Mouse vs. Touch Screen as Input Device: Does it Influence Memory Retrieval?

Research-in-Progress

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Abstract

The main objective of this research is to investigate how input device type influences users' memory retrieval (i.e., stimulus recognition). We build upon prior research on the somatosensory (tactile) system to argue that the use of a direct input device (i.e., touch screen) involves a multisensory experience and more cerebral activities than an indirect input device (i.e., mouse), leading to richer information encoding, and consequently to better information retrieval from memory. A one-factor between-subject experimental design was used to test our hypotheses. Thirty participants were randomly assigned to either a mouse or touch screen input device condition. Our results indicate that for individuals with higher need for touch, input device influences activity in the posterior parietal cortex (PPC), a brain region associated with multisensory experience, during memory retrieval and stimulus recognition.

Keywords: Input device, memory, recognition, ERP, need for touch.

Introduction

Although the computer mouse is still a very popular input device (Taveira and Choi 2009), the growing popularity of tablets and smartphones promotes a different type of input device, namely touch screens (eMarketer 2013). There is a dearth of research investigating how different types of input device (direct such as tablet or smartphone, or indirect such as mouse or joystick) influence users' information processing and retrieval. Thus, the main objective of this research is to investigate how input device type influences users' memory retrieval.

There has been research in human-computer interaction on the influence of input devices on users' performance (Rogers et al. 2005; Taveira and Choi 2009). Moreover, there has been research in marketing on the influence of physical touch of products on consumers' attitudes and behaviors (see a review by Spence and Gallace 2011). However, to the best of our knowledge, no peer-reviewed study has investigated the influence of direct input devices such as touch screens on user cognition. Given that marketing and psychology research have demonstrated that the sense of touch can influence consumers' attitudes and behaviors (Spence and Gallace 2011) as well as individuals' reactions (Hall and Veccia 1990), investigating the role of input devices on users' responses could have important implications for both theory and practice. For instance, human-computer interface designers could benefit from understanding the impact of touch screens on users' information processing and retrieval. Also, the online advertising industry could benefit from this stream of research by better understanding how different input devices influence advertising performance. In general, investigating the influence of input devices on users' memory retrieval has implications for research and practice in several domains, including information systems (IS), education, and marketing.

Based on prior research in human-computer interaction and neuroscience, we investigate the extent to which input device type has an influence on users' memory retrieval. We build upon prior research on the somatosensory (tactile) system to argue that the use of a direct input device involves a multisensory experience and more cerebral activities than an indirect input device, leading to richer information encoding, and consequently to better information retrieval from memory.

In the following sections, prior research on computer input devices, the somatosensory system, and multisensory experience is presented. Building upon these theoretical foundations, we present three hypotheses, followed by our research methodology. Then, we describe the preliminary findings of our study, and we close this paper with a discussion of the implications for theory and practice.

Theoretical Background

Computer Input Devices

According to Taveira and Choi (2009, p. 458), input devices "sense physical properties of the user (e.g., motions, touch, voice) and convert them into predefined signals to the computer." Common input devices include keyboard, mouse, trackball, joystick, touch screen, and light-pen (Taveira and Choi 2009). Input devices can be categorized as either direct (e.g., touch screen, light pen) or indirect (e.g., mouse, joystick, trackball) (Rogers et al. 2005). Direct input devices usually require the user to interact with the target object by touching it with her finger(s). Direct input devices offer advantages compared to indirect devices as they take advantage of hand-eye coordination, require minimal training, and increase ease of use in pointing tasks (Rogers et al. 2005). However, indirect input devices are more precise and can be adjusted for control-display ratio (for a review see Rogers et al. 2005). Accordingly, research suggests that the superiority of an input device depends on the task at hand (e.g., typing vs. pointing), as well as user characteristics such as age (e.g., Mahmud and Kurniawan 2005; Taveira and Choi 2009; Rogers et al. 2005). For instance, empirical evidence shows that touch is faster but less accurate than the mouse (Forlines et al. 2007), a finding that holds true particularly for small objects (Cockburn et al. 2012). Human-computer interaction research suggests that direct input devices such as touch screens can also provide information about the emotional state of the user (Goa et al. 2012).

