HOW DIGITAL ASSISTANTS EVOKE SOCIAL CLOSENESS: AN FMRI INVESTIGATION

Ting-Peng Liang
Electronic Commerce Research Center
National Sun Yat-sen University
70 Lien-hai Rd., Kaohsiung 80424, Taiwan
tpliang@mail.nsysu.edu.tw

Yu-Wen Li*
Department of Digital Content Application and Management
Wenzao Ursuline University of Languages
900 Mintsu 1st Road Kaohsiung 807, Taiwan
yuwen@mail.wzu.edu.tw

Nai-Shing Yen
Department of Psychology
National Chengchi University
nsy@nccu.edu.tw

Shen-Mou Hsu
Image Center for Integrated Body, Mind, and Culture Research
National Taiwan University
smhsu@nccu.edu.tw

Sachin Banker
Department of Marketing, Eccles School of Business
University of Utah
sachin.banker@eccles.utah.edu

ABSTRACT

The growing popularity of digital assistants (from Microsoft's Clippy to Amazon's Alexa) is changing how consumers acquire information and make decisions. Often embodied in anthropomorphized forms, digital assistants (DAs) are designed to serve consumers by suggesting relevant products to simplify purchasing decisions. In this work, we aim to understand how consumers evaluate social relationships with different types of DAs and their subsequent effects on purchasing. Our findings show that consumers judge DAs as being more socially close both when DAs are anthropomorphized and when they provide higher-quality recommendations. Evidence from fMRI indicated that both recommendation quality and anthropomorphization fostered greater feelings of social closeness by recruiting similar brain mechanisms involved in mental simulation (i.e., inferior frontal gyrus and cortical midline structures). Although anthropomorphized DAs were evaluated as more socially close, they did not facilitate increased purchase interest, suggesting that stimulation of neural reward networks is also necessary for driving greater purchasing.

Keywords: Digital assistants; Personalization; Anthropomorphization; Functional magnetic resonance imaging (fMRI); Electronic commerce

1. Introduction

Consumers increasingly rely upon personalized digital assistants when searching for information and making decisions. With the vast amount of data now accessible online, people often require tools to help them filter through information in order to advance their own personal goals. Digital assistants (DAs) help to fulfill this role, and they have displayed growing rates of adoption in various applications by both firms and consumers. For instance, a number

* Corresponding author

of banking institutions have implemented digital advisors and chatbots to assist customers with their inquiries (e.g., HSBC's Amy, Bank of America's Erica, and SEB's Aida), and among consumers themselves, nearly one in five Americans now make use of smart speakers within their own homes (e.g., Amazon's Alexa and Google Assistant), with an even larger number of individuals accompanied by digital assistants on their smartphones everywhere they go (Olmstead, 2017; Perez, 2018). Unlike traditional recommender systems, digital assistants are often embodied in a humanlike form, and these new decision aids are quickly changing the way in which people acquire new information and make choices. Rather than taking on all decision-making responsibilities themselves, consumers may delegate and automate elements of their decision-making processes to these "digital butlers" that act as personalized assistants addressing the unique needs of each user.

While digital assistants in general share the objective of assisting users by simplifying and improving decisions, they differ on dimensions that can have important consequences for user interactions. In the current work, we aim to understand how people evaluate their social relationships with digital assistants. Because people often apply social rules and expectations to technological artifacts such as computers, machines, and software agents just as they would to humans (Nass & Moon, 2000), interacting with a digital assistant can also exhibit aspects of a social relationship (Aggarwal & McGill, 2011; Gong & Nass, 2007; Kervyn et al., 2012; Lee, 2004; Nass et al., 1997; Nass & Brave, 2005; Nass & Lee, 2001). We focus our attention in particular upon the outcome of perceived social closeness (i.e., close social distance). Social distance was first conceptualized by Park (1924) as the level of "understanding and intimacy which characterize personal and social relations." It is an important dimension of social relationships that shapes interpersonal interactions and influences perceived fairness, trust, and sharing behaviors in person-to-person interactions (Bapna et al., 2017; Binzel & Fehr, 2013; Hong et al., 2016).

In specific, we study the effects of two key aspects of DAs on user evaluations of their social interactions: recommendation quality and anthropomorphization. By understanding how people evaluate social distance with DAs, we hope to shed light on how these emerging forms of decision aids influence user interactions. First, personalized recommendations in particular have emerged within a range of digital interfaces due to the increased ease with which firms may record personal user preferences during online interactions. A number of digital aids (e.g., Google Home, Samsung's Bixby) and online retailers (e.g., Amazon, Walmart, etc.) cater the presentation of items to users based on their expressed favorites, previously shared preferences, or even past browsing behavior. We examine if and how users may perceive DAs as being closer in social distance when digital assistants incorporate high-quality personalized recommendations.

Anthropomorphization elements are also central to a growing number of digital assistants. In addition to the range of voice assistants now common in Apple's Siri, Amazon's Alexa, and similar products, digital assistants are also frequently embodied within human forms through the use of avatars and human-like robots. Banking institutions (e.g., HSBC's Amy, SEB's Aida), online reservation systems (e.g., Amtrak's Ask Julie, Ticketmaster's Veronica), as well as customer support systems (e.g., Toshiba's Yoko) have all applied avatar-based digital assistants, often with the goal of providing users the experience of interacting with a live human agent. Thus, we also evaluate if and how the use of avatar-based digital assistants may facilitate perceptions of closer social distance. By examining subsequent purchase interest, our study furthermore evaluates whether fostering social closeness with a DA may be sufficient to increase downstream purchasing.

We employ a neuro-information system (i.e., neuroIS) approach to gain deeper insight into how these key features of digital assistants may influence perceptions of social closeness. These fMRI data allow us to identify areas of the brain that are recruited when interacting with digital assistants and enhance our understanding of this human-computer interaction. By employing a neuroIS approach, our data offer insights into the underlying mechanisms involved in fostering perceptions of social closeness of DAs. Neuroimaging tools are particularly valuable over traditional self-report data because people frequently have trouble expressing why they feel the way they do, and fMRI activation data allow us to "ask the brain, not the person" (Dimoka et al., 2011). In addition to providing a window into the psychological processes that connect features of DAs to social distance perceptions, neural data also physically localize the biological substrates involved in their implementation, which point to as novel lines of hypothesis development (ideas that we expand upon in the General Discussion).

2. Psychological and Neural Processes Involved in Digital Assistant Interactions

Recommendation quality and anthropomorphization are two common features of DAs. Both design elements serve to better communicate with customers and enhance customer relationships (Keeling et al., 2010; Komiak & Benbasat, 2006; Liang et al., 2006; Riedl et al., 2011; Short et al., 1976; Tam & Ho, 2005). Three types of psychological processes may be involved when interacting with digital assistants with such features, including self-referential processing, social cognitive processing, and reward processing. We posit that anthropomorphization may only be related to self-referential processing and social cognitive processing, while recommendation quality may be related to all three types of processes.

