Human Factors Consideration for the Design of Collaborative Machine Assistants

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1 Introduction

Recent improvements in technology have facilitated the use of robots and virtual humans not only in entertainment and engineering but also in the military (Hill et al., 2003), healthcare (Pollack et al., 2002), and education domains (Johnson, Rickel, & Lester, 2000). As active partners of humans, such machine assistants can take the form of a robot or a graphical representation and serve the role of a financial assistant, a health manager, or even a social partner. As a result, interactive technologies are becoming an integral component of people's everyday lives.

Developing useful and usable assistants in everyday situations requires an interdisciplinary approach involving engineering, computer science, and psychology. Engineering fundamentals and skills to produce a functional system are important as well as mathematical foundations of computing such as computer architecture, algorithm theory, and embedded systems (Kitts & Quinn, 2004). Understanding the interaction with such systems also requires the scientific knowledge of mental processes and behavior of the users. Our perspective is from this psychology side, specifically, human factors psychology. The goal of this branch of psychology is a better understanding of user characteristics, attitudes, roles, and expectations of machine assistants. Characteristics such as perceived usefulness, ease of use, and complexity are critical to consider during the design given that in a pervasive ambi-

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ent intelligent environment, user interaction with these assistants is moving into the foreground.

In this chapter, we propose multiple heuristic guidelines for understanding such user variables that influence the acceptance of advanced technologies in ambient intelligent environments. Providing designers with heuristic tools to be considered during the design process to increase acceptance of such technology is the fundamental goal of our chapter. This chapter can also inform marketing approaches and the development of training programs and materials that support virtual human and robotic technology use.

2 Collaborative Machine Assistants (CMAs)

Many terminologies are used interchangeably to refer to virtual humans or robots or to emphasize different aspects of them. Examples include affective virtual humans (Picard, 1997), anthropomorphic agents (Koda & Maes, 1996; Takeuchi & Naito, 1995), embodied conversational agents (Cassell, Sullivan, Prevost, & Churchill, 2000), relational agents (Bickmore & Picard, 2005), social robots (Breazeal, 2003), and assistive robots (Feil-Seifer & Mataric, 2005). These terms clearly overlap and are not exclusive.

Embracing such overlap, we introduce the term, Collaborative Machine Assistant (CMA), which we define as a system or device that performs or assists a human in the performance of a task in a collaborative manner. We intend this term to include both graphical (i.e., virtual humans) and physical (i.e., robots) representations of systems with the purpose of assisting human users in performing essentially any type of task. The nature of assistance is a recursive process where both entities, users and CMAs, work together toward a common goal. This is a radically different form of assistance than we have seen with traditional machines (e.g., servant robot), which tend to be exclusively task-driven. Some tasks that require precision, timing, and coordination may benefit from traditional assistants whereas other tasks that require flexibility and intelligent problem-solving would benefit more from the collaboration of humans and CMAs (cf., Fong, Thorpe, & Baur, 2003). Because these new machine characteristics are fundamentally different from those of traditional virtual humans and robots, we perceived the need for a label that captures these unique characteristics - hence, CMA.

There are two reasons we include both graphical assistants (virtual humans) and physical robots in our definition. First, we recognize a set of commonalities between the two non-human entities that have recently emerged in the ambient intelligent environment. Many characteristics involving acceptance of such high technology (e.g., perceived usefulness) apply to both entities and thus might help inform designers of both virtual agents and robots. Second, there is a disconnection between the two research communities but we would like to encourage more communication and collaboration between them. Specifically, literature on human-machine interaction has centered on either the virtual human or the physical robot, but rarely considered both type of agents (Dragone, Duffy, & O'Hare, 2005).

CMAs are different from traditional assistants because they are collaborative, adaptive, social, and personalized. That is, a CMA will likely adapt to support the needs of the users, thus becoming a personalized assistant. This is possible because personal robots can model abstraction of the world as opposed to traditional robots that use static models for preprogrammed commands.

CMAs are also capable of social interactions that require varying degrees of intelligence, including an ability to communicate with humans through natural language. Social interaction is important when CMAs assist users to perform self-care tasks (e.g., disease management) that require users to be convinced to make health-related changes. Characteristics of CMAs intertwine with task demands. For example, the need of social mechanisms and explicit communication is fundamental for tasks requiring collaboration and adaptivity.

3 User Acceptance of CMA

An individual's acceptance of a CMA becomes critical when considering personal use of such technology. Many variables have been identified as relevant to technology acceptance; some of which relate to the technology itself (technology characteristics) and others to the characteristics of the individual user (user characteristics). Understanding the potential variables that influence acceptance of a CMA may provide designers the opportunity to influence levels of acceptance. For example, variables such as knowledge and anxiety about a CMA may be changed through training and instruction.

