy. *C* and *d'* do not have easily interpretable units, however they do have interpretable signs. For *d'* positive values indicate higher than chance accuracy, negative values represent lower than chance accuracy, zero represents chance accuracy. For *C* positive values represent a 'lie bias' such that, all else being equal, the predicted response would be 'lie.' Negative values of *C* represent a 'truth bias' such that, all else being equal, the predicted response would be 'truth.' A zero value of *C* represents no response bias.

Footnotes

[1] The features of both deception tasks were manipulated to create the comparative experience of a ‘high-stakes’ vs. ‘low-stakes’ deception detection task based on previous research documenting salient task features applied here (Hartwig & Bond, 2011; Shaw & Lyons, 2016; Wright Whelan, Wagstaff, & Wheatcroft, 2015). Manipulated features for ‘high-stakes’ context include:

1. Use of real social interactions. This increases occurrence of naturalistic cues to deception and creates a more engaging task for participants.

2. Personal relevance. Each subject was actively playing along with the investment task during participation. This was designed to create an enhanced sense of involvement with the task an enhanced sense of involvement with the task. Participants were told one of their decisions would be randomly implemented at the end of the task, and if they were accurate on the selected trial they would receive a $50 bonus just like the video taped participants had.

3. Use of a large monetary bonus. Even if $50 did not represent a lot of money to our participants, it is uncommonly large as compared to other psychology studies, so hopefully, receiving a larger-than-anticipated bonus would foster a sense of personal stake involved even if they did not need the money. The bonus was distributed according #2 above. (Note: this was on top of a $100 participation payment)

Figure 1.

fMRI Task Experimental Design

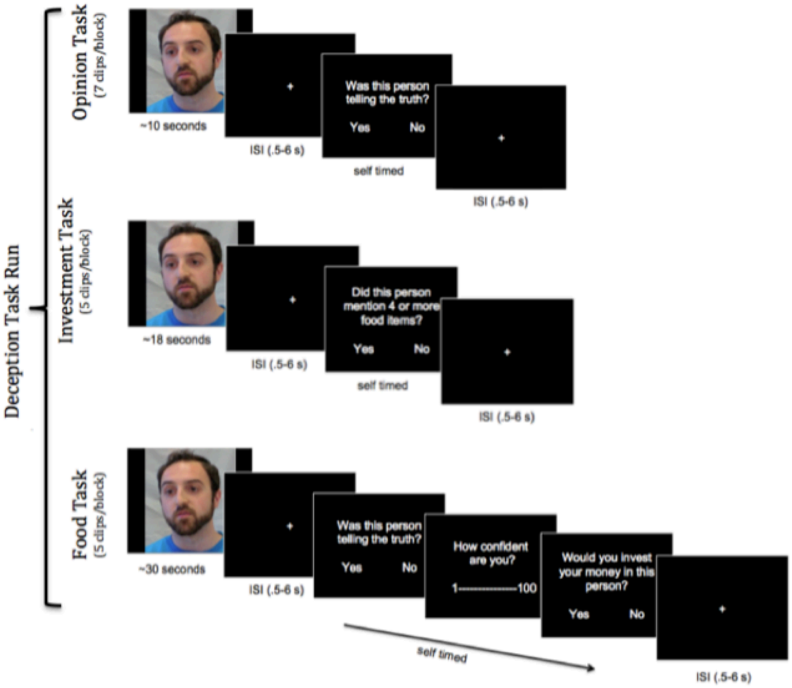
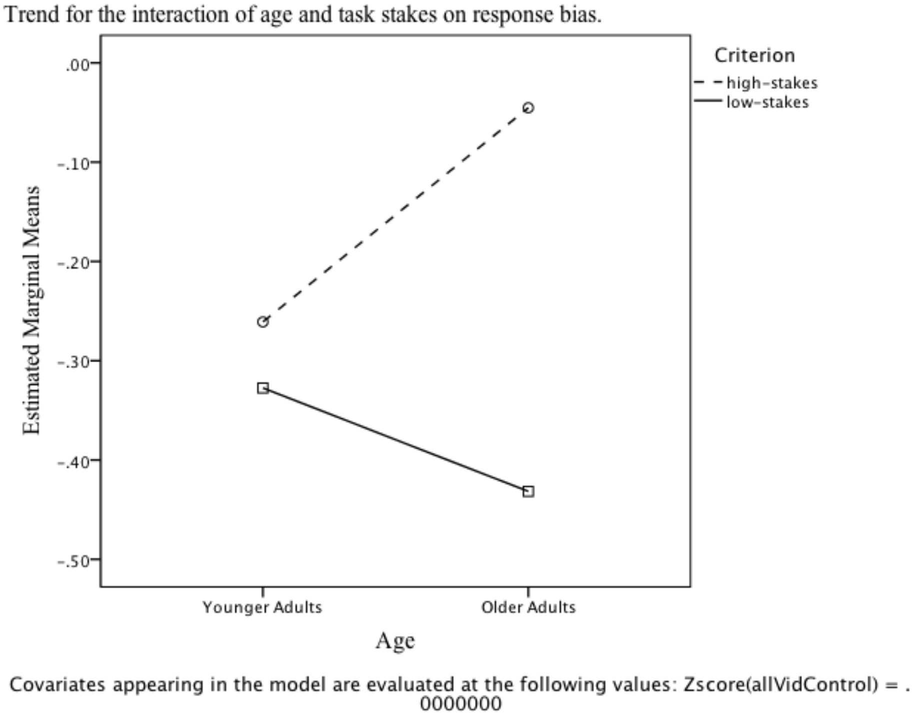


Figure 2a.

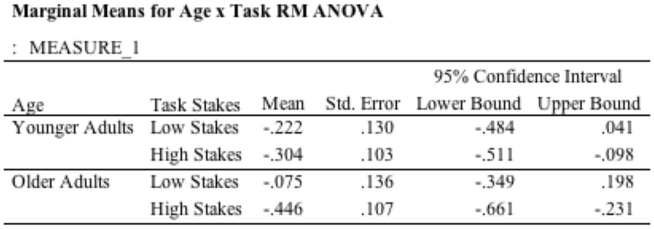
Trend for an interaction of the effects of age and task on response bias (*C)*



Covariates appearing in the model are evaluated at the following values: Zscore(allVidControl) = .0000000

Figure 2b.

Marginal Means for age by task repeated measures ANOVA with *C* as the dependent variable.



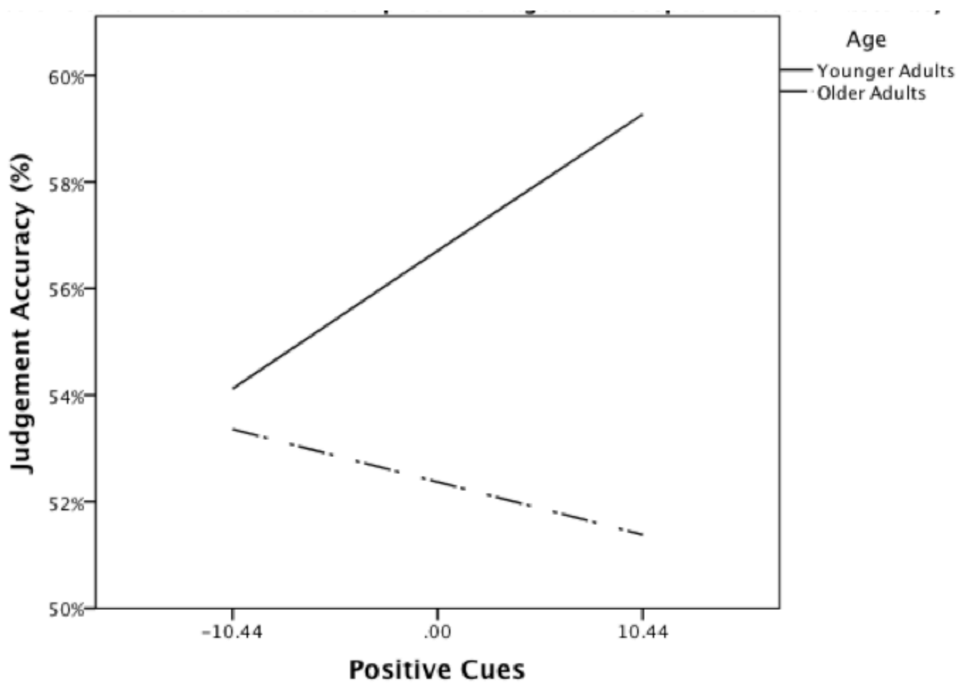
Marginal Means for Age x Task RM ANOVA

: MEASURE_1

Age	Task Stakes	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Younger Adults	Low Stakes	-.222	.130	-.484	.041
	High Stakes	-.304	.103	-.511	-.098
Older Adults	Low Stakes	-.075	.136	-.349	.198
	High Stakes	-.446	.107	-.661	-.231

Figure 3.

Binary Logistic Generalized Estimating Equations Model. Interaction between age group and positive cues predicts trial-by-trial accuracy.



References

Adolphs, R. (2002). Neural systems for recognizing emotion. *Current Opinion in Neurobiology*, *12*(2), 169–177. https://doi.org/10.1016/S0959-4388(02)00301-X

Albers, H. E. (2012). The regulation of social recognition, social communication and aggression: Vasopressin in the social behavior neural network. *Hormones and Behavior*, *61*(3), 283–292. https://doi.org/10.1016/j.yhbeh.2011.10.007

Baribeau, D. A., & Anagnostou, E. (2015). Oxytocin and vasopressin: Linking pituitary neuropeptides and their receptors to social neurocircuits. *Frontiers in Neuroscience*, *9*(SEP). https://doi.org/10.3389/fnins.2015.00335

Barraza, J. A., McCullough, M. E., Ahmadi, S., & Zak, P. J. (2011). Oxytocin infusion increases charitable donations regardless of monetary resources. *Hormones and Behavior*, *60*(2), 148–151. https://doi.org/10.1016/j.yhbeh.2011.04.008

Bartz, J. A., Zaki, J., Bolger, N., & Ochsner, K. N. (2011). Social effects of oxytocin in humans: Context and person matter. *Trends in Cognitive Sciences*, *15*(7), 301–309. https://doi.org/10.1016/j.tics.2011.05.002

Bester-Meredith, J. K., Fancher, A. P., & Mammarella, G. E. (2015). Vasopressin proves es-sense-tial: Vasopressin and the modulation of sensory processing in mammals. *Frontiers in Endocrinology*, *6*(FEB), 1–12. https://doi.org/10.3389/fendo.2015.00005

Bickart, K. C., Dickerson, B. C., Barrett, L. F., States, U., States, U., Unit, D., … States, U. (2014). The amygdala as a hub in brain networks that support social life. *Neuropsychologia*, 235–248. https://doi.org/10.1016/j.neuropsychologia.2014.08.013.The

Bielsky, I. F., Hu, S. B., Ren, X., Terwilliger, E. F., & Young, L. J. (2005). The V1a vasopressin receptor is necessary and sufficient for normal social recognition: A gene replacement study. *Neuron*, *47*(4), 503–513. https://doi.org/10.1016/j.neuron.2005.06.031

Birren, J. E. (1961). A Brief History of the Psychology of Aging. *The Gerontologist*, *1*(2), 69–77. https://doi.org/10.1093/geront/1.2.69

Bond, C. F., & Depaulo, B. M. (2006). Personality and Social Psychology Review. *Personal and Social Psychology Review*, *10*(214), 214–234. https://doi.org/10.1207/s15327957pspr1003

Bond, C. F., & Depaulo, B. M. (2008). Individual differences in judging deception: accuracy and bias. *Psychological Bulletin*, *134*(4), 477–492. https://doi.org/10.1037/0033-2909.134.4.477

Bond, C. F., & DePaulo, B. M. (2006). Accuracy of deception judgments. *Personality and Social Psychology Review : An Official Journal of the Society for Personality and Social Psychology, Inc*, *10*(3), 214–234. https://doi.org/10.1207/s15327957pspr1003_2

Bond, G. D., Thompson, L. a, & Malloy, D. M. (2005). Vulnerability of older adults to deception in prison and nonprison contexts. *Psychology and Aging*, *20*(1), 60–70. https://doi.org/10.1037/0882-7974.20.1.60

Bos, P. A., Panksepp, J., Bluthe, R. M., & Honk, J. van. (2012). Acute effects of steroid hormones and neuropeptides on human social-emotional behavior: A review of single administration studies. *Frontiers in Neuroendocrinology*, *33*(1), 17–35. https://doi.org/10.1016/j.yfrne.2011.01.002

Cacioppo, J. T., Berntson, G. G., Bechara, A., Tranel, D., & Hawkley, L. C. (2011). Could an Aging Brain Contribute to Subjective Well-Being?: The Value Added by a Social Neuroscience Perspective. In *Social Neuroscience: Toward Understanding the Underpinnings of the Social Mind*. https://doi.org/10.1093/acprof:oso/9780195316872.003.0017

Caffrey, M. K., Nephew, B. C., & Febo, M. (2010). Central vasopressin V1a receptors modulate neural processing in mothers facing intruder threat to pups. *Neuropharmacology*, *58*(1), 107–116. https://doi.org/10.1016/j.neuropharm.2009.06.023

Caldwell, H., & Iii, W. Y. (2006). Oxytocin and Vasopressin: Genetics and Behavioral Implications. *Handbook of Neurochemistry and Molecular Neurobiology*, 573–607. https://doi.org/10.1007/978-0-387-30381-9_25

Cardoso, C., Ellenbogen, M. A., Serravalle, L., & Linnen, A. M. (2013). Stress-induced negative mood moderates the relation between oxytocin administration and trust: Evidence for the tend-and-befriend response to stress? *Psychoneuroendocrinology*, *38*(11), 2800–2804. https://doi.org/10.1016/j.psyneuen.2013.05.006

Carstensen, L. L. (2006). The Influence of a Sense of Time on Human Development. *Science*, *312*(June), 1913–1916. https://doi.org/10.1126/science.1127488

Castle, E., Eisenberger, N. I., Seeman, T. E., Moons, W. G., Boggero, I. a, Grinblatt, M. S., & Taylor, S. E. (2012). Neural and behavioral bases of age differences in perceptions of trust. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(51), 20848–52. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3529090&tool=pmcentrez&rendertype=abstract

Chen, X., Hackett, P. D., DeMarco, A. C., Feng, C., Stair, S., Haroon, E., … Rilling, J. K. (2016). Effects of oxytocin and vasopressin on the neural response to unreciprocated cooperation within brain regions involved in stress and anxiety in men and women. *Brain Imaging and Behavior*, *10*(2), 581–593. https://doi.org/10.1007/s11682-015-9411-7

Chung, C. K., & Pennebaker, J. W. (2012). Linguistic Inquiry and Word Count (LIWC). *Applied Natural Language Processing*, (2015), 206–229. https://doi.org/10.4018/978-1-60960-741-

8.ch012

Critchley, H. D. (2009). Psychophysiology of neural, cognitive and affective integration: fMRI and autonomic indicants. *International Journal of Psychophysiology*, *73*(2), 88–94. https://doi.org/10.1016/j.ijpsycho.2009.01.012

De Dreu, C. K. W. (2012). Oxytocin modulates cooperation within and competition between groups: An integrative review and research agenda. *Hormones and Behavior*, *61*(3), 419–428. https://doi.org/10.1016/j.yhbeh.2011.12.009

De Dreu, C. K. W., Greer, L. L., Handgraaf, M. J. J., Shalvi, S., Van Kleef, G. A., Baas, M., … Feith, S. W. W. (2010). The Neuropeptide Oxytocin Regulates Parochial Altruism in Intergroup Conflict Among Humans. *Science*, *328*(5984), 1408–1411. https://doi.org/10.1126/science.1189047

Demeyer, I., & De Raedt, R. (2013). Attentional Bias for Emotional Information in Older Adults: The Role of Emotion and Future Time Perspective. *PLoS ONE*, *8*(6). https://doi.org/10.1371/journal.pone.0065429

Dennis, N. A., & Cabeza, R. (2008). Neuroimaging of healthy cognitive aging. *The Handbook of Aging and Cognition*, (November), 1–54. https://doi.org/10.1073/pnas.0703993104

DePaulo, B. M., Lindsay, J. J., Malone, B. E., Muhlenbruck, L., Charlton, K., & Cooper, H. (2003). Cues to deception. *Psychological Bulletin*, *129*(1), 74–118. https://doi.org/10.1037//0033-2909.129.1.74

Di Domenico, A., Palumbo, R., Mammarella, N., & Fairfield, B. (2015). Aging and emotional expressions: Is there a positivity bias during dynamic emotion recognition? *Frontiers in Psychology*, *6*(AUG), 1–5. https://doi.org/10.3389/fpsyg.2015.01130

Domes, G., Sibold, M., Schulze, L., Lischke, a, Herpertz, S. C., & Heinrichs, M. (2013).

