RECOGNIZING FACIAL EXPRESSIONS OF VIRTUAL AGENTS, SYNTHETIC FACES AND HUMAN FACES: THE EFFECTS OF AGE AND CHARACTER TYPE ON EMOTION RECOGNITION

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RECOGNIZING FACIAL EXPRESSIONS OF VIRTUAL AGENTS, SYNTHETIC FACES AND HUMAN FACES: THE EFFECTS OF AGE AND CHARACTER TYPE ON EMOTION RECOGNITION

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TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS iii

LIST OF TABLES vii

LIST OF FIGURES viii

SUMMARY ix

CHAPTER

1 INTRODUCTION 1

  Intelligent Agents 1

  Social Interactions with Intelligent Agents 2

  Social Agents and Emotion Expression 3

  Age-related Differences in Emotion Recognition 6

  Overview of Study 9

2 METHOD 13

  Participants 13

  Apparatus/Materials 14

    Virtual Agent Face 15

    Synthetic Human Face 15

    Human Face 16

    Standardization of Character Type 16

    Ability Tests and Questionnaires 17

  Design 18

  Procedure 18

3 RESULTS 21

Overview of Analysis 21

Emotion Recognition as a Function of Emotion, Character and Age 21

Age-related Differences in Emotion Recognition 23

Human Face 23

Synthetic Human Face 26

Virtual Agent Face 29

Emotion Recognition Over Time 32

Summary of Age-related Differences 33

Feature Discrimination 33

Feature Discrimination of Upper/Lower Face Regions 36

Summary of Feature Discrimination 37

Understanding Character Differences 37

Anger 37

Fear 39

Happiness 40

Sadness 42

Neutral 43

Summary of Understanding Character Differences 45

4 DISCUSSION 46

Theoretical Implications 47

Applied Implications 50

Methodological and Measurement Considerations 51

Conclusion and Next Steps 53

APPENDIX A: QUALITATIVE DESCRIPTIONS OF FACIAL EXPRESSIONS 55

APPENDIX B: EXPERIMENTAL PROTOCOL 56

APPENDIX C: FACIAL EXPRESSION IDENTIFICATION QUESTIONNAIRE 57

APPENDIX D: RESPONSE TIME ANOVA 81

APPENDIX E: RESPONSE TIME GRAPHS 82

APPENDIX F: CONFUSION MATRICES BY BLOCK SET 84

REFERENCES 90

LIST OF TABLES

Page

Table 1: Participant ability test scores 14

Table 2: Differences in Emotion Recognition Between Age Groups. 25

Table 3: Human Emotion Attributions Made by Older Adults 26

Table 4: Human Emotion Attributions Made by Younger Adults 26

Table 5: Differences in Emotion Recognition Between Age Groups 28

Table 6: Synthetic Human Emotion Attributions Made by Older Adults 28

Table 7: Synthetic Human Emotion Attributions Made by Younger Odults 29

Table 8: Differences in Emotion Recognition Between Age Groups 31

Table 9: Virtual Agent Emotion Attributions Made by Older Adults 31

Table 10: Virtual Agent Emotion Attributions Made by Younger Adults 32

Table 11: Similarity and Attribution Comparisons 35

Table 12: Difference between Character Type for Anger 38

Table 13: Difference between Character Type for Fear 40

Table 14: Difference between Character Type for Happiness 41

Table 15: Difference between Character Type for Sadness 43

Table 16: Difference between Character Type for Neutral 44

Table 17: Emotion x Character Type x Age Response Time ANOVA 81

Table 18: Human emotion attributions made over time by older adults 84

Table 19: Synthetic human emotion attributions made over time by older adults 85

Table 20: Virual agent emotion attributions made over time by older adults 86

Table 21: Human emotion attributions made over time by younger adults 87

Table 22: Synthetic human emotion attributions made over time by younger adults 88

Table 23: Virtual agent attributions made over time by younger adults 89

LIST OF FIGURES

Page

Figure 1: Five emotions for each character type 17

Figure 2: Mean proportion match and standard error for each character type 22

Figure 3: Younger and older adult emotion recognition for the human face 24

Figure 4: Younger and older adult emotion recognition for the synthetic human face 27

Figure 5: Younger and older adult emotion recognition for the virtual agent face 30

Figure 6: Emotion recognition for angry 38

Figure 7: Emotion recognition for fear 39

Figure 8: Emotion recognition for happiness 41

Figure 9: Emotion recognition for sadness 42

Figure 10: Emotion recognition for neutral 44

Figure 11: Younger and older adult response time for human face 82

Figure 12: Younger and older adult response time for synthetic human face 82

Figure 13: Younger and older adult response time for virtual agent face 83

SUMMARY

An agent's facial expression may communicate emotive state to users both young and old. Facial expression in particular is one of the most common non-verbal cues used to display emotion in on-screen agents (Cassell, Sullivan, Prevost, & Churchill, 2000). Understanding issues related to social characteristics of social agents may aid designers in creating agents that promote optimal human-agent interaction. The ability to recognize emotions has been shown to differ with age, with older adults more commonly misidentifying the facial emotions of anger, fear, and sadness (for summary see Ruffman, Henry, Livingstone, & Phillips, 2008).

A number of theoretical accounts attempt to explain age-related differences in emotion recognition. Theories of emotional-motivational age-related changes posit that shifts in emotional goals and strategies occur across adulthood, resulting in a bias toward processing positive information. The positivity effect suggests that attending to and remembering positive emotional information compared to negative seems to differ between age groups (Mather & Carstensen, 2005).

An alternative account for age-related differences in emotion recognition may be the way in which older and younger adults perceive or attend to the facial features (e.g., eyebrows or mouth) that convey an expression. Older adults may focus their attention on mouth regions of the face, rather than eye regions (Sullivan, Ruffman, & Hutton, 2007).

However, little research has been conducted which investigates how well younger and older adults recognize emotion displayed by on-screen virtual agents. This research study examined whether emotion recognition of facial expressions differed between different types of on-screen agents, and between age groups. Three on-screen characters were compared. The facial expressions depicted by each character were chosen or created based upon similar criteria for emotion generation. To assess emotion recognition across a variety of character types, the three agents represented a range of human-likeness: a human, a synthetic human, and a non-humanoid virtual agent.

Participants completed an emotion recognition task with these three characters. Static pictures of the characters were presented to participants demonstrating four basic emotions (anger, fear, happiness, and sadness) and neutral. Participants responded by selecting an emotion they thought was displayed by the face. The main dependent variable of interest was analyzed as the mean proportion of responses matching the emotion the character was designed to display

The human face resulted in the highest proportion match, followed by the synthetic human, then the virtual agent with the lowest proportion match. Age-related differences were found for all characters. Both the human and synthetic human faces resulted in age-related differences for the emotions anger, fear, sadness, and neutral, with younger adults showing higher proportion match. The virtual agent showed age-related differences for the emotions anger, fear, happiness, and neutral, with younger adults showing higher proportion match.

The data analysis and interpretation of the present study differed from previous work by utilizing two unique approaches to understanding emotion recognition. First, misattributions, or mislabels, participants made when identifying emotion were investigated. Overall, older adults made more misattributions than younger adults. Both age groups commonly labeled the emotion fear as surprise for all characters. Older adults commonly mislabeled the human and synthetic human emotion anger as disgust. For the virtual agent, older adults commonly mislabeled anger as disgust, sadness and neutral; whereas younger adults commonly mislabeled it as disgust.

Second, feature discriminability was assessed. A similarity index was calculated by comparing any two emotion feature arrangements displayed by the virtual agent. The similarity index suggested that some emotions were commonly misattributed as another emotion similar in appearance (e.g., the facial feature placement for the virtual agent's expression fear is similar to surprise).

Overall, these results suggest that age-related differences transcend human faces to other types of on-screen characters. The positivity effect is not a comprehensive explanation for age-related differences in emotion recognition, as negative emotions were often mislabeled as other negative emotions. Differences between older and younger adults in emotion recognition may be further explained by perceptual discrimination between two emotions of similar feature appearance. Designers should consider differences between age groups in emotion recognition when choosing an emotion expression repertoire for an agent. An older adult user may label an emotion displayed by a virtual character differently than a younger user.

CHAPTER 1

INTRODUCTION

Intelligent Agents

People have been fascinated with the concept of intelligent agents for decades. Science fiction examples of robots and other intelligent machines, such as Rosie from the Jetsons or C3PO from Star Wars, are idealized representations of someday coexisting with advanced forms of intelligent technology. Recent research and technology advancements have shed light onto the possibility of intelligent machines becoming a part of everyday living. Such technological advancements in the area of intelligent machines necessitate defining agents and intelligent agents, as well as discussing the nature of social interaction with such machines.

The label “agent” is widely used and there is no agreed upon definition. An agent can be broadly defined as a hardware or software computational system that is autonomous, proactive, reactive, and has social ability (Wooldridge & Jennings, 1995). Two common types of agents are robots and virtual agents.

Although robots and virtual agents can be broadly categorized as agents, there is differentiation between both terms, which is worth highlighting. A robot is a physical computational agent designed to use effectors and memory to perform tasks (Sheridan, 1992). A virtual agent can be similarly defined, but does not have physical properties; rather it is embodied as a computerized 2D or 3D representation. A robot may use infrared range finders as sensors, and motors as effectors, whereas a virtual agent is software based, with encoded bit strings as its percepts and actions (Russell & Norvig, 1995).

By identifying a system as a robot or virtual agent, it does not necessarily imply that it is an *intelligent* agent. Determining if an agent is intelligent or not, depends on the way in which the agent makes decisions and actions. In computer science, the term intelligent agent often refers to the autonomous characteristics of a machine or software. An intelligent agent is proactive, meaning that it does not just respond to the environment but actively and autonomously changes its own behaviors to reach goals. Furthermore, an intelligent agent can make goal-oriented decisions based upon the representation of knowledge collected from the environment (Russell & Norvig, 1995).

Social Interactions with Intelligent Agents

When many people think about the role of advanced agents, particularly robotics, they typically associate them with military applications, hazardous working conditions, or space exploration. However, due to continuing technological advancements, agents have a future in more social environments, which will require collaborative interaction with untrained humans (Breazeal, Brooks, Chilongo, Gray, Hoffman, Kidd, et al., 2004).

In 2008, there were projected to be over 4.5 million home-based robots in use, more than double the number in 2004 (United Nations Economic Commission/International Federation of Robotics, 2005). Generally, home-based robots are either designed to perform simple servant-like tasks (e.g., the robotic vacuum cleaner Roomba), or used purely for entertainment (e.g., Sony's robotic singing Elvis), and do not demonstrate advanced intelligent capabilities.

Nevertheless, a growing trend in intelligent agent research is addressing the development of socially engaging agents that may be applied to the home or healthcare setting (Dautenhahn, Woods, Kaouri, Walters, Koay, & Werry, 2005) and serve in a more *assistive* manner. For example, within the home, a robot could provide a range of assistive technology. One such healthcare robot, known as Pearl, includes a reminder system, tele-communication system, surveillance system, the ability to provide social interaction, and a range of movement to complete daily household tasks (Davenport, 2005). Furthermore, virtual agents, such as Microsoft's paper-clip embodied assistant, "clippit," may provide users with instructional assistance when using a software product.

The development of assistive intelligent technology has the promise of increasing the quality of life for older adults in particular. Americans are living longer (United States Census Bureau, 2005) and assistive agents may help individuals to perform the activities that they personally need or want help with as they age. With age, changes in perceptual, cognitive, and motor control occur; such age-related changes can be mitigated with the use of technology (Mayhorn, Rogers, & Fisk, 2004). Older adults prefer to age in place (Gitlin, 2003); that is, they prefer to age in their home setting, and may be amenable to having robots in their homes (Ezer, 2009). Robots, and other intelligent agents, have the potential to keep older adults independent longer, reduce healthcare needs, and provide everyday assistance (thus reducing care-giving needs). A better understanding of how older people socially interact with technology will directly impact the design of assistive agents.

Social Agents and Emotion Expression

Making better intelligent agents is not only about improving technology. It is crucial to understand issues related to social characteristics of robotic agents that promote optimal human-robot interaction. As robotic and virtual agent technology advance and gain the capabilities needed to serve as social entities, researchers are increasingly stressing the need for designers to keep the social characteristics of the agent in mind.

It is generally accepted in the research community that people are willing to apply social characteristics to technology. Humans have been shown to apply social characteristics to computers, even though the users admit that they believe these technologies do not possess actual human-like emotions, characteristics, or “selves” (Nass, Steuer, Henriksen, & Dryer, 1994). Humans have been shown to elicit social behaviors toward computers mindlessly (Nass & Moon, 2000), and treat computers as teammates and having personality, similar to human-human interaction (Nass, Fogg, & Moon, 1996; Nass, Moon, Fogg, Reeves, 1995).

Effective social interaction requires more than applying social characteristics to an agent. As technology becomes more advanced, agents and robots are more capable of actively demonstrating social cues. An agent specifically designed to display social cues and elicit social responses is often referred to as a *social agent* (Bickmore, 2003). Social agents can assume anthropomorphic (human-like) or non-anthropomorphic forms. However, note that human characteristics are crucial in facilitating human virtual agent social characteristics; these human characteristics can be identified as facial embodiment, voice embodiment, personality and emotion (see Park, 2008, for summary).

Social cues influence the way in which people will interact with an agent. For example, a robot that is able to use natural dialog, gesture, and non-verbal social cues creates a more cooperative relationship between the robot and human (Breazeal et al., 2004). Applying social attributes to robots is likely to impact the interaction of humans and robots in a team-like collaborative system. Breazeal, Kidd, Thomaz, Hoffman, and

Berlin (2005) investigated how a robot’s non-verbal explicit behavior (i.e., head nod, gesturing) and implicit cues (i.e., eye gaze) affected human-robotic teamwork. They found that implicit behavior was positively related with human-robot task performance, more particularly in understanding of the robot, efficient teamwork/performance, and alleviating miscommunication. Optimal human-robotic interaction may be dependent on the robot’s ability to demonstrate a level of believability by displaying behaviors such as attention, reactivity, facial expression (Breazeal, 2002).

Facial expression in particular is one of the most common non-verbal cues used to display emotion in on-screen agents (Cassell, Sullivan, Prevost, & Churchill, 2000). Facial expressions are an important medium for communicating emotional state (Collier, 1985), and a critical component in successful social interaction. Emotion expression may be one of the primary elements of creating a life-like social agent, whether robotic or virtual. Emotion is thought to create a sense of believability by allowing the viewer to assume that a social agent is capable of caring about its surroundings (Bates, 1994) and creating a more enjoyable interaction (Bartneck, 2003).

The emotion-expressive abilities of an agent may play a larger role in the development of advanced *intelligent* technology. Pichard (1997) stressed that emotion is a critical component and active part of intelligence. More specifically, Pichard stated that “computers do not need affective abilities for the fanciful goal of becoming humanoids; they need them for a meeker and more practical goal: to function with intelligence and sensitivity toward humans” (p. 247).

The role of social cues, such as emotion, is not only critical in creating intelligent agents that are sensitive and reactive toward humans, but also in the way in which people respond to the agent. Previous research has shown that participants' accuracy of recognizing facial-emotion of robotic characters and virtual agents are similar (Bartneck, Reichenbach, & Breemen, 2004). Furthermore, simulated affective displays (both visual and audio) are reported to be as convincing as human faces (Barneck, 2001), further supporting the assumption that humans will apply social attributes to technology (e.g., Nass et al., 1996; Nass & Moon, 2000; Nass et al., 1995; Nass et al., 1994).

Although research has been conducted investigating the role of social cues in human-agent interaction, little research has explored people's accuracy of recognizing and identifying the emotion displayed by a social agent. It is critical to understand how people of all ages interpret social cues the agent is displaying, particularly emotion. A review of how humans interpret *human* facial expressions may provide some insight on how they might recognize agent facial expressions.