One important dimension of technology acceptance is whether the product is incrementally new or radically new. As described earlier, CMAs are radically different from traditional robots or virtual humans. Radical technologies such as CMAs are revolutionary, original, and discontinuous (Green, Gavin, & Aiman-Smith, 1995). Variables that predict acceptance of incremental technology may not be applicable to radical technology such as CMAs.

3.1 What is Acceptance?

What does it mean to accept a given CMA? Defining what is acceptance of a CMA and specifying a valid index of acceptance (or rejection) is important to understanding factors that influence acceptance. Consensus from the acceptance literature is that acceptance is a combination of attitudinal, intentional, and behavioral acceptance (Fishbein & Ajzen, 1975) as described in Table 1.

The idea is that attitudes influence intentions that in turn influence behaviors. Thus a person may have positive beliefs about a CMA, may have decided to

Table 1 *Acceptance Types* (adapted from Fishbein & Ajzen, 1975)

Acceptance Type	Definition	Example
Attitudinal Acceptance	Positive evaluation; beliefs about something.	"I think that is a useful product."
Intentional Acceptance	Decisions to act in a certain way.	"I will buy that product."
Behavioral Acceptance	Actions.	Using the product.

purchase that CMA, or actually carried out acceptance behaviors such as purchase and use. The fact that CMAs are a radical technology means that designers must be mindful of the attitudinal level of acceptance because radical technologies are often not as readily accepted as incremental innovations (Dewar & Dutton, 1996; Green, Gavin, & Aiman-Smith, 1995).

3.2 User Characteristics

3.2.1 Age

Chronological age is a general demographic variable that is thought to be related to technology acceptance. Early work led to the view that age negatively influences new product acceptance (e.g., Gilly & Zeithaml, 1985). However, a closer look into the relationship between age and acceptance provides interesting insights. Age relates to acceptance through mediators such as feelings of inability to adopt and use new technology (Breakwell & Fife-Schaw, 1988). Specific acceptance of a robot in the home environment was related to age in one study whereby younger adults had more positive attitudes regarding this idea (Dautenhahn et al., 2005); however, this study assessed individuals only up to age 55 and the mediating variables for this effect were not clear. Age also moderates the relationship between user perceptions and acceptance (Venkatesh, Morris, Davis, & Davis, 2003). Specifically, perceived ease of use (which we will delve more into in the following section) positively influences acceptance more so for older adults than younger individuals.

More fully understanding the relationship between age and technology acceptance is important because older adults could potentially benefit from CMAs. The growth in the older segment of the population (i.e. over age 65) and the shortage of labor in the healthcare population inspired the application of robotics in assisted-living environments (Pollack, 2005). Similarly, CMAs might perform a variety of collaborative activities with older adults, allowing them to continue their independent living at home.

Providing training programs and materials that support CMA use may diminish fears of adopting a radical technology such as CMAs. Consideration of whether a certain design change could make the CMA more easy to use is very important for older adults. Benefits of using CMAs should be presented effectively and clearly because older adults are willing to accept advanced technology if the benefit of using it is evident to them (Caine, Fisk, & Rogers, 2007; Melenhorst, Rogers, Bouwhuis, 2006).

Robots with social skills may be more favored by older adults than robots with fewer social skills. Older adults were reportedly more comfortable having a social interaction (i.e., a conversation) with a robot that had more social characteristics such as attentive listening, smiling, and using the older person's name (Heerink, Krose, Wielinga, & Evers, 2006). The social characteristics of a CMA may contribute to the increment in social presence when interacting with a CMA companion and result in a higher acceptance, through higher enjoyment.

One important point not to gloss over is that technology developments such as CMAs should be designed to augment the capabilities of older adults; that is, to enable them to do as much as possible independently. Designers should carefully allocate functions (either to the human user or to the machine) that would assist older adults but not impede or substitute their capabilities as it is critical that these technologies are there to support older adults' chosen living environment (Carpenter, Van Haitsma, Ruckdeschel, & Lawton, 2000).

3.2.2 Technophobia (Fear of Technology)

Technophobia is defined as fear of or dislike for new technology. Perceived anxiety toward technology negatively influences acceptance (Brosnan, 1999). Some CMAs may be disliked because they almost are too human-like, an idea called the "uncanny valley" originally proposed by Mori (1970, in Japanese) and discussed in MacDorman (2005; See Figure 1). The uncanny valley concept refers to increasing acceptance as a robot increases its human-likeness, up until a critical point. This point, referred as the uncanny valley, is when the similarity to the human becomes almost but not completely perfect. The subtle imperfections become disturbing or even repulsive. To create more accepted and useful CMAs designers should be aware that depending on the goal of CMA usage it may be wise to adopt a less realistic or caricatured representation.