Intranasal oxytocin increases covert attention to positive social cues. *Psychological Medicine*, *43*(8), 1747–53. https://doi.org/10.1017/S0033291712002565

Ebitz, R. B., Watson, K. K., & Platt, M. L. (2013). Oxytocin blunts social vigilance in the rhesus macaque. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(28), 11630–5. https://doi.org/10.1073/pnas.1305230110

English, T., & Carstensen, L. L. (2015). Does positivity operate when the stakes are high? Health status and decision making among older adults. *Psychology and Aging*, *30*(2), 348–355. https://doi.org/10.1037/a0039121

Feifel, D. (2012). Oxytocin as a Potential Therapeutic Target for Schizophrenia and Other Neuropsychiatric Conditions. *Neuropsychopharmacology Reviews*, *37*(1), 304–305. https://doi.org/10.1038/npp.2011.184

Fischer-Shofty, M., Levkovitz, Y., & Shamay-Tsoory, S. G. (2013). Oxytocin facilitates accurate perception of competition in men and kinship in women. *Social Cognitive and Affective Neuroscience*, *8*(3), 313–317. https://doi.org/10.1093/scan/nsr100

Gamer, M., Zurowski, B., & Büchel, C. (2010). Different amygdala subregions mediate valence-related and attentional effects of oxytocin in humans. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(20), 9400–5. https://doi.org/10.1073/pnas.1000985107

Ghisletta, P., & Spini, D. (2004). An Introduction to Generalized Estimating Equations and an Application to Assess Selectivity Effects in a Longitudinal Study on Very Old Individuals. *Journal of Educational and Behavioral Statistics*, *29*(4), 421–437. https://doi.org/10.3102/10769986029004421

Grady, C. L. (2008). Cognitive neuroscience of aging. *Annals of the New York Academy of*

Sciences, *1124*, 127–144. https://doi.org/10.1196/annals.1440.009

Graustella, A. J., & MacLeod, C. (2012). A critical review of the influence of oxytocin nasal spray on social cognition in humans: Evidence and future directions. *Hormones and Behavior*, *61*(3), 410–418. https://doi.org/10.1016/j.yhbeh.2012.01.002

Groppe, S. E., Gossen, A., Rademacher, L., Hahn, A., Westphal, L., Gründer, G., & Spreckelmeyer, K. N. (2013). Oxytocin influences processing of socially relevant cues in the ventral tegmental area of the human brain. *Biological Psychiatry*, *74*(3), 172–179. https://doi.org/10.1016/j.biopsych.2012.12.023

Hartwig, M., & Bond, C. F. (2011). Why do lie-catchers fail? A lens model meta-analysis of human lie judgments. *Psychological Bulletin*, *137*(4), 643–659. https://doi.org/10.1037/a0023589

Hauch, V., Blandón-Gitlin, I., Masip, J., & Sporer, S. L. (2012). Linguistic cues to deception assessed by computer programs: A meta-analysis. *Proceedings of the EACL 2012 Workshop on Computational Approaches to Deception Detection*, 1–4.

Heinrichs, M., von Dawans, B., & Domes, G. (2009). Oxytocin, vasopressin, and human social behavior. *Frontiers in Neuroendocrinology*, *30*(4), 548–557. https://doi.org/10.1016/j.yfrne.2009.05.005

Heinrichs, M., Von Dawans, B., & Domes, G. (2009). Oxytocin, vasopressin, and human social behavior, *30*(4), 548–557.

Iidaka, T., Okada, T., Murata, T., Omori, M., Kosaka, H., Sadato, N., & Yonekura, Y. (2002). Age-related differences in the medial temporal lobe responses to emotional faces as revealed by fMRI. *Hippocampus*, *12*(3), 352–362. https://doi.org/10.1002/hipo.1113

Israel, S., Hart, E., & Winter, E. (2014). Oxytocin decreases accuracy in the perception of social deception. *Psychological Science*, *25*(1), 293–5. https://doi.org/10.1177/0956797613500794

Kalenzaga, S., Lamidey, V., Ergis, A., Clarys, D., & Piolino, P. (2016). The Positivity Bias in Aging : Motivation or Degradation ? *Emotion*, *16*(5), 602–610. https://doi.org/10.1037/emo0000170

Keightley, M. L., Chiew, K. S., Winocur, G., & Grady, C. L. (2007). Age-related differences in brain activity underlying identification of emotional expressions in faces. *Social Cognitive and Affective Neuroscience*, *2*(4), 292–302. https://doi.org/10.1093/scan/nsm024

Kéri, S., & Benedek, G. (2009). Oxytocin enhances the perception of biological motion in humans. *Cognitive, Affective & Behavioral Neuroscience*, *9*(3), 237–41. https://doi.org/10.3758/CABN.9.3.237

Kosfeld, M., Heinrichs, M., Zak, P. J., Fischbacher, U., & Fehr, E. (2005). Oxytocin increases trust in humans. *Nature*, *435*(7042), 673–677. https://doi.org/10.1038/nature03701

Kubzansky, L. D., Mendes, W. B., Appleton, A. A., Block, J., & Adler, G. K. (2012). A heartfelt response: Oxytocin effects on response to social stress in men and women. *Biological Psychology*, *90*(1), 1–9. https://doi.org/10.1016/j.biopsycho.2012.02.010

Levine, T. R., Park, H. S., & McCornack, S. a. (1999). Accuracy in detecting truths and lies: Documenting the “veracity effect.” *Communication Monographs*, *66*(2), 125–144. https://doi.org/10.1080/03637759909376468

Lichtenberg, P. A., & Paulson, D. (2013). Is Psychological Vulnerability Related to the Experience of, *36*(2), 1–13. https://doi.org/10.1080/07317115.2012.749323.Is

Lim, K. T. K., & Yu, R. (2015). Aging and wisdom: Age-related changes in economic and social decision making. *Frontiers in Aging Neuroscience*, *7*(JUN), 1–11. https://doi.org/10.3389/fnagi.2015.00120

Löckenhoff, C. E., & Carstensen, L. L. (2007). Aging, emotion, and health-related decision strategies: motivational manipulations can reduce age differences. *Psychology and Aging*, *22*(1), 134–46. https://doi.org/10.1037/0882-7974.22.1.134

Macmillan, N. A. (2004). *Detection theory: A user's guide*.

Macmillan, N. a, & Creelman, C. D. (2005). *Detection Theory: A User's Guide*. *Detection theory: A user's guide (2nd ed.)*. https://doi.org/10.1017/CBO9781107415324.004

Mather, M., & Carstensen, L. L. (2003). Aging and attentional biases for emotional faces. *Psychological Science*, *14*(5), 409–415. https://doi.org/10.1111/1467-9280.01455

Mather, M., & Knight, M. (2005). Goal-directed memory: the role of cognitive control in older adults' emotional memory. *Psychology and Aging*, *20*(4), 554–570. https://doi.org/10.1037/0882-7974.20.4.554

Mather, M., & Knight, M. R. (2006). Angry faces get noticed quickly: threat detection is not impaired among older adults. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences*, *61*(1), P54-57. https://doi.org/61/1/P54 [pii]

McDowell, I. (2006). The State-Trait Anxiety Inventory. *Measuring Health: A Guide to Rating Scales and Questionnaires*, (1).

McEwen, B. B. (2004). Brain–Fluid Barriers: Relevance for Theoretical Controversies Regarding Vasopressin and Oxytocin Memory Research. *Advances in Pharmacology*, *50*, 531–592. https://doi.org/10.1016/S1054-3589(04)50014-5

Meissner, C. A., & Kassin, S. M. (2002). " He's guilty !": Investigator Bias in Judgments of Truth and Deception 1, *26*(5).

Meyer-Lindenberg, A., Domes, G., Kirsch, P., & Heinrichs, M. (2011). Oxytocin and vasopressin in the human brain: social neuropeptides for translational medicine. *Nature*

Reviews. Neuroscience, *12*(9), 524–538. https://doi.org/10.1038/nrn3044

Mooney, C., Duval, R., & Duvall, R. (1993). *Bootstrapping: A nonparametric approach to statistical inference*. Retrieved from https://books.google.com/books?hl=en&lr=&id=ZxaRC4I2z6sC&oi=fnd&pg=PR4&dq=why+bootstrapping&ots=oPp3HvbUnE&sig=zhKuwpymuuuu26aY0wtGLBp_Xm4

Motoki, K., Sugiura, M., Takeuchi, H., Kotozaki, Y., Nakagawa, S., Yokoyama, R., & Kawashima, R. (2016). Are plasma oxytocin and vasopressin levels reflective of amygdala activation during the processing of negative emotions? A preliminary study. *Frontiers in Psychology*, *7*(APR), 1–9. https://doi.org/10.3389/fpsyg.2016.00480

Mumford, J. A., & Nichols, T. (2006). Modeling and inference of multisubject fMRI data. *IEEE Engineering in Medicine and Biology Magazine*, *25*(2), 42–51. https://doi.org/10.1109/MEMB.2006.1607668

Nave, G., Camerer, C., & McCullough, M. (2015). Does Oxytocin Increase Trust in Humans? A Critical Review of Research. *Perspectives on Psychological Science*, *10*(6), 772–789. https://doi.org/10.1177/1745691615600138

Nevin, J. a. (1969). Signal detection theory and operant behavior: A review of David M. Green and John A. Swets' signal detection and psychophysics. *Journal of the Experimental Analysis of Behavior*, *12*(3), 475–480. https://doi.org/10.1901/jeab.1969.12-475

Peng, C.-Y. J., & So, T.-S. H. (2002). Logistic Rrgression Analysis and Reporting: A Primer. *Understanding Statistics*.

Percy, C. H. (1983). Consumer Fruads and Elderly persons: A Growing Problem Specail Committee on Aging United States Senate.

Peterson, J. C., Burnes, D. P. R., Caccamise, P. L., Mason, A., Henderson, C. R., Wells, M. T., Lachs, M. S. (2014). Financial Exploitation of Older Adults: A Population-Based Prevalence Study. *Journal of General Internal Medicine*, *29*(12), 1615–1623. https://doi.org/10.1007/s11606-014-2946-2

Petrican, R., English, T., Gross, J. J., Grady, C., Hai, T., & Moscovitch, M. (2013). Friend or foe? Age moderates time-course specific responsiveness to trustworthiness cues. *Journals of Gerontology - Series B Psychological Sciences and Social Sciences*, *68*(2), 215–223. https://doi.org/10.1093/geronb/gbs064

Petrovic, P., Kalisch, R., Singer, T., & Dolan, R. J. (2008). Oxytocin Attenuates Affective Evaluations of Conditioned Faces and Amygdala Activity. *Journal of Neuroscience*, *28*(26), 6607–6615. https://doi.org/10.1523/JNEUROSCI.4572-07.2008

Phelps, E. A., & LeDoux, J. E. (2005). Contributions of the amygdala to emotion processing: From animal models to human behavior. *Neuron*, *48*(2), 175–187. https://doi.org/10.1016/j.neuron.2005.09.025

Reed, A. E., & Carstensen, L. L. (2012). The theory behind the age-related positivity effect. *Frontiers in Psychology*, *3*(SEP), 1–9. https://doi.org/10.3389/fpsyg.2012.00339

Reed, A. E., Chan, L., & Mikels, J. a. (2014). Meta-analysis of the age-related positivity effect: age differences in preferences for positive over negative information. *Psychology and Aging*, *29*(1), 1–15. https://doi.org/10.1037/a0035194

Riggio, R. E., & Friedman, H. S. (1983). Individual differences and cues to deception. *Journal of Personality and Social Psychology*, *45*(4), 899–915. https://doi.org/10.1037/0022-3514.45.4.899

Rilling, J. K., DeMarco, A. C., Hackett, P. D., Chen, X., Gautam, P., Stair, S., … Pagnoni, G. (2014). Sex differences in the neural and behavioral response to intranasal oxytocin and vasopressin during human social interaction. *Psychoneuroendocrinology*, *39*(1), 237–248. https://doi.org/10.1016/j.psyneuen.2013.09.022

Rose, J. D., & Moore, F. L. (2002). Behavioral neuroendocrinology of vasotocin and vasopressin and the sensorimotor processing hypothesis. *Frontiers in Neuroendocrinology*. https://doi.org/10.1016/S0091-3022(02)00004-3

Ross, M., Grossmann, I., & Schryer, E. (2014). Contrary to Psychological and Popular Opinion, There Is No Compelling Evidence That Older Adults Are Disproportionately Victimized by Consumer Fraud. *Perspectives on Psychological Science*, *9*(4), 427–442. https://doi.org/10.1177/1745691614535935

Ruffman, T., Murray, J., Halberstadt, J., & Vater, T. (2012). Age-related differences in deception. *Psychology and Aging*, *27*(3), 543–549. https://doi.org/10.1037/a0023380

Samanez-Larkin, G. R., & D'Esposito, M. (2008). Group comparisons: Imaging the aging brain. *Social Cognitive and Affective Neuroscience*, *3*(3), 290–297. https://doi.org/10.1093/scan/nsn029

Samanez-Larkin, G. R., Hollon, N. G., Carstensen, L. L., & Knutson, B. (2008). Individual differences in insular sensitivity during loss anticipation predict avoidance learning. *Psychological Science*, *19*(4), 320–3. https://doi.org/10.1111/j.1467-9280.2008.02087.x

Samanez-Larkin, G. R., & Knutson, B. (2015). Decision making in the ageing brain: changes in affective and motivational circuits. *Nature Reviews. Neuroscience*, *16*(5), 278–289. https://doi.org/10.1038/nrn3917

Seltman, H. J. (2014). Chapter 15 Mixed Models. *Experimental Design And Analysis*, 357–378.

Shamay-Tsoory, S. G., & Abu-Akel, A. (2016). The Social Salience Hypothesis of Oxytocin. *Biological Psychiatry*, *79*(3), 194–202. https://doi.org/10.1016/j.biopsych.2015.07.020

Shaw, H., & Lyons, M. (2016). Lie Detection Accuracy—the Role of Age and the Use of Emotions as a Reliable Cue. *Journal of Police and Criminal Psychology*. https://doi.org/10.1007/s11896-016-9222-9

Singer, T., Critchley, H. D., & Preuschoff, K. (2009). A common role of insula in feelings, empathy and uncertainty. *Trends in Cognitive Sciences*, *13*(8), 334–340. https://doi.org/10.1016/j.tics.2009.05.001

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: applications to dementia and amnesia. *Journal of Experimental Psychology. General*, *117*(1), 34–50. https://doi.org/10.1037/0096-3445.117.1.34

Song, Z., McCann, K. E., McNeill, J. K., Larkin, T. E., Huhman, K. L., & Albers, H. E. (2014). Oxytocin induces social communication by activating arginine-vasopressin V1a receptors and not oxytocin receptors. *Psychoneuroendocrinology*, *50*, 14–19. https://doi.org/10.1016/j.psyneuen.2014.08.005

Sorkin, R. D. (1999). Spreadsheet signal detection. *Behav Res Methods Instrum Comput*, *31*(1), 46–54. https://doi.org/10.3758/BF03207691

Spreng, R. N., Karlawish, J., & Marson, D. C. (2016). Cognitive, social, and neural determinants of diminished decision-making and financial exploitation risk in aging and dementia: A review and new model. *Journal of Elder Abuse & Neglect*, *28*(4–5), 08946566.2016.1237918. https://doi.org/10.1080/08946566.2016.1237918

St. Jacques, P., Dolcos, F., & Cabeza, R. (2010). Effects of aging on functional connectivity of the amygdala during negative evaluation: A network analysis of fMRI data. *Neurobiology of Aging*, *31*(2), 315–327. https://doi.org/10.1016/j.neurobiolaging.2008.03.012

Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior*

Research Methods, Instruments, {&} Computers, *31*(1), 137–149. https://doi.org/10.3758/BF03207704

Stanley, J. T., & Blanchard-Fields, F. (2008). Challenges older adults face in detecting deceit: the role of emotion recognition. *Psychology and Aging*, *23*(1), 24–32. https://doi.org/10.1037/0882-7974.23.1.24

Sweeney, C. D., & Ceci, S. J. (2014). Deception detection, transmission, and modality in age and sex. *Frontiers in Psychology*, *5*(JUN), 1–10. https://doi.org/10.3389/fpsyg.2014.00590

Tabak, B. A., Meyer, M. L., Castle, E., Dutcher, J. M., Michael, R., Han, J. H., … Eisenberger, N. I. (2016). Warmth : a Randomized Controlled Trial, 253–261. https://doi.org/10.1016/j.psyneuen.2014.10.006.Vasopressin

Tabak, B. A., Meyer, M. L., Dutcher, J. M., Castle, E., Irwin, M. R., Lieberman, M. D., & Eisenberger, N. I. (2016). Oxytocin, but not vasopressin, impairs social cognitive ability among individuals with higher levels of social anxiety: A randomized controlled trial. *Social Cognitive and Affective Neuroscience*, *11*(8), 1272–1279. https://doi.org/10.1093/scan/nsw041

Tausczik, Y. R., & Pennebaker, J. W. (2010). The Psychological Meaning of Words: LIWC and Computerized Text Analysis Methods. *Journal of Language and Social Psychology*, *29*(1), 24–54. https://doi.org/10.1177/0261927X09351676

Taylor, S. E. (2006). Biobehavioral Bases of Affiliation Under Stress, *15*(6), 273–277.