Age-related Differences in Emotion Recognition

Due to the importance of emotion recognition in social interaction, it is not surprising that considerable research has been conducted investigating how accurately people recognize human emotion. The ability to recognize emotions has been shown to differ between age groups. Isaacowitz et al. (2007) summarized the research in this area conducted within the past fifteen years. Their summary (via tabulating the percentages of studies resulting in significant age group differences) found that of the reviewed studies, 83% showed an age-related difference for the identification of anger, 71% for sadness, and 55% for fear. No consistent differences were found between age groups for the emotions happy, surprise, and disgust. These age-group differences were also reported in a recent meta-analysis (Ruffman, Henry, Livingstone, & Phillips, 2008).

Older and younger adults' differences in labeling emotions appear to be relatively independent of cognitive changes that occur with age (Keightley et al., 2006; Sullivan & Ruffman, 2004). Therefore, a number of theoretical accounts may provide a possible explanation for age-related differences in emotion recognition, namely motivational accounts, feature detection/attention, as well as neural changes in the brain.

Theories of emotional-motivational age-related changes posit that shifts in emotional goals and strategies occur across adulthood. One such motivational explanation, the socioemotional selectivity theory, suggests that time horizons influence goals (Carstensen, Isaacowitz, & Charles, 1999). The experience of time constraints, such as the sense that lifetime is running out, prioritizes emotionally gratifying experiences and brings about a motivational shift from achievement-oriented goals to emotionally-relevant goals. Other related motivational accounts suggest that emotional-motivational changes are a result of compensatory strategies to adapt to age-related declining resources (e.g., Labouvie-Vief, 2003) or emotional-regulation strategies actually becoming less effortful with age (e.g., Scheibe & Blanchard-Fields, 2009).

A motivational tendency to focus on emotional goals or strategies may result in a bias toward processing positive information. The positivity effect, sometimes referred to as the positivity bias, suggests that attending to and remembering positive emotional information compared to negative seems to differ between age groups (Mather & Carstensen, 2005). For example, older adults are more likely to fixate on positive information longer than negative (Mather & Carstensen, 2003) and are more likely to attend to and memorize positive stimuli to preserve a positive emotional state (Carstensen & Mikels, 2005).

The claim that older and younger adults differ in motivation for positive emotional experiences could also imply that the perception of emotions also differs with age. The positivity effect has been suggested as a possible explanation for age-related differences in emotion recognition (Ruffman, Henry, Livingstone, & Phillips, 2008; Williams et al., 2006). Older adults generally show lower emotion recognition for negative emotions such as anger, fear, and sadness; however, the effect does not explain why older adults have been shown to recognize disgust just as well, if not better, than younger adults (Calder et al., 2003).

An alternative account for age-related differences in emotion recognition may be the way in which older and younger adults perceive or attend to the individual facial components (e.g., facial features) that convey an expression. Individual facial features such as the eyebrows or mouth may be a critical factor in processing an emotional expression (see Frischen, Eastwood, & Smilek, 2008 for summary). Differences in the way older adults detect and attend to facial features may provide an explanation for age-related differences in emotion recognition. For example, older adults may focus their attention on mouth regions of the face, rather than eye regions (Sullivan, Ruffman, & Hutton, 2007). One explanation for this bias is that the mouth is less threatening than the eyes. Because negative emotions are generally assumed to be more distinguishable according to changes in the eyes, attending to mouth regions may result in less accurate emotion identification (Calder, Young, Keane, & Dean, 2000).

Finally, researchers have argued that age group differences in recognition may be due to neural changes that occur as a process of natural aging (e.g., Calder et al., 2003; Sullivan & Ruffman, 2004). Structural decline in frontal/temporal regions and changes in neurotransmitters may impair the processing of negative stimuli, supporting a neuropsychological explanation of emotion-recognition differences in older adults (Ruffman, Henry, Livingstone, & Phillips, 2008).

Whatever the cause, differences between younger and older adults in recognizing emotion is a factor to consider when designing social agents. Further research is needed to better understand emotion recognition of facial expressions displayed by a variety of on-screen agents, as well as how well different age groups recognize emotion displayed by those agents.

Overview of Study

As social intelligent agents move toward being more commonplace and used in different contexts, several open questions emerge. First, will age-related differences in emotion recognition transcend human faces? Age-related differences have been documented for the recognition of *human* facial expression, suggesting that older adults commonly mislabel the emotions of anger, fear, and sadness (Ruffman et al. 2008). Although some research has examined recognition of virtual agent facial expressions (e.g., Beer, Fisk, & Rogers, 2009), the generality of age-related differences across a variety of agent faces remains an open question.

Second, is emotion recognition equal across different types of on-screen agents? Agents have been applied to a variety of settings, and are depicted anywhere on a continuum from humanoid (e.g., human video game avatars) to non-humanoid (e.g., Microsoft's paper clip). Assessing emotion recognition by using a variety of on-screen faces might tease apart some of these open questions. The goal of the present study was to investigate older and younger adults' emotion recognition of multiple agent types.

For this study, three on-screen characters were compared. The facial expressions depicted by each character were chosen or created based upon similar criteria for emotion generation. To assess emotion recognition across a variety of character types, the three agents represented a range of human-likeness. A human, a synthetic human, and a non-humanoid virtual agent character were used.

Photographs of *human* faces were used in this study to allow the comparison of a human character to other on-screen characters of less human-likeness. Accordingly, a non-humanoid *virtual agent* was used to represent a character less human-like on the continuum (i.e., it was cat-like in appearance). This type of virtual agent was used because its facial features were able to demonstrate human-like facial expression via manipulation of individual facial feature placement (e.g., eyes, eyebrows). Additionally, the precise placement of facial features permitted the calculation of similarity between any two emotion feature arrangements.

Finally, a *synthetic human* character was used in this study because fundamental visual differences existed between the virtual agent and the photographs of human faces. For example, the virtual agent demonstrated facial expressions by only using geometric positioning of facial features such as the eyebrows, mouth, and eyelids. The agent was incapable of demonstrating texture based transformations, such as wrinkling of the nose, which were present in the photographs of human faces. Similar to the virtual agent the synthetic faces displayed emotion using only facial feature geometric cues, yet its overall appearance was more humanoid by nature.

To evaluate possible age-related differences in emotion recognition of various character types, participants in the present study completed an emotion recognition task with human faces, synthetic faces, and virtual agent faces. Static pictures of these characters were presented to participants demonstrating four basic emotions (anger, fear, happiness, and sadness) and neutral. Participants responded by selecting an emotion they thought was displayed by the face. Using this method, the goals of this study were to investigate possible age-related differences in emotion recognition of the three characters (human, synthetic human, and virtual agent) and to compare emotion recognition of these three characters to one another.

Because the emotions were generated using the same criteria generally used for *human* facial expression (Ekman & Friesen, 1975), it was expected that age-related differences would occur for all characters, particularly for the emotions of anger, fear, and sadness. Investigating differences in emotion recognition between the characters was exploratory, and no specific predictions were made.

Previous work in emotion recognition has focused almost exclusively on the proportion of participants' responses that matched the emotion a face was intending to display. The data analysis and interpretation of the present study differs from previous work by focusing on two additional analyses to understanding emotion recognition. First, age-related differences in emotion recognition may be evidenced not only by the proportion of matched responses, but also by the nature of the misattributions either age group commits. Patterns in misattributions, or mislabels, participants made when identifying emotion were investigated. If the positivity effect explains age-related differences in emotion recognition, then older adults may demonstrate a response bias toward labeling facial expressions as positive.

Second, feature discriminablity was assessed. If older and younger adults differ in the detection of or attention to facial features, the misattributions may be seen between emotions with similar feature configuration. A similarity index for the virtual agent was calculated by comparing the numerical values any two emotion feature arrangements. The similarity index scores were generally compared to the misattributions participants made. Additionally, similarity of upper face and lower face regions are compared.

Evaluating older and younger adults' emotion recognition of various on-screen characters is important from a practical standpoint because as intelligent agents become more commonplace, they have potential to interact and assist users of all ages in daily activities. For users to socially interact with such agents, they will need to recognize the facial expressions the agent is portraying. Investigating recognition of basic emotions may provide building block for designers to create agents capable of demonstrating a range of expressions that are recognizable by target user groups, both young and old.

From a theoretical viewpoint, the goal of this study was to expand knowledge of age-related differences in emotion recognition to synthetic and virtual agent facial expressions. Investigating not only when participants make a match in labeling an emotion but also when they do not may provide specific information about the psychological mechanisms contributing to age-related differences in emotion recognition.

CHAPTER 2

METHOD

Participants

Forty-two younger adults, between the age of 18 to 28 (*M* = 19.74, *SD* = 1.43, equal number of males and females), and forty-two older adults, between the age of 65 to 85 (*M* = 72.48, *SD* = 4.69, equal number of males and females) participated in this study. The younger adults were recruited from the Georgia Institute of Technology undergraduate population, and received credit for participation as a course requirement. The older adults were community-dwelling Atlanta-area residents, and were recruited from the Human Factors and Aging Laboratory testing database. The older adults received monetary compensation of $25 for their participation in this study. All participants were screened to have visual acuity of 20/40 or better for far and near vision (corrected or uncorrected). Both younger (*M* = 3.83, *SD* = .935) and older adults (*M* = 3.71, *SD* = .835) rated themselves as having good health (scale 1 = poor, 5 = excellent). The older adults were highly educated, with 86% of the participants reporting having some college or higher education.

All participants completed six ability tests: Benton Facial Discrimination Test-short form (Levin, Hamsher & Benton, 1975), choice reaction time test (locally developed), Digit Symbol Substitution (Wechsler, 1997), Digit Symbol Substitution Recall (Rogers, 1991), Reverse Digit Span (Wechsler, 1997), Shipley Vocabulary (Shipley, 1986), and the Snellen Eye chart (Snellen 1868).

Independent sample *t*-tests were conducted to analyze participant ability tests scores (Table 1). Overall age differences ($p < .05$) were as follows: Younger adults were faster on choice reaction time, and provided more correct answers for digit-symbol substitution, recall, digit span, and vocabulary; whereas older adults performed better than younger adults for the vocabulary test. No difference between age-groups was found for the Benton Facial Recognition task. These data were consistent with past research (Czaja, Charness, Fisk, Hertzog, Nair, Rogers, & Sharit, 2006; Benton, Eslinger, & Damasio, 1981) and all participants' ability scores were within the expected range for their age group.

Table 1

Participant ability test scores

	Younger Adults		Older Adults		
	M	SD	M	SD	*t* value
Benton Facial Recognition[a]	48.26	2.95	47.71	3.62	0.76
Choice Reaction Time[b]	319.98	51.72	418.10	86.92	-6.29 *
Digit-Symbol Substitution[c]	74.52	11.06	51.36	11.58	9.38 *
Digit-Symbol Recall[d]	8.24	1.08	5.62	2.5	6.24 *
Reverse Digit Span[e]	10.83	2.33	9.12	2.41	3.32 *
Shipley Vocabulary[f]	31.93	3.25	35.60	3.88	-4.69 *

*p<.05. [a]Facial discrimination (Levin, Hamsher & Benton, 1975); score was total number correct converted to 54 point scale. [b]Reaction time (locally developed); determined by 45 trial test in ms for both hands. [c]Perceptual speed (Weschler, 1997); score was total number correct of 100 items. [d]Implicit memory (Rogers, 1991); score was total number correct of 9 items. [e]Memory span (Weschler, 1997); score was total correct for the 14 sets of digits presented.. [f]Semantic knowledge, (Shipley, 1986); score was the total number correct from 40.

Apparatus/Materials

The experiment was conducted using Dell Optiplex GX260 computers running Microsoft Windows XP Professional. The system included a 17 inch monitor, configured to display 1280 x 1024 pixels. The software program was developed using E-prime 2.0 (Psychology Software Tools, Pittsburgh, PA). The software program measured accuracy and response time for each trial. All measurements were recorded by the program in a separate data file for later analysis.

All on-screen textual instructions and stimuli were displayed in 18 font size. Sequence controls ensured that no more than two of the same stimuli were shown in a row. The software program presented all pictorial stimuli on a computer monitor. The pictures were shown with approximate pixel size of 384 x 515. Given a viewing distance of 22.8in the face stimuli subtended 14.99 and 17.45 degrees visual angle for width and height, respectively. Responses were collected using a standard QWERTY keyboard, with numeral/symbol keys `, 2, 4, 6, 8, 0, and = tagged with emotion labels in the following order: anger, disgust, fear, happy, sad, surprise, and neutral.

Virtual Agent Face

The Philips iCat robot is equipped with 13 servo motors, 11 of which control different features of the face, such as the eyebrows, eyes, eyelids, mouth and head position. The virtual agent used was an animated replica of the iCat robot, capable of creating the same facial expressions with the same level of control. The virtual agent's emotions were created using Philips's Open Platform for Personal Robotics (OPPR) software. OPPR consists of a Robot Animation Editor for creating the animations, providing control over each individual servo motor. The virtual agent's emotions were created according to Ekman and Friesen's qualitative descriptions of facial expressions (Ekman & Friesen, 1975; 2003) (see Appendix A for Ekman and Friesen's qualitative descriptions of emotion).

Synthetic Human Face

The synthetic faces were obtained from a database of digitized grayscale male and female photographs. Wilson and colleagues created these faces using MATLAB to digitize 37 points on the face (for full description, see Wilson et al., 2002; Goren &

Wilson, 2006). Wilson and Wilson (2006) morphed the faces to express emotion according to Ekman and Friesen’s qualitative descriptions of facial expressions (Ekman & Friesen, 1975). In developing these pictures, changes to eyebrows, eyelid position, and closed mouth were made, whereas features such as wrinkles, hair and skin textures, color and luminance was removed (Goren & Wilson, 2006). For this study, the mean female synthetic face was selected. The mean female face comprises an average of the 37 numbers used to create the set of faces (Wilson et al. 2002), creating a generic female eye, nose, and mouth template.

Human Face

The human faces were obtained from the Montreal Set of Facial Displays of Emotion (MSFDE). In this set, each expression was created using a directed facial action task and was Facial Action Coding System (FACS) coded to assure identical expressions across actors. For this study, photographs of female faces were used. The same female actor was chosen for each of the emotions and was selected according to visual similarity to the female synthetic face.

Standardization of Character Type

The stimuli were displayed for a longer duration than most studies with young adults (up to 20,000 ms compared with typically <150 ms; e.g., Frank & Ekman, 1997; Schweinberger et al., 2003) to ensure both older and younger participants had ample time to process the face stimuli and determine what, if any, emotion was conveyed.

All characters were shown in black and white, and only a frontal view of the face was displayed. The statistical distribution of color (M=93.7, SD = 1.75) for all pictures was balanced using the GNU Image Manipulation Program 2.6 (GIMP). The iCat is more often depicted as female (e.g., Meerbeek, Hoonhout, Bingley, & Terken, 2006). Therefore, the average female synthetic human face, and a female face from the MSFDE was used.

The emotions anger, fear, happiness, sadness, and neutral were used. These emotions were chosen based on data from a previous study (Beer, Fisk & Rogers, 2008) demonstrating age-related differences in emotion recognition of the virtual agent's facial expressions of anger, fear, happiness, and neutral. Preliminary testing indicated that faces displaying medium-intensity emotion ensured that recognition of the emotions was not at ceiling. Emotion depicted by the MSFDE human faces were displayed at medium emotion intensity (60%). The facial emotions displayed on the synthetic human and virtual agent were also displayed at medium (60%) intensity level. Sixty percent emotion intensity was created by calculated geometric placement of facial features between neutral and 100% emotion. See Figure 1 for examples of the characters and emotions.

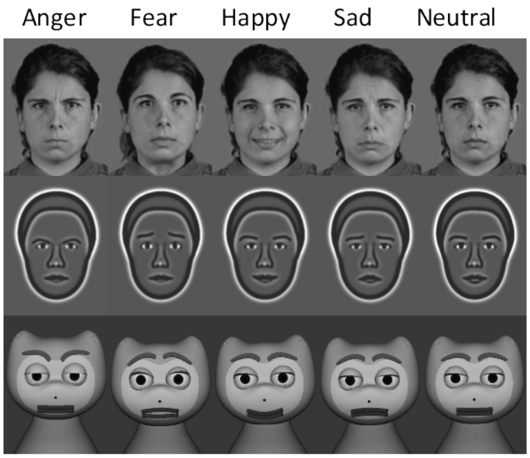


Figure 1. Five emotions for each character type.