Researchers do not yet understand the full extent of this uncanny valley; that is, at which point people become apprehensive about a human-like robot. For example, Oyedele, Hong, and Minor (2007) found that people's perceptions of robots differ depending on the context. More specifically, participants were indifferent about the humanness of robotic images in the context of touching or holding a robot. However, participants showed more concern for robotic images' similar to that of humans in the context of communicating with robots, watching robots in a movie, and living in the same house with robots.

3.2.3 Knowledge

One factor that influences the acceptance of technology is the users' existing knowledge of a product group. Prior knowledge influences the content of thinking (Alba & Hutchinson, 1987) which, in turn, influences diffusion success (Gatignon & Robertson, 1985). Based on the literature, there appears to be a complicated relationship between knowledge levels and technology acceptance. Users' knowledge levels may constrain their ability to understand an innovation depending on the continuity of the technology (Moreau, Markman, & Lehmann, 2001). For continuous innovation, experts reported higher levels of comprehension and preferences for the technology as well as higher perceptions of benefits. A different pattern was observed for discontinuous innovations; compared to novices, experts' entrenched knowledge related to lower comprehension and preferences and fewer perceived benefits. The same effect is most probable when replacing "accepted" ways of completing a given activity. Careful consideration of target user population and their level of knowledge should precede the design of CMAs.

3.2.4 Culture

The most prominent model describing the acceptance of technology is the Technology Acceptance Model (TAM; Davis, 1986). The TAM is suggested to be robust across technologies, persons, and times (Davis, 1986; 1989; Davis, Bagozzi, & Warshaw, 1989); however, it may not predict technology use across all cultures. Straub,

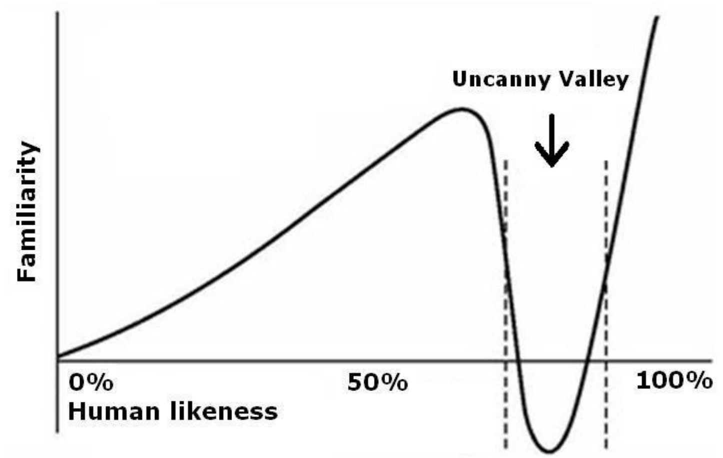

Fig. 1 An illustration of the uncanny valley idea (adapted from MacDorman, 2005, and based on Mori, 1970) whereby perceived familiarity increases with human likeness of a robot but at some point it decreases dramatically.

Keil, and Brenner (1997) administered the same instrument on technology (email) use to employees of airlines of three different countries: Japan, Switzerland, and the U.S. When system use (measured as self-reported frequency of use of emails) and perceived usefulness and perceived ease of use were analyzed, the TAM significantly explained about 10% of the variance in usage behavior in both the U.S. and Swiss samples but was non-significant for the Japanese sample. Perceived usefulness predicted usage behavior for both the U.S. and Swiss samples, but not for the Japanese sample. Perceived ease of use was not significant for any of the three country samples but this is consistent with other studies (Adams, Nelson, & Todd, 1992; Davis, 1989) suggesting that perceived ease of use exerts an indirect effect on system use (through perceived usefulness) or the impact of perceived ease of use becomes less important at post-adoption stage. Based on Hofstede's (1980) research on cultural dimensions, Straub et al. (1997) suggested that cultural factors such as uncertainty avoidance and collectivist sentiments might influenced the differential results of Japan.

The literature is inconclusive as to how cultural factors influence the use and acceptance of CMAs. Shibata's (2004) examination on individual assessment of robots from a cross-cultural perspective revealed that there were no significant disparities between all countries surveyed. However, Oyedele, Hong, and Minor (2007) reported that U.S. respondents were less apprehensive to robotics images than were the South Korean respondents.