Consumers and Touch

Prior research in marketing has investigated how the sense of touch influences consumers' product evaluation, either through direct product interaction (e.g., McCabe and Nowlis 2003) or through product packaging (e.g., McDaniel and Baker 1977). Even passive touch experiences (e.g., seating on a soft vs. hard chair) influence how people perceive and negotiate with a vendor (Ackerman et al. 2010). Spence and Gallace (2011) suggest that consumers integrate touch with information from other senses in order to evaluate products in a multisensory fashion. Prior research also suggests that all consumers do not have the same "need for touch", which is the "preference for the extraction and utilization of information obtained through the haptic system" (Peck and Childers 2003, p. 431). Moreover, research indicates that barriers to touch increase consumers' frustration and decrease their product choice confidence, especially for high "need for touch" consumers (Peck and Childers 2003).

Somatosensory System and Multisensory Experiences

Dijkerman and de Haan (2007) suggest that the somatosensory system is central to our understanding of touch and that different neural structures are involved in somatosensory experiences, depending on factors such as touch intention (action-related vs. recognition and memory) and the stimuli (internal: body-related vs. external: object-related). The tactile memory system is involved "in the storage and retrieval of information about stimuli that impinge the body surface and objects that people explore haptically" (Gallace and Spence. 2009, p. 380). Thus, tactile memory plays an important role in our daily lives, particularly because it allows for storing and retrieving haptic information of objects previously explored.

The somatosensory system is spread across the human body and is concerned with conveying the bodily sensations to form the percepts of touch and other related sensations, such as body position, temperature, or pain (see, for example, Gazzaniga et al. 2009 for a review of this system). In the somatosensory system, the sensation of fine touch results from the stimulation of primary neurons concentrated in the tips of the fingers, referred to as mechanoreceptors. Basically, a three-neuron system relays the sensory information from the periphery via a dedicated neuronal pathway to the central nervous system (spinal cord → brain). Once information enters the brain via the brainstem, the thalamus relays sensory and motor signals to the cerebral cortex. Specifically, the thalamus projects to the *primary somatosensory cortex* (Brodmann Areas 1, 2, 3; Figure 1). For example, in case of index finger touch (the main finger used with touch devices) functional brain imaging research locates the finger's touch representation in BA 3B, a specific part of BA 3 (Schweizer et al. 2008).

Figure 1. Primary Somatosensory Cortex (see Brodmann Areas 1, 2, 3) and Posterior Parietal Cortex (see Brodmann Areas 5, 7)
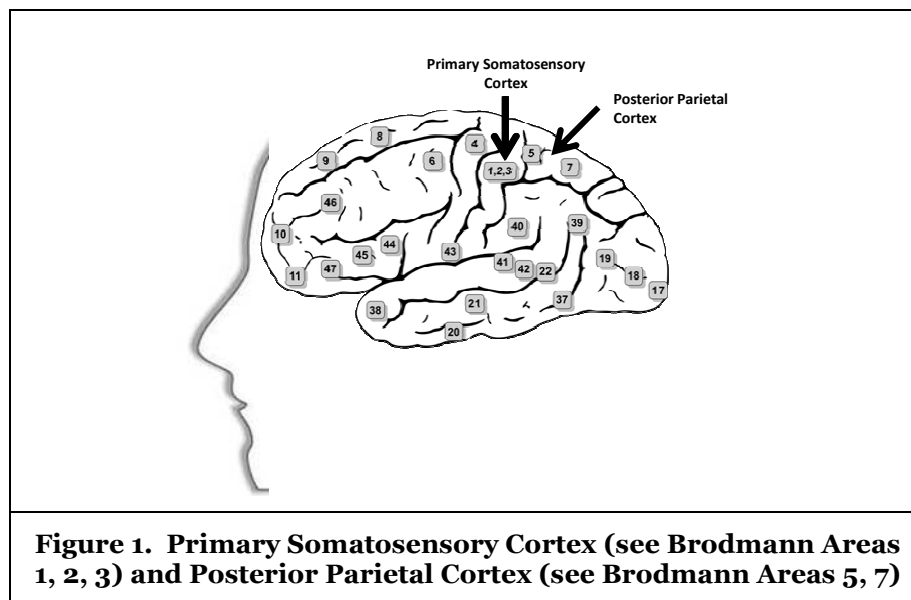
Previous research reports that multisensory experiences (i.e., experiences involving multiple senses such as visual, auditory, and tactile) are generally associated with better memory performance, if compared to experiences which are based on one sense only (unisensory experiences). However, Lehmann and Murray (2005) suggest that for multisensory experiences to outperform unisensory experiences in terms of memory performance, their stimuli must be congruent. In addition, Spence, McDonald, and Driver (2004) report that touching at a specific location of a colored space will improve the perception of colors, even though the touch does not convey information about color. It is argued that using touch in combination with a second sense may increase the salience of information processed by that second sense (Spence and Gallace 2011).