Ability Tests and Questionnaires

To assess visual acuity, reaction time, perceptual speed, memory, semantic knowledge, and facial discrimination, the Snellen Eye chart (Snellen 1868), choice reaction time test, Digit Symbol Substitution (Wechsler, 1997), Digit Symbol Substitution Recall (Rogers, 1991), Reverse Digit Span (Wechsler, 1997), Shipley Vocabulary (Shipley, 1986), and the Benton Facial Discrimination Test-short form (Levin, Hamsher & Benton, 1975) tests was administered. These ability tests were administered to describe the sampled population.

A demographic and health questionnaire was completed by all participants (Czaja, Charness, Dijkstra, Fisk, Rogers, & Sharit, 2006). Demographic information, such as age, current health status, and medication administration, was collected from this questionnaire (Appendix D). Additionally, a facial expression identification questionnaire was administered at the completion of the experimental session. The facial expression identification questionnaire consisted of 21 short answer and Likert scale questions that assessed participants' own labels of each emotion and the facial features they use to identify facial expression. The questionnaire is provided in Appendix C.

Design

The experiment used a 3x5x2 design. Within participant variables were Character Type (Virtual Agent, Synthetic Face, and Human Face) and Emotion Type (Anger, Fear, Happiness, Sadness, and Neutral). Age (Older and Younger adults) was a grouping variable. The dependent variable was Proportion Match (Emotion Recognition) and Response Time. Proportion match is defined as the mean proportion of participant responses matching the emotion the character was designed to display.

Procedure

Participants were treated in accordance with APA ethical requirements. Upon providing informed consent, participants completed demographic and health questionnaires and the ability tests in the following order: demographic and health questionnaires, Snellen Eye chart (Snellen 1868), reaction time test, Reverse Digit Span (Wechsler, 1997), Digit Symbol Substitution (Wechsler, 1997), Digit Symbol Recall (Rogers, 1991), Shipley Vocabulary (Shipley, 1986), and finally Benton Facial Discrimination Test-short form (Levin, Hamsher & Benton, 1975). The participants were then offered a short break before beginning the experimental task.

Participants received instructions on the task, and were told that accuracy was more important than the time it took to make a response. Participants then completed a block of practice trials. During the practice trial block, the participants were presented with 42 trials with each trial containing a single word on the computer screen. The words were anger, disgust, fear, happy, sad, surprise, and neutral. The participants were instructed to press the corresponding labeled key on the keyboard. Separate from the key pressing practice, participants viewed a neutral picture of each character, to familiarize themselves with each character. The practice trials were designed to allow each participant to become familiar with the keyboard, learn where the labeled keys were located, and become familiar with the appearance of the stimuli.

After completion of practice the participants began the experimental session. Character Type presentation was blocked (i.e., each block of trials consisting of a single Character Type). Presentation order of the Character Types (human face, virtual agent, synthetic face) was counter-balanced across participants using a partial Latin-Square, and the Emotions (anger, fear, happy, sad, and neutral) within each block were randomly permuted with the constraint that each emotion occurred three times with no more than two of the same emotions shown in a row. There were a total of 135 trials. There were a total of nine blocks, three blocks for each Character Type, and 15 trials per block. Breaks were offered between each block of trials.

A trial began by the participant pressing the space bar. A focal point (+) was shown for 1.0 seconds, followed by a facial stimulus. Participants pressed the key on their keyboard representing the name of the emotion they thought was displayed by the face. Participants had up to 20 seconds to make a response. Although only four emotions types and neutral were used for this experiment participants selected from the six basic emotions (Ekman & Friesen, 1975) and neutral on the keyboard, allowing assessment of misattributions associated with each emotion used in previous research (Ekman & Friesen, 1975). Immediately following the experimental session, the participants were asked to complete the facial expression identification questionnaire.

CHAPTER 3

RESULTS

Overview of Analysis

Unless otherwise noted, for all statistical tests alpha was set at $p < .05$, all t-tests were conducted using two-tailed analysis, and all error bars indicate standard errors. Huyhn-Feldt corrections were applied where appropriate.

Data collected from the emotion identification questionnaire are not included in this report, and shall be reserved for future analysis. Although response time data were collected, the instructions provided to participants indicated that the time it took them to make a response was considered secondary to accuracy. Therefore, analysis of response time is included in the appendix. The remainder of the results analysis will pertain to proportion match.

Emotion Recognition as a Function of Emotion, Character, and Age

To determine whether emotion, character type, or age affected participants' emotion recognition, a repeated measures Emotion (5) X Character Type (3) X Age Group (2) analysis of variance (ANOVA) was conducted; Age was a grouping variable, and Emotion and Character Type were within participants variables.

A main effect of Emotion was found $F(2.91, 238.32) = 195.91$, $p < .001$, $\eta^2 = .39$, suggesting that for older and younger adults combined, recognition varied by emotion. Happiness revealed the highest proportion match ($M = .94$, $SD = .08$), followed by neutral ($M = .90$, $SD = .13$), sadness ($M = .86$, $SE = .019$), anger ($M = .60$, $SD = .17$), then finally fear ($M = .41$, $SD = .23$). The main effect of Age Group was also significant F(1,

82) = 55.13, $p < .001$, $\eta^2 = .40$, with older adults (*M* = .66, *SD* = .10) more likely to mislabel emotions than younger adults (*M* = .82, *SD* = .10).

There was also a significant main effect of Character Type *F*(2,164) = 86.91, $p < .001$, $\eta^2 = .05$, suggesting that overall emotion recognition differed between characters. Having found a significant main effect of Character Type, this effect was further analyzed. Each participant's proportion match for each character was aggregated across emotion. Paired sample t-tests were then conducted, comparing emotion recognition for each character type. The human face demonstrated highest overall proportion match (*M* = .82, *SD* = .14), and significantly differed t(2,83) = 4.11, $p < .001$ from the synthetic human face (*M* = .76, *SD* = .16). The virtual agent (*M* = 0.64, SD=0.14) showed the lowest proportion match, and differed significantly from the synthetic face *t*(2,83) = -12.71, $p < .001$ and the human face *t*(2,83) = -9.24, $p < .001$. Mean proportion match for each character is shown in Figure 2.

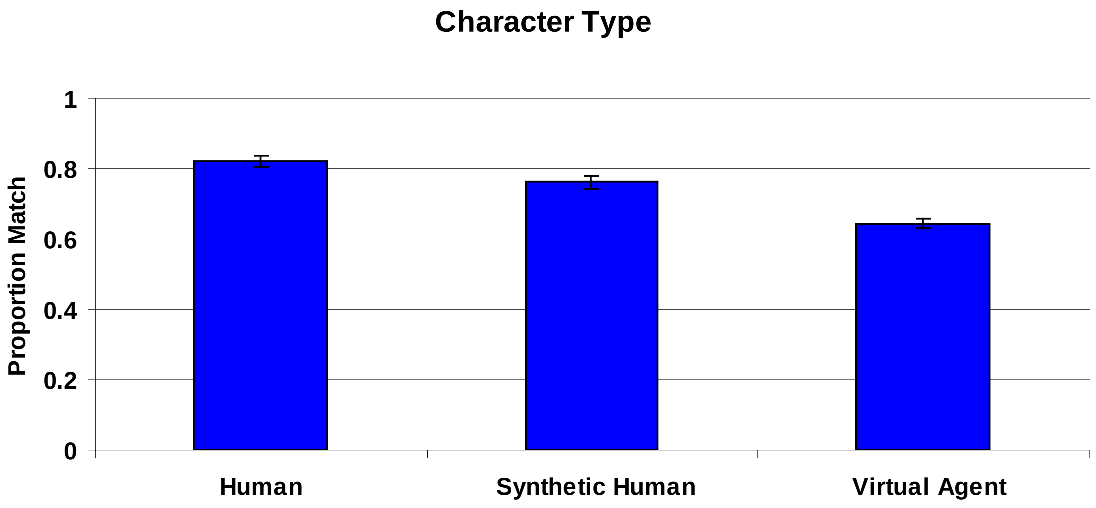


Figure 2. Mean proportion match and standard error for each character type.

The main effects were qualified by two significant interactions. First, the Emotion X Age Group interaction was significant *F*(2.91, 238.32) = 6.68, $p < .001$, $\eta^2 = .01$ indicating that for all characters combined, emotion recognition differed as a function of emotion and age. Second, the Character Type X Emotion interaction was significant *F*(5.60,459.03) = 52.09, $p<.001$, $\eta^2 = .13$, suggesting that for both age groups combined, recognition for each emotion differed for each character type. Both interactions will be further explored in later sections, as a part of the planned analysis.

The analysis revealed no significant Character Type X Age interaction *F*(2,164) = 0.65, $p = .52$, nor a significant three way interaction between Emotion, Character Type, and Age *F*(8,656) = 1.93, $p = .08$.

Age-related Differences in Emotion Recognition

To further investigate how emotion recognition differed as a function of emotion and age, separate Emotion X Age ANOVAs were conducted for each character type. The following sections describe the results found for each individual character.

Human Face

The main effect of Emotion was significant for the human face *F*(2.74, 224.28) = 67.99, $p < .001$, $\eta^2 = .45$, suggesting recognition between human emotions differed. As expected, a significant main effect of Age Group was found *F*(1, 82) = 4.08, $p < .05$, $\eta^2 = .29$, with older adults showing less proportion match for the human face. Finally, a significant Emotion X Age Group interaction was found *F*(2.74, 224.28)=32.17, $p < .001$, $\eta^2 = .03$, showing that age-related differences depended on the emotion displayed. Proportion match for each human emotion is shown in Figure 3.

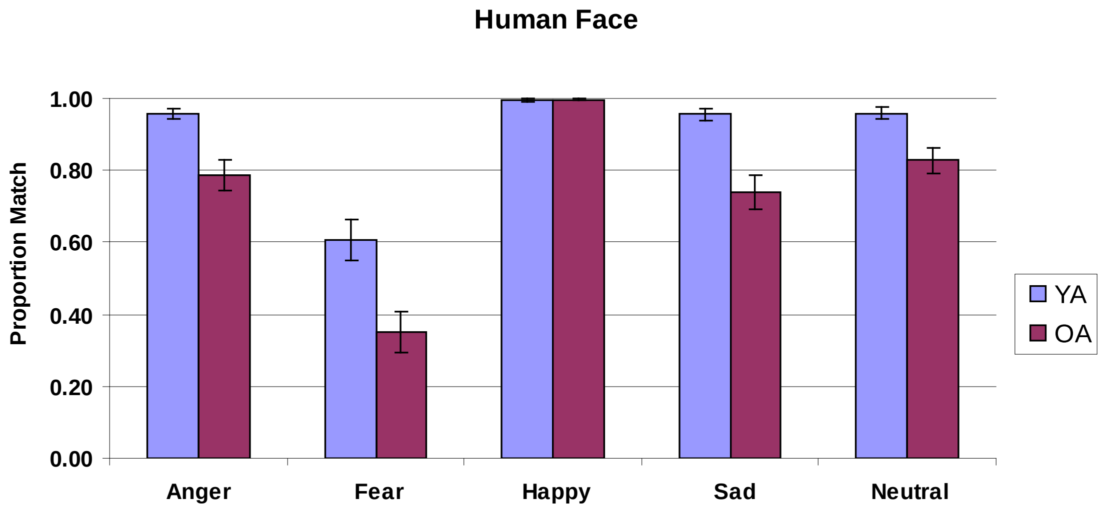


Figure 3. Younger and older adult emotion recognition for the human face (error bars indicate standard error).

Independent samples *t*-tests were conducted to further explore the interaction between Age and Emotion (Table 2). In parallel with previous emotion recognition research on human faces (e.g., Ruffman, Henry, Livingstone, & Phillips, 2008), the Bonferroni corrected *t* tests revealed significant age-related differences in emotion recognition for the emotions anger, fear, and sadness. Younger adults showed a higher proportion match for labeling these three emotions. The human face also revealed a significant age-related difference for the emotion neutral, with older adults more likely to mislabel neutral as having some emotion. All significant t-tests reveal at least medium effect size.

Table 2

Differences in Emotion Recognition Between Age Groups.

	Age Group	**Human Face Mean**	**SD**	***t*(1,82)**	***p***	***d***
Anger	Younger	0.96	0.08	3.59	0.001 *	0.80
	Older	0.79	0.29			
Fear	Younger	0.61	0.37	3.11	0.003 *	0.69
	Older	0.36	0.36			
Happiness	Younger	0.99	0.02	-0.58	0.56	0.50
	Older	1.00	0.02			
Sadness	Younger	0.96	0.12	4.04	<0.001 *	0.89
	Older	0.75	0.31			
Neutral	Younger	0.96	0.10	3.42	0.001 *	0.76
	Older	0.83	0.22			

* significant *p* values (*p*<.01) with Bonferroni corrections for multiple comparisons.

To assess misattributions, attribution matrices were created for each age group Tables 3 – 4. The purpose of these matrices was to reveal the misattributions, or mislabels, between the researcher constructed emotions and the participant perceived emotions. A benefit of the attribution matrices was to easily asses whether participants were commonly misattributing one emotion to another. The rows represent the emotion displayed by the experimental program, and the columns represent the emotion selected by participants. Each cell represents the proportion of the total number of trials that a displayed emotion (rows) was attributed to a selected emotion (columns) across all participants. Grey cells represent the proportion of total trials participants identification matched the emotion the human face was designed to display.

Table 3

Human Emotion Attributions Made by Older Adults

Older Adult Attribution Matrix

Human Face

Emotion Selected

Emotion Displayed		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
	Anger	0.79	0.19	0.01	0.00	0.01	0.00	0.00
	Fear	0.11	0.09	0.36	0.01	0.02	0.24	0.18
	Happy	0.00	0.00	0.00	1.00	0.00	0.00	0.00
	Sad	0.10	0.08	0.06	0.00	0.75	0.02	0.01
	Neutral	0.04	0.06	0.01	0.00	0.06	0.00	0.83

Table 4

Human Emotion Attributions Made by Younger Adults

Younger Adult Attribution Matrix

Human Face

Emotion Identified

Emotion Displayed		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
	Anger	0.96	0.03	0.00	0.00	0.00	0.00	0.00
	Fear	0.01	0.07	0.61	0.00	0.02	0.20	0.09
	Happy	0.00	0.00	0.00	0.99	0.00	0.00	0.00
	Sad	0.01	0.01	0.03	0.00	0.96	0.00	0.00
	Neutral	0.00	0.03	0.00	0.00	0.01	0.00	0.96

For the human face, older adults tended to frequently misattribute the emotion anger with disgust, whereas fear was often mislabeled as surprise and neutral. The misattributions for the human emotion sadness were distributed, with older adults sometimes mislabeling it as anger, disgust, and fear. Younger adults were highly precise in proportion match for all human emotions except fear which was frequently misattributed as surprise.

Synthetic Human Face

A significant main effect of Emotion was found for the synthetic face $F(3.35, 274.55) = 62.99$, $p < .001$, $\eta^2 = .42$. As expected, there was a significant main effect of Age Group $F(1, 82)= 38.13$, $p < .001$, $\eta^2 = .32$, with older adults showing less proportion match for the synthetic human face. Lastly, a significant Emotion X Age Group interaction was found for the synthetic human face $F(3.35, 274.55) = 4.86$, $p < .01$, $\eta^2 = .03$, suggesting that age-related differences depended on the emotion displayed. Proportion match for each synthetic human emotion is shown in Figure 4.