2.1. Self-Referential Processing

Self-referential processing refers to the cognitive process of experiencing a stimulus as relevant to oneself (Northoff et al., 2006). When one perceives specific objects or information to be related to his or her self, self-referencing processes are engaged. Personalized product suggestions often also include self-referential labels that address the user directly, and therefore they tend to draw attention toward products in a way that increases focus upon the self and warp preference construction processes. As a result, personalized recommendations can lead users to perceive a digital assistant as being more relevant to their own interests, eliciting more favorable evaluations. In fact, when users are provided with information relevant to their pre-existing interests, users display greater depth of processing related to the self (Tam & Ho, 2005). When a user interacts with an anthropomorphized DA, it may also allow the user to perceive that some of the interactive content is related to him or her. In addition to appearance, the content and tone of the dialogue of a highly anthropomorphized DA is often also humanized. For example, in a conversation with a user, anthropomorphized DAs may mention the user's name, or use other words that make the user feel that he/she is in a one-to-one interaction, such as "for you". This kind of content may make users more self-aware and enhance self-referential processing.

Research in the neurosciences has converged upon a remarkably robust network of brain areas involved in instantiating self-referencing processes. This brain network involves the cortical midline structures in particular, consisting of regions of the brain including the precuneus, posterior cingulate cortex, and medial frontal gyrus. Across a range of domains, evidence indicates that tasks associated with the self consistently elicit increased activation in these cortical midline structures (see Northoff et al., 2006; Northoff & Bermpohl, 2004; Northoff & Panksepp, 2008 for comprehensive reviews). For example, assessing whether a personality trait describes oneself elicits greater activity in these networks relative to assessing whether it describes another person (Kelley et al., 2002). Similar patterns of activation are found when participants indicate their own current emotional response to a picture (e.g., “How pleasant do you feel in response to this picture?”) compared to when making a judgment that is not self-relevant (e.g., “Is the picture of an indoor or outdoor scene?”) (Gusnard et al., 2001; Johnson et al., 2005; Ochsner et al., 2004). Additionally, increased activity in cortical midline structures has been observed when making judgments about the self rather than about personally known others and when remembering personally-relevant information (Heatherton et al., 2006; Macrae et al., 2004). Moreover, disruption to this brain network through lesions or seizures has even been shown to adversely impact self-reflective processes (Cavanna & Trimble, 2006).

2.2. Social Cognitive Processing

Social cognition refers to the process of perceiving social stimuli, interpreting social information, and making social responses (Frith & Frith, 2007). When users perceive social cues such as the human-like attributes provided by anthropomorphization and social value offered by recommendation agents, sociocognitive processes are engaged. Using human-like assistants is a popular way to create social cues on the Internet (Keeling et al., 2010; Wang et al., 2007; Waytz et al., 2010). Exhibiting human-like attributes within websites can facilitate more human-like social connection (Waytz et al., 2010) such that users may feel that online interactions with a website is similar to those with humans. Evidence has indicated that anthropomorphization engages social processing by activating goals for social interaction (Aggarwal & McGill, 2011). Thus, the application of avatars within a digital interface can activate such social processes, and while avatars may not evoke the same degree of a social response as elicited by a face-to-face human interaction (Riedl et al., 2014), they do trigger heightened social processing. Personalized content delivery is another popular strategy for showing social cues by responding to user’s needs. Liang et al. (2009) argued that personalized recommendation can be viewed as empathic responses in interactions with users. Websites use advanced information technologies (IT) to analyze user preference from their previous purchasing data and offer tailored contents accordingly. This can convey social information such as feelings of caring and understanding to users, and consequently trigger sociocognitive process.

Neuroscientific findings have suggested that social interactions often spontaneously prompt activation in brain networks involved in social simulation (Gallese & Goldman, 1998). Since observing the behavior of others often automatically prompts social simulation through nonconscious means (Bargh & Chartrand, 1999; Chartrand & Bargh, 1999; Chartrand & Lakin, 2013; Dijksterhuis et al., 2007), the presence of an avatar may similarly spur such social processing. In humans, such social simulation processes have been shown to specifically recruit areas of the inferior frontal gyrus (see Iacoboni, 2009 for a review; Iacoboni et al., 1999). For instance, greater activity in the inferior frontal gyrus was observed when participants were asked to imitate hand gestures made by a guitar player when performing a chord (Buccino et al., 2004). Transcranial magnetic stimulation methods, which temporarily disrupt function in an area of the brain, have also established that regions of the inferior frontal gyrus indeed play an essential causal role in these social processes (Heiser et al., 2003).

2.3. Reward Processing

Rewards are attractive stimuli that can drive customer behavior. When a beneficial stimulus is presented to customers, reward processing takes place and may motivate them to approach the stimulus (Schultz, 2015). Compared with anthropomorphization, high-quality personalized recommendations can offer customers with real benefits and thus present users with more rewarding product offers. Personalized recommendation systems often rely on advanced information technology to provide tailored services to meet customer's needs, and can help customers quickly find shopping information and make purchasing decisions easily. Prior work has aimed to understand the various ways in which personalization may influence user psychology. For example, Liang et al. (2006) examined two competing theories for interpreting the effect of personalization: effort reduction and individual motivation. Effort reduction in decision making is a direct benefit to a decision maker, and thus can activate reward processing mechanisms in the brain. These theories provide a base for explaining reward processing caused by personalization.

Neuroscientific evidence offers a fairly clear characterization of the brain networks involved in driving purchase decisions. Specifically, decisions to purchase are associated with increased activation in brain reward networks involved in the representation of subjective value, which have displayed highly consistent localization to areas including the striatum and ventromedial prefrontal cortex (Bartra et al., 2013). The striatum consists of several different brain regions including both the putamen and caudate nucleus. The putamen has been shown to be involved in the reward processing of both social and nonsocial rewards (Fudge & Haber, 2002; Groenewegen & Uylings, 2000), and it belongs to the mesolimbic dopamine system that is often associated with the pursuit of pleasure and the formation of product preference (Knutson et al., 2007; Knutson et al., 2008a). The caudate nucleus has also been implicated in the processing reward-related information (Delgado et al., 2004) and is correlated with prediction of reward (Haruno & Kawato, 2006). In general, activation within areas of the striatum is related to the subjective value of the item and predicts whether or not individuals will purchase various products (Knutson et al., 2007). Thus, if personalization features of digital assistants foster social closeness and facilitates greater purchase intention, such effects should occur through greater recruitment of reward-related brain networks, and specifically the striatum.

3. Literature Review and Theoretical Development

3.1. Digital Assistants and Social Closeness

Social distance, or the level of "understanding and intimacy which characterize personal and social relations" (Park, 1924) is an important aspect of social relationships. Often linked to the degree of affectivity a person feels toward others in an interaction (Bogardus, 1947), social distance reflects the interpersonal intimacy related to understanding one another's needs. People differentiate not only between the self and others, but also make distinctions between close others and distant others. Furthermore, because people apply similar social rules and expectations to the technological artifacts they interact with (Liang, 2009; Moon, 2000; Nass et al., 1995; Nass & Moon, 2000), the extent to which individuals perceive digital assistants to be near or far in social distance can also influence user interactions and downstream behaviors.

Research has established that social distance plays an important role in shaping both thoughts and behaviors in many different ways during interpersonal interactions. For instance, people who are perceived as close in social distance tend to be described and construed in more concrete terms than those who are more distal (Fiedler et al., 1995; Trope et al., 2007). As a result, interactions with close others lead individuals to focus on more concrete information in contrast to more abstract themes (Liviatan et al., 2008). Social distance also influences behaviors within interpersonal interactions. In social referral systems, people display concern for equality when sharing rewards, but only when individuals are socially distant from one another; thus concerns for fairness drive online referral behavior differently depending on the social distance between users (Hong et al., 2016). People also display greater trust toward others who are socially close, both online and in-person (Bapna et al., 2017; Binzel & Fehr, 2013) and are more generous toward close others (Charness & Gneezy, 2008). Understanding how people evaluate relationships with digital assistants can thus have important implications regarding their design.