Recent research argues that multisensory experience involves the use of information from multiple senses to form an overall judgment of a stimulus (Driver and Noesselt 2008). Also, it has been argued that the brain areas used for processing different types of information are similar to the areas used for storing the information (Fiehler et al. 2007). The *posterior parietal cortex* (PPC, BA 5 and 7; see Figure 1), in particular, is a structure involved in the processing and retrieving of haptic information (Murray et al. 2004). Specifically, research indicates that the *PPC* receives input from both *touch and visual sensory modalities* (Driver and Noesselt 2008). Moreover, it is reported that damage to the PPC can lead to deficits in perception and memory of spatial relationships, resulting in reaching and grasping deficits (e.g., Pinel 2007). Also, Berryhill et al. (2008) show that "parietal lobe damage disproportionately impairs old/new recognition as compared to cued recall across stimulus categories". While it remains unclear exactly how multisensory representation of a given stimulus is coded and stored in the brain, researchers argue that the "presentation of a tactile information may help people to retrieve the multisensory qualities of the objects and stimuli they interact with physically" (Gallace and Spence 2009, p. 388).

Research Model

Memory can be defined as the "neurocognitive capacity to encode, store, and retrieve information" (Tulving 2000, p. 36). One important aspect of memory processes is memory retrieval and its associated sub-processes of memory recognition and recall, which are important to and commonly studied in consumer research. Recognition is the association of a presented stimulus with one previously experienced or encountered (e.g., Do you recognize this computer brand?), whereas recall involves remembering information that is not currently being presented (e.g., List the computer brands you know.). For this research, we focused on the recognition of stimuli encountered during users' computer interactions.

Prior research suggests that multisensory experiences lead to greater activity in the posterior parietal cortex (PPC; Driver and Noesselt 2008) and better recognition under certain conditions (Lehmann and Murray 2005) than unisensory experiences. We suggest that input devices providing users the opportunity to directly interact with an object on the screen (e.g., touch screen) create a greater and more congruent multisensory experience than indirect input devices (e.g., mouse), thus users interacting with objects via direct input devices should more accurately recognize them than users interacting with objects via indirect input devices (H1). Moreover, research suggests that need for touch influences consumers responses in a way that high need for touch consumers have more positive responses in environments where touch is permitted (Peck and Childers 2003), because they prefer using their haptic system to process information. Thus, we suggest that the influence of need for touch on the stimulus recognition (H2) and the PPC activation (H3) will differ according to the type of input device used.

> *H1: Direct input devices lead to greater stimulus recognition than indirect input devices.*

> *H2: The influence of need for touch on stimulus recognition differs according to the type of input device used.*

> *H3: The influence of need for touch on the posterior parietal cortex (PPC) activation during memory retrieval differs according to the type of input device used.*