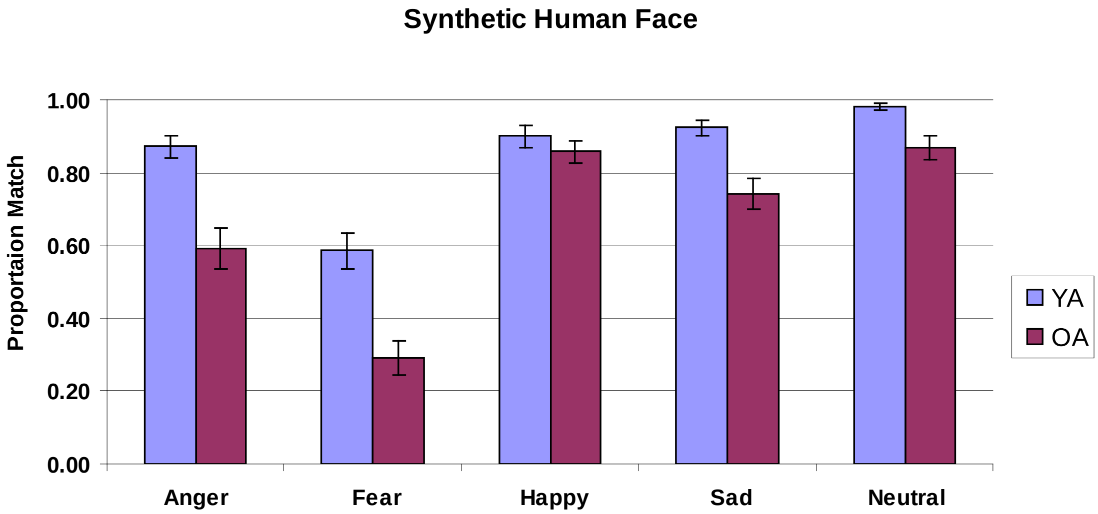


Figure 4. Younger and older adult emotion recognition for the synthetic human face (error bars indicate standard error).

To further explore the interaction between Age and Emotion, independent samples *t*-tests were conducted (Table 5). The Bonferroni corrected *t* tests revealed that the synthetic human face showed similar patterns in emotion recognition as the human face. Significant age-related differences in emotion recognition were found for the emotions anger, fear, and sadness, with younger adults showing higher proportion match. Also, the synthetic human face revealed a significant age-related difference for the emotion neutral, with older adults being more likely to label it as some emotion. All significant t-tests reveal at least medium effect size.

Table 5

Differences in Emotion Recognition Between Age Groups

		Synthetic Human Face				
	Age Group	**Mean**	**SD**	***t* (1,82)**	***p***	***d***
Anger	Younger	0.87	0.20	4.16	<0.001 *	0.91
	Older	0.60	0.37			
Fear	Younger	0.58	0.31	4.48	<0.001 *	0.98
	Older	0.28	0.30			
Happiness	Younger	0.90	0.21	0.89	0.38	0.20
	Older	0.86	0.20			
Sadness	Younger	0.92	0.14	3.82	<0.001 *	0.84
	Older	0.74	0.27			
Neutral	Younger	0.98	0.05	3.36	0.002 *	0.72
	Older	0.87	0.21			

* significant *p* values *(p*<.01) with Bonferroni corrections for multiple comparisons.

To assess misattributions, attribution matrices were created for each age group Tables 6 – 7. The rows represent the emotion displayed by the experimental program, and the columns represent the emotion selected by participants. Each cell represents the proportion of the total number of trials that a displayed emotion (rows) was attributed to a selected emotion (columns) across all participants. Grey cells represent the proportion of total trials participants identification matched the emotion the synthetic human face was designed to display.

Table 6

Synthetic Human Emotion Attributions Made by Older Adults

Older Adult Attribution Matrix

		Synthetic Face						
		Emotion Selected						
Emotion Displayed		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
	Anger	0.60	0.15	0.02	0.01	0.01	0.03	0.18
	Fear	0.03	0.05	0.28	0.00	0.04	0.56	0.04
	Happy	0.00	0.00	0.00	0.86	0.00	0.03	0.11
	Sad	0.03	0.08	0.05	0.00	0.75	0.02	0.07
	Neutral	0.00	0.00	0.01	0.08	0.01	0.03	0.87

Table 7

Synthetic Human Emotion Attributions Made by Younger Adults

Younger Adult Attribution Matrix							
			Synthetic Face				
	Emotion Identified						
Emotion Displayed	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.87	0.07	0.00	0.00	0.01	0.00	0.05
Fear	0.00	0.00	0.58	0.00	0.19	0.21	0.01
Happy	0.00	0.00	0.00	0.90	0.00	0.00	0.10
Sad	0.00	0.03	0.04	0.00	0.92	0.00	0.01
Neutral	0.00	0.00	0.00	0.01	0.00	0.00	0.98

The attribution matrix shows that older adults commonly mislabeled the emotions anger and fear in particular. Older adults commonly mislabeled anger as neutral and disgust, and fear as surprise. Although age-related differences were found for the synthetic human emotions of sadness and neutral, the attributions for these emotions were distributed with no clear pattern of mislabels. Similar to the human face, the younger adults showed high proportion match for all emotions except fear. The synthetic human emotion of fear was commonly misattributed with surprise as well as sadness.

Virtual Agent Face

The main effect of Emotion was significant for the virtual agent face $F(2.77, 226.96) = 220.69$, $p < .001$, $\eta^2 = .72$. As predicted there were age-related differences in emotion. A main effect of Age Group was found $F(1, 82) = 40.47$, $p < .001$, $\eta^2 = .33$), with older adults showing less proportion match for each character type. Finally, a significant Emotion X Age Group interaction was found for the virtual agent face $F(2.77, 226.96) = 3.22$, $p < .05$, $\eta^2 = .01$, suggesting that age-related differences depended on the emotion displayed. Proportion match for each virtual agent emotion is shown in Figure 5.

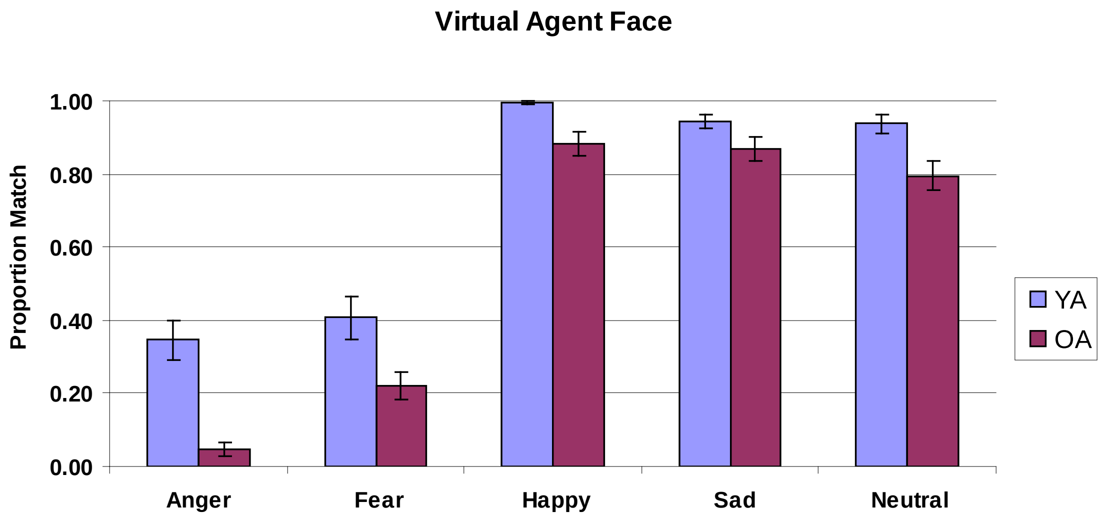


Figure 5. Younger and older adult emotion recognition for the virtual agent face (error bars indicate standard error).

Independent samples *t*-tests were conducted to further explore the interaction between Age and Emotion (Table 8). Younger adults demonstrated statistically significant higher emotion recognition the virtual agent emotions anger, fear, happiness, and neutral. However, without Bonferroni corrections for multiple comparisons, younger adults also demonstrated statistically significant higher emotion recognition for the virtual agent emotion sadness, $p < .05$. Whereas age-related differences for anger, fear, and neutral were also found for the human and synthetic human faces, the virtual agent was the only character to reveal an age-related difference for the recognition of happiness. All significant t-tests reveal at least medium effect size.

Table 8

Differences in Emotion Recognition Between Age Groups

	Age Group	Virtual Agent Mean	SD	*t* (1,82)	*p*	*d*
Anger	Younger	0.35	0.35	5.26	<0.001 *	1.15
	Older	0.05	0.12			
Fear	Younger	0.41	0.38	2.74	0.008 *	0.62
	Older	0.21	0.25			
Happiness	Younger	0.99	0.02	3.37	0.002 *	0.74
	Older	0.88	0.21			
Sadness	Younger	0.94	0.12	2.08	0.041	0.42
	Older	0.87	0.2			
Neutral	Younger	0.94	0.17	2.99	0.004 *	0.67
	Older	0.80	0.24			

* significant *p* values (*p*<.01) with Bonferroni corrections for multiple comparisons.

To assess misattributions, attribution matrices, were created for each age group Tables 9 – 10. The rows represent the emotion displayed by the experimental program, and the columns represent the emotion selected by participants. Each cell represents the proportion of the total number of trials that a displayed emotion (rows) was attributed to a selected emotion (columns) across all participants. Grey cells represent the proportion of total trials participants identification matched the emotion the virtual agent face was designed to display.

Table 9

Virtual Agent Emotion Attributions Made by Older Adults

Older Adult Attribution Matrix

Virtual Agent
Emotion Selected

Emotion Displayed	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.05	0.16	0.01	0.00	0.57	0.00	0.20
Fear	0.03	0.04	0.22	0.02	0.03	0.65	0.01
Happy	0.00	0.01	0.01	0.88	0.03	0.03	0.05
Sad	0.03	0.04	0.02	0.00	0.87	0.02	0.03
Neutral	0.01	0.01	0.01	0.00	0.13	0.04	0.80

Table 10

Virtual Agent Emotion Attributions Made by Younger Adults

Younger Adult Attribution Matrix

Virtual Agent

Emotion Identified

Emotion Displayed	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.35	0.37	0.00	0.00	0.08	0.00	0.21
Fear	0.00	0.01	0.41	0.00	0.01	0.58	0.00
Happy	0.00	0.00	0.00	0.99	0.00	0.00	0.00
Sad	0.01	0.02	0.00	0.00	0.94	0.00	0.02
Neutral	0.01	0.01	0.00	0.03	0.01	0.00	0.94

Overall, older adults demonstrated more misattributions for the virtual agent than the other two characters. Older adults often misattributed anger with sadness, and fear with surprise. Although age-related differences were found for the emotions happiness and neutral, the older adult misattributions for these emotions were distributed. Younger adults showed lower proportion match for the virtual agent emotions of anger and fear in particular. Similar to the human and synthetic face, the younger adults misattributed the virtual agent emotion of fear with surprise, and misattributed anger with disgust.

Emotion Recognition Over Time

Age-related differences in emotion recognition were further analyzed by investigating whether younger and older adults' misattribution differed as a function of time. An ANOVA was conducted comparing overall emotion recognition across three time intervals (Time 1 = blocks 1-3, Time 2 = blocks 4-6, Time 3 = blocks 7-9) for each age group. Although the older adults' emotion overall recognition improved over the course of the experiment $F(2, 82) = 3.72$, $p = .029$, $\eta^2 = .082$, the general patterns of attribution errors remained the same. Appendix G shows attribution matrices for older adults at successive intervals of the experiment. Younger adults did not demonstrate a significant recognition improvement over time.

Summary of Age-Related Differences

Overall older adults had more misattributions than younger adults, particularly for the virtual agent character. Age-related differences were found for the human and synthetic human facial expressions of anger, fear, sadness, and neutral. The virtual agent facial expressions revealed age-related differences for the emotions anger, fear, happy, and neutral.

The age-related differences in emotion recognition for these emotions were qualified by investigating the common misattributions participants made. For older adults there were a higher number of mislabels than for younger adults, across all three characters. Although younger adults did not make as many attribution errors as older adults, the comparison of pattern of misattributions between age groups is informative. For the human and synthetic human characters, older adults often labeled anger as disgust. In addition, agent older adults most commonly labeled anger as sadness, whereas younger adults commonly mislabeled it as disgust. Finally, for all three characters, both age groups often mislabeled fear as surprise.

Feature Discrimination

Attribution matrices indicate the types of attribution errors participants made, but they do not indicate why such mislabels occurred. To investigate whether common attribution errors were a result of similarities or differences between facial feature configurations, feature comparisons between emotions was evaluated. Due to the numerical facial feature position provided by the OPPR software used to program the virtual agent, difference scores between emotions could be calculated for this character.

The software provided a numerical value for the servo motor rotational position for each individual virtual agent facial feature (ranging from -100 to 100 for all features except eyelids which ranged from 0 to 100). A difference score was calculated for each of the manipulable facial features: (1) eyelids, (2) eye gaze, (3) eyebrows, (4) upper lip, and (5) lower lip. These values were then summed to provide a feature difference score. The highest possible total difference score was 900. The highest possible difference score for the upper face (eyelids, eye gaze, and eyebrows) was 500, and for the lower face (upper and lower lip) was 400. Using these values, the similarity proportion was calculated using the following formula:

Similarity = 1.0 – [(sum of feature difference scores)/(highest possible difference score)]

High numbers thus indicate more similarity, with a maximum value of 1.00. The similarity proportions between each virtual agent emotion are shown in Table 11. Although only five emotions were shown to the participants, the similarity calculations include the emotions disgust and surprise. The numerical values for feature placements for the disgust and surprise emotions (at 60% intensity) were adopted from Smarr (2010). In addition to the similarity proportions, the older adult and younger adult attribution proportions are also displayed. Using these data, general comparisons can be made to determine if similar emotions are often attributed as one another.

Table 11

Similarity and Attribution Comparisons

		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Emotion Displayed	**Anger**							
	Similarity (total)	**1.00**	**0.92**	**0.78**	**0.73**	**0.80**	**0.75**	**0.90**
	Similarity (upper face)	*1.00*	*0.99*	*0.71*	*0.86*	*0.79*	*0.71*	*0.86*
	Similarity (lower face)	*1.00*	*0.82*	*0.86*	*0.58*	*0.82*	*0.79*	*0.94*
	Older Adult Attribution	**0.05**	**0.16**	**0.01**	**0.00**	**0.57**	**0.00**	**0.20**
	Younger Adult Attribution	**0.35**	**0.37**	**0.00**	**0.00**	**0.08**	**0.00**	**0.21**
	Fear							
	Similarity (total)	**0.78**	**0.82**	**1.00**	**0.72**	**0.88**	**0.96**	**0.85**
	Similarity (upper face)	*0.71*	*0.70*	*1.00*	*0.86*	*0.90*	*1.00*	*0.85*
	Similarity (lower face)	*0.86*	*0.96*	*1.00*	*0.54*	*0.86*	*0.90*	*0.86*
	Older Adult Attribution	**0.03**	**0.04**	**0.22**	**0.02**	**0.03**	**0.65**	**0.01**
	Younger Adult Attribution	**0.00**	**0.01**	**0.41**	**0.00**	**0.01**	**0.58**	**0.00**
	Happy							
	Similarity (total)	**0.73**	**0.73**	**0.72**	**1.00**	**0.69**	**0.76**	**0.84**
	Similarity (upper face)	*0.86*	*0.85*	*0.86*	*1.00*	*0.92*	*0.86*	*0.99*
	Similarity (lower face)	*0.58*	*0.58*	*0.54*	*1.00*	*0.40*	*0.64*	*0.64*
	Older Adult Attribution	**0.00**	**0.01**	**0.01**	**0.88**	**0.03**	**0.03**	**0.05**
	Younger Adult Attribution	**0.00**	**0.00**	**0.00**	**0.99**	**0.00**	**0.00**	**0.00**
	Sad							
	Similarity (total)	**0.80**	**0.80**	**0.88**	**0.69**	**1.00**	**0.84**	**0.85**
	Similarity (upper face)	*0.79*	*0.78*	*0.90*	*0.92*	*1.00*	*0.90*	*0.93*
	Similarity (lower face)	*0.82*	*0.82*	*0.86*	*0.40*	*1.00*	*0.76*	*0.76*
	Older Adult Attribution	**0.03**	**0.04**	**0.02**	**0.00**	**0.87**	**0.02**	**0.03**
	Younger Adult Attribution	**0.01**	**0.02**	**0.00**	**0.00**	**0.94**	**0.00**	**0.02**
	Neutral							
	Similarity (total)	**0.90**	**0.84**	**0.85**	**0.84**	**0.85**	**0.82**	**1.00**
	Similarity (upper face)	*0.86*	*0.85*	*0.85*	*0.99*	*0.93*	*0.85*	*1.00*
	Similarity (lower face)	*0.94*	*0.82*	*0.86*	*0.64*	*0.76*	*0.79*	*1.00*
	Older Adult Attribution	**0.01**	**0.01**	**0.01**	**0.00**	**0.13**	**0.04**	**0.80**
	Younger Adult Attribution	**0.01**	**0.01**	**0.00**	**0.03**	**0.01**	**0.00**	**0.94**

Consider the display of anger; the highest similarity ratings (.80 or greater) were for sad, neutral, and disgust. Those emotions were also the most likely misattributions for older adults (sad, neutral, and disgust) and for younger adults (disgust and neutral). Although the relationship between similarity and attributions was not perfect for older adults (according to the similarity proportion, it may expected for anger to be *most* commonly misattributed as disgust), the overall pattern suggests that similarity could have played a role in the labels older adults and younger adults were choosing for the virtual agent emotion of anger.