Taylor, S. E., Klein, L. C., Lewis, B. P., Gruenewald, T. L., Gurung, R. a, & Updegraff, J. a. (2000). Biobehavioral responses to stress in females: tend-and-befriend, not fight-or-flight. *Psychological Review*, *107*(3), 411–429. https://doi.org/10.1037/0033-295X.107.3.411

Thompson, R., Gupta, S., Miller, K., Mills, S., & Orr, S. (2004). The effects of vasopressin on human facial responses related to social communication. *Psychoneuroendocrinology*, *29*(1), 35–48. https://doi.org/10.1016/S0306-4530(02)00133-6

Thompson, R. R., George, K., Walton, J. C., Orr, S. P., & Benson, J. (2006). Sex-specific influences of vasopressin on human social communication. *Proceedings of the National Academy of Sciences of the United States of America*, *103*(20), 7889–7894. https://doi.org/10.1073/pnas.0600406103

Uchino, B. N. (2006). Social support and health: A review of physiological processes potentially underlying links to disease outcomes. *Journal of Behavioral Medicine*, *29*(4), 377–387. https://doi.org/10.1007/s10865-006-9056-5

Unkelbach, C., Guastella, A. J., & Forgas, J. P. (2008). Oxytocin selectively facilitates recognition of positive sex and relationship words: Short report. *Psychological Science*, *19*(11), 1092–1094. https://doi.org/10.1111/j.1467-9280.2008.02206.x

Uzefovsky, F., Shalev, I., Israel, S., Knafo, A., & Ebstein, R. P. (2012). Vasopressin selectively impairs emotion recognition in men. *Psychoneuroendocrinology*, *37*(4), 576–580. https://doi.org/10.1016/j.psyneuen.2011.07.018

Wright Whelan, C., Wagstaff, G. F., & Wheatcroft, J. M. (2015). Subjective cues to deception/honesty in a high stakes situation: an exploratory approach. *The Journal of Psychology*, *149*(5), 517–534. https://doi.org/10.1080/00223980.2014.911140

Wudarczyk, O. a, Earp, B. D., Guastella, A., & Savulescu, J. (2013). Could intranasal oxytocin be used to enhance relationships? Research imperatives, clinical policy, and ethical considerations. *Current Opinion in Psychiatry*, *26*(5), 474–84. https://doi.org/10.1097/YCO.0b013e3283642e10

Young, L. J., & Flanagan, L. M. (2011). Editorial Comment: Oxytocin, Vasopressin, and Social

Behavior. *Biological Bulletin*, *221*(1), 18–34. https://doi.org/10.1038/jid.2014.371

Zebrowitz, L. A., Boshyan, J., Ward, N., Gutchess, A., & Hadjikhani, N. (2017). The Older Adult Positivity Effect in Evaluations of Trustworthiness: Emotion Regulation or Cognitive Capacity? *Plos One*, *12*(1), e0169823. https://doi.org/10.1371/journal.pone.0169823

Zink, C. F., & Meyer-Lindenberg, A. (2012). Human neuroimaging of oxytocin and vasopressin in social cognition. *Hormones and Behavior*, *61*(3), 400–409. https://doi.org/10.1016/j.yhbeh.2012.01.016

Zink, C. F., Stein, J. L., Kempf, L., Hakimi, S., & Meyer-, A. (2010). NIH Public Access, *30*(20), 7017–7022. https://doi.org/10.1523/JNEUROSCI.4899-09.2010.Vasopressin

Paper 3:

Vasopressin, but not Oxytocin, Increases Deception Detection Accuracy: A Randomized Controlled Trial

Elizabeth C. Castle, Shelley E. Taylor, Meghan L. Meyer, Janine M. Dutcher, Michael R. Irwin,

Matthew D. Lieberman, Naomi I. Eisenberger, and Benjamin A. Tabak

Abstract

Oxytocin and vasopressin are closely related neuropeptides that seem to play an important role in both biological homeostasis, as well as regulation of socioemotional states related to mammalian social behavior including pair bonding, social communication, parental care, and social aggression (Heinrichs, Von Dawans, & Domes, 2009). In both neuropeptides, animal models have been linked to preferential processing of salient social information, with oxytocin seeming to be particularly sensitive to affiliation, while vasopressin has more often been linked to competition, however, much remains unknown still about how these neuropeptides impact *human* social behavior (Bartz, Zaki, Bolger, & Ochsner, 2011; Zink, Stein, Kempf, Hakimi, & Meyer-Lindenberg, 2010). In light of these findings, the present study aims to characterize the effects of oxytocin and vasopressin on social cognitive *accuracy* using a competitive deception detection task. In a randomized, double blind, placebo controlled, between subjects study design, we examined the separate effects of oxytocin and vasopressin on deception detection accuracy and trust-related behavior. Results indicated that vasopressin, but not oxytocin, significantly increased deception detection accuracy when compared with placebo, and neither oxytocin nor vasopressin impacted trust-related behavior relative to placebo. To see whether there was any evidence that neuropeptides changed the way social information was used to identify deceit, naturally occurring cues to deception were behaviorally coded from the video stimuli and then regressed against accuracy within each drug condition. This revealed a significant relationship between vasopressin and effective utilization of certain deception cues, suggesting that this social regulation may be partially underpinned by enhanced sensitivity to certain social cues and that vasopressin's impact on social communication may extend to humans.

Oxytocin is an endogenous neuropeptide known for it's prominent role in mammalian social behavior. It is also responsible for capturing the imagination of the popular press in recent years with headlines like *Oxytocin: 'The Cuddle Chemical,'* ' *This is Your Brain on Love,'* and even *'Love/Hate Relationship? Oxytocin has a dark side…'* While these headlines seem excessively sensational, the public is not alone in their excitement. Over the past 10 years, scientists have studied exogenous intranasal oxytocin as a potential panacea for everything from schizophrenia (Feifel, 2012) to divorce (Wudarczyk, Earp, Guastella, & Savulescu, 2013). Fortunately, this fascination has created immense momentum to expand the research focus on this phylogenetically ancient neuropeptide hormone from primarily animal models to include investigation of its role in human social behavior. In fact, publications on 'oxytocin and social behavior' have more than doubled in the past decade and presently number in the thousands (NCBI PubMed results summary tool, 2017). This enthusiasm seems contagious, as evidenced by the recent boon to the popularity of the closely related neuropeptide hormone: vasopressin. While popular press coverage of vasopressin has been slightly less outlandish (notable exceptions include: *'Why Prairie Voles Fall in Love: A Chemical Romance'* and '*Hugs and Cuddles Have Long-Term Effects'*), like oxytocin, the majority of published work on vasopressin has focused on animal models so there is still much to be learned about how this may (or may not) translate to human behavior.

Oxytocin (OT) and arginine vasopressin (AVP) only differ in their chemical structure by two amino acids, and have both been shown to be involved in both social behavior and cognition including, pair bonding, parental care, and social aggression (Bos, Panksepp, Bluthe, & Honk, 2012; Heinrichs, von Dawans, & Domes, 2009). Both neuropeptides are produced in the hypothalamus and get released into the bloodstream by the pituitary glad where they act as peptide hormones in support of homeostatic functions like fluid retention (AVP), thermoregulation (AVP + OT), and childbirth (OT) (Caldwell & Iii, 2006). There is even some evidence that the neuropeptides might bond to both OT and AVP receptors in some cases (Song et al., 2014).

Given this recent explosion of research, it would be fair to assume we have a solid handle on how these critical neuropeptides influence social processes in humans, however this is far from the case. A variety of factors have influenced this including, complications associated with conducting drug studies in human populations (Bos et al., 2012), limitations on they types of conclusions that can be drawn from nonhuman animal - primarily rodent - models of social behavior and receptor location/density (Young & Flanagan, 2011), confusion surrounding appropriate interpretation of different measurement and administration strategies (e.g. unclear behavioral consequences of neuropeptide levels in plasma vs. central nervous system) (McEwen, 2004; Nave, Camerer, & McCullough, 2015), and highly context dependent findings that make generalization and replication difficult (Bartz et al., 2011). Luckily, the field has persisted and OT/AVP intranasal administration (IN) experiments are becoming more common, which has expanded our understanding of how these neuropeptides have causal impact on certain behaviors.

For example, one of the first major IN-OT studies was conducted by Kosfeild et al. (2005) and found that OT increased trust-related behavior when participant's played an economic game with another human, but not computer, interaction partner. This allowed the authors to conclude that OT enhanced trusting behavior specific to the context of a social interaction. This was an incredibly influential result that shaped the burgeoning field of OT research in humans by inspiring dozens of follow-up studies (with at least 6 attempts at fairly direct replication), and receiving over 2,000 citations in under 10 years. Regrettably, the vast majority of these studies did not show a significant effect of OT on trust-related behavior, a fact which has been formally corroborated by a recent meta-analysis (Nave et al., 2015). This issue is not specific to trust experiments however, Bartz et al. (2011) have noted that more than half of OT studies have failed to find a main effect of drug condition and this has likely led to confusing and sometimes contradictory findings implicating OT in both prosocial (e.g. trusting or cooperative) and antisocial (e.g. aggressive or parochial) processes depending on the context (De Dreu et al., 2010; Kosfeld, Heinrichs, Zak, Fischbacher, & Fehr, 2005). As a result, it seems the field has come to a consensus that perhaps it is more appropriate to broaden our view of OT beyond the scope of pure prosociality. In this vein, Shamay-Tsoory and others have proposed a social salience hypothesis, which suggests that OT enhances the sensitivity to social cues as a function of context (Bartz et al., 2011; Shamay-Tsoory & Abu-Akel, 2016). Notably, this broad framework integrates several other, more specific accounts of OT that have already received partial support. Specifically, an intergroup account which suggests OT fosters in-group favoritism, and sometimes even out-group derogation (De Dreu et al., 2010; Carsten K W De Dreu, 2012) and 'tend and befriend,' which suggests that OT elevates during stress, acting both as a social stress biomarker and motivating some (particularly women) to seek out affiliation under stress rather than activate 'fight or flight' (Cardoso, Ellenbogen, Serravalle, & Linnen, 2013; S E Taylor et al., 2000; Shelley E Taylor, 2006; R. R. Thompson, George, Walton, Orr, & Benson, 2006).

Support has also been shown for the social salience hypothesis, with OT appearing to prepare lower-level perceptual processes to receive social information. For instance, OT has been shown to increase gaze to the eye-region of faces (Gamer, Zurowski, & Büchel, 2010), and create a heightened sensitivity to detection of biological motion (Kéri & Benedek, 2009) both of which can aid speed and accuracy of social recognition. OT has also been implicated in preferential processing of positive social cues in the absence of threat (Domes et al., 2013; Petrovic, Kalisch, Singer, & Dolan, 2008; Unkelbach, Guastella, & Forgas, 2008) with one fMRI study that used happy and angry faces to reward and punish task performance (respectively) even showing that OT intensified the response to *both* happy and angry faces (but not neutral), and this was moderated by context valence (Groppe et al., 2013). However, other research has found that OT blunts social vigilance in macaques presented with visual threat cues (Ebitz, Watson, & Platt, 2013), reduces the negative evaluation of fear conditioned pictures of faces (Kéri & Benedek, 2009), and can dampen the amygdala response during threat (Zink & Meyer-Lindenberg, 2012) These data are consistent with the notion that OT may help buffer stress (Baribeau & Anagnostou, 2015; Kubzansky, Mendes, Appleton, Block, & Adler, 2012) and reduce anxiety in preparation for social engagement during threat (S E Taylor et al., 2000; Shelley E Taylor, 2006), but when viewed from the lens of the social salience framework, it is surprising that negative cues would not be privileged in a threatening context. Overall, it has been difficult to determine the role that OT plays in negative or threatening situations, which might partially account for the comparative lack of data that speaks to how OT impacts social cognition in less overtly positive contexts.

AVP tends to evoke the opposite association, with it’s role social aggression frequently emphasized despite the fact that it has also been shown to be a critical part of affiliative processes like pair bonding, parental behavior, and social communication (Albers, 2012; Bos et al., 2012; Heinrichs, Von Dawans, et al., 2009). In nonhuman animals, one way that AVP impacts social communication through its role in homeostatic water retention. By dictating the osmolarity of urine, AVP is able to affect both content and frequency of social messaging through marking behavior of rodents (Albers, 2012). Likely due to its fairly diffuse receptor distribution in the central nervous system (Bos et al., 2012), AVP also plays a role in how animals perceive and remembers their social world, possibly by changing the way sensory stimuli are perceived (Bester-Meredith, Fancher, & Mammarella, 2015; Caffrey, Nephew, & Febo, 2010; Rose & Moore, 2002). While it is important to exercise caution before drawing conclusions about human behavior from animal models, it is possible that AVP also impacts human social perception through attentional gaiting of lower lever sensory processes (Bester-Meredith et al., 2015; Zink & Meyer-Lindenberg, 2012).

The present study utilized a randomized, double blind, placebo-controlled, between subjects experiment to advance our understanding of how both OT and AVP influence human social cognition in an investment-based deception detection paradigm. Since this is the first experiment ever conducted to test the affects of AVP on human deception detection ability, it is inherently exploratory work. That being said, there are several pieces of evidence that lead us to hypothesize that AVP will enhance deception detection accuracy in humans. First, AVP has been shown to heighten sensitivity to certain social stimuli by interacting with low-level sensory processes in nonhuman animals (Bester-Meredith et al., 2015; Bielsky, Hu, Ren, Terwilliger, & Young, 2005); however the effects of AVP on human social perception accuracy are mixed (Heinrichs, Von Dawans, et al., 2009; Meyer-Lindenberg, Domes, Kirsch, & Heinrichs, 2011; Rilling et al., 2014; R. Thompson, Gupta, Miller, Mills, & Orr, 2004). Given AVP's well established role in the regulation of defensive social aggression (e.g. maternal aggression, territorial aggression and even pathological aggression (Albers, 2012; Zink et al., 2010)), the early detection of threat would be clearly advantageous in certain situations. Therefore, it is possible that AVP only selectively enhances sensitivity to subtle negative social cues (e.g. cues to deception) in competitive contexts where threat cues are more likely to be present (Caffrey et al., 2010). Similarly, the social salience hypothesis would predict that OT would enhance sensitivity to relevant social cues (i.e. cues to deception) and produce a corresponding boost in deception detection accuracy (Shamay-Tsoory & Abu-Akel, 2016). However, in the only study to date examining this question, males administered IN-OT actually showed a significant decrease (compared to placebo) in deception detection ability (Israel, Hart, & Winter, 2014). This and other evidence suggests that IN-OT may create an attentional bias *away* from negative stimuli; notably however, support for this has only been seen in males (Domes et al., 2013; Ebitz et al., 2013), suggesting the possibility of a sexually dimorphic effect (Fischer-Shofty, Levkovitz, & Shamay-Tsoory, 2013; Rilling et al., 2014; R. R. Thompson et al., 2006). The investment-based deception detection task used in this study creates a competitive environment where attending to negative social signals (cues to deception) is advantageous, and provides a quantifiable measure of successful attention to these cues (deception detection accuracy). This produces an ideal environment to test whether, consistent with the social salience account, OT increases sensitivity to relevant social cues regardless of valence, or, whether this enhanced sensitivity is selective for positive cues, or perhaps even biases attention away from negative threat cues.

