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Younger and older users' recognition of virtual agent facial expressions ☆

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ABSTRACT

As technology advances, robots and virtual agents will be introduced into the home and healthcare settings to assist individuals, both young and old, with everyday living tasks. Understanding how users recognize an agent's social cues is therefore imperative, especially in social interactions. Facial expression, in particular, is one of the most common non-verbal cues used to display and communicate emotion in on-screen agents (Cassell et al., 2000). Age is important to consider because age-related differences in emotion recognition of human facial expression have been supported (Ruffman et al., 2008), with older adults showing a deficit for recognition of negative facial expressions. Previous work has shown that younger adults can effectively recognize facial emotions displayed by agents (Bartneck and Reichenbach, 2005; Courgeon et al., 2009, 2011; Breazeal, 2003); however, little research has compared in-depth younger and older adults' ability to label a virtual agent's facial emotions, an import consideration because social agents will be required to interact with users of varying ages. If such age-related differences exist for recognition of *virtual agent* facial expressions, we aim to understand if those age-related differences are influenced by the intensity of the emotion, dynamic formation of emotion (i.e., a neutral expression developing into an expression of emotion through motion), or the type of virtual character differing by human-likeness. Study 1 investigated the relationship between age-related differences, the implication of dynamic formation of emotion, and the role of emotion intensity in emotion recognition of the facial expressions of a virtual agent (iCat). Study 2 examined age-related differences in recognition expressed by three types of virtual characters differing by human-likeness (non-humanoid iCat, synthetic human, and human). Study 2 also investigated the role of configural and featural processing as a possible explanation for age-related differences in emotion recognition. First, our findings show age-related differences in the recognition of emotions expressed by a virtual agent, with older adults showing lower recognition for the emotions of anger, disgust, fear, happiness, sadness, and neutral. These age-related difference might be explained by older adults having difficulty discriminating similarity in configural arrangement of facial features for certain emotions; for example, older adults often mislabeled the similar emotions of fear as surprise. Second, our results did not provide evidence for the dynamic formation improving emotion recognition; but, in general, the intensity of the emotion improved recognition. Lastly, we learned that emotion recognition, for older and younger adults, differed by character type, from best to worst: human, synthetic human, and then iCat. Our findings provide guidance for design, as well as the development of a framework of age-related differences in emotion recognition.

1. Introduction

People have been fascinated with the concept of intelligent agents for decades. Science fiction machines, such as Rosie from the Jetsons or C3PO from Star Wars, are idealized representations of advanced forms of technology coexisting with humans. Recent research and technology advancements have shed light onto the possibility of intelligent machines becoming a part of everyday living and socially interacting with human users. As such, understanding fluid and natural social

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interactions should not be limited to only the study of human–human interaction. Social interaction is also involved when humans are interacting with an agent, such as a robot or animated software agent (e.g., virtual agent).

The label "agent" is widely used and there is no agreed upon definition. Robots and virtual agents can both be broadly categorized as agents; however, there is differentiation between the terms. A robot is a *physical* computational agent (Murphy, 2000; Sheridan, 1992). A virtual agent does not have physical properties; rather, it is embodied as a computerized 2D or 3D software representation (Russell and Norvig, 2003). Whether an agent is robotic or virtual, it can be broadly defined as a hardware or software computational system that may have autonomous, proactive, reactive, and social ability (Wooldridge and Jennings, 1995). The social ability of the agent may be further defined as social interaction with either other agents or people.

It is generally accepted 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 et al., 1994). Humans have been shown to elicit social behaviors toward computers mindlessly (Nass and Moon, 2000), as well as to treat computers as teammates with personalities, similar to human–human interaction (Nass et al., 1995, 1996).