3.3 Technology Characteristics

3.3.1 Perceived Usefulness

Perceived usefulness is defined as the extent to which a technology is expected to improve a potential user's performance (Davis, 1989, 1993) and is considered as a summary measure of all benefits related to a technology. In general, perceived usefulness increases the acceptance of technologies (Chau & Hu, 2002) for all three levels of acceptance, that is, for attitudinal acceptance, intentional acceptance, and behavioral acceptance. The consensus in the literature is that perceived usefulness is more important than ease of use (Davis, 1989), especially for post-adoption attitude formation (Karahanna, Straub, & Chervany, 1999). This implies that whether CMAs meet users' needs and expectations is the key for their continual and persistent use.

Many robotics engineers claim that their robots are useful and intuitive without considering users in the design process or deploying appropriate user testing (Adams, 2002). However, human factors research has repeatedly shown that the development of effective and usable interfaces or systems requires the consideration of the users' point of view from the beginning of the design process (e.g., Cooke & Durso, 2007). Failure to do so results in an interface users are unwilling to accept.

3.3.2 Perceived Ease of Use

Ease of use refers to the amount of effort required to effectively use a technology. Acceptance increases with an increase in the perceived ease of use (Davis, 1989) in all three levels of acceptance. People's initial decision to use a technology is more influenced by whether it seems easy to use than its perceived usefulness. One potential characteristic related to perceived ease of use is the flexibility of making a technology perform its functions. The less performance flexibility a technology has, the lower the perceived ease of use of a technology. If flexible usage is not possible then operation of the technology should be concise and intuitive.

3.3.3 Perceived Complexity

Perceived complexity can be defined as the degree to which an innovation is perceived as difficult to understand and use (Rogers, 2003). The consensus is that complexity decreases the acceptance of technology (Aiman-Smith & Green, 2002). This closely relates to users' beliefs about their ability to use the technology (i.e., self-efficacy; Fang, 1998). The more complex a technology is, the lower someone's belief about one's ability to use the technology, and the lower the degree of technology acceptance.

3.3.4 Perceived Social Skill of the CMA (Social Intelligence)

Social intelligence is defined as a person's ability to get along with people in general (Vermon, 1933). A socially intelligent person has a better ability to perceive and judge other people's feelings, thoughts, and attitudes (Ruyter, Saini, Markopoulos, & Breemen, 2005).

In our context, the general idea is that a socially intelligent robot can communicate more effectively compared with a robot absent of such intelligence; will be more pleasant to interact with; and therefore more readily accepted (e.g., see Heerink et al., 2006). The benefits of social intelligence have been reported by Ruyter et al. (2005). They used the Wizard of Oz technique to simulate human social behaviors through a robotic interface (iCat). A robotic interface with some social intelligence generated a positive bias in the user's perception of technology in the home environment and enhanced user acceptance for such systems. The social robot also triggered social behavior by the users such as more laughter and relational conversation than the neutral robot.

3.4 Relational Characteristics

Everyday interactions with CMAs are typically long-term, persistent, and relational. Some researchers purposely design a CMA to build and maintain social and emotional relationship with their users (e.g., Bickmore & Picard, 2005). Relationship is viewed in social psychology as a formulation based on an interaction where a change in behavior and the cognitive and emotional state of a person produces a change in the state of other person (Kelley, 1983). Hence, for two people to be in a relationship with each other they must interact and, as a consequence, each partner's behavior must have been influenced (Berscheid & Reis, 1998). In our context, this change of state can be mutual in all three levels (behavior and cognitive and emotional state). However, in most circumstances of interaction with a CMA, changing the users' state (e.g., learned a task, informed, entertained) and not the CMA's is the intended goal. For example, CMAs take an assistant or advisor role in many cases, making the primary goal of the interaction to advise the user (i.e., change of cognitive state; Park & Catrambone, 2007). For another example, a CMA can play a comforting and caring role (Bickmore & Schulman, 2006), where the goal of the interaction is to provide emotional support (i.e., change of emotional state).

Bickmore and his colleagues have conducted relationship research to gain insights into designing a CMA purposely built to maintain long-term, social-emotional relationship with their users. For example, Bickmore and Picard (2005) investigated techniques for constructing and maintaining a human-computer long-term relationship. They identified a number of constructs (e.g., trust, engagement, enjoyment, and productivity) known to be related to relationship quality in social psychology, and applied them in designing a long-term interaction. Applying such constructs, they developed and evaluated an exercise adoption system that employed a CMA-like system, in a long-term experiment with many participants, who were asked to interact with it daily over one month. Compared to a CMA without any relationship-building skills, the relational CMA was respected more, liked more, and trusted more. In addition, participants expressed a significantly greater desire to continue working with the relationship agent.