Methods

Participants

Participants were 125 undergraduate students from the University of California, Los Angeles (60 female, age range = 18-31 years, Mean age = 20.84, *SD* = 2.71). They were randomly assigned to receive intranasal oxytocin (OT) (n=42; 30 female), intranasal vasopressin (n=42; 30 female), or placebo (n = 41; 30 female). Exclusion criteria included any medical or psychiatric illness, pregnancy, breastfeeding, and smoking >15 cigarettes per day. Participants were asked to refrain from using medication or alcohol for 24 hours, caffeine for 4 hours, and food or drinks (except water) for 2 hours preceding the experiment. The sample consisted of participants who self-identified as Asian (55.4%), Hispanic/Latino (20.5%), White (15.7%), and "Other" (8.4%). Participants who completed all aspects of the study were paid $40-$50 depending on their choices in another task not relevant to the present study. Informed consent was obtained in accordance with guidelines set by the Office of Protection for Human Subjects at UCLA.

Procedure

As described in Tabak et. Al. (2015), each participant completed two sessions. In the first session, participants completed screening questions and several self-report questionnaires not relevant to the present study[1].

In the second session (completed on average 17.89 days after the first session, *SD* = 16.02), participants arrived in groups of 2-15 at a computer lab where they each had their own independent computer. All participants completed the second session between the hours of 2:00pm and 5:30pm. Participants first completed a set of questionnaires pre-administration. All participants also provided a urine sample, which was tested for possible pregnancy and drugs. Research nurses then checked all participants' temperature, heart rate, and blood pressure to ensure that they were in the accepted limits: systolic blood pressure between 90 and 130, diastolic blood pressure between 60 and 90, heart rate between 55 and 100 beats per minute, and temperature less than 100 degrees Fahrenheit. If vital signs were slightly out of range, participants rested for 10-15 minutes and measurements were repeated until readings were within acceptable limits.

Approximately one hour after arriving, participants received either OT, or placebo using a randomized, double blind, placebo-controlled, between-subjects procedure. We used sterile 6ml amber glass bottles with metered nasal pumps from Advantage Pharmaceuticals, Inc. Participants first received instructions on how to use the nasal sprays from the first author and a UCLA research nurse. Participants were then instructed to deliver one spray per nostril in an alternating fashion every 30 seconds when prompted.

OT (Syntocinin) was provided by Novartis Pharmaceuticals Switzerland. OT (24 IU/ml) was transferred into the bottles with attached intranasal applicators (1 puff = 0.1ml). Participants then self-administered 5 puffs per nostril (2.4 IU/puff) for a total dose of 24 IU. Placebo (used previously by Rilling et al., 2014) consisted of 2 mls glycerine and 3mls purified water (methylparaben and propylparaben mixed according to purified water formula) for a total of 5 ml. This was filtered with a 5mu filter and transferred to the bottles with attached intranasal applicators (1 puff = .1ml). Participants then self-administered 5 puffs per nostril.

As in previous research (e.g., Tabak et al., 2015; Rilling et al., 2012; 2014), following completion of administration, participants waited approximately 40 minutes before beginning the tasks. During this time, participants were asked to sit quietly and read from a stack of 10 magazines (e.g., Newsweek). They were also instructed to turn off their phones and refrain from speaking to one another. Participants then completed measures of positive and negative affect. Next, they completed a series of computer-based tasks that were presented in randomized order to prevent order effects.

Task design. Although participants completed multiple tasks[3], the present study is focused on only one: the deception detection task. In this task, participants viewed the same 17 videos of truthful and deceptive investment pitches drawn from the video stimulus set described in Appendix 1 of Study 2 and presented in a random order (Mean pitch duration in seconds = 24.24, SD = 5.55). Truthful pitches and deceptive pitches were randomly distributed throughout the task with a mean deception base-rate of 47.06%. Deception base-rate did not differ between the OT and placebo groups and was not disclosed to participants. After viewing each investment pitch, participants indicated 1) whether they thought the person was telling the truth, 2) their 0-100% confidence rating of that judgment, and 3) whether they would invest their money in the person.

Deception cue coding. Each investment pitch video was coded by a set of four independent raters (blind to truth/lie video condition) to quantify social 'cues' that have been linked to the perception of deception as well as actual deceptive behaviors(Hartwig & Bond, 2011). Raters observed body language and facial expressions with video sound muted to identified frequency of chin raises, manual illustrators (hand motion), unusual blinking behavior, fidgeting, and lip presses, all of which have been linked to deception prior research, although multiple reports indicate that while physical cues are strongly related to lay notions of deceit, they tend to be less likely to predict actual deception (DePaulo et al., 2003; Hartwig & Bond, 2011; Riggio & Friedman, 1983). These measures were concatenated into a single index of '*physical lie cues*'. Subjective cues to deception have been previously demonstrated to be the most informative to observers (C. F. Bond & Depaulo, 2006; DePaulo et al., 2003; Wright Whelan et al., 2015), raters assessed each video on a subjective 5 point Likert scale for suspiciousness, uncertainty, nervousness, warmth, liking positive affect, and trustworthiness. An index of '*subjective lie cues'* was created by averaging all raters judgments of suspiciousness, uncertainty, and nervousness and an index of *'subjective truth cues'* was created by averaging all raters judgments of warmth, liking, positive affect, and trustworthiness. Finally, linguistic cues have also been linked to accurate deception detection (Hauch, Blandón-Gitlin, Masip, & Sporer, 2012; Wright Whelan et al., 2015) so we subjected the transcripts of video investment pitches to an automated Linguistic Inquiry and Word Count (LIWC) to identify linguistic features which have been previously associated with discriminating truth from deception (Chung & Pennebaker, 2012). An index of '*verbal lie cues'* was created by averaging frequencies of a set of predetermined cues within each investment pitch video. Selected cues were: fillers, non-fluency, negations, lack of immediacy (including impersonal pronouns, frequent usage of 'I,' and infrequent usage of 'we'), and reverse coded certainty as well as affect. An index of '*verbal truth cues'* was created in the same manner using frequency of positive and negative emotion (as identified from text with LIWC) as enhanced emotional tone tends to predict honesty (Chung & Pennebaker, 2012; Tausczik & Pennebaker, 2010). All cue indices were mean centered before incorporation in analyses. While it has been firmly established that detectors tend to use some combination of social cues to deception when judging deceit (Hartwig & Bond, 2011), not cues are indicative of actual deceptive behavior all of the time as they can vary across context and individuals (C. F. Bond & Depaulo, 2008; Riggio & Friedman, 1983). All of the cue indices here significantly correlated (*Ps* < .025) with the presence of actual deception in this experiment (see Figure 1). All of these correlations occurred in the expected direction with the exception of *'physical lie cues,'* essentially rendering this a 'false cue' in the context of this study.

Measures

Since most people show some degree of truth bias when performing deception detection tasks (Levine, Park, & McCornack, 1999; Meissner & Kassin, 2002) deception detection accuracy was assessed here using a measure of pure sensitivity independent of response bias derived from signal detection theory known as d-Prime (*d'* or discriminability). *d'* measures how well someone can detect whether or not an event occurred (e.g. signal is present) without undue influence of their bias towards a particular response (Nevin, 1969). In the present study, 'lie' videos where characterized as signal and 'truth' videos were characterized as noise. Discriminability is calculated by comparing the difference between hit-rate (HR) and false alarm rate (FAR) against the standard deviation of the noise distribution; $d' = z(HR) - z(FAR)$ (N. a Macmillan & Creelman, 2005; Stanislaw & Todorov, 1999). Since 'lie' videos represent signal in this case, HR was calculated as: (number of lies identified as lies/total number of lies) and FAR: (number of truths identified as lies/total number of truths) for each participant. Since signal detection theory does not support extreme but realistic HRs/FARs (i.e. 0% or 100%), a correction was applied such that rates of '0' were assigned to '.001' and rates of '1' were assigned to .999 (N. a Macmillan & Creelman, 2005; Sorkin, 1999). Next, the z-score of each rate was then computed using MATLAB's 'NORMINV' function which computes the inverse of the normal cumulative distribution function for a data sample at the value of P (in this case HR or FAR) (MATLAB and Statistics Toolbox Release 2009b, The MathWorks Inc.). Finally, d' was calculated for each participant using the formula: $d' = z(HR) - z(FAR)$ (see Figure 1 for descriptive statistics of deception measures for this study).

A measure of subject response bias known as the criterion variable (*C*) was also calculated for each subject. *C* reflects an individual subject's baseline tendency (all else being equal) to favor ‘lie’ vs. ‘truth’ judgments. When *C* is positive, this indicates that (all else being equal) a subject has higher likelihood of reporting presence of signal (e.g. ‘lie’). When *C* is negative this indicates that (all else being equal) a subject has higher likelihood of reporting the absence of signal (e.g. ‘truth’). *C* was calculated here from the FAR and the noise distribution, using the formula; $C = z(FAR) - d'/2$ (Snodgrass & Corwin, 1988) (see Figure 1 for descriptive statistics of deception measures for this study).

Anxiety. To assess trait anxiety, participant’s completed the trait portion of the Spielberg State and Trait Anxiety Index (McDowell, 2006) at a screening session prior to the day of the experiment. To assess state anxiety, the state portion of the STAI was completed before and after drug administration on the day of the experiment. To assess change in state anxiety, a difference score was calculated from the *(post – pre)* administration STAI questionnaires and mean centered for later analysis. These measures were not used in the present analyses, but descriptive statistics can be found in Table 2.

Statistical analysis

Next, we subjected measures reflecting participants’ deception detection accuracy (*d’*) and trust-behavior[4] to a Univariate Analysis of Variance to determine whether deception detection differs as a function of drug condition. Since previous work has identified sex-specific effects of OT and AVP (Fischer-Shofty et al., 2013; Rilling et al., 2014; R. R. Thompson et al., 2006), sex was included in the ANOVA models, in a 2 (drug condition *vs*. placebo) x 2 (male *vs*. female) factorial design. Since we did not have any hypotheses directly comparing the two neuropeptides, analyses for Oxytocin *vs*. placebo and Vasopressin *vs*. placebo were conducted separately.

Finally, to test the hypothesis that drug condition impacts the way cues to truthfulness or deception influence deception judgments, a hierarchical binary logistic regression was performed on participant's binary (0 = truth, 1 = lie) response to each investment pitch with the placebo group acting as the reference category. Since we were interested in whether the deception cue x drug interaction could help predict participant deception judgment, all main effects (as well as sex interactions) were entered in the first regression block as a 'control.' These predictors include: main effects for drug condition, sex, subjective deception cues, subjective truthfulness cues, and sex interactions. Deception cues x drug condition and truthfulness cues x drug condition were entered in to the regression in the second block.

Results

Oxytocin

First, we examined the effects of OT *vs*. placebo, and sex on deception detection accuracy. Participant's deception detection accuracy scores *(d')* were subjected to an (OT *vs*. placebo) x (male *vs*. female) Univariate ANOVA and no significant effects were found. Thus we found no main effect of drug condition (F(1, 79)= .03, *p* = .86), no main effect of sex (F(1, 79)= 1.82, *p* = .18) , and no interaction of drug condition (OT *vs*. placebo) and sex (F(1, 79)= 1.62, *p* = .21], on deception detection accuracy (see Table 1). Similarly, OT *vs*. placebo did not have a significant effect on participant's decisions to trust others with investment money (F(1, 79) = .16, *p* = .69), and this was equally true for both sexes (F(1, 79) = .82, *p* = .37) (see Table 2).

Vasopressin

We also examined the effects of AVP *vs.* placebo, and sex on deception detection accuracy by subjecting participant's deception detection accuracy scores *(d')* to an (AVP *vs.* placebo) x (male *vs.* female) ANOVA. We found a main effect of drug condition (F(1,79) = 6.94, p = .01, $\eta_\rho{}^2 = .08$) such that participant's administered Vasopressin experienced a significant deception detection accuracy boost (M = .031, SE = .183) compared to those administered placebo (M = -.046, SE = .140). There was a trend for the main effect of sex (F(1,79) = 2.29, p = .13) such that men (M = .035, SE = .33) are more accurate than women (M = -.025, SE = .21). There was also a trend for an interaction between drug condition (AVP *vs.* placebo) and sex (F(1,79) = 2.52, p = .12) (see Figure 2, Table 3, and Table 4). Although *d'* is a signal detection sensitivity measure that already takes response bias into account (N. A. Macmillan, 2004), but just to confirm this effect could not be accounted for by a change in the proportion of truths *vs.* lies reported, we performed an additional (AVP *vs.* placebo) x (male *vs.* female) ANOVA on a mean-centered count of total 'truth' decisions made while judging deception in the investment task. No significant main effects or interactions were observed (*p*'s > .731) (see Table 5).

To see if AVP had an effect on participant's decisions to trust others with investment money, we subjected mean-centered count of total 'trust' decisions made during the investment task to an (AVP *vs.* placebo) x (male *vs.* female) ANOVA. AVP *vs.* placebo did not have a significant effect on participant's decisions to trust others with investment money (F(1,79) = .098, p = .755), and this was true for both sexes (F(1,79) = 1.463, p = .230), in both drug conditions (F(1,79) = .073, p = .788).

Cues to deception

Cues to deception are subtle signals expressed through typical channels of social communication (e.g. the face, voice, body language, etc.) during expression of deceit. Prior research has demonstrated both the reliability of the certain cues to deception, as well as their often fragile nature (i.e. easily drowned out by noise, or only expressed in certain contexts (DePaulo et al., 2003; Riggio & Friedman, 1983). Some of the most robust cues to deception were chosen for the present work based on an extensive meta analysis of 158 cues to (DePaulo et al., 2003). However, since it was unclear which cues (if any) were likely to be preferentially attended as a result of drug condition, an effort was made to identify cues across different modalities including linguistic cues, verbal cues, and physical cues. This way if a particular modality of social communication was selectively affected by drug condition, we would have a higher likelihood of observing it. In addition to these traditional cues to deception, we also coded several 'subjective cues' to deception (Hartwig & Bond, 2011; Wright Whelan et al., 2015).

Subjective cues differ from more traditional cues to deception in that they are less likely to rely on a particular sensory mode, instead requiring a higher-level 'gestalt' impression to be formed. While these higher level, generalist cues may not feel precise enough to base judgments of deception on, they have repeatedly surfaced in recent work as the most useful in aiding observers to accurately predict deception. Most people are not very practiced (or successful) deception detectors (C. F. Bond & DePaulo, 2006) however, humans do spend much of their time 'practicing' making social inferences about other people and their social environment. So it is possible that the use of subjective cues takes advantage of skilled social inference by working within a comfortable environment.

To test whether participant's judgments of deception detection could be predicted, in any part, by deception cues present in the video stimuli, a hierarchical binary logistic regression was performed on participant's binary (0 = truth, 1 = lie) response to each investment pitch. The behavioral accuracy differences observed between OT and AVP groups provided an opportunity to observe natural variation in effective utilization of deception cues (i.e. the reliance on impotent cues might yield a strong *cue x drug* relationship that does not translate into an accuracy boost (Hartwig & Bond, 2011; Riggio & Friedman, 1983). To take advantage of this, OT and AVP were both compared against placebo (the reference category) in the same model. To examine the predictive ability of an interaction, the main effects (of no interest in this context) must first be modeled (Peng & So, 2002). As a result, the first user-specified block contained a set of 'control' variables of no interest including main effects of sex and condition. When these were the only predictors included in the model, $\chi^2(5, \mathrm{N} = 2125) = 5.41, p = .368$ and prediction success was (0% for truths and 100% for lies), but when the main effects of deception cues index (*verbal truth, verbal lie, physical lie, subjective truth,* and *subjective lie*[5]) were entered in block two, $\chi^2(25, \mathrm{N} = 2125) = 37.67, p < .001$, the prediction success was (19.7% for truths and 85% for lies), and the Wald criterion demonstrated all deception cues made a significant contribution to the model at $p < .029$, except of verbal deception cues where $p =$ .059. This corroborates the overall importance of deception cues in making accurate deception judgments.

The last user-specified block modeled the predictive ability of the *cue x drug* interaction for each deception cue index and drug condition which yielded another significant model, $\chi^2(20, \mathrm{N} = 2125) = 56.03, p < .001$, with a prediction success of (32.9% for truths and 76.7% for lies; 57.5% for the model overall). Here, the Wald criterion indicated that *AVP x subjective truth cues* was the only new variable that contributed significantly to the prediction of deception judgment (p = .009), although there was trend observed for *OT x subjective lie cues* (p = .058) which should be interpreted with caution because p = .081 for the overall *drug x subjective lie cues* term (see Table 7). The odds ratio (Exp(B) = .56) can be interpreted to mean that participants in the AVP group are less likely to report a lie in the presence of subjective positive cues than placebo subjects and this is not true for the OT group. Since presence of subjective truth cues was negatively related to real deception in this experiment ($r(2125) = -.381$, $p < .001$), this is consistent with our finding that the AVP group achieved the highest deception detection accuracy.