The determinants of social distance with DAs are multifaceted. In general, perceptions of close social distance can arise due to the increased involvement of: (i) self-referential processing, (ii) social cognitive processing, or (iii) reward processing. First, when individuals engage in greater self-focused, egocentric processing, they have a tendency to see themselves in others. People tend to believe that others like what they like and share the same opinions (Krueger & Clement 1994; Ross et al., 1977). These tendencies are heightened when people exhibit more self-referential processing as evidenced in extreme contexts. For example, in narcissistic pathologies, people see everything around them as somehow relating to themselves (John & Robins, 1994). Greater self-focused processing can evoke perceptions of social closeness by leading individuals to identify aspects of oneself represented within others. In this way, DAs may facilitate perceptions of social closeness among users by increasing self-referencing processes, where the subject under evaluation centers upon the users themselves. Prior information systems research suggests that more

DAs enhance self-referencing processes (Ahn & Bailenson, 2011; Keyzer et al., 2015; Tam & Ho, 2006), which may thus foster social closeness.

By contrast, socially-focused processes can independently shape perceptions of social distance when the subject under evaluation centers upon others rather than the self. For instance, when others are seen to be belonging to the same group, individuals perceive them to be closer in social distance (Miller et al., 1998; Tesser, 1988). Similarly, when others possess greater facial resemblance, even when unknown to participants themselves, they also elicit behaviors indicative of a closer social relationship (DeBruine, 2002; DeBruine, 2005). That is, rather than increasing focus upon the self, DAs may instead facilitate perceptions of social closeness by changing aspects of the social environment, in which interactions with the digital assistant may be evaluated as more natural or familiar. Thus, whereas self-focused processes may lead individuals to see themselves in others (e.g., "my interests are reflected within this digital assistant"), socially-focused processes may lead individuals to see others as being more familiar to oneself (e.g., "using this digital assistant feels like a familiar interaction"). These distinct psychological mechanisms have different implications around who may be more prone to developing closer relationships with DAs and how such relationships can be managed. Prior IS research suggests that DAs may enhance social processing (Bente et al., 2008), which could thus foster social closeness.

Finally, reward processing may reduce social distance by evaluating the value gained from the interaction with DAs. On the Internet, users must serve themselves. DAs are designed to help users achieve their goal on the website easily and quickly. For example, DAs can provide users with information about best-selling product in the same category as the user is browsing. This may help users find the product they need and save them time searching for product through large amounts of product information (Liang et al., 2006). The benefits obtained from the interactions with DAs will trigger their reward processing and make them willing to building a close relationship with DAs, which may thus foster social closeness (Gounaris et al., 2007; Liang, 2009; Liang et al., 2009).

The effect of anthropomorphized DAs. A few previous studies have argued that anthropomorphized DAs such as avatars could serve to increase trust (Holzwarth, 2006; Jin & Bolebruch, 2009; Qiu & Benbasat, 2009; Wang et al., 2007). Findings have revealed that when communication with another human is mediated through an avatar-based (rather than text-based) interface, people develop greater trust and perceive greater intimacy (Bente et al., 2008). Survey data also reveal that these findings extend toward the use of online shopping portals, where people evaluate websites incorporating avatars as expressing greater social orientation, engendering greater trust, and evoking increased desire to use the online store (Keeling et al., 2010). Qiu and Benbasat (2009) furthermore demonstrate that actual user interactions with recommendation agents featuring embedded avatars improve social relationships by increasing social presence, trust, and intentions to use the decision aid. The existence of the human-like agent in a website can make the communication more effective and appealing due to the creation of social presence (Aljukhadar et al., 2010; Pavlou et al., 2007). Prior research suggests that human faces play an instrumental role in facilitating mental simulation (Behrens et al., 2009; Emery, 2000; Schilbach, 2010), anthropomorphized DAs could lead to perceptions of social closeness with digital assistants. In order to successfully transmit social cues, the messages conveyed by anthropomorphized DAs usually includes self-reference words such as "you", "your", or "for you". Therefore, when interacting with an anthropomorphized DA, both social processing and self-referential processing may occur to foster user's perception of social closeness. If DAs embedded with anthropomorphic avatars foster perceptions of closer social distance because of greater social processing and self-referential processing, then underlying brain networks involved in instantiating these processes, such as the inferior frontal gyrus and cortical midline structures (e.g., the precuneus, posterior cingulate cortex, and medial frontal gyrus), may be recruited.

Proposition 1*: Anthropomorphized DAs facilitate user perceptions of social closeness and recruit brain networks involved in both social processing and self-referential processing.*

The effect of personalized DAs. Relationships are usually built on meaningful interactions, because people learn about others through their interactions with them. Prior research argued that perceived empathic response is one of the main factors in building close relationships (Laurenceau et al., 1998; Liang et al., 2009). When users feel understood and cared for during the interactions, it may help reduce social distance. Liang et al. (2009) contended that personalization provides users with tailored services, which happens to be an empathic response to meet user's needs and further facilitate the perception of social closeness. Research has established that featuring personalized products within a user interface can increase the depth of self-referential processing (Ahn & Bailenson, 2011; Keyzer et al., 2015; Tam & Ho, 2006). Because higher quality recommendations can signal the understanding of user needs, such DAs could in this way ease mentalizing and drive perceptions of greater social closeness (Arioli et al., 2018). When features of digital assistants ease mentalizing processes, users may consequently find it simpler to understand the intentions and mental state of the DA, leading to perceptions of greater social closeness. In other words, if a DA looks like butler and acts like a butler rather than a machine, they may treat it like one; it can be easier for users to ascribe mental states to the DA, seeing it as a close, humanlike assistant rather than a more distant digital artifact. When users interact with a personalized DA, three types of relational benefits can be obtained and contribute to close relationship building, including social benefits, customization benefits, and economic benefits (Gwinner et al., 1998). These three benefits may trigger social processing, self-referential processing, and reward processing, respectively. Personalized services can be viewed as an empathic response that satisfies user's social needs and triggers user's social processing. Moreover, the tailored services that meet the individual needs of users are related to the users themselves and thus may activate self-referential processes. Finally, time-saving or labor-saving caused by personalized recommendation is the reward, which helps trigger reward processing. Thus, if DAs embedded with personalized favorites foster perceptions of closer social distance because of greater engagement of social processing, self-referential processing, and reward processing, then the brain networks involved in these three types of processing should specifically exhibit greater activation during interactions with DAs. This would be reflected within inferior frontal gyrus, cortical midline structures (e.g., the precuneus, posterior cingulate cortex, and medial frontal gyrus), and striatum (e.g., putamen and caudate), respectively.

Proposition 2*: Personalized DAs facilitate user perceptions of social closeness and recruit brain networks involved in social processing, self-referential processing, and reward processing.*

3.2. Digital Assistants and Purchase Intention

Relationship marketing argues that social relationships have a considerable effect on purchase intention. Because both recommendation quality and anthropomorphization features may foster closer social relationships with users, they could each drive greater purchase intention by creating a more intimate interaction. One would, not surprisingly, anticipate that DAs providing higher quality product recommendations tailored to user preferences would be of greater interest to users and elicit increased purchasing relative to lower quality recommendations.