The purpose of this current section is to illustrate the psychological constructs and theories, in social psychology, that would potentially provide insights into understanding a human's long-term relationship with a CMA. We have taken both a top-down and a bottom-up approach in this process. From a top down approach, we have reviewed and organized the factors important when forming and developing a relationship. Additionally, we have separated the relationship interaction into beginning and maintaining stages, because different constructs play different roles at different stages of the relationship (e.g., attraction is relatively less important after the beginning stage). Designers of CMAs should be mindful of such relationship development. This is important not only when designing CMAs with the purpose of having a relationship (i.e., relational agent) but also when expecting a lengthy (long-term) interaction with CMAs not specifically designed to form a relationship.

From a bottom-up approach, we describe two specific long-term relationship models: the service relationship model and the advisor-advisee relationship model, which have similarity to the human-CMA relationship. Within these models, we discuss relevant social constructs (expectations, communications, trust, etc.) that have been identified as key variables influencing the relationship between people and examine how these variables should be considered in the design of an effective and useful CMA.

3.4.1 Beginning a Relationship

Voluntariness. The voluntariness dimension plays an important role in a relationship (Berscheid & Reis, 1998). Specifically, it provides insights in understanding the future development of the relationship. If a partner's initial interaction is involuntary, their interaction will continue only if those conditions are not subject to change (e.g., they are forced to work in the same office). Conversely, if the interaction is voluntary, continuation of the relationship depends mostly on the attraction to each other (e.g., human attraction to a CMA). More importantly, certain psychological processes induced by voluntariness may be generated that will affect the relationship's subsequent quality and future. For example, Seligman, Fazio, and Zanna (1980) induced dating couples to adopt either an intrinsic cognitive set (i.e., their enjoyment as motivations to continue the relationship) or extrinsic set (i.e., external reasons to continue the relationship). They found that those individuals whose awareness of their extrinsic reasons for continuing the relationship were heightened viewed the probability of marrying their partners as significantly lower and reported less affection for their partners than did individuals in the intrinsic group. This association between an individual's perception (i.e., intrinsic or extrinsic motivation) and relationship outcomes is also supported by correlational data (Blaise et al., 1990; Fletcher et al., 1987).

Although many relationship scholars are finding the voluntariness dimension to be useful in understanding premarital and marital relationships (Rempel, Holmes, & Zanna, 1985) as well as friendships (Fischer, 1975), little research has investigated the voluntariness dimension for human-CMA interactions. Xiao, Catrambone, and Stasko (2003) investigated whether CMAs should be proactive or reactive with a paradigm in which participants were introduced to a text editing system that used key press combinations to invoke the different editing operations. Participants were asked to make changes to a document with the aid of a virtual agent. The proactive virtual humans did not enhance performance but were instead viewed as intrusive. The fact that users were forced to interact with virtual agents may have been the problem. This may be one of the reasons why the well-known Microsoft Office Assistant ("Clippit") failed. The virtual agent appears on the screen uninvited and offers unsolicited advice. Designers of CMAs should be mindful of the distinction between involuntary and voluntary interactions and its effect on long-term interactions.

Attraction. Attraction to another individual is the most frequent motivator of voluntary attempts to initiate interaction (Berscheid & Reis, 1998). Two basic principles of attraction from the social psychology literature have relevancy to CMAs: familiarity and physical attractiveness.

Familiar people usually are judge to be relatively safer than unfamiliar people. The general effect has been demonstrated in an experiment where people were asked to give their impressions of various national groups, including a fictitious group called the "Danerians." Participants reported that the unfamiliar groups including the Danerians have undesirable qualities and disliked them (Hartley, 1946). Familiarity is responsible for the universal findings that people are more likely to initiate relationships with people in close physical proximity than they are with people even a short distance away (Segal, 1974).

Familiarity as a major factor of attraction, which induces initial interaction with others, provides insights into CMAs. Users undeniably vary in preferences and background, and therefore feel varying degrees of familiarity with CMAs. The well-known Microsoft Office Assistant ("Clippit") was implemented universally in terms of appearance and behaviors to different users from different nations. The only difference was the regional language. It is doubtful whether users from other countries would feel the same level of familiarity as a user from the U.S. in terms of not only the appearance but also its manner of interaction (e.g., level of politeness, custom of greeting and farewell).

In fact, it is probably impossible to embrace everyone's familiarity and come up with a universal CMA. Consequently, a good design approach is to provide users a choice from a range of virtual agents or social robots. On this basis Xiao et al. (2007) found that the user experience of CMA-like interactions depended largely on the individual's preconceived notions (e.g., familiarity) and preferences and that people, when allowed to choose a CMA, viewed the familiar CMAs as more likable, more trustworthy, and more valuable.