Method

In order to test these hypotheses, a one factor between-subject experimental design was used. Participants were randomly assigned to either a mouse or touch screen input device condition. Thirty subjects (*N*=30) were recruited from a university subject panel (undergraduate business students) and were compensated with a $30 Amazon gift card. Subjects were screened for neurological (e.g., epilepsy) and ocular (e.g., astigmatism, laser eye surgery) deficits.
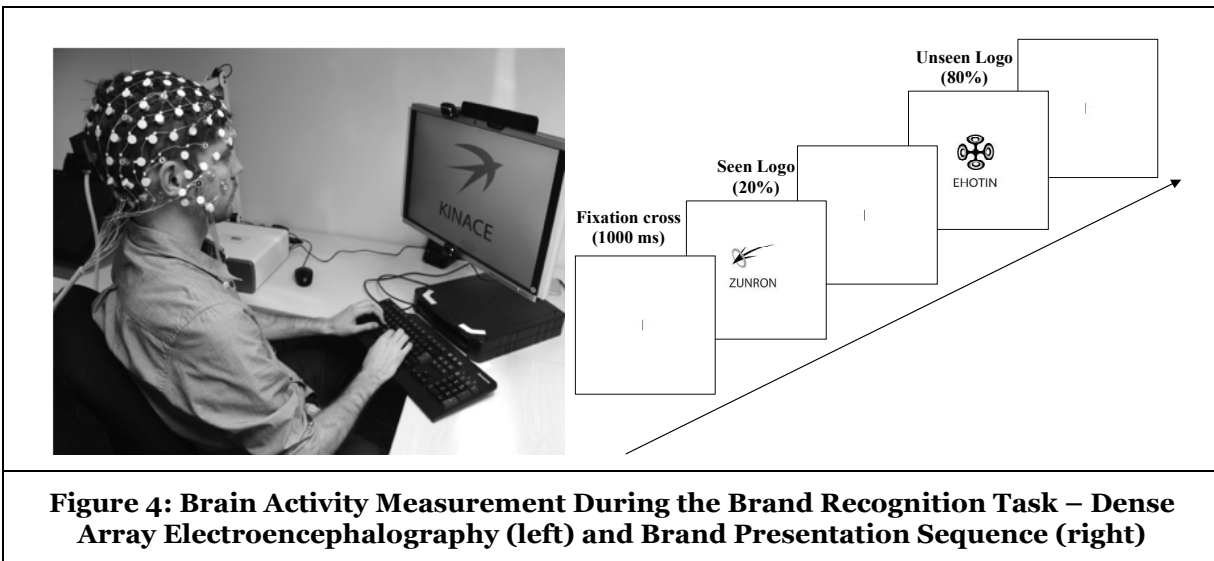
In each condition, participants were asked to perform a series of 14 product choice tasks each between two similar competing products. They used either a touch screen or a mouse to interact with the products (images, characteristics, brand names and logos). As shown in Figure 2, the choice task involved five steps: 1) initial presentation of the two products and brands; 2) presentation of five pictures of the first product along with its brand name and logo, 3) presentation of five pictures of the second product; 4) display of a comparison of product characteristics, and 5) participants' indication of their final choice. All brand names and logos were fictitious, displayed in grayscale, and resized to the same scale (logos were adapted from the following website: *http://all-free-download.com/free-vector/vector-logo/*).