Could the simple addition of humanlike features facilitate purchasing behavior? While anthropomorphization features do not cater suggestions to users, they are still generally thought to foster greater purchase intention through improved user relationships from relationship marketing perspective. Evidence suggests that anthropomorphized aids can increase user intent to use shopping portals again in the future (Keeling et al., 2010; Qiu & Benbasat, 2009; Wang et al., 2007) without influencing product quality evaluations (Yuan & Dennis, 2019). That is, anthropomorphized DAs may only affect user's perception of social closeness, but will not directly affect the purchase intention of recommended products. However, high-quality personalized recommendations deliver product suggestions specifically tailored to the individual's preferences; thus, DAs that incorporate personalized favorites would present offerings of greater interest to users and drive increased purchase intention compared to DAs that do not effectively cater suggestions to the user's preferences.

Several studies have demonstrated that personalized recommendations help foster user purchase intention (Bues et al., 2017; Liang et al., 2006; Tam & Ho, 2005; Tam & Ho, 2006). Tam and Ho (2005) argued that personalization is a persuasion strategy that can convince users through the central route (such as preference matching) and the peripheral route (such as customer rating). Both routes can change user's attitude toward recommended product and further increase user's purchase intention. In addition, when personalized recommendations are presented to users, the two characteristics of personalization, namely self-reference and content relevance, will attract user's attention, and active subsequence cognitive processing (Tam & Ho, 2006). Self-referencing refers to personalized messages that contain self-referencing words such as user's name, which may activate self-referential processing. Content relevance refers to personalized messages related to user's processing goal. Such relevant messages may save user's searching time and be empathic response to users in the interactions (Liang et al., 2006; Liang et al., 2009). The reward processing and social processing will be triggered. Both self-reference and content relevance have been found to have significant impact on user's purchase intention (Tam & Ho, 2006).

Proposition 3*: Personalized DAs increase user purchase intention and recruit brain networks involved in reward processing.*

4. Research Methodology

We apply brain imaging methodology in this research because of its ability to offer direct insights into the underlying processes employed by users. Neuroscientific methods have been acknowledged to provide a number of advantages in the study of information systems phenomena over traditional self-report measures (Dimoka et al., 2011; Dimoka et al., 2012; Riedl et al., 2014; Riedl et al., 2017; Riedl & Léger, 2016). Brain data can circumvent issues related to unreliable self-reports common in behavioral research, provide evidence distinguishing between conflicting psychological explanations for phenomena, and can also drive hypothesis development by exposing the shared neural networks connecting phenomena traditionally considered to operate through independent mechanisms. Leveraging these advantages, we conducted a functional magnetic resonance imaging (fMRI) study to gain insight into the mechanisms through which aspects of DAs impact user interactions. Although fMRI imposes particularly significant challenges in terms of the cost and expertise required for the execution of such studies, this method offers many unique benefits relative to other neuroimaging methodologies, providing high spatial resolution and the valuable ability to precisely localize implicated brain regions (Camerer et al., 2005).

4.1. Participants

Participants were recruited via bulletin board announcements. All participants were healthy, were right-handed (assessed by Edinburgh Handedness Inventory; Oldfield, 1971), had normal or corrected-to-normal vision, and were experiment-naïve. The experimental procedures were approved by the Institutional Review Board of Research Ethics Committee of National Taiwan University. All participants provided written informed consent and were paid approximately $20 for participating in the experiment. Three participants were excluded because they expressed inconsistent product category preferences which invalidated the recommendation quality manipulation, and five participants were excluded due to excessive head motion. This led to a final sample of 24 participants (12 females; age range 18-25), in line with typical sample size for fMRI studies.

4.2. Procedures

We applied a 2 (high quality vs. low quality recommendation) x 2 (with avatar vs. without avatar) within-subject fMRI design to manipulate elements of a digital assistant in an online shopping context. During the experiment, participants (n=24) browsed through a series of online retailer webpages that guided consumers through a shopping experience. Each page featured a product presented by the digital assistant and manipulated recommendation quality and anthropomorphized avatars. The product was either from a personally favored category for users (high quality recommendation condition), or from a less favored product category (low quality recommendation condition). As a manipulation check, perceptions recommendation personalization was measured by a single item ("The digital assistant provides the product I need"); the difference in the subjects' perception of personalization between high-quality personalized DAs and low-quality personalized DAs was significant (t=3.16, p=0.003). In addition, on each page participants were either shown an avatar conveying the message displayed adjacent to the product (with avatar condition) or were instead shown a neutral placeholder within the message area of the webpage stimulus (without avatar condition). Participants each completed a total of 128 product trials, where in each trial they viewed the digital assistant, then evaluated social distance, and lastly provided their purchase intention. Sharing purchase intention allowed us to observe downstream effects on behavior and simulate the experience of browsing through products online. Four different online retailers were created to correspond to each of the conditions in order to allow individuals to develop a connection to them. See Figure 1.

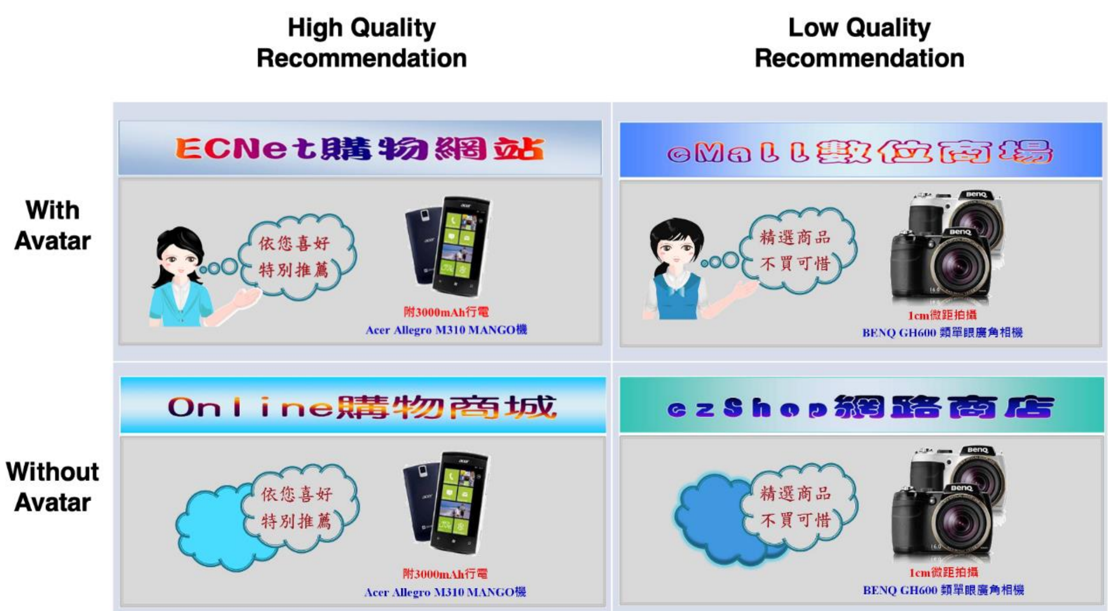

Figure 1: Experimental Stimuli

To simulate a typical website interaction, participants were asked to register for each of the respective online retailers and provided each web assistant with demographic information. In the high-quality recommendation trials, the products displayed to participants were catered to the user's top selections. Prior to the fMRI scan, users' preferences were obtained by ranking six popular product categories: smartphones, digital cameras, stereos, printers, LCD monitors, and dashcams. Each product category included a total of sixteen different products, where all items were selected to be valued at approximately $170, ensuring that items were of equivalent price across categories. All of these electronics categories were considered to be desirable (i.e., less favored categories were not undesirable) and all categories involved similar electronics features. In the high-quality recommendation trials, participants were shown products from their first and second ranked categories and were presented with a message explaining that the item had been recommended based on their individual preferences. In the low-quality recommendation trials, participants were instead shown items from their fifth and sixth ranked categories. Our key outcome of interest involved understanding effects on perceived social closeness of the DA, where DAs may or may not feature high quality recommendations and may or may not be anthropomorphized. Our study design also provided insight into effects on purchase intention; although the objective price and resale value of the items were held constant across products, participants would clearly derive greater subjective value from their most favored product categories, relative to less favored product categories. This provided a helpful benchmark which allowed us to evaluate the relative strength of anthropomorphization features on facilitating purchase intention, which past literature also conjectured could have considerable effects on purchase intention.