How are social cues communicated? Facial expressions are one of the most important media for humans to communicate emotional state (Collier, 1985), and a critical component in successful social interaction. Similarly, facial expression is one of the most common non-verbal cues used to display emotion in onscreen agents (Cassell et al., 2000). Humans learn and remember hundreds (if not thousands) of faces throughout a lifetime. Face processing may be special for humans and primates due to the social importance placed on facial expressions. Emotional facial expressions may be defined as configurations of facial features that represent discrete states recognizable across cultures and norms (Ekman and Friesen, 1975). These discrete states, as proposed by Ekman and Friesen, are often referred to as 'basic emotions.' Research on emotions has evolved over the decades, with the exact number and definition of basic emotions debated. In later research Ekman considered as many as 28 emotions as having some or all of the criteria for being considered basic (Ekman and Cordaro, 2011). Nonetheless, six of these emotions (anger, disgust, fear, happiness, sadness, and surprise) have been studied in detail (Ekman and Friesen, 2003; Calder et al., 2003; Sullivan and Ruffman, 2004). Internationally standardized photograph sets (Beaupre and Hess, 2005; Ekman and Friesen, 1978) make it possible to compare results across studies for this set of emotions.

An agent may make use of facial expressions to facilitate social interaction, communication, and express emotional state, requiring the user to interpret its facial expressions. To facilitate social interaction, a virtual agent will need to demonstrate emotional facial expression effectively to depict its intended message. 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 ability of an agent to express emotion may play a role in the development of intelligent technology. Picard (1997) stressed that emotion is a critical component and active part of intelligence. More specifically, Picard 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).

Social cues, such as emotional facial expression, are not only critical in creating intelligent agents that are sensitive and reactive toward humans, but will also affect the way in which people respond to the agent. The impetus of this research was to investigate how basic emotions may be displayed by virtual agents that are appropriately interpreted by humans.

1.1. Emotion expression of virtual and robotic agents

There are many agents, applied to a variety of applications, developed to express emotion. Virtual agents, such as eBay's chatbots, 'Louise and Emma,' have been used to provide users with instructional assistance when using a web-based user interface. Video game users both young and old engage in virtual words, interacting with other agents or avatars in a social manner. Previous research has shown that participants' recognition of facial emotion of robotic characters and virtual agents are similar (Bartneck et al., 2004), and commercial robot toys, such as Tiger Electronics and Hasbro's Furby, have been designed to express emotive behavior and social cues.

The development of agents with social capabilities affords future applications in social environments, requiring collaborative interaction with humans (Breazeal, 2002; Breazeal et al., 2004). In fact, a growing trend in intelligent agent research is addressing the development of socially engaging agents that may serve the role of assistants in home or healthcare settings (Broekens et al., 2009; Dautenhahn et al., 2005). Assistive agents are expected to interact with users of all ages; however, the development of assistive intelligent technology has the promise of increasing the quality of life for older adults in particular. Previous research suggests that older adults are willing to consider having robotic agents in their homes (Ezer, 2008; Ezer et al., 2009). For example, one such home/healthcare robot, known as Pearl, included a reminder system, telecommunication system, surveillance system, the ability to provide social interaction, and a range of movements to complete daily household tasks (Davenport, 2005).

Many agent applications may require some level of social interaction with the user. The development of social agents has a long academic history, with a number of computational systems developed to *generate* agent facial emotion. Some of these generation systems (e.g., Breazeal, 2003; Fabri et al., 2004) have been modeled from psychological-based models of emotion facial expression, such as FACS (Ekman and Friesen, 1978) or the circumplex model of affect (Russell, 1980). Another approach has focused on making use of animation principles (e.g., exaggeration, slow in/out, arcs, timing; Lasseter, 1987) to depict emotional facial expression (e.g., Becker-Asano and Wachsmuth, 2010) and other non-verbal social cues (Takayama et al., 2011). Emotion generation systems are generally developed with the emphasis of creating "believable" agent emotive expression.

Although some previous research has incorporated the generation of agent facial expression based on the human emotion expression literature (i.e., how humans demonstrate emotion), the design of virtual agents can be further informed by the literature on human emotion *recognition* (i.e., how humans recognize and label emotion). Can agents be designed to express facial expression effectively? Studies that have investigated humans' recognition of agent emotional facial expressions have suggested that the agent faces are recognized categorically (Bartneck and Reichenbach, 2005; Bartneck et al., 2004), and can be labeled effectively with a limited number of facial cues (Fabri et al., 2004). As previously mentioned, emotion recognition is integral in humans' everyday activities; however, humans' ability to recognize agent expression likely depend on many factors. For example, wrinkles, facial angle, and gaze are all design factors known to affect recognition and perceptions of expressivity for virtual agents (Courgeon et al., 2009, 2011; Lance and Marsella, 2010). Given that assistive agents are likely to interact with a range of