Figure 2. Product Choice Task
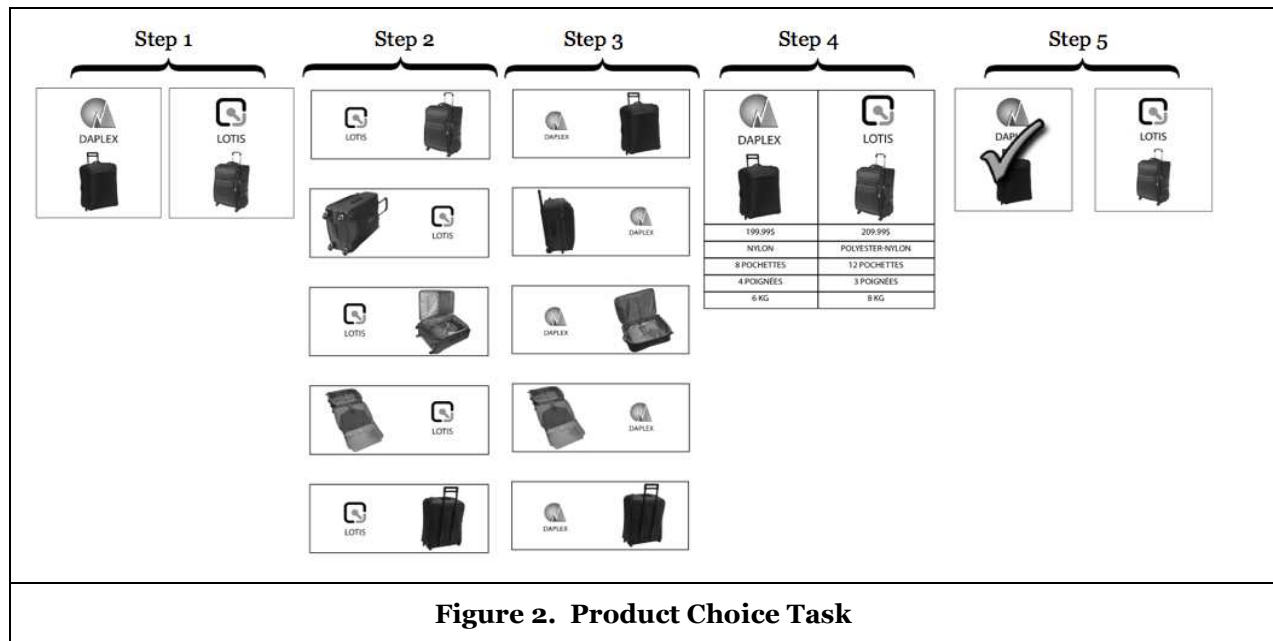
As shown in Figure 3, participants had to use the mouse, or the touch screen, to navigate the website. Products in both conditions were presented using Internet Explorer 8 on a 23" Acer T232HL multi-touch monitor. In the touch condition, participants were instructed to touch the page to browse, which involved interacting physically with the brand names, logos or images of the products. Furthermore, the browser width was predetermined and fixed in such a way that participants had to touch the products in order to visualize all images in steps 2 and 3. In the mouse condition, a mouse without a scroll wheel was used to force the use of the browser scroll bar in order to minimize the differences between the two experimental conditions. In step 5, participants had to select the preferred product by clicking on or touching the logo, brand name, or picture of their selected product. On average, the product choice task took 30 minutes to complete. Participants were seated in an ergonomic chair in which the task for both conditions was comfortable. In the touch condition, participants were resting their elbow on the adjustable chair arm and did not have to hold up their arm to interact with the monitor. A Tobii X60 eye tracker was used to measure fixation time for each product evaluation in order to control for total visual attention in the brand recognition task.

Figure 3. Touch Condition (Left) and Mouse Condition (Right)
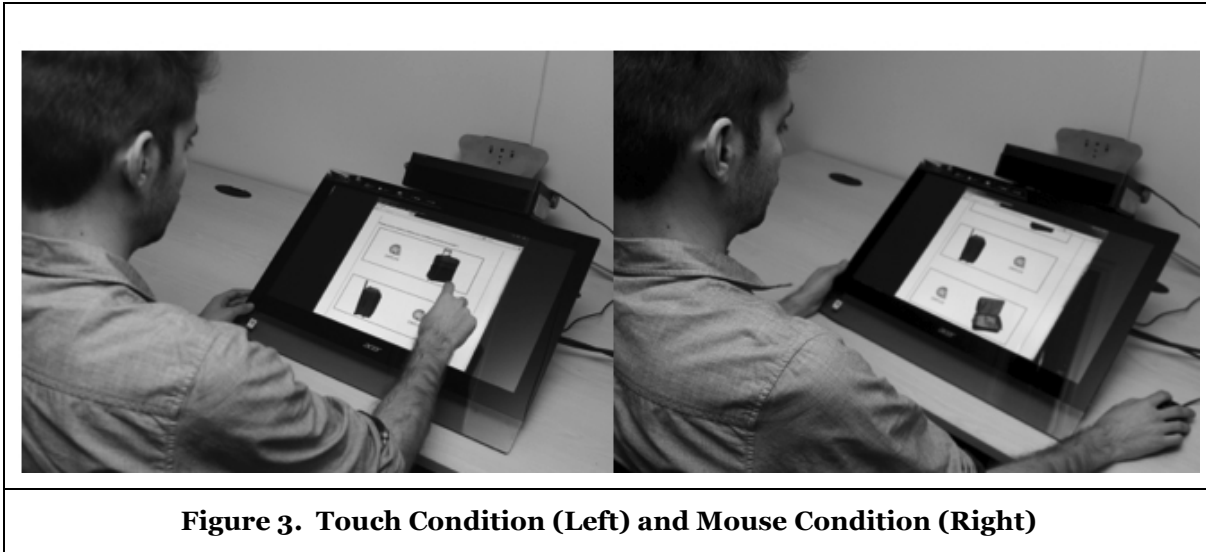
Following their product choices, participants were asked to complete a brand recognition task (see Figure 4). Using an Event-Related Potential (ERP) technique (Luck 2005) which is based on electroencephalography (EEG), participants were randomly exposed to a set of brand names and their logos via a stimulus presentation software (ePrime 2). Finally, they had to complete a questionnaire thereby assessing their need for touch (Peck and Childers 2003) and collecting demographic data.