A similar pattern of misattribution/similarity is evident for ratings for fear. Older adults and younger adults most often labeled the virtual agent expression of fear as surprise. The similarity proportion between these two emotions is .96, suggesting that the close similarity between these two emotions might lead to misattributions.

Feature Discrimination of Upper/Lower Face Regions

Table 11 also depicts the calculated similarity between emotions based only on the eye region (upper face) or the mouth region (lower face). These calculations were conducted because older adults may attend to mouth regions of the face more so than eye regions (Sullivan, Ruffman, & Hutton, 2007). If the older adults in this study were in fact attending to the mouth region more so than the eye region, their misattributed emotions should be with other emotions of similar mouth configurations (i.e., upper lip and lower lip). The data, however, were mixed.

For the emotion anger, the virtual agent’s lower face features were most similar with neutral (similarity = .94) and fear (similarity = .86). Although older adults sometimes misattributed anger as neutral, they more often misattributed anger with sadness, which had a similarity score of .82. For fear, older adults often misattributed as surprise. Fear and surprise showed a similarity proportion of .90. However, fear was also similar to disgust (similarity = .96), which older adults did not show a high proportion of mislabels for (attribution proportion = .04). If older adults were only attending to the lower facial region of the face, the present data are not consistent with this idea.

Summary of Feature Discrimination

Using numerical values representing the servo placement of the virtual agent's facial features, similarity proportions could be calculated for each of the agents' basic emotions (anger, disgust, fear, happy, sad, surprise, and neutral). These calculations were then generally compared to younger and older adult's proportion of attributions. Although the relationship between similarity and attributions was not completely consistent, the patterns suggest that similarity could have played a role in the labels older adults and younger adults were attributing to the virtual agent's expressions. Comparisons of upper and lower facial regions did not clearly suggest that older adults were attending to the lower facial regions.

Understanding Character Differences

To answer whether the type of character (human, synthetic human, or virtual agent) affected emotion recognition, planned separate Age Group X Character Type ANOVAs were conducted for each emotion.

Anger

An Age Group X Character Type ANOVA revealed a significant main effect of Character Type for the emotion anger $F(2, 164) = 199.23$, $p < .001$, $\eta^2 = .70$, suggesting that emotion recognition differed according to character type. A significant main effect of Age Group was also found $F(1, 82) = 40.01$, $p < .001$, $\eta^2 = .33$, with younger adults showing a trend of higher proportion match compared to older adults. The interaction for Age Group and Character Type was not significant $F(2, 164) = 1.91$, $p = .15$. Proportion match for anger is shown in Figure 6.

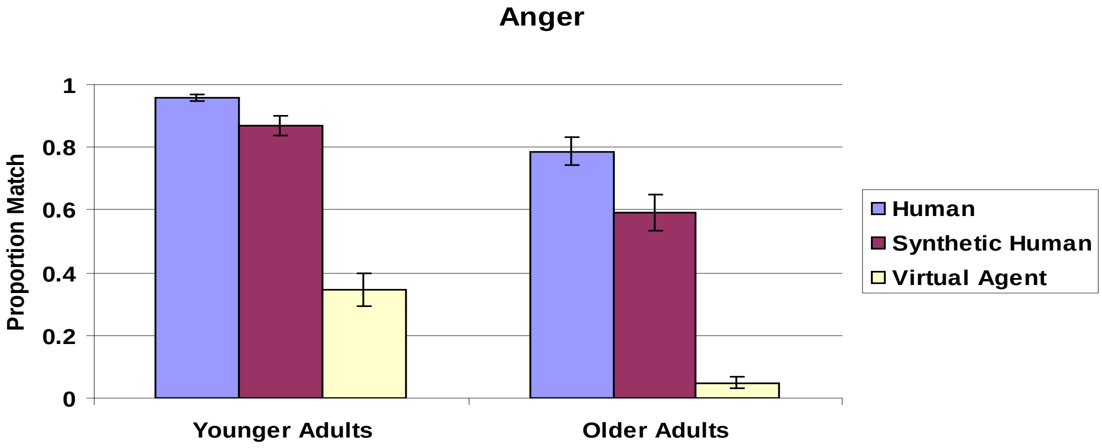


Figure 6. Emotion recognition for angry (error bars indicate standard error).

Table 12

Difference between Character Type for Anger

Anger					
Younger Adults			**Older Adults**		
Character	***t(2,41)***	***p***	***Character***	***t(2,41)***	***p***
Virtual Agent Synthetic Human	-9.28	<.001 *	Virtual Agent Synthetic Human	-9.82	<.001 *
Virtual Agent Human	-10.78	<.001 *	Virtual Agent Human	-17.12	<.001 *
Synthetic Human Human	-2.99	0.005 *	Synthetic Human Human	-3.46	<.001 *

* significant *p* values (*p*<.008) with Bonferroni corrections for multiple comparisons.

To further investigate the main effect of character type for both younger and older adults paired sample t-tests comparing character types were conducted for anger (Table 12). The differences between each character were statistically significant for younger and older adults. Both age groups demonstrated the highest proportion match for the human anger face, followed by the synthetic human, then the virtual agent with the lowest match.

Fear

An Age Group X Character Type ANOVA revealed for the emotion Fear a significant main effect of Character Type $F(1.72, 142.18) = 7.70$, $p < .01$, $\eta^2 = .09$, suggesting that proportion match differed according to character type. The main effect of Age Group was statistically significant for fear $F(1, 82) = 23.59$, $p < .001$, $\eta^2 = .22$, with younger adults showing a trend of higher proportion match compared to older adults. The interaction for Age Group and Character Type was not significant $F(1.72, 142.18) = .76$, $p = .45$. Proportion match for fear is shown in Figure 7.

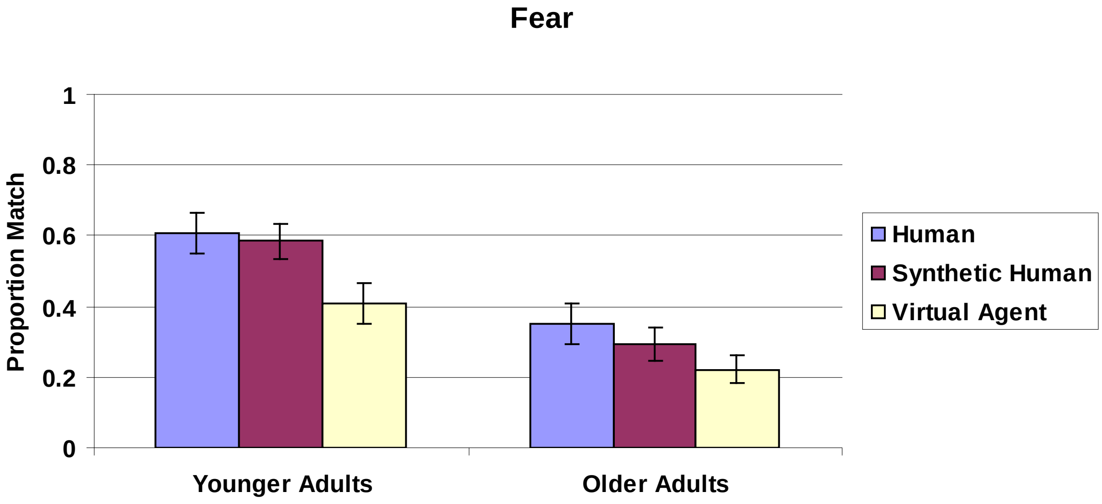


Figure 7. Emotion recognition for fear (error bars indicate standard error).

Table 13

Difference between Character Type for Fear

		Fear			
Younger Adults			**Older Adults**		
Character	***t(2,41)***	***p***	***Character***	***t(2,41)***	***p***
Virtual Agent Synthetic Human	-3.10	0.003 *	Virtual Agent Synthetic Human	-1.94	0.06
Virtual Agent Human	-2.40	0.02	Virtual Agent Human	-2.44	0.02
Synthetic Human Human	-0.28	0.78	Synthetic Human Human	-1.27	0.21

* significant *p* values (*p*<.008), with Bonferroni corrections for multiple comparisons.

To further investigate the main effect of character type for both younger and older adults paired sample t-tests comparing character types were conducted (Table 13). A significant difference was found between the younger adults' recognition of the virtual agent and synthetic human expressions of fear, with the virtual agent resulting in lower proportion match. After corrections for multiple comparisons, no significant differences were found between characters for the older adults. However, older adult proportion match was low (<.40) for all characters' fear expression.

Happiness

An Age Group X Character Type ANOVA was conducted for the emotion happiness. A significant main effect of Character Type was also found $F(1.60, 131.45) = 13.13$, $p < .001$, $\eta^2 = .13$. Additionally, a significant main effect of Age Group was found $F(1, 82) = 7.16$, $p < .001$, $\eta^2 = .08$, with younger adults showing a trend of higher proportion match compared to older adults. The interaction for Age Group and Character Type was not significant $F(1.60, 131.45) = 3.20$, $p = .06$. Proportion match for happiness is shown in Figure 8.

Figure 8. Emotion recognition for happiness (error bars indicate standard error).

Table 14

Difference between Character Type for Happiness

		Happiness			
Younger Adults			Older Adults		
Character	***t(2,41)***	***p***	***Character***	***t(2,41)***	***p***
Virtual Agent Synthetic Human	2.93	0.005 *	Virtual Agent Synthetic Human	0.54	0.60
Virtual Agent Human	0.00	1.00	Virtual Agent Human	-3.44	0.001 *
Synthetic Human Human	-2.91	0.006 *	Synthetic Human Human	-4.41	<.001 *

* significant *p* values (p<.008), with Bonferroni corrections for multiple comparisons.

To further investigate the main effect of character type for both younger and older adults paired sample t-tests comparing character types were conducted (Table 14). Younger adults reached ceiling for proportion match for the human and virtual agent expressions of happiness. For younger adults, the synthetic human proportion match was significantly lower than other two characters. Older adults' proportion match reached ceiling for human expression of happiness, with significantly higher proportion match than for the synthetic human or virtual agent faces.

Sadness

An Age Group X Character Type ANOVA revealed a significant main effect of Character Type for sadness *F*(2, 164) = 5.37, $p < .01$, $\eta^2 = .06$, suggesting that proportion match differed according to character type. A significant main effect of Age Group was found *F*(1, 82) = 16.92, $p < .001$, $\eta^2 = .17$. Younger adults showed a trend of higher proportion match compared to older adults. The interaction for Age Group and Character Type was also significant *F*(2, 164) = 4.89, $p < .01$, $\eta^2 = .05$. Proportion match for sadness is shown in Figure 9.

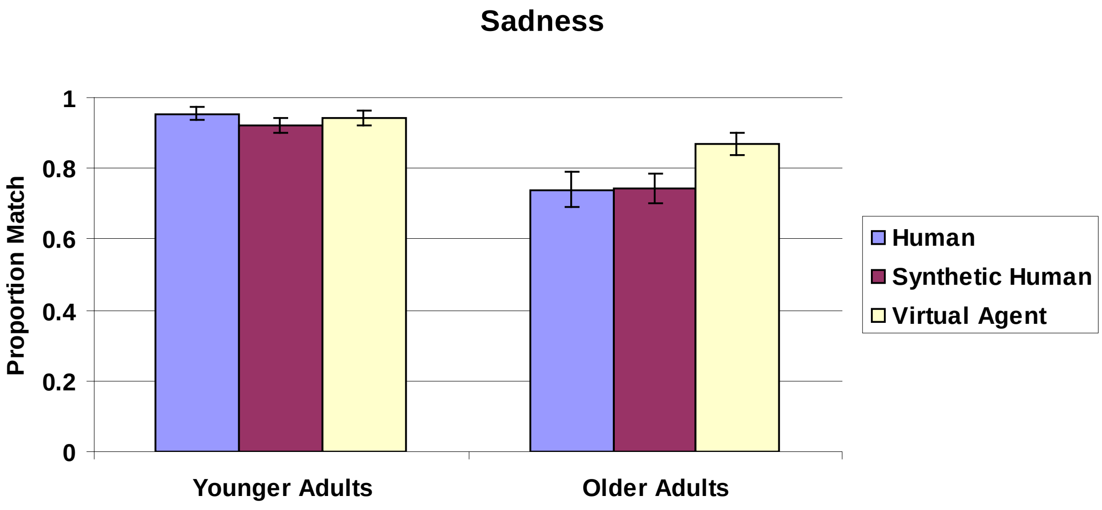


Figure 9. Emotion recognition for sadness (error bars indicate standard error).

Table 15

Difference between Character Type for Sadness

Sadness					
Younger Adults			**Older Adults**		
Character	***t(2,41)***	***p***	***Character***	***t(2,41)***	***p***
Virtual Agent Synthetic Human	0.63	0.53	Virtual Agent Synthetic Human	3.58	0.001 *
Virtual Agent Human	-0.49	0.63	Virtual Agent Human	3.02	0.004 *
Synthetic Human Human	-1.91	0.06	Synthetic Human Human	-0.05	0.96

* significant *p* values *(p*<.008), with Bonferroni corrections for multiple comparisons.

To further investigate the main effect of character type for both younger and older adults paired sample t-tests comparing character types were conducted (Table 15). Younger adults' proportion match for the expression of sadness did not differ between characters, suggesting this emotion was similarly identified across characters. However, older adults showed significantly higher proportion match for the virtual agent expression of sadness compared to the other two characters.

Neutral

An Age Group X Character Type ANOVA was conducted for the emotion neutral. The main effect of Character Type was significant $F(2, 164) = 3.29$, $p < .05$, $\eta^2 = .04$. Also a significant main effect of Age Group was found for neutral $F(1, 82) = 18.70$, $p < .001$, $\eta^2 = .19$. Younger adults showed a trend of higher proportion match compared to older adults. The interaction for Age Group and Character Type was not significant $F(2, 164) = .169$, $p = .85$. Proportion match for neutral is shown in Figure 10.