Discussion

Oxytocin and vasopressin are endogenous neuropeptides that play a key role in the regulation mammalian social behavior. While their impact on nonhuman animals is better understood, much is still unknown about how these critical neuropeptides affect human social cognition. This dearth of information has been exacerbated by a relative scarcity of intranasal-drug administration experiments that examine the effects of OT and AVP using the same tasks in the same sample, and even fewer that have sampled both men and women (Rilling et al., 2014), making it difficult to know whether conflicting evidence between studies was due to the lack of a true effect or gender variability in sampling.[i] The present study tested 1) whether social salience hypothesis would still be able to account for the effects of OT on behavior in a context where *negative* cues are critical to task success (and therefore preferentially attended), and in a sample of both men and women; and 2) if AVP would confer a social cognitive benefit during competition, in the form of enhanced deception detection accuracy.

As compared to placebo, OT did not significantly change deception detection accuracy in men or women, and there was no evidence for attention to any specific cues to deception. Thus the social salience account of OT is not supported by these data. In addition, there was no significant interaction effect between sex (male, female) and drug condition (placebo, OT) on deception detection accuracy, which places these results at odds with Israel et. al. (2014) who found that OT significantly decreased deception detection accuracy in men. It has been suggested that this 'threat blindness' is the result of a positivity bias directing attention away from negative or threatening stimuli (Ebitz et al., 2013; Israel et al., 2014). While this account is consistent with OT's well documented role in fostering prosociality (Barraza, McCullough, Ahmadi, & Zak, 2011; Bartz et al., 2011), the effect has since been shown to be highly context dependent, with negative or competitive environments rendering increases in prosocial behavior unlikely (Bartz et al., 2011; Nave et al., 2015). Given the competitive context of the deception detection investment game in the present study (where participant's max pay-outs are at odds with each other), we did not predict OT to increase trust-related behavior or cultivate a positivity bias. Consistent with that prediction, OT did not affect trust behavior, nor did OT participants show any heightened sensitivity to positive cues during the deception task (notably, this is also true for OT participants in the Israel et. al. paper (2014)). Given the complete absence of evidence that OT enhanced positivity at all in in this context, it does not seem to be a likely candidate to explain these data.

Although it is impossible to fully explain why support was these data are contrary to our expectations, it is consistent with the seeming unreliability of effects typical of this literature (Bartz et al., 2011; Graustella & MacLeod, 2012). We could also speculate that participants were not sufficiently engaged in the task, possibly due to the hypothetical nature of potential rewards (i.e. participants were asked to report whether they would trust the person in the video with a hypothetical investment, but were not offered any tangible monetary incentive for accuracy); a factor that is of particular import in this case, because motivation to detect deception is thought to impact accuracy rates (C. F. Bond & Depaulo, 2006). While this was obviously consistent across conditions, OT has been shown to have anxiolytic effects in some (but not all) cases, and even has the potential to cause sleepiness compared to placebo (potentially hindering attention to the task) whereas AVP typically has anxiogenic effects, increasing baseline arousal and potentially facilitating attention to the task (Chen et al., 2016; Heinrichs, Von Dawans, et al., 2009; Motoki et al., 2016).

A different pattern of results emerged for vasopressin however, revealing a significant effect of AVP on deception detection accuracy, with certain cues to deception significantly contributing to detection accuracy. These results demonstrate AVP's ability to directly regulate human social cognitive accuracy in certain competitive contexts, which has potential implications for regulating/supporting the social communication surrounding perception of threat leading up to and during conflict. Although outside the scope of present inquiry, this seems consistent with what is understood about AVP's important role in social aggression, particularly for men, which maps onto the fact that the AVP accuracy boost observed here was strongest for men. It seems plausible that impacting social perception during conflict or competition is a potential avenue through which AVP might regulate social aggression, and since our data cannot directly speak to this, it seems like an excellent starting place for future research.

AVP has also been linked to social perception in the animal literature (R. R. Thompson et al., 2006; Uzefovsky, Shalev, Israel, Knafo, & Ebstein, 2012), so to explore what this might mean for human social perception, we tested the predictive ability of 4 different types of cues to truth and deception that had been previously associated with detection accuracy: linguistic cues correlated with deceit (e.g. use of filler words like 'um'), linguistic cues correlated with honesty (higher incidence of emotion-related words), physical cues correlated with deceit (e.g. lip presses or chin raises), and two indices of subjective cues respectively correlated with deceit (e.g. impressions of uncertainty, nervousness, and suspicion) and honesty (e.g. impressions of liking,) Subjective cues differ from other cues to deception because instead of coding for presence or absence of discrete events, they represent a gestalt feeling or impression. These cues are theorized to represent a subjective computation of internal impressions of honesty vs. deceit generated in an individual observer. Critically however, although entirely subjective, these cues tend to reliably correlated between observers and have even been demonstrated to be the most successful category of cues to deception detection in certain past work (DePaulo et al., 2003; Hartwig & Bond, 2011; Wright Whelan et al., 2015). The fact that IN-AVP strengthened the relationship between the presence of subjective cues to honesty and the likelihood of deciding to trust someone's investment pitch, implies that participants assigned to the AVP drug condition were more likely to be accurate in their assessment of an investment pitch if subjective cues honesty cues were present. Notably, this does not indicate that AVP subject's were purposefully using these cues; in fact, due to their subjective nature, they are not commonly reported by observers as a conscious strategy to detect deception (Hartwig & Bond, 2011; Wright Whelan et al., 2015). Additionally, while we could reasonably hypothesize that AVP caused these participants to rely on subjective cues more often, this analysis characterizes the relationship in terms of likelihood of accuracy rather than frequency of use; thus allowing us to conclude that participants dosed with IN-AVP were able to more effectively use subjective cues to honesty than participants in the placebo group.

Compared to other deception cues, less is understood about the neurocognitive mechanisms underpinning these internally generated subjective impressions, so interpreting our finding in the context of AVP animal models of social sensory regulation is not entirely straightforward. We might speculate that privileged processing of higher-level subjective impression information is less likely to be the result of low-level sensory processes, but instead might reflect a processing benefit a little further downstream, perhaps during integration of sensory information; an effect that has already been observed in certain nonhuman mammals (Bester-Meredith et al., 2015). This suggestion is consistent the highly context-dependent nature of these neuropeptide's effects, but further research is required before any concrete conclusions can be drawn. Regardless of interpretation, additional caution is warranted with respect to this analysis of deception cues because, while statistically significant, it represents such a small effect that the true impact on behavior is likely negligible. Despite this word of caution, we believe the effect is still worthy of conversation because so little is known about AVP's impact on social cognition, that as long as caution as taken with how the information is presented or applied, even small clues can provide helpful guidance regarding where to direct future research.

Since these data speak to AVP's involvement in human social processes in a context where we might expect to see maximum impact (i.e. competitive context with presence of subtle yet detectable negative cues), future research should attempt to establish boundary conditions by examining similar processes under different circumstances (e.g. an affiliative rather than competitive context, or varying the degree of task difficulty). As the first study to examine the effect of AVP on deception detection accuracy, this work has demonstrated AVP's ability to directly regulate the accuracy of social cognition. These data represent an important step towards a more complete understanding of the important, yet complex role that neuropeptides play in human social behavior.

Table 1.
ANOVA Between Drug Condition (OT vs. Placebo), and Sex

Source	df	F	Sig.	η_ρ^2
Corrected Model	3	1.24	0.30	0.05
Intercept	1	6.68	0.01	0.08
Sex	1	1.82	0.18	0.02
Drug Condition	1	0.03	0.86	0.00
Sex * Drug Condition	1	1.62	0.21	0.02

Note: Dependent variable is deception detection accuracy (*d'*).

R Squared = .045 (Adjusted R Squared = .009)

Table 2.
ANOVA Between Drug Condition (OT vs. Placebo), and Sex

Source	df	F	Sig.	$\eta_\rho{}^2$
Corrected Model	3	0.32	0.81	0.01
Intercept	1	4.37	0.04	0.05
Sex	1	0.82	0.37	0.01
Drug Condition	1	0.16	0.69	0.00
Sex * Drug Condition	1	0.07	0.79	0.00

Note: Dependent variable is trust behavior accuracy (*d'*).

R Squared = .012 (Adjusted R Squared = -.025)

Table 3.
ANOVA Between Drug Condition (AVP vs. Placebo), and Sex

Source	df	F	Sig.	$\eta_\rho{}^2$
Corrected Model	3	3.25	0.03	0.11
Intercept	1	0.07	0.79	0.00
Sex	1	2.29	0.13	0.03
Drug Condition	1	6.94	0.01	0.08
Sex * Drug Condition	1	2.52	0.12	0.03

Note: Dependent variable is deception detection accuracy (*d'*).

R Squared = .110 (Adjusted R Squared = .076).

Table 4.
Marginal means for the ANOVA between, drug condition (AVP vs. Placebo), and sex.

				95% Confidence Interval	
Sex	Drug Condition	Mean	Std. Error	Lower Bound	Upper Bound
male	Placebo	-.048	.048	-.144	.048
	AVP	.118	.046	.026	.210
female	Placebo	-.045	.029	-.103	.013
	AVP	-.004	.029	-.062	.054

Note: Dependent variable is deception detection accuracy (*d'*).

Table 5.
ANOVA Between, Drug Condition (AVP vs. Placebo), and Sex

Source	df	F	Sig.	$\eta_\rho{}^2$
Corrected Model	3	0.07	0.98	0.00
Intercept	1	853	0.00	0.92
Sex	1	0.06	0.82	0.00
Drug Condition	1	0.12	0.73	0.00
Sex * Drug Condition	1	0.06	0.82	0.00

Note: Dependent variable is number of truth responses.
R Squared = .003 (Adjusted R Squared = -.035).

Table 6

Correlations Among Cues to Deception and between Presence of Deceit.

	M (*SD*)	Deception	Verbal Truth Cues	Verbal Lie Cues	Physical Lie Cues	Subjective Lie Cues	Subjective Truth Cues
Deception	1.47 (.50)		-.049*	.261**	-.089**	.106**	-.381**
Verbal Truth Cues	4.51 (2.85)			-.189**	.113**	.100**	.360**
Verbal Lie Cues	1.54 (0.80)				.110**	.178**	-.292**
Physical Lie Cues	1.36 (0.67)					-.124**	.089**
Subjective Lie Cues	2.45 (0.97)						-.276**
Subjective Truth Cues	3.20 (0.57)						

Note: * $p < .05$ ** $p < .01$ *** $p < .001$

Table 7

Hierarchical Logistic Regression Models Predicting Likelihood that Deception (vs. Truth) is Present

Variables	**Model 2**				**Model 3**			
	B	**SE**	**OR**	***95% C.I.***	**B**	**SE**	**OR**	***95% C.I.***
Verbal Truth Cues	0.10	0.05	1.10	(0.99 - 1.22)	.089**	.030	.915	(.862 - .971)
Verbal Lie Cues	2.17	0.72	8.75	(2.12 - 36.09)	-.008	.103	.992	(.811 – 1.213)
Physical Lie Cues					-.291*	.122	.747	(.588 - .949)
Subjective Lie Cues					.214*	.087	1.238	(1.044 –1.469)
Subjective Truth Cues					.496**	.162	1.642	(1.196 – 2.254)
Verbal Truth Cues by OT					.070	.042	1.072	(.987 – 1.165)
Verbal Truth Cues by AVP					.056	.043	1.057	(.973 – 1.150)
Verbal Lie Cues by OT					-.146	.144	.864	(.652 – 1.146)
Verbal Lie Cues by AVP					-.163	.144	.850	(.640 – 1.128)
Physical Lie Cues by OT					.172	.170	1.188	(.852 – 1.657)

Table 7 continued

Variables	Model 2				Model 3			
	B	SE	OR	*95% C.I.*	B	SE	OR	*95% CI*
Physical Lie Cues by AVP					.007	.172	1.007	(.719 – 1.410)
Subjective Lie Cues by OT					-.231	.122	.794	(.626 – 1.008)
Subjective Lie Cues by AVP					.007	.123	1.008	(.792 – 1.281)
Subjective Truth Cues by OT					-.294	.225	.746	(.480 – 1.158)
Subjective Truth Cues by AVP					-.585**	.225	.557	(.358 - .866)
(Constant)	-.062				-1.074			
Model χ^2	32.535***				50.468***			
-2 Log Likelihood	2880.706				2862.301			
Likelihood Ratio Test	χ^2 (df = 17) = 18.405, p = 0.36							

Note: *p < .05; **p<.01; ***p<.001. Type of video stimulus is the dependent variable (true = 0, lie = 1) with true videos modeled as the reference category.

Footnotes

1. Complete list and discussion of individual difference measures can be found in Tabak et. al. (2015)).

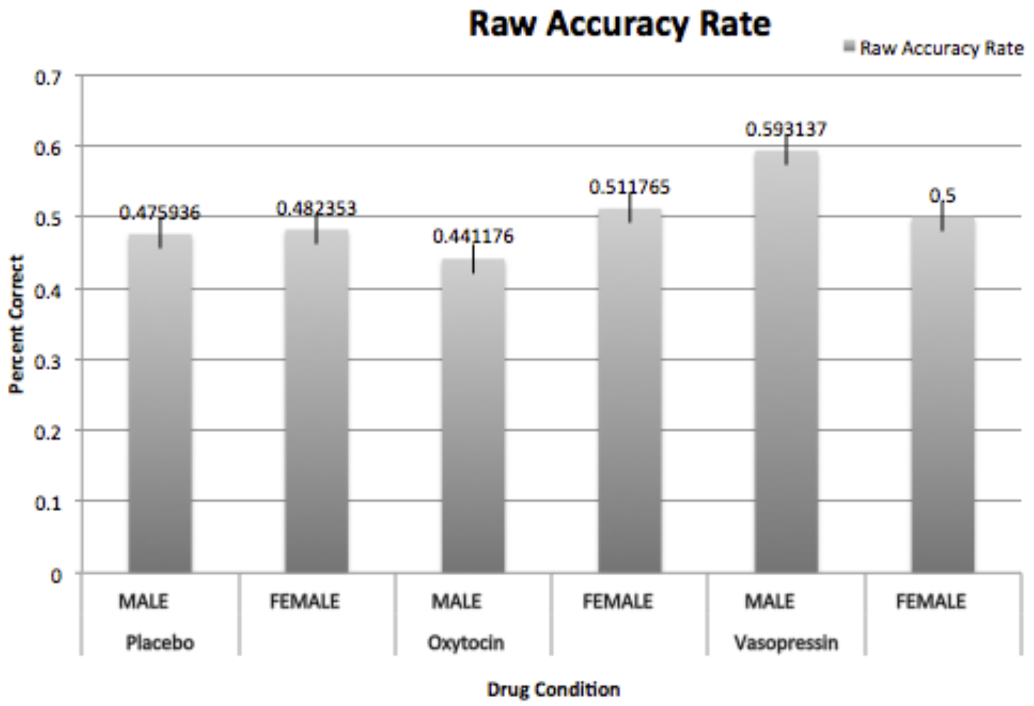
2. Further discussion of other tasks and individual difference measures can be found in Tabak, Meyer, Castle, et al., 2016 or Tabak, Meyer, Dutcher, et al., 2016.

3. Trust behavior as indexed by mean centered total count of ‘trust’ decisions made in the Investment task. These decisions are reflective of a participant’s willingness to invest money after hearing a pitch, and were collected separately from deception judgments.

4. See additional information about deception cue selection, definition, and coding in Methods.

Figure 1.