Figure 4: Brain Activity Measurement During the Brand Recognition Task – Dense Array Electroencephalography (left) and Brand Presentation Sequence (right)

EEG is a non-invasive measure of electrical brain activity. Specifically, it measures the fluctuation of voltage due to spontaneous and synchronous activations of a large number of neurons in a specific region of the brain. ERP relies on repeated presentation of a specific stimulus to participants. With high temporal precision (to the millisecond), the neural responses to the stimulus (EEG) are then averaged and contrasted (Luck 2005). By averaging, the signal-to-noise ratio increases, but it implies a loss of information related to unsystematic variations between the single-trials; therefore only neural information time-locked to the stimuli remains with a sufficient number of trials. An odd-ball paradigm was used to measure the reaction of unpredictable but recognizable events. Participants were randomly exposed to 70 trials during the brand recognition task: to 20% of the fictitious brands and their logos previously encountered during the experiment, and to 80% additional fictitious brand names and their

logos (to which they were not exposed during the choice task). As shown in Figure 4, each stimulus presentation was preceded by a fixation cross for a period of 1 second. Participants from both conditions were asked to indicate if they recognized the brands (yes or no, total number: 70) by pressing predefined green or red keys on the keyboard. During the brand recognition task, neural activity was recorded continuously from 32 electrodes using EGI's dense array electroencephalography (dEEG) (see Figure 4). Stimuli presentation was synchronized with EGI via Noldus Observer XT and the ePrime synchronization package.

The proportion of correctly recognized seen brands was used to test H1 and H2, and the evoked potential difference between seen brands and unseen brands during participants' recognition task was used to test H3.

Results

Hypothesis 1 states a relationship between input device and brand recognition. During the brand recognition task, participants were asked if they remembered 70 different brands (i.e., brand name and its logo; 14 seen and 56 unseen during the product choice phase). Table 1 gives the proportion of seen brands correctly recognized and unseen brands correctly unrecognized for each group. To test whether the difference between seen brands was statistically significant, we performed a logistic regression to estimate the odds of recognizing a seen brand. Table 2 shows that the estimated odds of recognizing a seen brand is 21.0% higher for people using a direct input device. However, this difference was not statistically significant (one-sided p-value =.165) with our currently available sample size of N=30 (N_{direct}=15, $N_{indirect}$=15).

Table 1: Proportions of Seen Brands Recognized and Unseen Brands Unrecognized For Each Group			
Group	Subjects	Recognized seen brands	Unrecognized unseen brands
Direct Input Device	15	54.3%	90.0%
Indirect Input Device	15	49.5%	88.1%

Table 2 : Logistic Regression for the Probability of Recognizing a Seen Brand Given the Type of Input Device Used (H1)					
Parameter	Beta	Std. Error	Wald Chi-Square	P-value (two-sided)	Odds ratio
(Intercept)	-.019	.1380	.019	.890	0.981
Direct Input Device	.191	.1955	.953	.329	1.210

Hypothesis 2 suggested that the influence of need for touch on brand recognition differs according to the type of input device used. Table 3 shows the results of a logistic regression model where the interaction between the type of input device and the need for touch is significant (p=.008). H2 was thus supported. In addition, Figure 5 shows the estimated probability of recognizing a seen brand according to the observed values for need for touch. We can see that the estimated trend is increasing when the subject was using a direct input device and decreasing when an indirect input device was used.