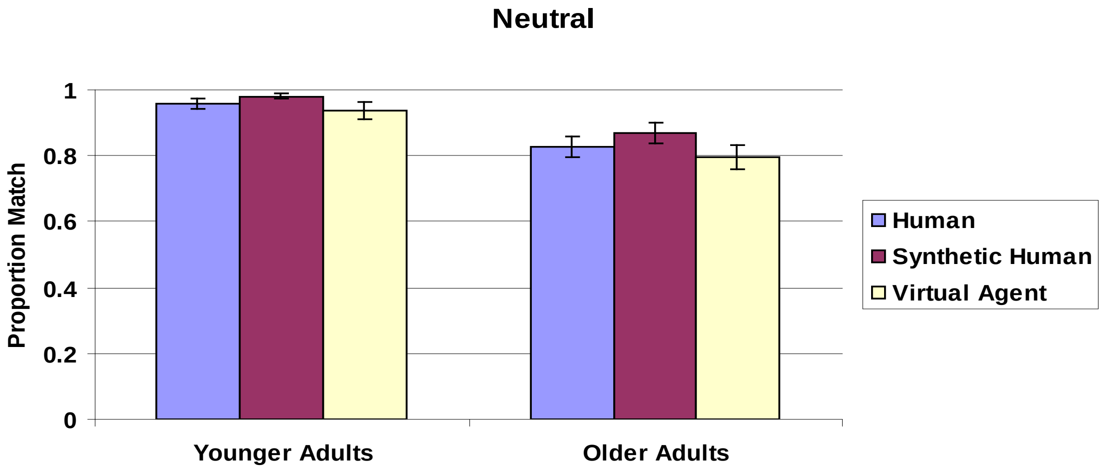


Figure 10. Emotion recognition for neutral (error bars indicate standard error).

Table 16

Difference between Character Type for Neutral

		Neutral			
Younger Adults			**Older Adults**		
Character	***t(2,41)***	***p***	***Character***	***t(2,41)***	***p***
Virtual Agent Synthetic Human	-1.68	0.10	Virtual Agent Synthetic Human	-2.18	0.04
Virtual Agent Human	-0.73	0.47	Virtual Agent Human	-0.78	0.44
Synthetic Human Human	1.24	0.22	Synthetic Human Human	1.00	0.32

* significant *p* values (*p*<.008), with Bonferroni corrections for multiple comparisons.

To further investigate the main effect of character type for both younger and older adults paired sample t-tests comparing character types were conducted (Table 16). Although the Age Group X Character Type ANOVA indicated a significant main effect of Character Type, after correcting for multiple comparisons, neutral did not reveal significant differences in proportion match between any of the characters for either age group.

Summary of Understanding Character Differences

These finding suggest that, in general, the human face showed higher emotion recognition overall. However, the pattern of differences in emotion recognition between character types varied for each emotion. For both age groups, character type differed significantly for the emotion anger, with the human expression of anger revealed highest recognition, followed by the synthetic human, then the virtual agent for both age-groups. Younger adults' proportion match for the emotion fear revealed a significant difference between the virtual agent and the synthetic human, with the virtual agent having lower proportion match.

Happiness differed by character type, with younger adults showing a statistically significant lower recognition for the synthetic face compared to the human and agent faces. Older adults, however, revealed higher emotion recognition for the human facial expression of happiness, compared to both the synthetic human and virtual agent. Older adults revealed higher emotion recognition for the virtual agent emotion of sadness, compared to the other two characters. Finally, neutral revealed no significant differences, indicating that the pattern of proportion match was similar between character types.

CHAPTER 4

DISCUSSION

This study provides evidence that age-related differences in emotion recognition transcend human faces to on-screen characters of varying human-likeness. By extending emotion recognition research to the field of social agents, the present study was designed to examine the extent to which age-related differences in emotion recognition are generalizable across emotive agents. Specifically, the following questions were addressed: is emotion recognition equal across different types of characters and age groups?

Overall, the human face resulted in the highest proportion match, followed by the synthetic human, then the virtual agent. As expected, age-related differences were found for the emotion recognition of facial expressions of all three characters: the human, synthetic human, and virtual agent. More specifically, emotion recognition of the human and synthetic human faces resulted in older adults showing lower proportion match than younger adults for the emotions of anger, fear, sadness, and neutral. The virtual agent yielded age-related differences for the emotions anger, fear, happiness, and neutral, with older adults showing lower proportion of matches. Overall, older adults made more misattributions than younger adults. However, both age groups commonly labeled the emotion fear as surprise for all characters. Older adults also commonly labeled the human and synthetic human emotion anger as disgust. For the virtual agent emotion anger, older adults commonly mislabeled it as disgust, sadness and neutral; whereas younger adults commonly labeled it as disgust. Similarity in emotions (e.g., the facial feature placement for the virtual agent's expression fear is similar to surprise) may provide a possible explanation for common misattributions.

Theoretical Implications

Previous work in emotion recognition has focused almost exclusively on the proportion of participants' responses that matched the emotion a face was intended to display. However, in the present work the patterns of labeling (attributions) were viewed as a crucial component of measuring emotion recognition. Compared to many previous studies, the current research differs in its approach by assessing the nature of participants' misattributions in labeling of emotions. Investigating misattributions may provide specific information about the psychological mechanisms responsible for why age-related differences occur, particularly in relation to two possible accounts for age-related differences in emotion recognition: the positivity effect and perceptual feature discrimination.

One cited account for differences between older and younger adults' emotion recognition is the positivity effect (e.g., Williams et al., 2006). The positivity effect suggests that older adults show a preference toward attending to and remembering positive emotional information compared to negative (Mather & Carstensen, 2005). Given the positivity effect, one may assume that patterns in attributions would reveal a response bias for older adults to label facial expressions as positive. However, older adults demonstrated lower proportion match for labeling the virtual agent's facial expression of happiness, as compared to younger adults.

Age-related differences in labeling human happiness expressions have been reported (e.g., Isaacowitz et al., 2007). However, the presence of an age-related difference in the recognition of happiness has been inconsistently found in the literature (Ruffman et al., 2008). In fact, the recognition for this emotion is often subject to ceiling effects; this is sometimes referred to as the ‘happy face advantage’ (Isaacowitz et al., 2007). Ceiling effects may explain why this difference was not found for the human happy expression in the current data set.

Also, inconsistent with the positivity effect, older adults often misattributed negative emotions (e.g., anger) with other negative emotions (e.g., disgust) for all character types. Although the emotion disgust was not included in the present study, older adults frequently mislabeled other negative emotions as disgust. In fact, in previous studies, older adults have sometimes shown better emotion recognition for labeling disgust compared to younger adults (Calder et al., 2003). Although older adults commonly misattributed negative emotion with other negative emotion, it is noted that of the seven possible emotion response labels participants had to choose from, four of which were negative (therefore increasing the likelihood of selecting a negative emotion).

In light of the common misattributions older adults made, these data suggest that the positivity effect is not a comprehensive explanation for age-related differences in emotion recognition. An alternate explanation may lie in the facial features themselves. Differences between older and younger adults in emotion recognition may be further explained by perceptual discrimination; that is, the way in which participants used the facial features that compose each emotion as cues to discriminate which emotion they thought was present.

Data collected on participants’ attributions as well as the calculated feature similarity between the virtual agent’s expressions provide support for this account. For the virtual agent emotions of anger and fear, both younger and older participants showed low emotion recognition. These emotions were commonly misattributed with other emotions similar in appearance (as determined by feature placement). These data suggest that emotions similar in nature may be harder to distinguish between, and may lead to a higher proportion of mislabeling.

Another goal of this study was to investigate possible differences between the characters, and what that may suggest about emotion recognition in general. Overall, the human face resulted in higher emotion recognition than the synthetic human, and the virtual agent showed the lowest emotion recognition of all the characters. Participants' interpretation of facial features could provide an explanation for differences between character types. The three characters were created based upon generally the same criterion of emotion expression (Ekman & Friesen, 1975, FACS); however, a significant main effect of character was still found.

A possible explanation for emotion recognition differences between the characters may be explained by the number or nature of the facial feature cues available for participants to identify. Certain feature cues present in the human face were not available in the synthetic human or virtual agent faces. For example, the human face demonstrated skin texture, wrinkles, and shadowing which may provide additional cues to interpreting the emotion the face was intended to display.

Additionally, the virtual agent has the same basic structural facial features as other characters (eyes, eyebrows, lips). However, the virtual agent's facial features did not represent a one-to-one size proportion ratio to human and synthetic human facial features. For example, the virtual agent has more pronounced cartoon-like eyes and mouth. Finally, the virtual agent used in this study was incapable of moving its lower eyelid. Without this facial feature cue, the agent may not have demonstrated some emotions as effectively as the other characters. Investigating how and if visual differences in features proportion or prominence influence emotion recognition has yet to be investigated.

Applied Implications

Whatever the underlying psychological mechanism, these data indicate that older and younger adults do differ in labeling human, synthetic human, and virtual agent facial expressions. By investigating age-related differences in the emotion recognition of virtual agents, this research has taken steps toward enriching the facial expression principles that designers may use in developing emotionally-expressive robots, virtual agents, and avatars.

The present findings suggest that designers should consider differences between older and younger populations when designing on-screen characters. In an applied setting, this research is a preliminary step in understanding how older adults may identify emotional-expressive virtual agents.

Designers might believe that certain negative emotions displayed by a robot or virtual agent would be useful for conveying an error or a misunderstanding. However, if older adults commonly mislabel certain emotions they may not interpret the agent's intended message correctly. For example, an older adult user may label an emotion displayed by a virtual character differently than a younger user, particularly if it is a negative emotion such as anger. Designers may also need to consider that older adults may label a *lack* of affective state differently than younger adults. Older adults commonly mislabeled the emotion neutral as having emotion, for all character types.

These data provide insight for guidelines for developers creating on-screen agents that range from human-like to more cartoon-like. Overall, the human face resulted in higher recognition accuracy than the synthetic human, and the virtual agent showed the lowest emotion recognition of all the characters. If an agent is likely to display anger or fear, a developer may want to consider designing a character more humanoid in nature, such as the human or synthetic human face, which may be better suited to depict the intended emotion accurately for both age groups.

On the other hand, if a product requires a virtual agent similar to the virtual iCat, the designer may want to choose a set of emotions for the agent that would reduce the number of discriminations required by the user. For example, the designer may want to avoid the agent expressing fear and surprise in close temporal proximity, as both younger and older adults may commonly mismatch those emotions for this character.

Methodological and Measurement Considerations

Although this research has theoretical and applied implications for the area of emotion recognition and agent design, there are a number of caveats worth discussing to determine the boundaries of such implications.

First, as discussed by other researchers (Ruffman et al. 2008), stimuli often used in emotion recognition tasks are not genuine facial expressions in response to some emotional context. The facial expressions for all three characters used in this study were created by constructing facial features to produce prototypical facial emotion as defined by experimentally created conventional norms. Additionally, the emotions used in this study were static, presented at medium (60%) intensity, and the participants did not view the onset of emotion (i.e., facial expression shifting from one emotion to the next). Contextual and dynamic cues may provide an overall emotion recognition advantage for viewing the dynamic formation of emotion, rather than static conditions (Ambadar, Schooler, & Cohn, 2005). The role of dynamic emotion expression in virtual agents needs further investigation.

Second, related to the first point, it is important to clarify and define what is meant by *emotion recognition* in this study. Age-related differences in labeling facial expressions do not necessarily suggest that older adults are *worse* at emotion recognition. Therefore, I am careful not to describe the results using terminology such as *accuracy* or *errors* for example. Rather, the dependent variable of emotion recognition is defined, and was discussed, as the match or attribution between the research constructed emotions displayed and the participant constructed emotion labels.

Third, one may consider whether all of the investigated emotions are relevant to virtual agents and their applications. In what contexts would a user want a virtual agent to express certain negative emotions, such as anger or fear? However, the question of interest for this research is not *should* agents demonstrate such emotions for any given application. Rather, this research aimed at understanding *how well* an agent can demonstrate recognizable emotion for younger and older adults.

The data gained from this study may provide preliminary steps toward better understanding how to best design emotional agents to portray an intended facial expression for younger and older users. Studying how users label basic emotions may provide the building blocks to creating future complex socially intelligent agents that might require a large repertoire of emotion expression.

Conclusion and Next Steps

Although much research has been conducted investigating age-related differences in *human* faces, the results of the current study suggest that age-related differences in emotion recognition are generalizable to emotive synthetic human faces and virtual agent faces. Age-related differences in emotion recognition of human faces, as reflected in the literature (Ruffman et al., 2008), point to the need to also understand recognition of virtual agent facial expressions.

The results from this study suggest that age-related differences in emotion recognition transcend *human* faces and occur for both synthetic human and virtual agent faces. This finding implies some level of generalizability of age-related differences in emotion recognition to varying degrees of less-humanoid characters. These data are an important contribution to both the general understanding of emotion recognition and the field of human-agent interaction.

The answer as to *why* such age-related differences occur has yet to be answered. Further research is needed to investigate if and to what extent differences in the discriminability of facial feature cues may influence the recognition of on-screen characters' facial expressions . Similarity between expressions may provide an explanation for misattributions of certain emotions. Further research investigating the role of facial features from a feature search perspective has yet to be conducted.

In conclusion, the findings from this study are particularly important because they provide evidence that some age-related differences in emotion recognition may not be exclusive to human faces. By extending emotion recognition research to the field of social agents, researchers can examine the extent to which age-related differences in emotion recognition are generalizable to biologically inspired emotive agents.

APPENDIX A

QUALITATIVE DESCRIPTIONS OF FACIAL EXPRESSIONS

Ekman & Friesen (1975; 2003)

Emotion	Eyebrows	Eyelids	mouth
Anger	Brows are drawn down and together	Eyelids are tensed. Upper eyelid is tensed (may or may not be raised), and upper lid is tense and may or may not be lowered by the action of the brow.	Lips are either (1) pressed firmly together with corners straight or down; or (2) open, tensed in a square-ish shape as if shouting.
Fear	Raised and straightened. Inner corners of eyebrows are closer together.	Opened and tense. Upper eyelid raised and lower eyelid is tensed and drawn up.	Open mouth, but lips are either tense and drawn back, or stretched and drawn back.
Happiness	none	Lower eyelid may be raised but not tense.	Corners of lips are drawn back and up (lips may or may not be parted)
Sadness	Inner corners of eyebrows are raised and drawn together.	Lower eyelid is raised. Eyes are slightly cast down.	The corners of the lips are down.

APPENDIX B

EXPERIMENTAL PROTOCOL

Task	**Time (Younger Adults)**	**Time (Older Adults)**
Informed Consent	5	5
Demographics and Health Questionnaire	12	15
Visual Acuity Test	2	2
Reaction Time Test	2	3
Reverse Digit Span	5	5
Digit Symbol Substitution	5	5
Verbal Ability Test	6	10
Benton Facial Discrimination Test	12	16
Break	**5**	**5**
Practice Block	5	7
Experimental Block 1	5	7
Break	**Self Paced**	**Self Paced**
Experimental Block 2	5	7
Break	**Self Paced**	**Self Paced**
Experimental Block 3	5	7
Break	**Self Paced**	**Self Paced**
Experimental Block 4	5	7
Break	**Self Paced**	**Self Paced**
Experimental Block 5	5	7
Break	**Self Paced**	**Self Paced**
Experimental Block 6	5	7
Break	**Self Paced**	**Self Paced**
Experimental Block 7	5	7
Break	**Self Paced**	**Self Paced**
Experimental Block 8	5	7
Break	**Self Paced**	**Self Paced**
Experimental Block 9	5	7
Facial Expression Identification Questionnaire	3	5
Debriefing	3	5
Total Time	**~2hrs**	**~2.5hrs**

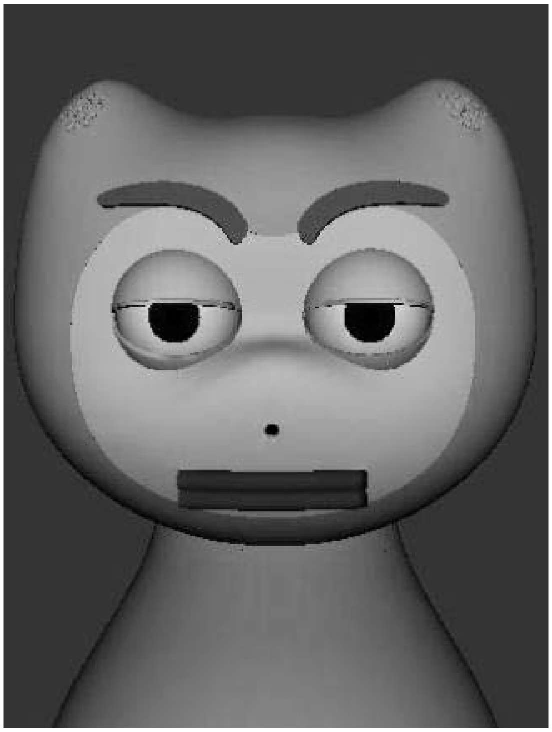
APPENDIX C

FACIAL EXPRESSION IDENTIFICATION QUESTIONNAIRE

Subject ID______ Condition 1

Please fill out the survey below.