Another basic principle of attraction is physical attractiveness. There is a great deal of evidence that physical attractiveness influences a partner's interaction (Funder & Dobroth, 1987; Goldstein & Papageorge, 1980). The well-known "what is beautiful is good" stereotype effect - that physical attractiveness is linked to the inference of positive personal qualities - has been replicated many times (Berscheid & Reis, 1998). In a meta-analysis to examine this stereotype's strength and generality, Eagly et al. (1991) found that generally people do ascribe more favorable personality traits and more successful life outcomes to attractive people than to less attractive people. The magnitude of the effect was largest on the social-competence dimensions and intellectual-competence dimensions, and nonexistent on the integrity and concern for others.

This finding implies that attractiveness has an effect on CMAs being regarded as more intelligent. Further empirical research is required to determine whether people ascribe favorable personality traits to CMAs, as they would do to humans. Nevertheless, we can at least speculate that depending on the CMA's roles as a companion or an assistant, varying its level of attractiveness might have different effects on the user.

3.4.2 Maintaining a Relationship

People continue to maintain relationships with only a small fraction of the persons they meet, even if the initial encounter generated attraction (Levinger, 1980). Attraction is not a requirement of a developing relationship but rather the partners' impact on each other (as in a CMA's impact on the user). People evaluate rewards and costs after the initial contact, and if the evaluations and expectations seem favorable, the relationship should continue to grow (Altman, 1974). Similarly, there is no reason to believe that a user will continue an interaction with a CMA. The user can always withdraw from it or simply not "turn it on" if that is possible. What is important for designers to understand is that the rewards, whether emotional or performance based, must be available for the user to observe.

Empathy is one of the important constructs in building and maintaining relationships. Empathy involves the process of attending to, understanding, and responding to another person's expression of emotion. Empathy is the foundation for behaviors that enhance relationships, including accommodation, social support, intimacy, effective communication, and problem solving (Berscheid & Reis, 1998). This is true not only for intimate relationships but also for working alliances (e.g., advisor-advisee relationship, physician-patient relationship).

Decreasing perceived social distance is important for maintaining a relationship. There are many strategies known in social psychology that decrease social distance and these are outlined in Table 2.

3.4.3 Service Relationship

We now turn to the two specific relationships models. These relationships were chosen due to their similarities to CMA-human interactions. A service relationship is a long- term relationship, wherein a customer expects to interact with the service provider again in the future. Interestingly, a marriage metaphor has been used to understand the service relationship (Celuch, Bantham, & Kasouf, 2006) which enabled researchers to explore how relationships develop and change; the importance of social elements (e.g., trust, commitment); and cooperative problem solving.

As expectation forms the core of relationship schemata (Planalp, 1987), it also plays a major role in the marriage metaphor. Expectation relates to behaviors that contribute to the outcome (e.g., a partner behaving in a cooperative and collaborative manner) and the outcomes themselves (Benun, 1986). Partners might improve interaction either by altering expectations on desired outcomes or by altering expectations on how they would interact. With CMAs, users' expectations are certainly different from when they interact with traditional agents. Users generally expect more human-like behavior and more flexibility from CMAs. Xiao (2006) claimed that expectations or perceptions of users of CMAs are subject to enormous individual differences. For this reason, Xiao further emphasizes the importance of flexibility in CMA design. Providing sufficient training or practice with the virtual agent

Table 2 *Strategies Beneficial to Maintaining a Relationship* (adapted from Bickmore & Picard, 2005)

Strategy for maintaining a relationship	Examples	References
Continuity behavior	Behavior (e.g., greetings, farewells, and talk about time spent apart) to bridge the time people are apart are important to maintain a sense of persistence in a relationship.	Gilbertson et al. (1998)
Emphasizing commonalities	Increases solidarity and rapport.	Gill et al. (1999)
Maintaining the history of interaction	Talking about the past and future and reference to mutual knowledge are one of the most reliable cues people use to differentiate interaction between acquaintances and strangers.	Planalp, (1993); Planalp & Benson (1992)
Being positive and cheerful	Prosocial strategies (e.g., being nice) are known to predict liking and increase relational satisfaction.	Dindia & Baxter (1987)
Reciprocal deepening self-disclosure	Reciprocal sharing increases trust, closeness, and liking, and has been demonstrated to be effective in text-based human-computer interactions.	Altman & Taylor (1973); Moon (1998)
Sharing tasks	Helping out or sharing tasks have relational benefits by communicating affection or commitment to the partner.	Stafford & Canary (2001)
Use of humor	One of important relationship maintenance strategy and has been demonstrated to increase liking in human-computer interaction as well as with virtual agents.	Cole & Bradac (1996); Morkes, Kernal, & Nass (1999); McGuire (1994); Stafford & Canary (1991)

might provide opportunity and time for users to adjust their expectations of what they can achieve through the interaction and how to best interact with CMAs.