Each 12-second product trial consisted of a 4s phase in which participants viewed the website, 4s during which they responded with perceived social distance, and 4s in which they indicated their intent to purchase the item. Each trial also included a 2s fixation screen and a jittered 4-8s inter-trial interval. Responses to social distance (1=distant, 4=intimate) and purchase intention (1=low, 4=high) were provided using a 4-point button box, following a design approach applied in fMRI studies (e.g., Baek et al., 2017; Dimoka, 2011; Eddington et al., 2007; Karmarkar et al., 2015; Knutson et al., 2007; Knutson et al., 2008b; Ochsner et al., 2004; Phan et al., 2004). See Figure 2 for the trial sequence. All participants were screened for physical and psychiatric disorders prior to the MRI scan. The scan included a structural acquisition for anatomic normalization for ten minutes followed by functional scans that split the trials into four runs, each run with 32 trials.

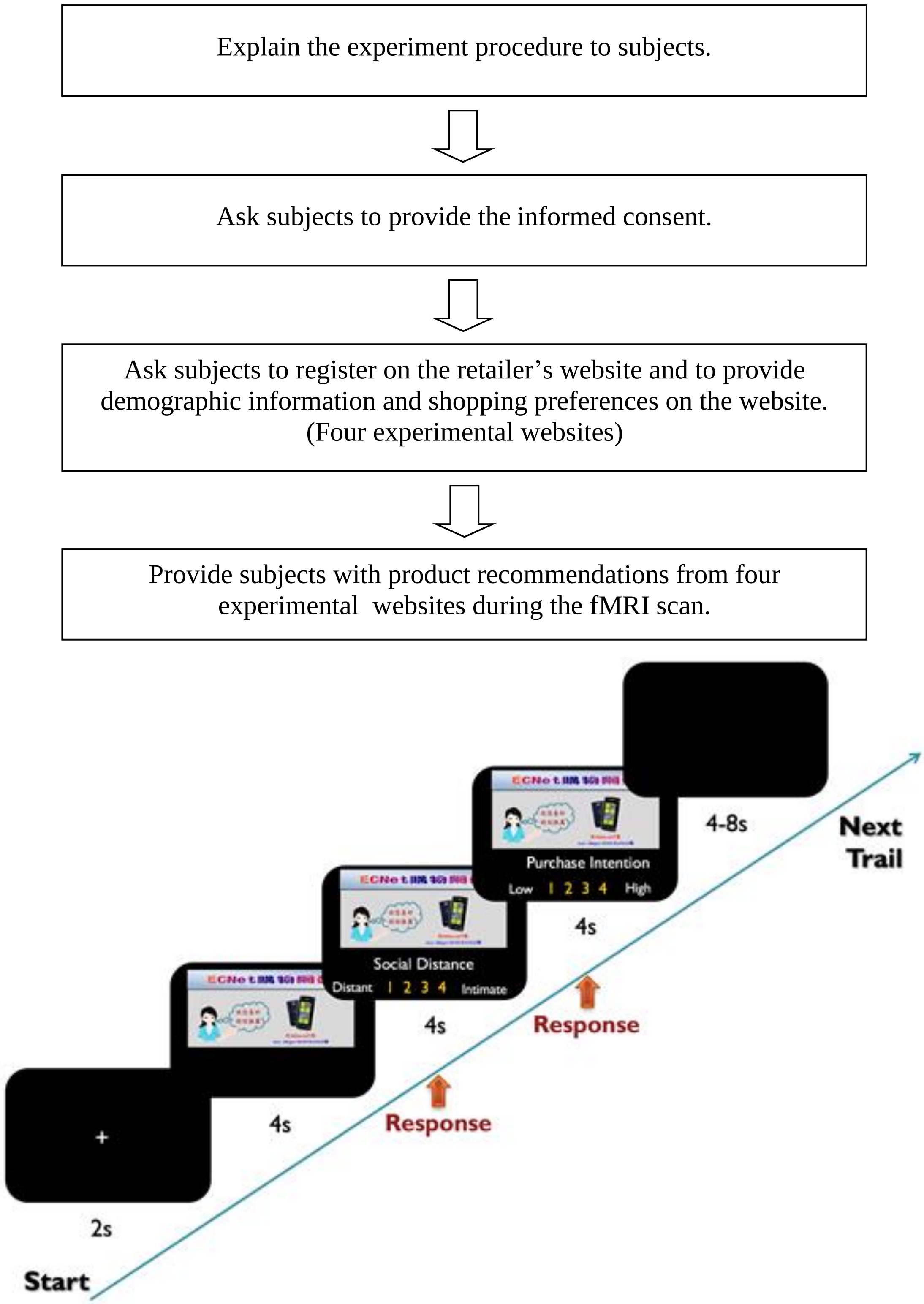

Figure 2: Experimental Procedure Sequence (Above) and Trial Sequence (Below)

4.3. fMRI Image Acquisition and Analyses

Images were acquired with a Siemens MAGNETOM Skyra 3T MRI scanner. A single-shot T2*-weighted gradient-echo EPI sequence was used for fMRI scans. Thirty-five contiguous axial slices were acquired with a slice thickness of 3 mm to cover the whole brain. Other imaging parameters included repetition time (TR) = 2000 ms; echo time (TE) = 30 ms; flip angle = 90º; field of view (FOV) = 192 x 192 mm; and matrix size = 64 x 64. The anatomical MRI was acquired using a T1-weighted, three-dimensional, gradient-echo pulse sequence. This sequence provides high-resolution (1 x 1 x 1 mm) images of the entire brain. All preprocessing and general linear model (GLM) estimation were carried out with the SPM8 software (Wellcome Department of Cognitive Neurology, Institute of Neurology, London, UK) implemented in MATLAB (The MathWorks, Natick, MA, USA). The functional images were corrected for slice acquisition time and for participant motion. Maps of contrast coefficients for regressors of interest were coregistered with structural maps, spatially normalized by warping to the Montreal Neurological Institute (MNI) space, and spatially smoothed to minimize effects of anatomical variability (FWHM = 8 mm).

Statistical analyses were performed in native space for each participant using a GLM. Regressors-of-interest were created by convolving a boxcar function during the stimulus duration with a canonical double-gamma hemodynamic response function. Functional analyses were based on binary regressors for each factor (personalization vs. non-personalization and with avatar vs. without avatar); six motion control regressors were also included. Group level analysis integrated the results from the participant-level by applying GLM. One binary regressor modeled a constant effect of all the participant-level parameter estimates on the group level. The contrasts of the task conditions were examined by voxel-specific t-tests (SPM{t}) for each participant. The t-statistics were transformed to Z-statistics to create a statistical parametric map (SPM{z}) of the contrast. The SPM{z} map was interpreted by referring to the probabilistic behavior of Gaussian random fields. Resulting statistical maps were corrected for multiple comparisons using cluster-wise false discovery rates (FDR), and then set the threshold at $p < 0.001$ with cluster size > 96.