1.) Please label the emotion this virtual agent is expressing. You may use any label(s) you like (i.e., labels used in this study, or your own).



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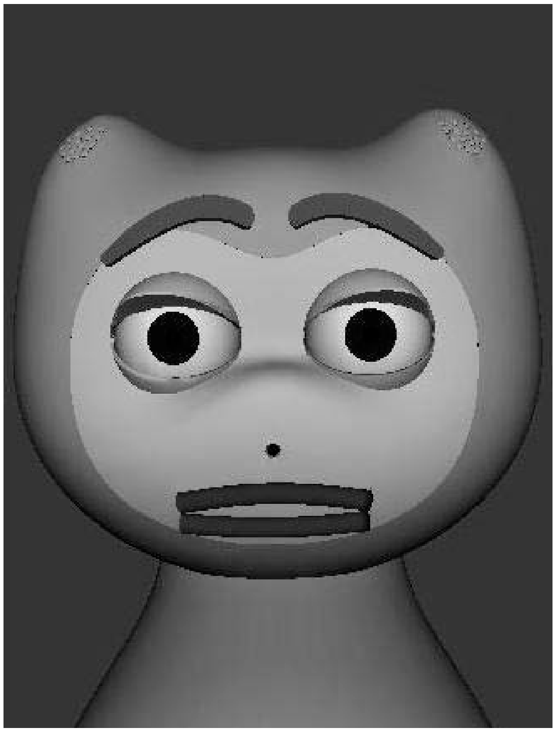
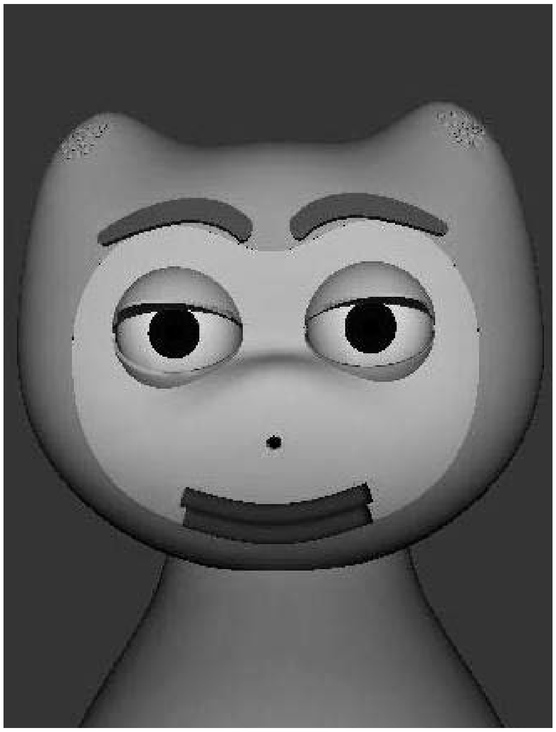
2.) Please label the emotion this virtual agent is expressing. You may use any label(s) you like (i.e., labels used in this study, or your own).



3.) Please label the emotion this virtual agent is expressing. You may use any label(s) you like (i.e., labels used in this study, or your own).



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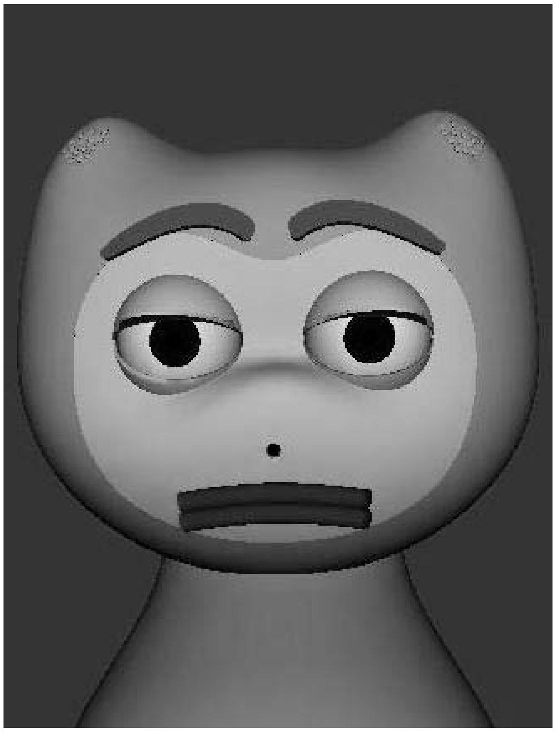
4.) Please label the emotion this virtual agent is expressing. You may use any label(s) you like (i.e., labels used in this study, or your own).



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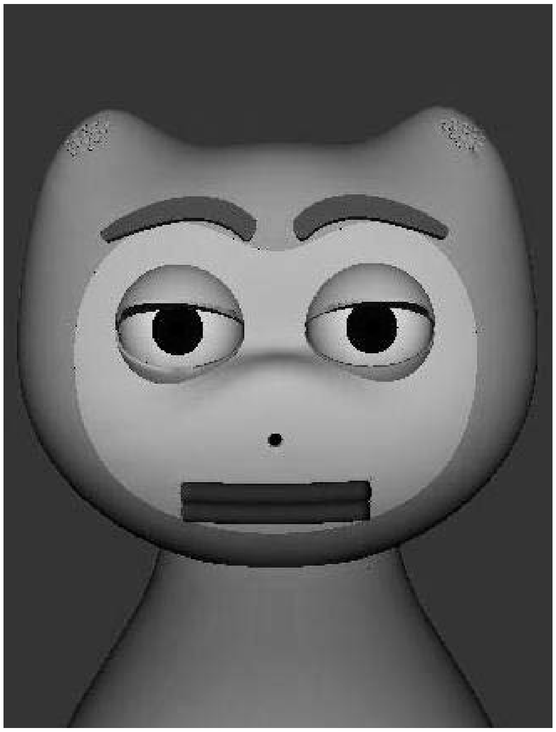
5.) Please label the emotion this virtual agent is expressing. You may use any label(s) you like (i.e., labels used in this study, or your own).



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6.) Please label the emotion this synthetic face is expressing. You may use any label(s) you like (i.e., labels used in this study, or your own).

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7.) Please label the emotion this synthetic face is expressing. You may use any label(s) you like (i.e., labels used in this study, or your own).

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8.) Please label the emotion this synthetic face is expressing. You may use any label(s) you like (i.e., labels used in this study, or your own).

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9.) Please label the emotion this synthetic face is expressing. You may use any label(s) you like (i.e., labels used in this study, or your own).

10.) Please label the emotion this synthetic face is expressing. You may use any label(s) you like (i.e., labels used in this study, or your own).

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11.) Please label the emotion this person is expressing. You may use any label(s) you like (i.e., labels used in this study, or your own).

12.) Please label(s) the emotion this person is expressing. You may use any label you like (i.e., labels used in this study, or your own).

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13.) Please label the emotion this person is expressing. You may use any label(s) you like (i.e., labels used in this study, or your own).

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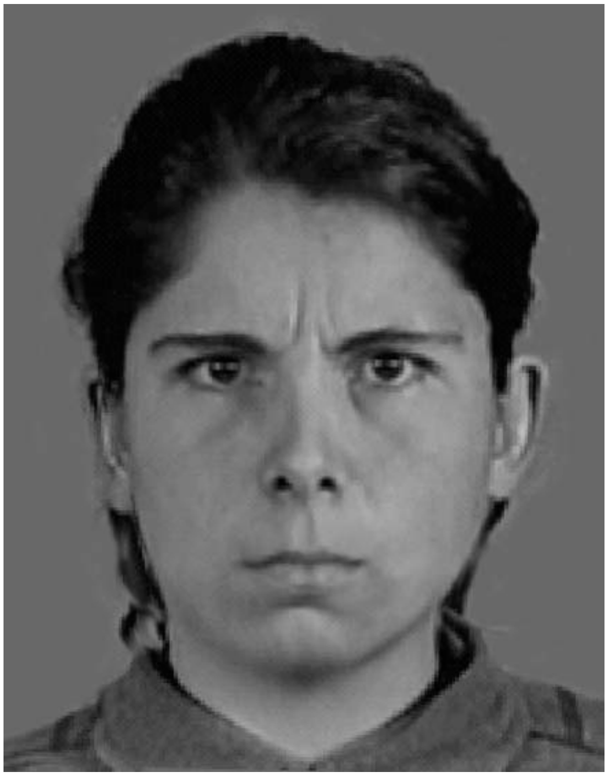
14.) Please label the emotion this person is expressing. You may use any label(s) you like (i.e., labels used in this study, or your own).

15.) Please label the emotion this person is expressing. You may use any label(s) you like (i.e., labels used in this study, or your own).



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16.) Please list the **facial features** you primarily looked at to identify each of the following emotions. Please indicate if these features differed according to each character (iCat, synthetic human, human).

Anger

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____

Disgust

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Fear

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Happy

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____

Sad

____

____

Surprise

____

____

Neutral

____

____

17.) Please rank the **Importance** of each facial feature for each determining emotion (rank 1-4, with 1=not very important, 4=very important)

Anger

Eye Brows 1 2 3 4
Not very important Very Important

Eye Gaze 1 2 3 4
Not very important Very Important

Eye Lids 1 2 3 4
Not very important Very Important

Mouth 1 2 3 4
Not very important Very Important

Other ______________________(specify)
1 2 3 4
Not very important Very Important

Disgust

Eye Brows 1 2 3 4
Not very important Very Important

Eye Gaze 1 2 3 4
Not very important Very Important

Eye Lids 1 2 3 4
Not very important Very Important

Mouth 1 2 3 4
Not very important Very Important

Other ______________________(specify)
1 2 3 4
Not very important Very Important

Fear

Eye Brows 1 2 3 4
Not very important Very Important

Eye Gaze 1 2 3 4
Not very important Very Important

Eye Lids 1 2 3 4
Not very important Very Important

Mouth 1 2 3 4
Not very important Very Important

Other ______________________(specify)
1 2 3 4
Not very important Very Important

Happy

Eye Brows 1 2 3 4
Not very important Very Important

Eye Gaze 1 2 3 4
Not very important Very Important

Eye Lids 1 2 3 4
Not very important Very Important

Mouth 1 2 3 4
Not very important Very Important

Other ______________________(specify)
1 2 3 4
Not very important Very Important

Sad

Eye Brows 1 2 3 4
Not very important Very Important

Eye Gaze 1 2 3 4
Not very important Very Important

Eye Lids 1 2 3 4
Not very important Very Important

Mouth 1 2 3 4
Not very important Very Important

Other _______________________(specify)
1 2 3 4
Not very important Very Important

Surprise

Eye Brows 1 2 3 4
Not very important Very Important

Eye Gaze 1 2 3 4
Not very important Very Important

Eye Lids 1 2 3 4
Not very important Very Important

Mouth 1 2 3 4
Not very important Very Important

Other _______________________(specify)
1 2 3 4
Not very important Very Important

Neutral

Eye Brows 1 2 3 4
Not very important Very Important

Eye Gaze 1 2 3 4
Not very important Very Important

Eye Lids 1 2 3 4
Not very important Very Important

Mouth 1 2 3 4
Not very important Very Important

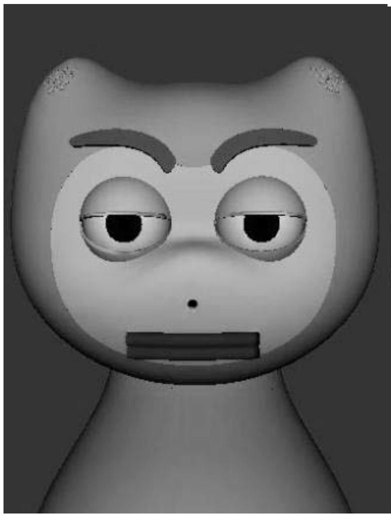
Other ______________________(specify)
1 2 3 4
Not very important Very Important

18.) Please indicate if the labels provided in the experiment (anger, disgust, fear, happiness, sadness, surprise, neutral) described the facial expressions you saw today? (i.e., could all of the facial expressions be described by at least one of the labels?)

1	2	3	4	5
None of the facial expression		Some of the facial expressions		All of the facial expressions

19.) Please match the following by writing the emotion that corresponds with the picture in the blank. Please use each emotion only ONCE.

Anger
Fear
Happy
Sad
Neutral



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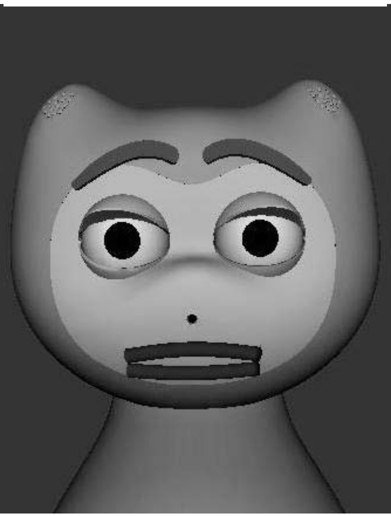

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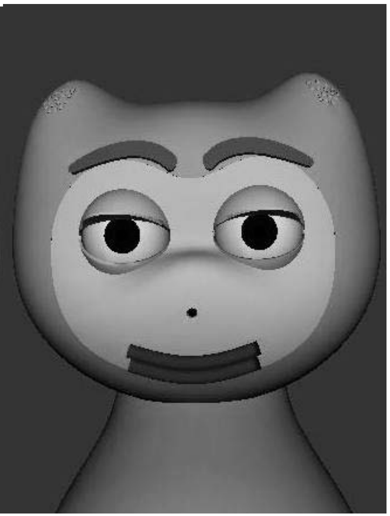

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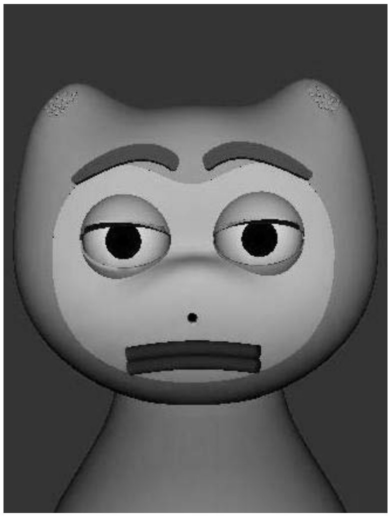

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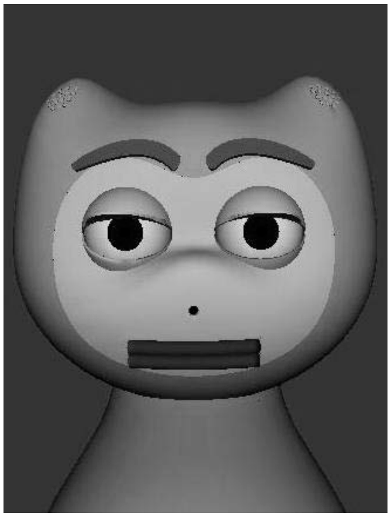

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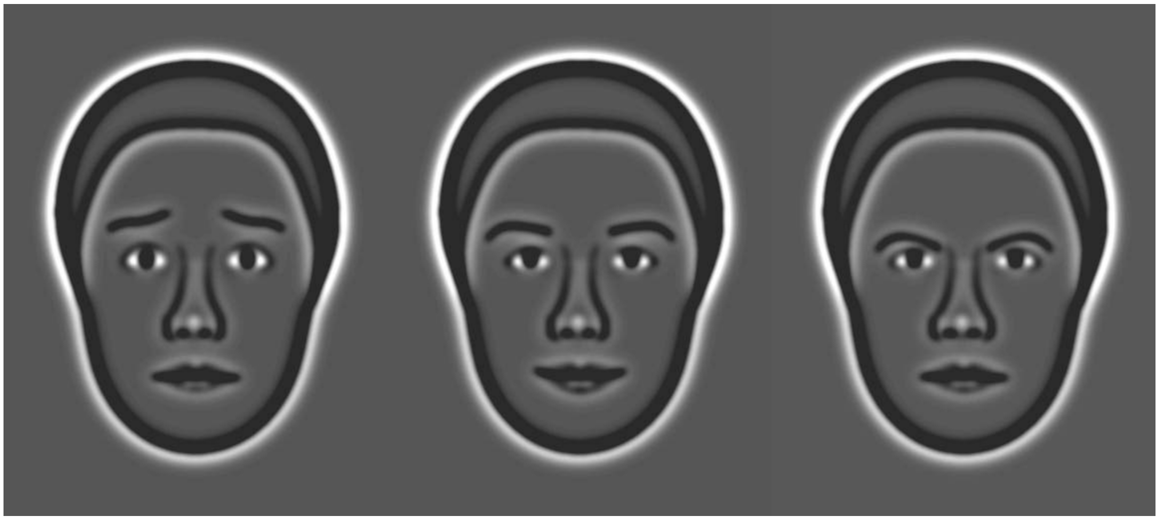
20.) Please match the following by writing the emotion that corresponds with the picture in the blank. Please use each emotion only ONCE.