Table 3 : Logistic Regression for the Probability of Recognizing a Seen Brand Given the Need for Touch and the Type of Input Device Used (H2)					
Parameter	Beta	Std. Error	Wald Chi-Square	P-value (two-sided)	Odds ratio
Intercept	1.317	.6071	4.705	.030	3.732
Direct Input Device	-1.862	.7872	5.593	.018	0.155
Need for Touch	-0.263	.1161	5.120	.024	0.769
Interaction "Direct Input Device" & "Need for Touch"	0.433	.1633	7.038	.008	1.542
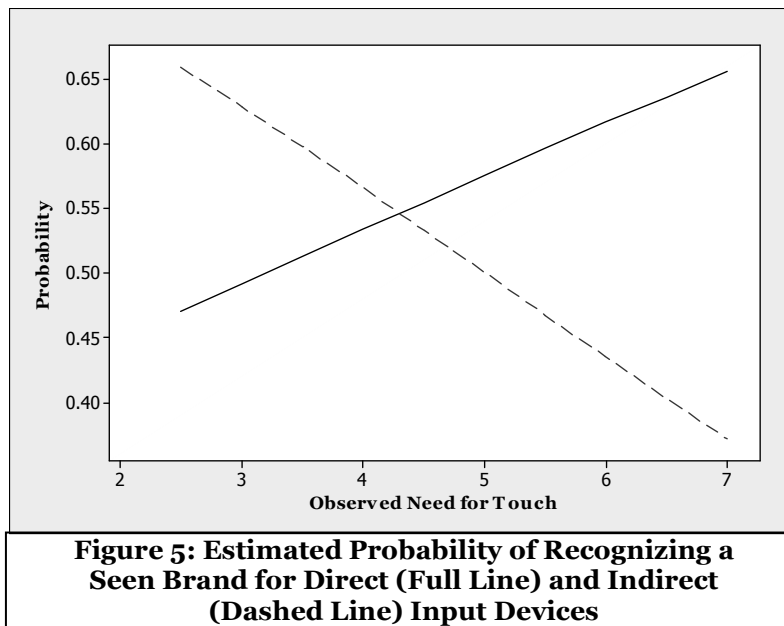
Figure 5: Estimated Probability of Recognizing a Seen Brand for Direct (Full Line) and Indirect (Dashed Line) Input Devices

Finally, Hypothesis 3 posited that the interaction between need for touch and the type of input device has a significant effect on assessing PPC activity. PPC activity during memory retrieval was assessed using the Pz electrode site. Following a classic ERP approach (Luck 2005), we computed the evoked potential difference between seen brands and unseen brands during participants' recognition task. As demonstrated by numerous studies, the presentation of a rare stimulus generates an ERP with a specific positive pattern within a time window of 300 to 600 milliseconds (ms) after the presentation of the stimulus onset (Luck, 2005). To test the third hypothesis, a linear regression was performed.[1] Table 4 shows that the interaction between the type of input device and the need for touch was significant (p=0.004), supporting H3. In addition, we observe that the estimated slope is positive when the subject was using a direct input device and negative when an indirect input device was used.

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[1] Some technical difficulties made the calculation of the PPC activation impossible for 8 subjects. The sample size for this regression was thus *N*=22 (N_{direct}=12, $N_{indirect}$=10).

Table 4 : Linear Regression on PPC Activation Given the Need for Touch and the Type of Input Device Used (H3)				
Parameter	Beta	Std. Error	Wald Chi-Square	P-value (two-sided)
Intercept	.066	.7204	.008	.927
Direct Input Device	-2.017	.9394	4.611	.032
Need for Touch	-.108	.1379	.607	.436
Interaction "Direct Input Device" & "Need for Touch"	.569	.1977	8.295	.004

Conclusion

To the best of our knowledge, no research has investigated how input device influences memory retrieval. Against the background of the rapidly increasing use of touch screens (smartphones, tables), this is problematic because psychological and brain research have shown that information acquired directly via the haptic sense (along with information from other senses) may result in significant cognitive performance effects (e.g., better memory performance), explained by specific neural processes (Driver and Noesselt 2008).

Our results suggest that for individuals with higher need for touch, input devices do influence memory retrieval. More specifically, our results suggest that when high needs for touch individuals use a touch screen instead of a mouse, they are able to better recognize the stimulus encountered during their navigation. The present study contributes to theory development in IS research and human-computer interaction. Furthermore, the proposed research sheds light on underlying neural mechanism explaining the relationship between input device and memory retrieval. This research also suggests several opportunities for future research including examining how long these differences in memory retrieval last and whether these findings hold for other use contexts.

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