We apply a standard fMRI contrast approach (e.g., see Dimoka, 2010; Dimoka, 2012) to identify areas of the brain that are differentially activated when forming social distance evaluations (and when sharing purchase intentions) with digital assistants that vary on two dimensions. For example, in identifying the effect of the avatar, a contrast would involve examining neural activation of the with-avatar condition *minus* neural activation of the without-avatar condition during the social distance evaluation. The remnant activation pattern therefore exposes neural processes that are *differentially* more active when forming social distance evaluations with an avatar-based DA compared to a non-avatar DA. Thus, such contrast analysis provides insight into recruited brain areas that facilitate perceptions of greater social closeness.

5. Results

5.1. Behavioral Results on Social Distance

We first examined how features of the digital assistant influenced perceptions of social distance. Summary statistics are reported in Table 1. To evaluate the effects of personalized favorites and anthropomorphized avatars on perceived social distance toward the DA, we conducted a RM-ANOVA. Our findings revealed a significant main effect of recommendation quality on perceived social distance as well as a significant main effect of avatar presence on perceived social distance. See Table 2. Thus, when participants interacted with digital assistants that were embedded with either high quality recommendations or with anthropomorphic avatars, they evaluated the DA as being closer in social distance. We did not observe a statistically significant interaction effect. These findings demonstrate that design elements of a decision assistant can in fact change perceptions of the social relationship between the user and DA, but they do not appear to have a multiplicative effect.

Table 1: Descriptive Statistics on Social Distance

	Mean	SD
Anthropomorphic Avatar		
With Avatar	2.69	0.728
Without Avatar	2.38	0.763
Recommendation Quality		
High Quality Recommendation	2.73	0.753
Low Quality Recommendation	2.34	0.715

Table 2: RM-ANOVA Results on Perceived Closeness

Source	F Statistic	Sig.
Avatar	134.768	.000
Personalization	232.877	.000
Avatar × Personalization	2.817	.093

5.2. FMRI Results on Social Distance

Effects of Anthropomorphization. Behavioral evidence indicated that anthropomorphized DAs increased evaluations of social closeness. Neural activation data provided additional insight into how anthropomorphization features led to this effect. In particular, when participants interacted with anthropomorphized DAs, they exhibited increased activation in both cortical midline structures (specifically, within the precuneus) as well as in the inferior frontal gyrus, in line with Proposition 1. Please see Figure 3 and Table 3.

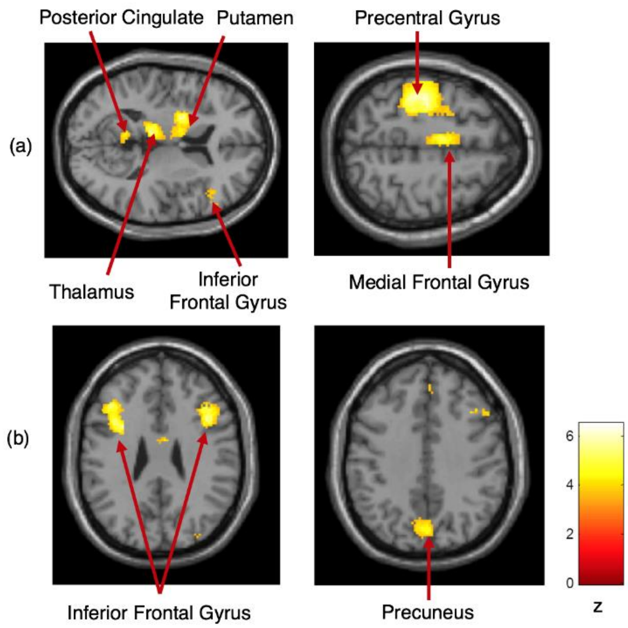

Figure 3: Activation Map during Social Distance Assessment: (a) High Quality vs. Low Quality Recommendation Contrast, (b) With Avatar vs. Without Avatar Contrast

Table 3: Brain Activation during the Social Distance Assessment, ROIs Italicized

Brain Region	MNI coordinates			t-value	cluster size
	x	y	z		
High Quality Recommendation > Low Quality Recommendation					
L. Thalamus	-14	-28	8	4.82	615
L. Putamen	-22	0	4	4.3	440
L. Medial Frontal Gyrus	-4	-8	58	4.88	209
L. Precentral Gyrus	-32	-18	58	6.02	950
L. Middle Frontal Gyrus	-32	-8	62	4.7	217
L. Posterior Cingulate	-8	-52	14	4.58	268
L. Postcentral Gyrus	-34	-36	58	5.09	716
R. Fusiform Gyrus	38	-48	-18	3.84	467
L. Fusiform Gyrus	-38	-52	-20	4.56	221

R. Lingual Gyrus	12	-80	-8	5.41	701
R. Inferior Frontal Gyrus	44	22	14	5.07	360
Low Quality Recommendation > High Quality Recommendation: No Significant Clusters Observed					
With Avatar > Without Avatar					
R. Middle Occipital Gyrus	44	-80	4	3.94	123
R. Fusiform	30	-68	-12	3.86	118
L. Precuneus	-4	-74	38	4.25	131
R. Middle Frontal Gyrus	44	22	32	4.36	358
L. Middle Frontal Gyrus	-41	26	26	5.06	151
L. Superior Frontal Gyrus	-5	30	52	6.08	267
R. Inferior Frontal Gyrus	32	21	-8	4.41	142
Without Avatar > With Avatar: No Significant Clusters Observed					

Anthropomorphic avatars may thus foster perceptions of social closeness through the increased recruitment of brain networks involved in processing social stimuli. Neural activation data indicated that users indeed recruited brain networks involved in social processing and self-referential processing to a greater extent when interacting with digital assistants embedded with avatars compared to those without avatars, in line with ideas suggesting that anthropomorphic avatars foster perceptions of closer social distance through the increased engagement of social processing and self-referential processing (Proposition 1). Specifically, when participants expressed that they felt greater levels of social closeness during their interactions with an avatar-based digital assistant, they exhibited increased neural activation within the inferior frontal gyrus and precuneus relative to when interacting with a digital assistant that did not incorporate anthropomorphization elements.

Effects of Recommendation Quality. Our behavioral findings indicated that simply providing higher quality recommendations to users increased evaluations of social closeness. Neural data enabled us to explore the mechanisms underlying this effect and revealed that when interacting with DAs that offered high quality recommendations, participants displayed greater activation within the key brain networks involved in mental simulation. Specifically, DAs offering high quality recommendations increased recruitment of cortical midline structures (posterior cingulate cortex and medial frontal gyrus), the inferior frontal gyrus, and putamen, in line with Proposition 2. Please see Figure 3 and Table 3.

Personalized favorites may foster perceptions of social closeness through the increased recruitment of self-referential, social, and reward brain networks. Our findings indicated that the inclusion of personalized favorites within the digital assistant indeed led to significantly greater activation in cortical midline structures, inferior frontal gyrus, and putamen associated with self-referential processing, social processing, and reward processing during the social distance assessment. This result is consistent with the idea that personalized favorites lead to perceptions of social closeness by increasing self-referencing, social processing, and reward processing (Proposition 2). Specifically, when participants formed social distance evaluations, they recruited the posterior cingulate cortex, medial frontal gyrus, inferior frontal gyrus, and putamen to a greater extent when the DA featured personalized favorites, compared to when it did not.