Anger
Fear
Happy
Sad
Neutral



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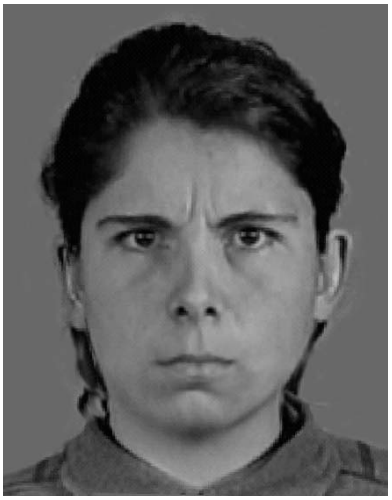
21.) Please match the following by writing the emotion that corresponds with the picture in the blank. Please use each emotion only ONCE.

Anger
Fear
Happy
Sad
Neutral

______________ ______________ ______________



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APPENDIX D

RESPONSE TIME ANOVA

Table 17

Emotion x Character Type x Age ANOVA

Source	***df***	***F***	***p***	η^2_p
Emotion (E)	4	48.23	<0.001*	0.37
Character (C)	2	11.68	<0.001*	0.13
Age (A)	1	60.97	<0.001*	0.426
C x A	2	0.75	0.47	0.01
E x A	4	2.11	0.08	0.03
C x E	8	16.37	<0.001*	0.17
E x C x A	8	3.60	.001*	0.04

Note: *p<.05

APPENDIX E

RESPONSE TIME GRAPHS

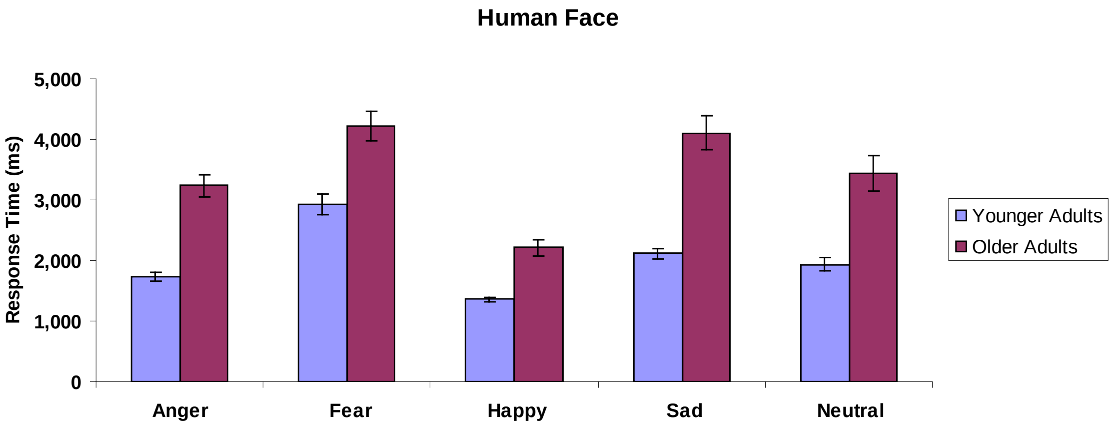

Figure 11. Younger and older adult response time for human face.

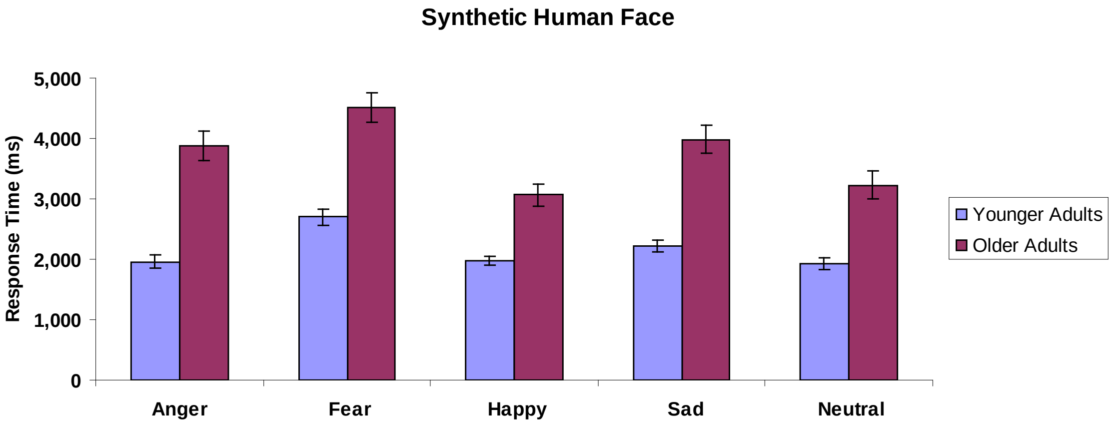

Figure 12. Younger and older adult response time for synthetic human face.

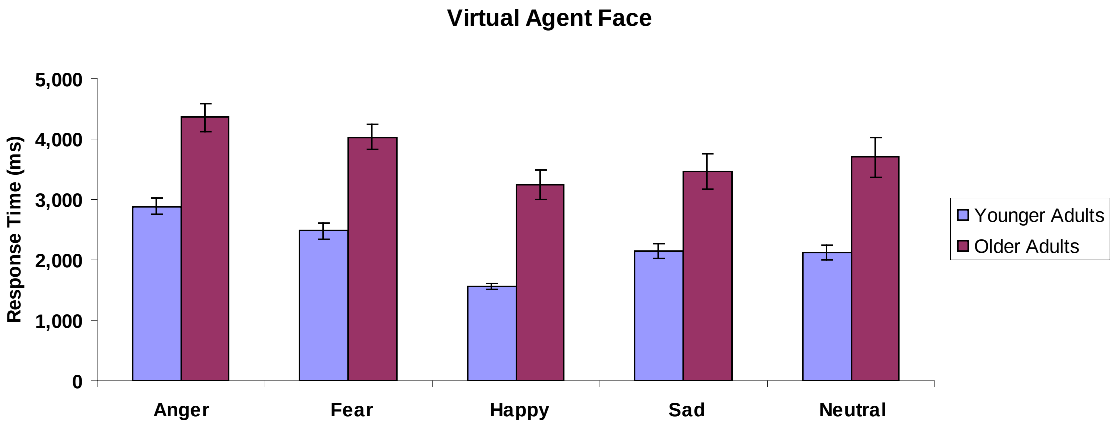

Figure 13. Younger and older adult response time for virtual agent face.

APPENDIX F

CONFUSION MATRICES BY BLOCK SET

Table 18

Human emotion attributions made over time by older adults

Older Adult Attribution Matrix

Human Face

Emotion Displayed

Block Set 1

Emotion Selected

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.77	0.20	0.02	0.00	0.01	0.01	0.00
Fear	0.07	0.09	0.32	0.01	0.04	0.26	0.21
Happy	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Sad	0.06	0.10	0.09	0.00	0.71	0.03	0.02
Neutral	0.02	0.06	0.03	0.00	0.02	0.00	0.87

Block Set 2

Emotion Selected

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.80	0.19	0.01	0.00	0.00	0.00	0.00
Fear	0.13	0.11	0.39	0.01	0.01	0.21	0.13
Happy	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Sad	0.13	0.06	0.04	0.00	0.76	0.01	0.00
Neutral	0.04	0.04	0.00	0.01	0.07	0.01	0.83

Block Set 3

Emotion Selected

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.80	0.18	0.00	0.00	0.02	0.00	0.00
Fear	0.11	0.07	0.37	0.01	0.00	0.25	0.20
Happy	0.01	0.00	0.00	0.99	0.00	0.00	0.00
Sad	0.10	0.07	0.04	0.00	0.77	0.01	0.00
Neutral	0.06	0.07	0.00	0.00	0.08	0.00	0.79

Table 19

Synthetic human emotion attributions made over time by older adults

Older Adult Attribution Matrix

Synthetic Human Face

Emotion Displayed

Block Set 1

Emotion Selected

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.56	0.18	0.02	0.02	0.02	0.03	0.17
Fear	0.02	0.07	0.21	0.01	0.04	0.61	0.04
Happy	0.00	0.00	0.01	0.89	0.00	0.02	0.08
Sad	0.04	0.11	0.06	0.00	0.70	0.02	0.06
Neutral	0.00	0.00	0.00	0.07	0.02	0.07	0.84

Block Set 2

Emotion Selected

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.63	0.10	0.02	0.01	0.00	0.03	0.21
Fear	0.03	0.03	0.31	0.00	0.05	0.55	0.03
Happy	0.00	0.00	0.00	0.85	0.00	0.03	0.12
Sad	0.01	0.10	0.04	0.00	0.75	0.02	0.06
Neutral	0.01	0.00	0.01	0.07	0.01	0.02	0.89

Block Set 3

Emotion Selected

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.60	0.17	0.03	0.02	0.00	0.03	0.16
Fear	0.02	0.03	0.33	0.00	0.04	0.53	0.04
Happy	0.00	0.00	0.00	0.84	0.00	0.02	0.13
Sad	0.02	0.04	0.03	0.00	0.77	0.04	0.08
Neutral	0.00	0.00	0.02	0.09	0.00	0.02	0.88

Table 20

Virtual agent emotion attributions made over time by older adults

Older Adult Attribution Matrix

Virtual Agent Face

Block Set 1

Emotion Selected

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.03	0.17	0.02	0.00	0.57	0.00	0.21
Fear	0.02	0.09	0.19	0.03	0.03	0.62	0.02
Happy	0.00	0.02	0.01	0.87	0.02	0.03	0.06
Sad	0.02	0.04	0.00	0.00	0.87	0.02	0.04
Neutral	0.00	0.00	0.01	0.00	0.11	0.07	0.81

Block Set 2

Emotion Selected

Emotion Displayed	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.04	0.16	0.00	0.00	0.61	0.00	0.19
Fear	0.03	0.01	0.21	0.03	0.02	0.69	0.00
Happy	0.00	0.00	0.00	0.87	0.03	0.04	0.06
Sad	0.04	0.06	0.03	0.00	0.85	0.02	0.01
Neutral	0.02	0.03	0.00	0.00	0.14	0.01	0.80

Block Set 3

Emotion Selected

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.07	0.16	0.02	0.00	0.53	0.01	0.21
Fear	0.04	0.02	0.25	0.01	0.02	0.65	0.02
Happy	0.00	0.00	0.01	0.92	0.02	0.02	0.03
Sad	0.02	0.04	0.02	0.00	0.88	0.01	0.03
Neutral	0.00	0.01	0.03	0.00	0.13	0.05	0.79

Table 21

Human emotion attributions made over time by younger adults

Younger Adult Attribution Matrix

Human Face

Block Set 1

Emotion Selected

Emotion Displayed	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.96	0.03	0.00	0.00	0.00	0.01	0.00
Fear	0.01	0.06	0.58	0.00	0.03	0.19	0.13
Happy	0.00	0.01	0.00	0.99	0.00	0.00	0.00
Sad	0.00	0.00	0.04	0.00	0.96	0.00	0.00
Neutral	0.00	0.02	0.00	0.00	0.02	0.00	0.95

Block Set 2

Emotion Selected

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.95	0.03	0.01	0.00	0.01	0.00	0.00
Fear	0.00	0.10	0.59	0.00	0.02	0.21	0.09
Happy	0.00	0.00	0.01	0.99	0.00	0.00	0.00
Sad	0.01	0.02	0.02	0.00	0.96	0.00	0.00
Neutral	0.00	0.03	0.00	0.00	0.00	0.00	0.97

Block Set 3

Emotion Selected

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.96	0.04	0.00	0.00	0.00	0.00	0.00
Fear	0.02	0.06	0.65	0.00	0.00	0.21	0.06
Happy	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Sad	0.01	0.01	0.04	0.00	0.94	0.00	0.00
Neutral	0.01	0.03	0.00	0.00	0.01	0.00	0.95

Table 22

Synthetic human emotion attributions made over time by younger adults

Younger Adult Attribution Matrix

Synthetic Human Face

Emotion Displayed

Block Set 1

Emotion Selected

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.89	0.06	0.00	0.00	0.01	0.00	0.05
Fear	0.00	0.00	0.59	0.00	0.22	0.17	0.02
Happy	0.00	0.00	0.00	0.92	0.00	0.00	0.08
Sad	0.00	0.04	0.03	0.00	0.92	0.00	0.01
Neutral	0.00	0.01	0.00	0.02	0.00	0.01	0.97

Block Set 2

Emotion Selected

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.84	0.08	0.00	0.00	0.02	0.00	0.06
Fear	0.00	0.01	0.56	0.00	0.21	0.22	0.01
Happy	0.00	0.00	0.00	0.89	0.00	0.00	0.11
Sad	0.01	0.00	0.04	0.00	0.94	0.00	0.01
Neutral	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Block Set 3

Emotion Selected

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.88	0.09	0.00	0.00	0.00	0.00	0.03
Fear	0.00	0.00	0.61	0.00	0.13	0.25	0.01
Happy	0.00	0.00	0.00	0.89	0.00	0.01	0.10
Sad	0.00	0.04	0.06	0.00	0.90	0.00	0.00
Neutral	0.00	0.00	0.00	0.02	0.00	0.00	0.98

Table 23

Virtual agent emotion attributions made over time by younger adults

Younger Adult Attribution Matrix

Virtual Agent Face

Block Set 1

Emotion Selected

Emotion Displayed

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.36	0.30	0.00	0.00	0.12	0.01	0.21
Fear	0.00	0.00	0.41	0.01	0.02	0.56	0.00
Happy	0.00	0.00	0.00	0.99	0.01	0.00	0.00
Sad	0.00	0.02	0.00	0.00	0.96	0.00	0.02
Neutral	0.00	0.01	0.01	0.02	0.02	0.01	0.94

Block Set 2

Emotion Selected

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.33	0.38	0.00	0.00	0.09	0.00	0.21
Fear	0.00	0.01	0.40	0.00	0.00	0.60	0.00
Happy	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Sad	0.00	0.03	0.00	0.00	0.94	0.00	0.03
Neutral	0.01	0.02	0.00	0.03	0.00	0.00	0.94

Block Set 3

Emotion Selected

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.36	0.41	0.00	0.00	0.02	0.00	0.21
Fear	0.00	0.01	0.41	0.00	0.00	0.58	0.00
Happy	0.00	0.00	0.00	0.99	0.00	0.01	0.00
Sad	0.02	0.02	0.01	0.00	0.93	0.00	0.02
Neutral	0.01	0.01	0.00	0.03	0.02	0.00	0.94

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