In a service relationship, communication behaviors influence problem-solving efficacy. This includes non-defensive listening, paying attention to what a partner is saying while not interrupting; active listening, summarizing partner's viewpoint; disclosure, sharing of ideas and information, direct stating of point of view; and editing, interacting politely and not overacting to negative events (Bussod & Jacobson, 1983). One partner's communication behavior will influence the other partner's behavior. For example, often a failure to edit negative emotions will result in the expression of reciprocal negativity from the other partner (Celuch, Bantham,& Kasouf, 2006). Generally, a unilateral disclosure of information or ideas can elicit reciprocal disclosure from the other partner.

The nature of the tasks determines the nature of communication between users and CMAs, and the design of the communication method should be deliberate. For example, when a task requires disclosure of a user's view on a certain event, it is probably a good idea to provide the CMA's (i.e., designer's) view first and ask for one in return.

Expectations, communications, and appraisals (how one might evaluate the other) all influence the longer-term outcomes of the relationship such as satisfaction, trust, and commitment. Most marketing studies have noted that service providers should put emphasis on these variables to extend their relationship with their customers (Lee & Dubinsky, 2003). Designers who are specifically developing CMAs for a long-term relationship should be aware of these factors.

3.4.4 Advisor-Advisee Relationship

Another long-term relationship studied in-depth is the advisor-advisee relationship. Advice-giving situations are interactions where advisors attempt to help the advisees find a solution for their problems (Lippitt, 1959) and reduce uncertainty (Sniezek & Swol, 2001). Finding a solution or making a decision is social, because information or advice may be provided by others.

Research on advice taking has shown that decisions to follow a recommendation are not based on an advisee's assessment of the recommended options alone (Jonas, Schulz-Hardt, Frey, & Thelen, 2001) but also on other factors, such as characteristics of the advisee, the advisor, and the situation. For example, advisees are more influenced by advisors with a higher level of trust (Sniezek & Swol, 2001), confidence (Sniezek & Buckley, 1995), and a reputation for accuracy (Yaniv & Kleinberger, 2000).

Trust is the expectation that the advisor is both competent and reliable (Barber, 1983). Trust cannot emerge without social uncertainty (i.e., there must be some risk of getting advice that is not good for the advisee); trust can also reduce uncertainty, by limiting the range of behavior expected from another (Kollock, 1994). Bickmore and Cassell (2001) implemented a model of social dialogue with CMAs and demonstrated how it has an effect on trust.

Confidence is the strength with which a person believes that an opinion or decision is the best possible one (Peterson & Pitz, 1988). Higher confidence can act as a cue to expertise and influence the advisee to accept the advice. With virtual humans, a confident voice, facial expression, and tone of language can increase the acceptance of the CMA's recommendations.

Another factor in this relationship is the emotional bond or rapport. Building rapport is crucial in maintaining a collaborative relationship. Studies showed a significant emotional bond between therapist and client (Horvath & Greenberg, 1989), supervisor and trainee (Efstation, Patton, & Kardash, 1990), and graduate advisor and student (Schlosser & Gelso, 2001). Future studies might examine if rapport between humans and CMAs varies as a function of the length of the relationship, display of affect by the agent, and the type of task.

Despite the similarities we have been highlighting, there are factors in a human-CMA relationship that are likely to have a different weighting relative to a human-human relationship. For example, human-human advisor-advisee relationship can have monetary interdependency. The advisor might receive profits from advisee's decision or suffer loss of reputation and even job security (Sniezek & Swol, 2001). The decision making process is affected by this monetary factor which does not exist in a human-CMA relationship. In another example, studies show that advisors (e.g., travel agents, friends) conducted a more balanced information search than the advisee; however, when presenting information to their advisee, travel agents provided more information supporting their recommendation than conflicting with it (Jonas, Schulz-Hardt, Frey, & Thelen, 2001). Assuming CMAs provide objective and balanced information to the users, then CMAs may be favored compared to humans in some advisor-advisee relationships.

4 Design Guidelines

Soon people will be surrounded with embedded technology such as CMAs at home in the ambient intelligent environment (Aarts et al., 2001). Users may need to know how to communicate with an increasing number of devices in such an environment (Ruyter et al., 2005). This complexity necessitates that user-centered design principles proposed for technologies in general that are used by older adults (e.g., see Fisk, 1999; Rogers, Meyer, Walker, & Fisk, 1998) become more critical in the design of CMAs. The end user of a CMA should be given extensive attention early in, and at each stage of, the design process.