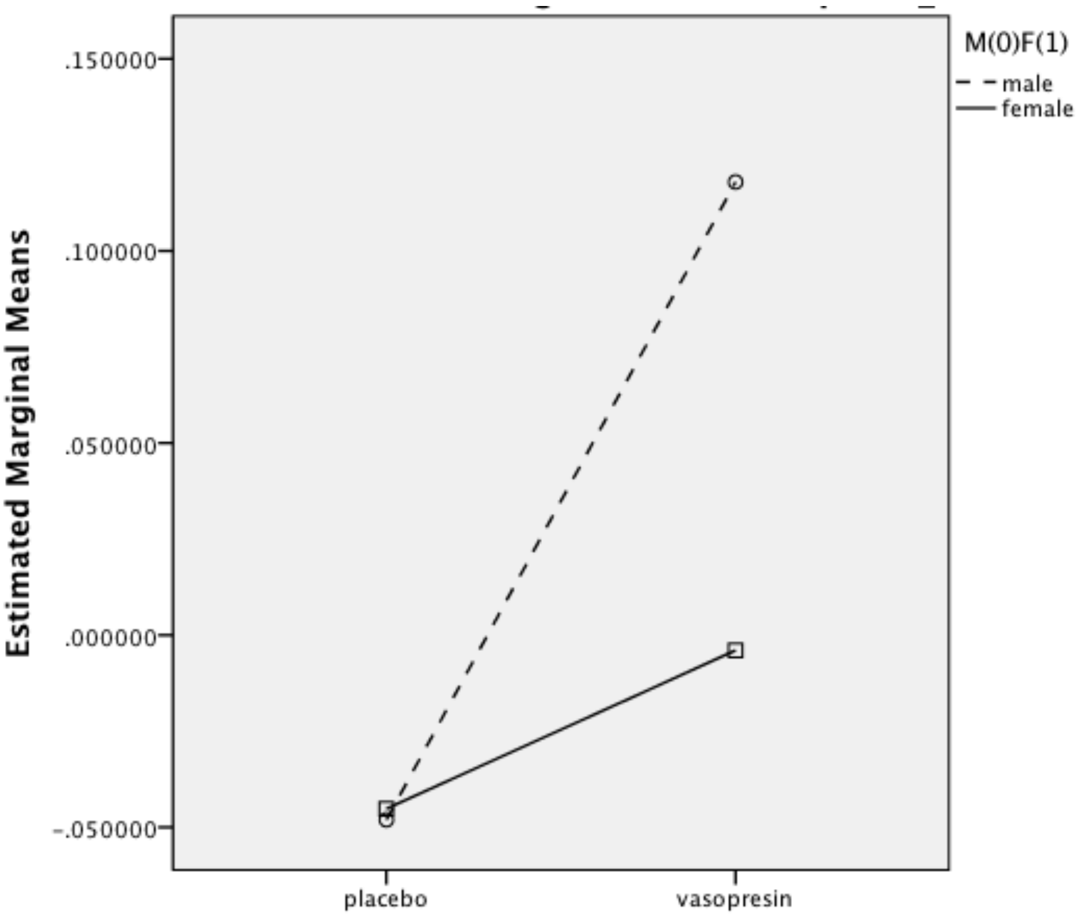
Deception Detection Accuracy rate for Drug Group x Gender



Note. Numbers are in percentage correct out of 100.

Figure 2.

Trend for an interaction between drug condition (AVP vs. Placebo) and sex (male vs. female)



References

Adolphs, R. (2002). Neural systems for recognizing emotion. *Current Opinion in Neurobiology*, *12*(2), 169–177. https://doi.org/10.1016/S0959-4388(02)00301-X

Albers, H. E. (2012). The regulation of social recognition, social communication and aggression: Vasopressin in the social behavior neural network. *Hormones and Behavior*, *61*(3), 283–292. https://doi.org/10.1016/j.yhbeh.2011.10.007

Baribeau, D. A., & Anagnostou, E. (2015). Oxytocin and vasopressin: Linking pituitary neuropeptides and their receptors to social neurocircuits. *Frontiers in Neuroscience*, *9*(SEP). https://doi.org/10.3389/fnins.2015.00335

Barraza, J. A., McCullough, M. E., Ahmadi, S., & Zak, P. J. (2011). Oxytocin infusion increases charitable donations regardless of monetary resources. *Hormones and Behavior*, *60*(2), 148–151. https://doi.org/10.1016/j.yhbeh.2011.04.008

Bartz, J. A., Zaki, J., Bolger, N., & Ochsner, K. N. (2011). Social effects of oxytocin in humans: Context and person matter. *Trends in Cognitive Sciences*, *15*(7), 301–309. https://doi.org/10.1016/j.tics.2011.05.002

Bester-Meredith, J. K., Fancher, A. P., & Mammarella, G. E. (2015). Vasopressin proves es-sense-tial: Vasopressin and the modulation of sensory processing in mammals. *Frontiers in Endocrinology*, *6*(FEB), 1–12. https://doi.org/10.3389/fendo.2015.00005

Bickart, K. C., Dickerson, B. C., Barrett, L. F., States, U., States, U., Unit, D., … States, U. (2014). The amygdala as a hub in brain networks that support social life. *Neuropsychologia*, 235–248. https://doi.org/10.1016/j.neuropsychologia.2014.08.013.The

Bielsky, I. F., Hu, S. B., Ren, X., Terwilliger, E. F., & Young, L. J. (2005). The V1a vasopressin receptor is necessary and sufficient for normal social recognition: A gene replacement study. *Neuron*, *47*(4), 503–513. https://doi.org/10.1016/j.neuron.2005.06.031

Birren, J. E. (1961). A Brief History of the Psychology of Aging. *The Gerontologist*, *1*(2), 69–77. https://doi.org/10.1093/geront/1.2.69

Bond, C. F., & Depaulo, B. M. (2006). Personality and Social Psychology Review. *Personal and Social Psychology Review*, *10*(214), 214–234. https://doi.org/10.1207/s15327957pspr1003

Bond, C. F., & Depaulo, B. M. (2008). Individual differences in judging deception: accuracy and bias. *Psychological Bulletin*, *134*(4), 477–492. https://doi.org/10.1037/0033-2909.134.4.477

Bond, C. F., & DePaulo, B. M. (2006). Accuracy of deception judgments. *Personality and Social Psychology Review : An Official Journal of the Society for Personality and Social Psychology, Inc*, *10*(3), 214–234. https://doi.org/10.1207/s15327957pspr1003_2

Bond, G. D., Thompson, L. a, & Malloy, D. M. (2005). Vulnerability of older adults to deception in prison and nonprison contexts. *Psychology and Aging*, *20*(1), 60–70. https://doi.org/10.1037/0882-7974.20.1.60

Bos, P. A., Panksepp, J., Bluthe, R. M., & Honk, J. van. (2012). Acute effects of steroid hormones and neuropeptides on human social-emotional behavior: A review of single administration studies. *Frontiers in Neuroendocrinology*, *33*(1), 17–35. https://doi.org/10.1016/j.yfrne.2011.01.002

Cacioppo, J. T., Berntson, G. G., Bechara, A., Tranel, D., & Hawkley, L. C. (2011). Could an Aging Brain Contribute to Subjective Well-Being?: The Value Added by a Social Neuroscience Perspective. In *Social Neuroscience: Toward Understanding the Underpinnings of the Social Mind*. https://doi.org/10.1093/acprof:oso/9780195316872.003.0017

Caffrey, M. K., Nephew, B. C., & Febo, M. (2010). Central vasopressin V1a receptors modulate neural processing in mothers facing intruder threat to pups. *Neuropharmacology*, *58*(1), 107–116. https://doi.org/10.1016/j.neuropharm.2009.06.023

Caldwell, H., & Iii, W. Y. (2006). Oxytocin and Vasopressin: Genetics and Behavioral Implications. *Handbook of Neurochemistry and Molecular Neurobiology*, 573–607. https://doi.org/10.1007/978-0-387-30381-9_25

Cardoso, C., Ellenbogen, M. A., Serravalle, L., & Linnen, A. M. (2013). Stress-induced negative mood moderates the relation between oxytocin administration and trust: Evidence for the tend-and-befriend response to stress? *Psychoneuroendocrinology*, *38*(11), 2800–2804. https://doi.org/10.1016/j.psyneuen.2013.05.006

Carstensen, L. L. (2006). The Influence of a Sense of Time on Human Development. *Science*, *312*(June), 1913–1916. https://doi.org/10.1126/science.1127488

Castle, E., Eisenberger, N. I., Seeman, T. E., Moons, W. G., Boggero, I. a, Grinblatt, M. S., & Taylor, S. E. (2012). Neural and behavioral bases of age differences in perceptions of trust. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(51), 20848–52. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3529090&tool=pmcentrez&rendertype=abstract

Chen, X., Hackett, P. D., DeMarco, A. C., Feng, C., Stair, S., Haroon, E., … Rilling, J. K. (2016). Effects of oxytocin and vasopressin on the neural response to unreciprocated cooperation within brain regions involved in stress and anxiety in men and women. *Brain Imaging and Behavior*, *10*(2), 581–593. https://doi.org/10.1007/s11682-015-9411-7

Chung, C. K., & Pennebaker, J. W. (2012). Linguistic Inquiry and Word Count (LIWC). *Applied Natural Language Processing*, (2015), 206–229. https://doi.org/10.4018/978-1-60960-741-

8.ch012

Critchley, H. D. (2009). Psychophysiology of neural, cognitive and affective integration: fMRI and autonomic indicants. *International Journal of Psychophysiology*, *73*(2), 88–94. https://doi.org/10.1016/j.ijpsycho.2009.01.012

De Dreu, C. K. W. (2012). Oxytocin modulates cooperation within and competition between groups: An integrative review and research agenda. *Hormones and Behavior*, *61*(3), 419–428. https://doi.org/10.1016/j.yhbeh.2011.12.009

De Dreu, C. K. W., Greer, L. L., Handgraaf, M. J. J., Shalvi, S., Van Kleef, G. A., Baas, M., … Feith, S. W. W. (2010). The Neuropeptide Oxytocin Regulates Parochial Altruism in Intergroup Conflict Among Humans. *Science*, *328*(5984), 1408–1411. https://doi.org/10.1126/science.1189047

Demeyer, I., & De Raedt, R. (2013). Attentional Bias for Emotional Information in Older Adults: The Role of Emotion and Future Time Perspective. *PLoS ONE*, *8*(6). https://doi.org/10.1371/journal.pone.0065429

Dennis, N. A., & Cabeza, R. (2008). Neuroimaging of healthy cognitive aging. *The Handbook of Aging and Cognition*, (November), 1–54. https://doi.org/10.1073/pnas.0703993104

DePaulo, B. M., Lindsay, J. J., Malone, B. E., Muhlenbruck, L., Charlton, K., & Cooper, H. (2003). Cues to deception. *Psychological Bulletin*, *129*(1), 74–118. https://doi.org/10.1037//0033-2909.129.1.74

Di Domenico, A., Palumbo, R., Mammarella, N., & Fairfield, B. (2015). Aging and emotional expressions: Is there a positivity bias during dynamic emotion recognition? *Frontiers in Psychology*, *6*(AUG), 1–5. https://doi.org/10.3389/fpsyg.2015.01130

Domes, G., Sibold, M., Schulze, L., Lischke, a, Herpertz, S. C., & Heinrichs, M. (2013).

Intranasal oxytocin increases covert attention to positive social cues. *Psychological Medicine*, *43*(8), 1747–53. https://doi.org/10.1017/S0033291712002565

Ebitz, R. B., Watson, K. K., & Platt, M. L. (2013). Oxytocin blunts social vigilance in the rhesus macaque. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(28), 11630–5. https://doi.org/10.1073/pnas.1305230110

English, T., & Carstensen, L. L. (2015). Does positivity operate when the stakes are high? Health status and decision making among older adults. *Psychology and Aging*, *30*(2), 348–355. https://doi.org/10.1037/a0039121

Feifel, D. (2012). Oxytocin as a Potential Therapeutic Target for Schizophrenia and Other Neuropsychiatric Conditions. *Neuropsychopharmacology Reviews*, *37*(1), 304–305. https://doi.org/10.1038/npp.2011.184

Fischer-Shofty, M., Levkovitz, Y., & Shamay-Tsoory, S. G. (2013). Oxytocin facilitates accurate perception of competition in men and kinship in women. *Social Cognitive and Affective Neuroscience*, *8*(3), 313–317. https://doi.org/10.1093/scan/nsr100

Gamer, M., Zurowski, B., & Büchel, C. (2010). Different amygdala subregions mediate valence-related and attentional effects of oxytocin in humans. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(20), 9400–5. https://doi.org/10.1073/pnas.1000985107

Ghisletta, P., & Spini, D. (2004). An Introduction to Generalized Estimating Equations and an Application to Assess Selectivity Effects in a Longitudinal Study on Very Old Individuals. *Journal of Educational and Behavioral Statistics*, *29*(4), 421–437. https://doi.org/10.3102/10769986029004421

Grady, C. L. (2008). Cognitive neuroscience of aging. *Annals of the New York Academy of*

Sciences, *1124*, 127–144. https://doi.org/10.1196/annals.1440.009

Graustella, A. J., & MacLeod, C. (2012). A critical review of the influence of oxytocin nasal spray on social cognition in humans: Evidence and future directions. *Hormones and Behavior*, *61*(3), 410–418. https://doi.org/10.1016/j.yhbeh.2012.01.002

Groppe, S. E., Gossen, A., Rademacher, L., Hahn, A., Westphal, L., Gründer, G., & Spreckelmeyer, K. N. (2013). Oxytocin influences processing of socially relevant cues in the ventral tegmental area of the human brain. *Biological Psychiatry*, *74*(3), 172–179. https://doi.org/10.1016/j.biopsych.2012.12.023

Hartwig, M., & Bond, C. F. (2011). Why do lie-catchers fail? A lens model meta-analysis of human lie judgments. *Psychological Bulletin*, *137*(4), 643–659. https://doi.org/10.1037/a0023589

Hauch, V., Blandón-Gitlin, I., Masip, J., & Sporer, S. L. (2012). Linguistic cues to deception assessed by computer programs: A meta-analysis. *Proceedings of the EACL 2012 Workshop on Computational Approaches to Deception Detection*, 1–4.

Heinrichs, M., von Dawans, B., & Domes, G. (2009). Oxytocin, vasopressin, and human social behavior. *Frontiers in Neuroendocrinology*, *30*(4), 548–557. https://doi.org/10.1016/j.yfrne.2009.05.005

Heinrichs, M., Von Dawans, B., & Domes, G. (2009). Oxytocin, vasopressin, and human social behavior, *30*(4), 548–557.

Iidaka, T., Okada, T., Murata, T., Omori, M., Kosaka, H., Sadato, N., & Yonekura, Y. (2002). Age-related differences in the medial temporal lobe responses to emotional faces as revealed by fMRI. *Hippocampus*, *12*(3), 352–362. https://doi.org/10.1002/hipo.1113

Israel, S., Hart, E., & Winter, E. (2014). Oxytocin decreases accuracy in the perception of social deception. *Psychological Science*, *25*(1), 293–5. https://doi.org/10.1177/0956797613500794

Kalenzaga, S., Lamidey, V., Ergis, A., Clarys, D., & Piolino, P. (2016). The Positivity Bias in Aging : Motivation or Degradation ? *Emotion*, *16*(5), 602–610. https://doi.org/10.1037/emo0000170

Keightley, M. L., Chiew, K. S., Winocur, G., & Grady, C. L. (2007). Age-related differences in brain activity underlying identification of emotional expressions in faces. *Social Cognitive and Affective Neuroscience*, *2*(4), 292–302. https://doi.org/10.1093/scan/nsm024

Kéri, S., & Benedek, G. (2009). Oxytocin enhances the perception of biological motion in humans. *Cognitive, Affective & Behavioral Neuroscience*, *9*(3), 237–41. https://doi.org/10.3758/CABN.9.3.237

Kosfeld, M., Heinrichs, M., Zak, P. J., Fischbacher, U., & Fehr, E. (2005). Oxytocin increases trust in humans. *Nature*, *435*(7042), 673–677. https://doi.org/10.1038/nature03701

Kubzansky, L. D., Mendes, W. B., Appleton, A. A., Block, J., & Adler, G. K. (2012). A heartfelt response: Oxytocin effects on response to social stress in men and women. *Biological Psychology*, *90*(1), 1–9. https://doi.org/10.1016/j.biopsycho.2012.02.010

Levine, T. R., Park, H. S., & McCornack, S. a. (1999). Accuracy in detecting truths and lies: Documenting the "veracity effect." *Communication Monographs*, *66*(2), 125–144. https://doi.org/10.1080/03637759909376468

Lichtenberg, P. A., & Paulson, D. (2013). Is Psychological Vulnerability Related to the Experience of, *36*(2), 1–13. https://doi.org/10.1080/07317115.2012.749323.Is

Lim, K. T. K., & Yu, R. (2015). Aging and wisdom: Age-related changes in economic and social decision making. *Frontiers in Aging Neuroscience*, *7*(JUN), 1–11. https://doi.org/10.3389/fnagi.2015.00120

Löckenhoff, C. E., & Carstensen, L. L. (2007). Aging, emotion, and health-related decision strategies: motivational manipulations can reduce age differences. *Psychology and Aging*, *22*(1), 134–46. https://doi.org/10.1037/0882-7974.22.1.134

Macmillan, N. A. (2004). *Detection theory: A user's guide*.