Thus, neural data suggest that both design elements (anthropomorphization and recommendation quality) may lead to evaluations of closer social distance by recruiting brain networks involved in mental simulation process. This mentalization account suggests that when features of DAs make it easier for users to see the digital artifact as object with mental states and capacity for mutual understanding, users will judge their relationships with them to be closer.

5.3. Behavioral Results on Purchase Intention

We next examined how aspects of DAs may impact downstream outcomes, in particular, purchase intention. Our findings revealed that perceptions of social closeness were positively correlated with purchase intention ($\rho = .511$, $p < .001$), such that users who perceived the digital assistant as being socially close were generally more inclined toward purchasing the product offered. We subsequently conducted a RM-ANOVA to evaluate the distinct effects of personalized favorites and anthropomorphization on perceived purchase intention. Summary statistics are reported in Table 4. Although, as reported above, high quality recommendations and anthropomorphization had similar effects on social distance perceptions, RM-ANOVA results suggested that these design elements had dissimilar effects on purchasing intention. While recommendation quality significantly increased purchase intention, we did not observe a similar main effect of avatar presence on purchase intention. These findings help to complement prior evidence which suggests that anthropomorphization can improve relationships with stores by encouraging repeat visits (Keeling et al., 2010; Qiu & Benbasat, 2009; Wang et al., 2007); the current findings suggest that anthropomorphic features may indeed facilitate closer relationships without necessarily conferring benefits to the perceived subjective value of products offered. See Table 5.

Table 4: Descriptive Statistics on Purchase Intention

	Mean	SD
Anthropomorphic Avatar		
With Avatar	2.60	1.009
Without Avatar	2.56	1.021
Recommendation Quality		
High Quality Recommendation	3.08	0.889
Low Quality Recommendation	2.07	0.872

Table 5: RM-ANOVA Results on Purchase Intention

Source	F Statistic	Sig.
Avatar	1.058	.304
Personalization	991.353	.000
Avatar × Personalization	0.003	.955

5.4. FMRI Results on Purchase Intention

Effects of Recommendation Quality. Personalized favorites present users with items that are better matched to their preferences, and should not surprisingly increase subjective value and subsequent purchase intention. Neural activation data confirmed that higher recommendation quality lead to increased activation in social, self-reference, and reward-related brain networks (Proposition 3). Specifically, we observed greater activation in inferior frontal gyrus, precuneus, medial frontal gyrus, and striatum (within the caudate nucleus) when participants shared their purchase intention, in line with Proposition 3. See Figure 4 and Table 6.

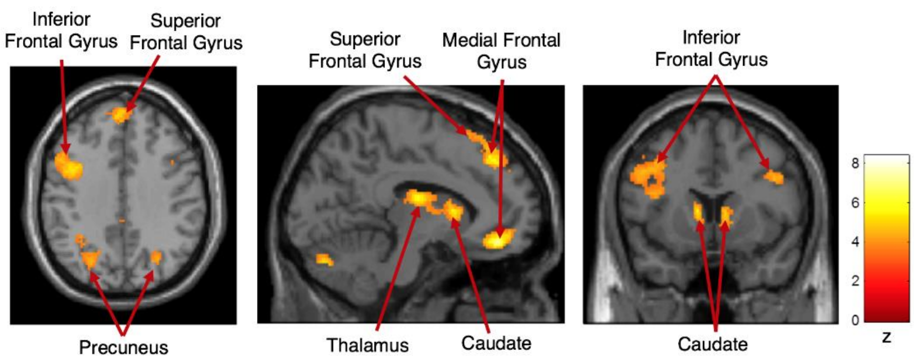

Figure 4: Activation Map of the High Quality Recommendation vs. Low Quality Recommendation Contrast during the Purchase Intention Assessment

Table 6: Brain Activation during the Purchase Intention Assessment, ROIs Italicized

Brain Region	MNI coordinates			t-value	cluster size
	x	y	z		
High Quality Recommendation > Low Quality Recommendation					
L. Precuneus	-26	-68	36	4.36	169
L. Thalamus	-10	-10	12	4.08	615
R. Thalamus	10	-10	18	5.61	180
L. Inferior Frontal Gyrus	-50	30	16	8.34	1197

R. Caudate	10	8	12	4.12	247
L. Superior Frontal Gyrus	-10	36	52	4.68	614
L. Medial Frontal Gyrus	-10	44	-14	7.25	392
R. Fusiform Gyrus	40	-66	-18	3.69	467
L. Fusiform Gyrus	-44	-54	-16	3.64	221
L. Inferior Occipital Gyrus	-36	-88	-10	5.08	272
L. Middle Occipital Gyrus	-30	-90	4	3.96	540
R. Middle Occipital Gyrus	48	-70	-10	3.63	372
L. Superior Parietal Lobule	-26	-66	48	4.51	286
Low Quality Recommendation > High Quality Recommendation					
R. Postcentral Gyrus	40	-32	58	4.08	607
R. Precentral Gyrus	34	-30	62	4.03	193
With Avatar > Without Avatar: No Significant Clusters Observed					
Without Avatar > With Avatar: No Significant Clusters Observed					

Effects of Anthropomorphization. While higher quality recommendations increased striatal activation, anthropomorphized DA did not lead to significant differences in brain activation during purchase intention assessments. These findings indicate that while avatars may serve to foster closer relationships with users and increase repeat patronage intentions, anthropomorphized agents may not directly increase the perceived value of product offerings. Instead, digital assistants drive greater purchasing through more personalized offerings that meet user needs, facilitated by the activation of neural reward networks.

6. General Discussion

6.1. Overview of the Current Findings

Digital assistants, from Microsoft's familiar Clippy to Tencent's Xiaowei assistant, have become increasingly widespread through their adoption by both firms and consumers. However, our understanding of how aspects of DAs influence user interactions with them has remained comparatively limited. We present evidence in this work illustrating that features of DAs can have important consequences for the relationships users form with them. In particular, we found when users interacted with digital assistants that varied in recommendation quality and anthropomorphization, each of these interface features shaped perceptions of closer social distance and changed the nature of the user relationship. Yet, our findings also revealed that although recommendation quality and anthropomorphization both increased social closeness with the DA, only higher quality recommendations (and not anthropomorphic elements) led to increases in purchase intention—this evidence suggests that anthropomorphized DAs improve relationships with users that can facilitate repatronage without necessarily increasing the perceived value of goods. The current study presents first evidence documenting neural processes implicated in user interactions with digital assistants and suggest that the recruitment of brain networks involved in mental simulation facilitate judgments of social closeness with DAs. In short, the current findings add in several ways to prior literature: (1) we show that personalization and anthropomorphization features of DAs foster social closeness, an important dimension of user relationships; (2) we find that personalization and anthropomorphization features both increase brain activation in self-referencing and social processing networks simultaneously in facilitating social closeness, a result that is not explained by prior IS theory; (3) we offer a refinement to prior conjectures in the literature by showing that while personalization can increase purchase intention, anthropomorphization is considerably weaker due to the inability of anthropomorphized DAs to increase activation in neural reward networks. Thus, our evidence not only introduces new findings related to how features of DAs impact perceived social distance, but also presents brain imaging results which point to a novel theoretical perspective and new lines of hypothesis development. We outline some of the key implications of these neural data below.