Obviously, the first step is to identify the probable users. Who are the users of CMA? What segment of user population is involved? The designer must consider information including but not limited to age, geographical location, cultural background, and the level of experience with technology in general and CMA technology specifically. Users may be a well-constrained group, for example, engineers with an extensive knowledge of robots; or, a general consumer group where the design process can be more complicated due to the size and diversity of the group (Aarts et al., 2001).

Age influences acceptance of CMA. Providing training and auxiliary materials reduces feelings of inability to adopt a radical technology (Rogers et al., 1996). Consideration of whether a certain design change could make the CMA easier to use is as important for older adults as it is for younger adults.

It is also critical to understand user's perception and attitudes toward CMAs. For example, what are the user's perceptions of a robot companion at home? The following are some questions to address (adapted from Dautenhahn et al., 2005, but based on general user-centered design principles):

- Are people accepting of the idea of CMA at home?
- What specific tasks do users want CMA to assist?
- What appearance of CMA is acceptable?
- What are users' attitudes towards a socially interactive CMA in terms of behavior and character traits?
- What aspects of social interaction do users find the most and least acceptable?

Dautenhahn et al. (2005) showed in their study that participants were generally in favor of a robot-as-companion, saw the robots' potential role as assistants, machines, or servants but not as friends. Human-like communication was desirable for a robot companion but human-like behavior and appearance were less important. Similar results were reported by Yee, Bailenson, and Rickertsen (2007) in their meta-analysis of human-like appearances in virtual human interfaces. They found that the presence of a facial representation produced more positive interactions (i.e., increment in task performance, increase in liking) than the absence of a facial representation; however, the realism of appearance did not have a significant effect. Nevertheless, the degree of human-like behavior and appearance of CMA should depend on the context, task space, and purpose of CMA.

It is also critical to consider technology characteristics (e.g., perceived usefulness, perceived ease of use) during the design. Designers of CMAs should ask themselves whether the following heuristics are met:

- Do users perceive a need for a CMA?
- Do users feel that the CMA is solving the problem, by helping them to do something they would otherwise be unable to do?
- Do users believe that the CMA will be easy to use?
- Are there any design changes that could make the CMA more easy to use?
- The CMA should be tested with potential users to validate that it is perceived as easy to use (and, of course, that it is easy to use
- Do users perceive the product as complicated or difficult to understand? Generally design should attempt to minimize the complexity that users perceive.

Ambient-intelligent environments can be achieved by user-centered design where the user is the center of the design process. Iterative design processes through user evaluations and testing (see Fisk, Rogers, Czaja, Charness, & Sharit, (2004; in press) for a review of requisite protocols) become more important in the design of CMAs than that of traditional robots because CMAs have collaborative and social functionalities that require rigorous testing with the user. Initial decisions to adopt and use CMAs may be most influenced by whether it seems easy to use and one's decision to continue to use a CMA may result from the perceived usefulness of the CMA. The appropriate CMA's social presence must be embedded in the design effort.

Equally important is verifying the correctness of the ambient intelligent environment in which the CMA is imbedded. Literature suggests while such systems execute decisions on behalf of people little attention has be given to ensure the correctness of those decisions (Augusto & McCullagh, 2007). This is especially important in a potentially feasible ambient intelligent environment such as hospitals where safety is critical. CMAs (e.g., nursebots) in such environment should be thoroughly tested to avoid accidents (e.g., CMA colliding with patients) perhaps by adopting predictive models of human motion patterns (Bennewitz, Burgard, & Sebestian, 2002). Augusto & McCullagh (2007) provided an effective tool to model intelligent systems and the behavioral patterns of users, helping to analyze and verify behavioral related events.

5 Conclusions

In this chapter, we attempted to provide a better understanding of user and technology characteristics of collaborative machine assistants, referred to as CMAs. We proposed heuristic guidelines for understanding characteristics such as perceived usefulness, ease of use, and complexity that influence the acceptance of CMAs. Our goal was to provide designers with a framework for use during the design process to increase acceptance of such radically new technology.

Human factors consideration in development of robots and virtual humans often tends to be an afterthought as the process stems from an engineering perspective (Adams, 2002). General principles of user-centered design should be considered from the beginning to develop useful and acceptable CMAs. Designers must assess users' perceptions early and throughout the design and development process. User tasks and goals should be clearly identified as well as users' knowledge and experience with virtual humans or robots. Actual usability of the CMA must be evaluated with time for modifications if the target user population finds the CMA less than easy to use, useful, or socially appropriate.

Understanding the range of potential variables that influence acceptance of CMA should inform designers of opportunities to influence levels of acceptance. Acceptance can be achieved through proper design and through proper training and instruction concerning the CMA.

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