Macmillan, N. a, & Creelman, C. D. (2005). *Detection Theory: A User's Guide*. *Detection theory: A user's guide (2nd ed.)*. https://doi.org/10.1017/CBO9781107415324.004

Mather, M., & Carstensen, L. L. (2003). Aging and attentional biases for emotional faces. *Psychological Science*, *14*(5), 409–415. https://doi.org/10.1111/1467-9280.01455

Mather, M., & Knight, M. (2005). Goal-directed memory: the role of cognitive control in older adults' emotional memory. *Psychology and Aging*, *20*(4), 554–570. https://doi.org/10.1037/0882-7974.20.4.554

Mather, M., & Knight, M. R. (2006). Angry faces get noticed quickly: threat detection is not impaired among older adults. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences*, *61*(1), P54-57. https://doi.org/61/1/P54 [pii]

McDowell, I. (2006). The State-Trait Anxiety Inventory. *Measuring Health: A Guide to Rating Scales and Questionnaires*, (1).

McEwen, B. B. (2004). Brain–Fluid Barriers: Relevance for Theoretical Controversies Regarding Vasopressin and Oxytocin Memory Research. *Advances in Pharmacology*, *50*, 531–592. https://doi.org/10.1016/S1054-3589(04)50014-5

Meissner, C. A., & Kassin, S. M. (2002). " He's guilty !": Investigator Bias in Judgments of Truth and Deception 1, *26*(5).

Meyer-Lindenberg, A., Domes, G., Kirsch, P., & Heinrichs, M. (2011). Oxytocin and vasopressin in the human brain: social neuropeptides for translational medicine. *Nature*

Reviews. Neuroscience, *12*(9), 524–538. https://doi.org/10.1038/nrn3044

Mooney, C., Duval, R., & Duvall, R. (1993). *Bootstrapping: A nonparametric approach to statistical inference*. Retrieved from https://books.google.com/books?hl=en&lr=&id=ZxaRC4I2z6sC&oi=fnd&pg=PR4&dq=why+bootstrapping&ots=oPp3HvbUnE&sig=zhKuwpymuuuu26aY0wtGLBp_Xm4

Motoki, K., Sugiura, M., Takeuchi, H., Kotozaki, Y., Nakagawa, S., Yokoyama, R., & Kawashima, R. (2016). Are plasma oxytocin and vasopressin levels reflective of amygdala activation during the processing of negative emotions? A preliminary study. *Frontiers in Psychology*, *7*(APR), 1–9. https://doi.org/10.3389/fpsyg.2016.00480

Mumford, J. A., & Nichols, T. (2006). Modeling and inference of multisubject fMRI data. *IEEE Engineering in Medicine and Biology Magazine*, *25*(2), 42–51. https://doi.org/10.1109/MEMB.2006.1607668

Nave, G., Camerer, C., & McCullough, M. (2015). Does Oxytocin Increase Trust in Humans? A Critical Review of Research. *Perspectives on Psychological Science*, *10*(6), 772–789. https://doi.org/10.1177/1745691615600138

Nevin, J. a. (1969). Signal detection theory and operant behavior: A review of David M. Green and John A. Swets' signal detection and psychophysics. *Journal of the Experimental Analysis of Behavior*, *12*(3), 475–480. https://doi.org/10.1901/jeab.1969.12-475

Peng, C.-Y. J., & So, T.-S. H. (2002). Logistic Rrgression Analysis and Reporting: A Primer. *Understanding Statistics*.

Percy, C. H. (1983). CONSUMER FRAUDS AND ELDERLY PERSONS : A GROWING PROBLEM SPECIAL COMMITTEE ON AGING UNITED STATES SENATE.

Peterson, J. C., Burnes, D. P. R., Caccamise, P. L., Mason, A., Henderson, C. R., Wells, M. T.,

… Lachs, M. S. (2014). Financial Exploitation of Older Adults: A Population-Based Prevalence Study. *Journal of General Internal Medicine*, *29*(12), 1615–1623. https://doi.org/10.1007/s11606-014-2946-2

Petrican, R., English, T., Gross, J. J., Grady, C., Hai, T., & Moscovitch, M. (2013). Friend or foe? Age moderates time-course specific responsiveness to trustworthiness cues. *Journals of Gerontology - Series B Psychological Sciences and Social Sciences*, *68*(2), 215–223. https://doi.org/10.1093/geronb/gbs064

Petrovic, P., Kalisch, R., Singer, T., & Dolan, R. J. (2008). Oxytocin Attenuates Affective Evaluations of Conditioned Faces and Amygdala Activity. *Journal of Neuroscience*, *28*(26), 6607–6615. https://doi.org/10.1523/JNEUROSCI.4572-07.2008

Phelps, E. A., & LeDoux, J. E. (2005). Contributions of the amygdala to emotion processing: From animal models to human behavior. *Neuron*, *48*(2), 175–187. https://doi.org/10.1016/j.neuron.2005.09.025

Reed, A. E., & Carstensen, L. L. (2012). The theory behind the age-related positivity effect. *Frontiers in Psychology*, *3*(SEP), 1–9. https://doi.org/10.3389/fpsyg.2012.00339

Reed, A. E., Chan, L., & Mikels, J. a. (2014). Meta-analysis of the age-related positivity effect: age differences in preferences for positive over negative information. *Psychology and Aging*, *29*(1), 1–15. https://doi.org/10.1037/a0035194

Riggio, R. E., & Friedman, H. S. (1983). Individual differences and cues to deception. *Journal of Personality and Social Psychology*, *45*(4), 899–915. https://doi.org/10.1037/0022-3514.45.4.899

Rilling, J. K., DeMarco, A. C., Hackett, P. D., Chen, X., Gautam, P., Stair, S., … Pagnoni, G. (2014). Sex differences in the neural and behavioral response to intranasal oxytocin and vasopressin during human social interaction. *Psychoneuroendocrinology*, *39*(1), 237–248. https://doi.org/10.1016/j.psyneuen.2013.09.022

Rose, J. D., & Moore, F. L. (2002). Behavioral neuroendocrinology of vasotocin and vasopressin and the sensorimotor processing hypothesis. *Frontiers in Neuroendocrinology*. https://doi.org/10.1016/S0091-3022(02)00004-3

Ross, M., Grossmann, I., & Schryer, E. (2014). Contrary to Psychological and Popular Opinion, There Is No Compelling Evidence That Older Adults Are Disproportionately Victimized by Consumer Fraud. *Perspectives on Psychological Science*, *9*(4), 427–442. https://doi.org/10.1177/1745691614535935

Ruffman, T., Murray, J., Halberstadt, J., & Vater, T. (2012). Age-related differences in deception. *Psychology and Aging*, *27*(3), 543–549. https://doi.org/10.1037/a0023380

Samanez-Larkin, G. R., & D'Esposito, M. (2008). Group comparisons: Imaging the aging brain. *Social Cognitive and Affective Neuroscience*, *3*(3), 290–297. https://doi.org/10.1093/scan/nsn029

Samanez-Larkin, G. R., Hollon, N. G., Carstensen, L. L., & Knutson, B. (2008). Individual differences in insular sensitivity during loss anticipation predict avoidance learning. *Psychological Science*, *19*(4), 320–3. https://doi.org/10.1111/j.1467-9280.2008.02087.x

Samanez-Larkin, G. R., & Knutson, B. (2015). Decision making in the ageing brain: changes in affective and motivational circuits. *Nature Reviews. Neuroscience*, *16*(5), 278–289. https://doi.org/10.1038/nrn3917

Seltman, H. J. (2014). Chapter 15 Mixed Models. *Experimental Design And Analysis*, 357–378.

Shamay-Tsoory, S. G., & Abu-Akel, A. (2016). The Social Salience Hypothesis of Oxytocin. *Biological Psychiatry*, *79*(3), 194–202. https://doi.org/10.1016/j.biopsych.2015.07.020

Shaw, H., & Lyons, M. (2016). Lie Detection Accuracy—the Role of Age and the Use of Emotions as a Reliable Cue. *Journal of Police and Criminal Psychology*. https://doi.org/10.1007/s11896-016-9222-9

Singer, T., Critchley, H. D., & Preuschoff, K. (2009). A common role of insula in feelings, empathy and uncertainty. *Trends in Cognitive Sciences*, *13*(8), 334–340. https://doi.org/10.1016/j.tics.2009.05.001

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: applications to dementia and amnesia. *Journal of Experimental Psychology. General*, *117*(1), 34–50. https://doi.org/10.1037/0096-3445.117.1.34

Song, Z., McCann, K. E., McNeill, J. K., Larkin, T. E., Huhman, K. L., & Albers, H. E. (2014). Oxytocin induces social communication by activating arginine-vasopressin V1a receptors and not oxytocin receptors. *Psychoneuroendocrinology*, *50*, 14–19. https://doi.org/10.1016/j.psyneuen.2014.08.005

Sorkin, R. D. (1999). Spreadsheet signal detection. *Behav Res Methods Instrum Comput*, *31*(1), 46–54. https://doi.org/10.3758/BF03207691

Spreng, R. N., Karlawish, J., & Marson, D. C. (2016). Cognitive, social, and neural determinants of diminished decision-making and financial exploitation risk in aging and dementia: A review and new model. *Journal of Elder Abuse & Neglect*, *28*(4–5), 08946566.2016.1237918. https://doi.org/10.1080/08946566.2016.1237918

St. Jacques, P., Dolcos, F., & Cabeza, R. (2010). Effects of aging on functional connectivity of the amygdala during negative evaluation: A network analysis of fMRI data. *Neurobiology of Aging*, *31*(2), 315–327. https://doi.org/10.1016/j.neurobiolaging.2008.03.012

Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior*

Research Methods, Instruments, {&} Computers, *31*(1), 137–149. https://doi.org/10.3758/BF03207704

Stanley, J. T., & Blanchard-Fields, F. (2008). Challenges older adults face in detecting deceit: the role of emotion recognition. *Psychology and Aging*, *23*(1), 24–32. https://doi.org/10.1037/0882-7974.23.1.24

Sweeney, C. D., & Ceci, S. J. (2014). Deception detection, transmission, and modality in age and sex. *Frontiers in Psychology*, *5*(JUN), 1–10. https://doi.org/10.3389/fpsyg.2014.00590

Tabak, B. A., Meyer, M. L., Castle, E., Dutcher, J. M., Michael, R., Han, J. H., … Eisenberger, N. I. (2016). Warmth : a Randomized Controlled Trial, 253–261. https://doi.org/10.1016/j.psyneuen.2014.10.006.Vasopressin

Tabak, B. A., Meyer, M. L., Dutcher, J. M., Castle, E., Irwin, M. R., Lieberman, M. D., & Eisenberger, N. I. (2016). Oxytocin, but not vasopressin, impairs social cognitive ability among individuals with higher levels of social anxiety: A randomized controlled trial. *Social Cognitive and Affective Neuroscience*, *11*(8), 1272–1279. https://doi.org/10.1093/scan/nsw041

Tausczik, Y. R., & Pennebaker, J. W. (2010). The Psychological Meaning of Words: LIWC and Computerized Text Analysis Methods. *Journal of Language and Social Psychology*, *29*(1), 24–54. https://doi.org/10.1177/0261927X09351676

Taylor, S. E. (2006). Biobehavioral Bases of Affiliation Under Stress, *15*(6), 273–277.

Taylor, S. E., Klein, L. C., Lewis, B. P., Gruenewald, T. L., Gurung, R. a, & Updegraff, J. a. (2000). Biobehavioral responses to stress in females: tend-and-befriend, not fight-or-flight. *Psychological Review*, *107*(3), 411–429. https://doi.org/10.1037/0033-295X.107.3.411

Thompson, R., Gupta, S., Miller, K., Mills, S., & Orr, S. (2004). The effects of vasopressin on human facial responses related to social communication. *Psychoneuroendocrinology*, *29*(1), 35–48. https://doi.org/10.1016/S0306-4530(02)00133-6

Thompson, R. R., George, K., Walton, J. C., Orr, S. P., & Benson, J. (2006). Sex-specific influences of vasopressin on human social communication. *Proceedings of the National Academy of Sciences of the United States of America*, *103*(20), 7889–7894. https://doi.org/10.1073/pnas.0600406103

Uchino, B. N. (2006). Social support and health: A review of physiological processes potentially underlying links to disease outcomes. *Journal of Behavioral Medicine*, *29*(4), 377–387. https://doi.org/10.1007/s10865-006-9056-5

Unkelbach, C., Guastella, A. J., & Forgas, J. P. (2008). Oxytocin selectively facilitates recognition of positive sex and relationship words: Short report. *Psychological Science*, *19*(11), 1092–1094. https://doi.org/10.1111/j.1467-9280.2008.02206.x

Uzefovsky, F., Shalev, I., Israel, S., Knafo, A., & Ebstein, R. P. (2012). Vasopressin selectively impairs emotion recognition in men. *Psychoneuroendocrinology*, *37*(4), 576–580. https://doi.org/10.1016/j.psyneuen.2011.07.018

Wright Whelan, C., Wagstaff, G. F., & Wheatcroft, J. M. (2015). Subjective cues to deception/honesty in a high stakes situation: an exploratory approach. *The Journal of Psychology*, *149*(5), 517–534. https://doi.org/10.1080/00223980.2014.911140

Wudarczyk, O. a, Earp, B. D., Guastella, A., & Savulescu, J. (2013). Could intranasal oxytocin be used to enhance relationships? Research imperatives, clinical policy, and ethical considerations. *Current Opinion in Psychiatry*, *26*(5), 474–84. https://doi.org/10.1097/YCO.0b013e3283642e10

Young, L. J., & Flanagan, L. M. (2011). Editorial Comment: Oxytocin, Vasopressin, and Social

Behavior. *Biological Bulletin*, *221*(1), 18–34. https://doi.org/10.1038/jid.2014.371

Zebrowitz, L. A., Boshyan, J., Ward, N., Gutchess, A., & Hadjikhani, N. (2017). The Older Adult Positivity Effect in Evaluations of Trustworthiness: Emotion Regulation or Cognitive Capacity? *Plos One*, *12*(1), e0169823. https://doi.org/10.1371/journal.pone.0169823

Zink, C. F., & Meyer-Lindenberg, A. (2012). Human neuroimaging of oxytocin and vasopressin in social cognition. *Hormones and Behavior*, *61*(3), 400–409. https://doi.org/10.1016/j.yhbeh.2012.01.016

Zink, C. F., Stein, J. L., Kempf, L., Hakimi, S., & Meyer-, A. (2010). NIH Public Access, *30*(20), 7017–7022. https://doi.org/10.1523/JNEUROSCI.4899-09.2010.Vasopressin

CONCLUSION

This dissertation has explored a variety of factors that underlie judgments of trustworthiness, and dishonesty. In Paper 1, we provided initial support for the phenomenon that, as compared to younger adults, older adults tend to be more trusting specifically of untrustworthy faces; a phenomenon that we argue may contribute to older adult's vulnerability to fraud. We also found that during these assessments of trustworthiness, older adults did not recruit the anterior insula to the same degree as younger adults, which we interpreted to mean that older adults were less engaged in the neurocognitive integration of negative emotional signals in the presences of untrustworthy faces. This is corroborated by the role that the anterior insula plays in the integration and translation of sensory cues with visceral feeling states to inform behavior (Adolphs, 2002; Singer et al., 2009). As these processes seem to be less robust in older adults, we suggest that older adults might have a reduced or lacking 'gut feeling' required to make a more accurate judgment.

In Paper 2, we built on Paper 1 by exploring the possibility that the observed age-related patterns might be the result of a broader emotion regulation strategy resulting in focus on positive features of the environment. While this positivity effect seems to be a feature of healthy aging, we hypothesized that, as observed with judgments of trust in Paper 1, deception detection accuracy would be compromised by attention to positivity. We found support for this hypothesis, with the presence of positive linguistic cues predicting decreases in lie detection accuracy for older adults but not younger adults. We suggested that this represents impoverished processing of important, negatively valenced cues to deception. Notably, we found the age differences in deception detection accuracy (and involvement of positive cues) to be most pronounced and reliable during a 'lower stakes' task that solicits less personal involvement and has simpler instructions. Thus suggesting that there are certain contexts where positivity has a smaller impact on older adult's judgments of trustworthiness and dishonesty and supporting the idea that the positivity effect is part of an age-related emotion regulation strategy only implemented when cognitive resources are available (Reed & Carstensen, 2012). This work created a more direct link between the older adult tendency to show an attentional bias towards positive stimuli, and the potential this has to increase vulnerability to fraud. By achieving a greater understanding of the mechanisms that create vulnerability to victimization among older adults, perhaps more robust tools can be developed to help protect this important societal demographic.