6.2. Implications and Directions for Research

The current neural findings add to the existing behavioral literature in that has examined effects of recommendation systems. Prior behavioral research has found that providing users with higher quality recommendations that are customized to individual can increase self-referential processing (Ahn & Bailenson, 2011; Keyzer et al., 2015; Tam & Ho, 2006). When customers are provided with information relevant to their pre-existing interests, users display greater depth of processing related to the self (Tam & Ho, 2005). Our current neural activation data contextualizes these findings, indicating that such effects could reflect the recruitment of a broader network of psychological processes involved in mental simulation, in which greater self-processing plays a role.

The neural findings point to a new perspective in thinking about how users form relationships with the digital assistants that they interact with. When features of digital assistants make it easier for users to attribute mental states to DAs, users are more likely to see the digital assistant as a socially-close, humanlike peer rather than a more distant, digital artifact (in other words, the more that a DA looks like and acts like a butler rather than a machine, the more that users will see them that way). This perspective is related to the concept of the "intentional stance" (Dennett, 1989): that is, when the simplest way to explain an agent's behavior and characteristics is by attributing mental states to the agent, then perceivers will treat the agent as indeed holding such mental states. Applied to digital assistants, personalization and anthropomorphization features may lead users to consider what the DA "thinks" rather than treating it merely as an object, which can facilitate perceptions of a closer social relationship.

Our brain imaging data fall in line with a mentalizing account in that the pattern of activation we observe aligns with prior neuroimaging findings regarding how individuals may simulate the mental states of other agents. In specific, evidence suggests that simulating the mental states of others when forming evaluations relies upon two systems within the brain: cortical midline structures and the social simulation system (see Mahy et al., 2014 for a recent review of related neuroscientific evidence). Thus, one interpretation of our current findings is that anthropomorphization and personalization features embedded within DAs facilitate mentalizing processes, making it easier to relate to the digital assistant, and consequently fostering social closeness. *This interpretation, which emerges from the brain data, offers a new perspective regarding how the features of a DA can influence relationships with the user.*

It is important to note the important limitations in drawing inferences from neural activation data. For instance, due to the methodological constraints in conducting brain imaging research, tradeoffs must be made in the experimental design to facilitate implementation while providing external validity. While the DAs implemented in the present study may not map on to cutting-edge interactive DAs in Amazon's Alexa and Tencent's Xiaowei, they do correspond to simpler DAs that are still used on various ecommerce platforms. In addition, while we aimed to improve external validity by allowing participants to interact with four distinct online stores, this created subtle differences in the stimuli; while we do not expect that such subtle differences in the stimuli would influence high-level brain processes, it is an important point to note. Readers should also appreciate issues of reverse inference, for example, and understand that increased activation in a brain area does not necessarily imply the involvement of particular psychological processes; other, distinct theoretical accounts could also potentially describe the current neural findings. Although a single study is rarely definitive, the current data are consistent with a theoretical perspective that parsimoniously explains the current findings as well as prior evidence in the literature, which warrants further inquiry and evaluation.

We believe that the current findings many point to many promising directions for further research, including those that can be addressed with behavioral research methods. For instance, exploring the factors that impact the tendency with which individuals attribute mental states and motivations to such technological artifacts could provide insight into types of DAs that users develop strong relationships. Such inquiries may examine the content and types of mental states users attach to digital assistants and under what conditions. While users may consider certain digital assistants to understand and have knowledge of their own personal needs, in what situations may people also ascribe emotional states to the machines they interact with, and how would this impact the perceptions of closeness and downstream behaviors? Further understanding how features of DAs influence the way in which individuals conceptualize their relationships with digital assistants through mentalizing processes could also provide insights into how users respond to DA failures. For example, if people are more inclined to ascribe mental states to personalized and anthropomorphized digital assistants, they may also be more inclined to hold the DA responsible for errors (e.g., in purchasing the wrong item through an online shopping portal). At the same time, if users are more inclined to ascribe emotional states to personalized and anthropomorphized digital assistants, they may be more inclined to forgive errors (e.g., rather than thinking "Alexa doesn't work," users may think "Alexa is confused, let me try again later"). This account of our brain imaging data clearly triggers a number of follow-up research questions that may offer important insights into user interactions with digital assistants.

These neural data also support unique lines of hypothesis development due to the identification of physical substrates associated with perceiving digital assistants as being close in social distance. Because neural activation data obtained via fMRI are typically correlational in nature, we cannot identify whether increased activity in cortical midline structures and the inferior frontal gyrus is necessary for personalized recommendations to foster closer perceptions of social distance, or whether activity in these areas is sufficient to foster perceptions of closer social distance.

We may first consider the case that recruitment of cortical midline structures and inferior frontal gyrus is necessary to generate perceptions of social closeness. If this is the case, then populations of users who exhibit impairment in these brain areas may interact differently with digital assistants because they do not develop the same degree of social closeness as other individuals. For example, evidence indicates that elderly populations display lower levels of connectivity in the brain as well as cortical midline function loss, particularly among those diagnosed with Alzheimer's (Ries et al., 2007; Sherwood et al., 2011). Similarly, depressed individuals also display less sensitivity to stimuli within cortical midline structures (Grimm et al., 2009). While these vulnerable populations may derive the most utility from digital assistants because they can simplify complex decision tasks, these individuals may also experience greater barriers in developing close relationships with DAs that may inhibit building trust. These novel propositions can be evaluated with behavioral research tools.

When considering the possibility that the recruitment of cortical midline structures and the inferior frontal gyrus is sufficient to generate perceptions of social closeness, greater caution is required when generating new hypotheses. Because fMRI measures changes in blood flow rather than activation patterns of individual neurons, one must be especially conservative in applying lines of reasoning that build on the fact that other treatments activate the same brain areas; a single brain area can represent different kinds of information in the neurons that constitute it. One may generate a more speculative hypothesis, for example, that because sad stimuli evoke greater neural activation within cortical midline structures (Farb et al., 2010), anthropomorphized DAs that exhibit sad emotions could foster closer social relationships with users. Such a proposition can also be evaluated with behavioral data.

Our findings also revealed that recommendation quality, but not anthropomorphization, increased purchasing behavior. In specific, we observed that only DAs with higher quality recommendations were able to elicit increased striatal activation, an area of the brain that has been shown to predict subsequent purchasing behavior (Knutson et al., 2007). One interpretation of these findings is that while anthropomorphic elements may engender a more natural interaction for users, these positive benefits are not transferred to the items presented by the digital assistant. Building on these findings, further research could explore how differences in avatar types change user perceptions of content relevance in a way that impacts perceived value. Some prior research indicates, for example, that matching avatars to the user's gender and ethnicity can increase the perceived value of its repeat interactions (Benbasat et al., 2010). If matched avatars are capable of increasing the perceived value of anthropomorphized DA output, they may consequently facilitate increased purchasing while simultaneously fostering closer relationships with users.

7. Concluding Remarks

Digital assistants are rapidly changing the way in which consumers find information and make purchasing decisions. This work provides an examination of the behavioral and neural processes involved in establishing close relationships with such digital assistants. Our findings show that the use of anthropomorphization and recommendation quality both foster perceptions of closeness, and neuroimaging data point to the involvement of mental simulation networks in the brain that drive these evaluations. The evidence presented here offers insights into how features of a digital assistant can shape the relationship users form with DAs and point to new propositions that may be evaluated by future research adopting both behavioral and neural methodologies. As people increasingly rely upon digital assistants in their everyday lives, deeper understanding of how users interact with them and are influenced by them will be increasingly important to their advancement and development.

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