Finally, in Paper 3, we explored two endogenous neuropeptides shown to play a key role in the regulation of mammalian social behavior: oxytocin and vasopressin, with an eye towards how these hormones might support human social communication more generally. We measured how delivery of intranasal oxytocin, vasopressin, or a placebo, impacts the processing of subtle social cues that aid in differentiating honest from deceptive communication. We found that contrary to the reputation of oxytocin as a 'prosocial panacea' it does not increase trust-related behavior. Interestingly, oxytocin did no enhance deception detection accuracy either, so we also did not find support for the alternative hypothesis that oxytocin enhances the salience of relevant social cues regardless of valence. In contrast, vasopressin was found to improve deception detection accuracy, particularly in men. This accuracy boost was also associated with subjective cues to deception. Thus suggesting that vasopressin impacts human social perception in a competitive context, however instead of leading to perceptual reliance on one specific modality (e.g. linguistic, physical, etc.), it may enhance a more gestalt social assessment.

In conclusion, this dissertation explored the involvement of multiple biological signals (neural and hormonal) in the social cognitive and perceptual processes involved in judging trustworthiness and detecting deception across the lifespan.

In conclusion, this dissertation has explored the biological underpinnings of the perception of complex social signals by studying the impacts of age and neuropeptide hormones on perceptions of trustworthiness and ability to detect deception. This work has contributed to the understanding of how complex biological systems interact to support aspects of social communication throughout the lifespan. However, there is much more work left to be done. It is my hope that this research has created a solid platform from which future research will hopefully spring.

APPENDIX 1

Creation of Video Stimuli

To explore the processing of deceptive communication, two distinct sets of video stimuli containing a mix of honest and deceptive messages were created, along with a third set of unrelated neutral video clips to act as a control comparison. These video clips were designed with two central goals in mind: *1) enhance naturalistic cues to deception,* and *3) minimize distracting trait features*. Discussion of how these aims were addressed follows.

Subjects. To create stimuli with our conditions of interest (honesty and deception) we recruited 37 adult participants (25-43 years; M = 29, SD = 3.58), and videotaped them as they completed two short interactive tasks with a confederate. Since gender has been shown to impact cues of deception and perceptions of trustworthiness (O'Hair & Cody, 1987; Wincenciak, Dzhelyova, Perrett, & Barraclough, 2013), we recruited all male video subjects (referred to here as 'senders').

Clip design. Certain contexts have been demonstrated to produce more reliable cues to deception in a sender's communication than others. For example, lies told while interacting with another person (as opposed to speaking to a video camera) typically contain more cues to deception (DePaulo et al., 2003). However, the type of interaction is important, because same versus opposite gender interactions can elicit different patterns of deception cues (DePaulo, Stone, bell, & Lassiter, 1985). In en effort to minimize superfluous heterogeneity in subtle social signals present in the video stimuli, each male sender interacted with the same female confederate. Additionally, lies are more easily identified if they are told by a motivated sender (DePaulo et al., 2003; DePaulo & Bond, 2006) with 'high stakes' lies often producing different types of cues to deception than lower stakes lies (Porter & Brinke, 2011). To address this concern, senders were offered significant compensation for participation ($50/half hour session with up to an additional $75 in performance based bonuses).

Procedure: At the start of each session, a video camera was placed on a tripod directly facing the participant and adjusted to hover above the confederate's right shoulder at face level. Zoom was adjusted to capture only the participant's face and shoulders and the camera remained in this position until all tasks had been completed. After signing a video release form, each sender was instructed to interact with our experimenter as if the camera were absent. Anecdotally, senders did not seem to be bothered by the presence of the camera, and instead were interacting quite fluidly with the confederate (who was instructed to be polite but not overly engaging).

Opinion videos. These stimuli were designed to act as snapshots of personally relevant deceit (i.e. lying about oneself). Senders were asked to share their opinion about common items (e.g. cars, food, office supplies, etc.) with their interaction partner in the form of short self-generated statements. Senders chose 4 items (2 they liked and 2 they disliked) to lie about and 4 different liked/disliked items to make true statements about. To incentivize senders to be as convincing as possible, they were told that as they expressed their opinions, their interaction partner would be judging their honesty and if the sender managed to deceive their partner for six out of eight trials, they would receive a $25 bonus. If they did not achieve this, they thought their interaction partner would receive the bonus instead. Our confederate's deception detection accuracy was calculated at the end of the session, and senders were awarded the bonus (or not) based on this outcome. This yielded video clips of 8 short statements (4 honest and 4 deceptive), for each sender. Videos were reviewed for content and sound quality, and acceptable clips were edited using iMovie.

Sample clips: Opinion videos

“I hate to wear sunglasses because they just don’t fit my face and I’ve never ever liked them I guess.”

“You know those Swiffer Sweepers? I also hate those because, you know it just doesn’t work very well first of all. And the little liquid never comes out when you want it to.”

“I love newspapers ‘cause I don’t like reading my news online.”

“I like Nike shoes, um because when I do play basketball they were the only ones that gave me the best support just in terms of my ankles and I love the little air bubbles, make me feel like I can jump higher.”

Procedure: Investment videos. These stimuli were designed to approximate high stakes (but non-criminal) deceit associated with a real behavioral consequence as this might better approximate the type of high-cost deception older adults are more vulnerable to.

Senders were told they would be playing an investment game where they would have the opportunity to earn an additional $50 bonus. Instructions were explained to the sender/confederate interaction pair simultaneously, and due to the game’s complexity, extra care was taken to ensure the sender fully understood the rules. For simplicities sake, the task is fully described here using the example of Jack (sender) and Jill (confederate interaction partner), and a task summary is also represented in Figure 1. Participants received $50 as payment before any bonuses. Jill was given an additional $10 bonus to play an investment game, which can be described as having three rules.

Rule 1 → Jill must choose to either:

a) keep the $10 -or- b) trust Jack with the $10 for a chance to get $40.

Rule 2 → If Jill chooses to 'invest' the $10 in Jack, this act of trust will grow her investment to $50.

Rule 3 → If Jill invests, Jack will have control over the $50. He must choose to either:

a) keep the $50 -or- b) split the $50 so Jill gets $40 and Jack keeps $10 (he is not allowed to divide the money in any other way)

Jack makes his own choice about whether he plans on splitting the money with Jill if she invests, *and privately records his decision*. Before Jill decides whether or not to invest her $10, Jack is given an opportunity to convince Jill to invest in him in the form of a short, persuasive investment pitch. Jack was allotted approximately one minute to prepare, and 30 seconds to deliver his pitch, and is free to say whatever he thinks would be most persuasive. These pitches serve as our video stimuli. Since Jack can only earn a bonus if Jill decides to invest, Jack tells Jill he will split the $50 with her, even if he plans on keeping it all for himself. After Jack's pitch, Jill decides whether she thinks Jack is telling the truth about splitting the money with her, which leaves three possible outcomes.

Outcome #1 → Jill thinks Jack does not plan on splitting the money and keeps the $10.

Outcome #2 → Jill thinks Jack will split the money and chooses to invest the $10 in him. The investment automatically matures to $50. Jack was being honest in his pitch, so the money is split such that Jill receives $40 and Jack keeps $10.

Outcome #3 → Jill thinks Jack will split the money and chooses to invest the $10 in him. The investment automatically matures to $50. Jack was lying in his pitch, so the money is not split between them. Instead Jack keeps $50 and Jill looses her bonus $10.

After the investment game has been completed, the session ended and bonus money was distributed according to the confederate's judgment. Notably, the sender was not required to do anything for the investment to mature from $10 to $50. This means that an optimal investment decision in this task should be based solely on whether or not you think the sender will split the money with you, independent of their skill as an investor. Also of note, the sender was required to record whether he was planning to split or steal the $50 *prior to making his pitch*. This means that the message in each video pitch can be definitively categorized as either honest or deceptive because the sender was not allowed to change his response after the fact. All videos were reviewed for content and sound quality, and acceptable clips were edited using iMovie. In pilot testing, the average deception detection accuracy rate (as judged by an independent online sample) was 49.98%, which is consistent with expectation (DePaulo & Bond, 2006).

> ***Sample clips: Investment videos***
>
> *"Here's my pitch: I, uh, am not a selfish person and, uh, I don't want anybody to not walk out of here without any money, so I think, um, you should invest your money in me because I'm not going to steal it, I promise."*
>
> *"So, I could walk away with 0, or I, I could walk away with 10 dollars. I would much prefer to walk away with 10 dollars, so if you agree to trust me, um, you can walk away with 40, and I can, I can walk away with 10, and we can both walk away with the same amount of money. Um, as far as my background goes, I was a marine for 5 years, a captain, and then I was a school principal. I'm in the business school right now, um, that's what my background is. Um, but really, I would just like for us both to walk away with a little bit of money in our pockets, and that's it."*

Procedure: Control videos. For the neutral control stimuli, 21 adult male participants (25-34 years; M=29.12, SD = 3.35) were recruited to interact with the same female experimenter who played the confederate in the previous videos. Again, the camera was placed on a tripod directly facing the sender, and adjusted to hover above the experimenter's right shoulder at face level, and zoom adjusted to capture only the sender's face and shoulders. Senders were asked to factually describe any breakfast food item or meal of their choice, without using any social context (e.g. using personal pronouns, recounting a memory, or describing their own experience). This was done to ensure neutral content and minimize social-cognitive resources necessary to process the clips. This procedure was repeated for lunch and dinner, such that each sender filmed three food clips. Videos were reviewed for content and sound quality, and acceptable clips were edited using iMovie; there are 41 total clips that range from 7-32 seconds (M = 17.86, SD = 5.87).

> ***Sample clips: Food videos***
>
> *"Steak can be baked. Steak can be fried. Steak can be um grilled. Steak can be combined with a variety of things, like French fries, like mashed potatoes, like greens."*
>
> *"Coffee and oatmeal are common breakfast items. Coffee is made from beans, it's black in color, contains caffeine, and few calories. Oatmeal is made from oats, water, and is a healthy breakfast choice."*

Coding cues to deception. Each investment pitch video was coded by a set of four independent raters (blind to truth/lie video condition) to quantify social 'cues' that have been linked to the perception of deception as well as actual deceptive behaviors(Hartwig & Bond, 2011). Raters observed body language and facial expressions with video sound muted to identified frequency of chin raises, manual illustrators (hand motion), unusual blinking behavior, fidgeting, and lip presses, all of which have been linked to deception prior research, although multiple reports indicate that while physical cues are strongly related to lay notions of deceit, they tend to be less likely to predict actual deception (DePaulo et al., 2003; Hartwig & Bond, 2011; Riggio & Friedman, 1983). These measures were concatenated into a single index of '*physical lie cues*'. Subjective cues to deception have been previously demonstrated to be the most informative to observers (C. F. Bond & Depaulo, 2006; DePaulo et al., 2003; Wright Whelan et al., 2015), raters assessed each video on a subjective 5 point Likert scale for suspiciousness, uncertainty, nervousness, warmth, liking positive affect, and trustworthiness. An index of '*subjective lie cues'* was created by averaging all raters judgments of suspiciousness, uncertainty, and nervousness and an index of *'subjective truth cues'* was created by averaging all raters judgments of warmth, liking, positive affect, and trustworthiness. Finally, linguistic cues have also been linked to accurate deception detection (Hauch et al., 2012; Wright Whelan et al., 2015) so we subjected the transcripts of video investment pitches to an automated Linguistic Inquiry and Word Count (LIWC) to identify linguistic features which have been previously associated with discriminating truth from deception (Chung & Pennebaker, 2012). An index of '*verbal lie cues'* was created by averaging frequencies of a set of predetermined cues within each investment pitch video. Selected cues were: fillers, non-fluency, negations, lack of immediacy (including impersonal pronouns, frequent usage of 'I,' and infrequent usage of 'we'), and reverse coded certainty as well as affect. An index of '*verbal truth cues'* was created in the same manner using frequency of positive and negative emotion (as identified from text with LIWC) as enhanced emotional tone tends to predict honesty (Tausczik & Pennebaker, 2010). All cue indices were mean centered before incorporation in analyses. While it has been firmly established that detectors tend to use some combination of social cues to deception when judging deceit (Hartwig & Bond, 2011), not all of these cues are necessarily indicative of actual deceptive behavior as they can vary across context and individuals (C. F. Bond & Depaulo, 2008; Riggio & Friedman, 1983). All of the cue indices here significantly correlate (*Ps* < .025) with the presence of actual deception in this experiment (see Table 6). All of these correlations occur in the expected direction with the exception of *'physical lie cues,'* essentially rendering this a 'false cue' in the context of this study.

Table 1 of Appendix 1

Correlations Among Cues to Deception and Between these Cues and Presence of Actual Deceit

	M (*SD*)	Deception	Verbal Truth Cues	Verbal Lie Cues	Physical Lie Cues	Subjective Lie Cues	Subjective Truth Cues
Deceit	1.47 (.50)		-.049*	.261**	-.089**	.106**	-.381**
Verbal Truth Cues	4.5 (2.85)			-.189**	.113**	.100**	.360**
Verbal Lie Cues	1.54 (0.80)				.110**	.178**	-.292**
Physical Lie Cues	1.36 (0.67)					-.124**	.089**
Subjective Lie Cues	2.45 (0.97)						-.276**
Subjective Truth Cues	3.20 (0.57)						

Notes. The correlations for ‘Deception’ in the first row represent correlations of the cues with the presence of actual deception. Negative values here mean frequency of this cues is related to truth and positive values mean frequency of this cue is related to lies. * $p < .05$ **$p < .01$ *** $p < .001$

REFERENCES FOR INTRODUCTION AND CONCLUSION

Adolphs, R. (2002). Neural systems for recognizing emotion. *Current Opinion in Neurobiology*, *12*(2), 169–177. https://doi.org/10.1016/S0959-4388(02)00301-X

Albers, H. E. (2012). The regulation of social recognition, social communication and aggression: Vasopressin in the social behavior neural network. *Hormones and Behavior*, *61*(3), 283–292. https://doi.org/10.1016/j.yhbeh.2011.10.007

Baribeau, D. A., & Anagnostou, E. (2015). Oxytocin and vasopressin: Linking pituitary neuropeptides and their receptors to social neurocircuits. *Frontiers in Neuroscience*, *9*(SEP). https://doi.org/10.3389/fnins.2015.00335

Caldwell, H., & Iii, W. Y. (2006). Oxytocin and Vasopressin: Genetics and Behavioral Implications. *Handbook of Neurochemistry and Molecular Neurobiology*, 573–607. https://doi.org/10.1007/978-0-387-30381-9_25

Castle, E., Eisenberger, N. I., Seeman, T. E., Moons, W. G., Boggero, I. a, Grinblatt, M. S., & Taylor, S. E. (2012). Neural and behavioral bases of age differences in perceptions of trust. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(51), 20848–52. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3529090&tool=pmcentrez&rendertype=abstract

Reed, A. E., & Carstensen, L. L. (2012). The theory behind the age-related positivity effect. *Frontiers in Psychology*, *3*(SEP), 1–9. https://doi.org/10.3389/fpsyg.2012.00339

Reed, A. E., Chan, L., & Mikels, J. a. (2014). Meta-analysis of the age-related positivity effect: age differences in preferences for positive over negative information. *Psychology and Aging*, *29*(1), 1–15. https://doi.org/10.1037/a0035194

Shamay-Tsoory, S. G., & Abu-Akel, A. (2016). The Social Salience Hypothesis of Oxytocin. *Biological Psychiatry*, *79*(3), 194–202. https://doi.org/10.1016/j.biopsych.2015.07.020

Singer, T., Critchley, H. D., & Preuschoff, K. (2009). A common role of insula in feelings, empathy and uncertainty. *Trends in Cognitive Sciences*, *13*(8), 334–340. https://doi.org/10.1016/j.tics.2009.05.001

Uchino, B. N. (2006). Social support and health: A review of physiological processes potentially underlying links to disease outcomes. *Journal of Behavioral Medicine*, *29*(4), 377–387. https://doi.org/10.1007/s10865-006-9056-5