Automatic adoption of touch as pointing modality on a touchscreen laptop: Beginners’ motivators and inhibitors

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Abstract

Touch modality is a widely integrated and a highly desirable feature in modern interactive technological devices. It is the de-facto interaction modality in touch-enabled mobile devices such as smartphones and tablets. Nowadays, the list of touchable interfaces is continuously expanding and even includes previously non-touchable devices such as laptops. Touch modality in laptops, however, does not stand out as the default modality for interacting with the device. Primarily, a laptop can be operated with either of the traditional point-and-click modality alternatives already present, the mouse and the trackpad. User studies on pointing modalities have generated little information on the automatic use of touch since these studies are often grounded on users' preferential intentions, but rarely on the drivers that facilitate or impede the adoption of touch.

This thesis endeavours to understand how certain factors such as background in touch usage, usage mode, type of pointing task, pointing targets and starting modality motivate or inhibit beginners' automatic adoption of touch modality for activating interactive web elements on a touchscreen laptop device.

An observation of users' pointing movements was conducted in two sets of possible laptop usage mode – on a desktop and on a couch – with the aim of identifying the frequency of touches occurring as first instance. The observation aims to investigate the automatic adoption of touch by having participants perform pointing tasks on interactive web elements.

The data obtained show that participants are motivated to automatically adopt touch within a more relaxed use context such as sitting on a sofa or on a playful task such as drawing.

In conclusion, while there are not too many interactions on a touchscreen laptop which would necessitate the use of touch, its automatic adoption is, nevertheless, possible and has the potential to become widespread if user interfaces convey discoverable features of 'touchability' and if perceived worthiness of using touch overrides existing habitual usage of non-touch modalities.

Keywords and terms: touch modality, automatic adoption, touchscreen laptop

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1. Introduction

The act of pointing is a fundamental bodily gesture in human-to-human communication. Studies in psychology have confirmed 'pointing' as an instinctive behavior in humans when communicating in the natural environment. It already manifests itself during infancy, particularly (1) to indicate the desire to reach for visual objects [Carpendale and Carpendale, 2010] and (2) to draw attention towards an object or to urgently request the acquisition thereof [Matthews et al., 2012].

In Human-Computer Interaction, pointing is a basic action that preludes major interactions with any interactive Graphical User Interface (GUI) [De Angeli et al., 1998]. Prior to the widespread availability of touchscreens and touch-ready interfaces, pointing on graphical elements could only be done by means of an intermediary pointing device. A pointing device controls the movements of a screen pointer or cursor. Examples of commonly used pointing devices that can manipulate screen pointers include the mouse, joystick, pointing stick, trackpad, light pen, and stylus. As a sub-group of input modalities, a pointing modality refers to a particular way through which a pointing device is used to carry out the finger-pointing metaphor on an interactive display surface, so that virtual objects therein can be targeted and activated. The use of mouse and similar indirect pointing devices is known as the 'point-and-click' method.

The point-and-click concept was first introduced with the public debut of a pointing device prototype (later called the mouse), which was invented by Douglas Engelbart and built together with William "Bill" K. English [Engelbart and English, 1968]. It was presented a decade before the popularization of GUI operating systems, and some years later, became widely adopted as the primary pointing modality on desktop computers.

Since the first commercial release of the mouse in 1983, point-and-click modality has been largely adopted on standard desktop computers. It perfectly suits the office-use context wherein the user maintains a sitting posture and there is adequate planar surface to slide the pointing tool along.

When hardware innovations in computing converted desktop computers into self-contained portable laptops, the mouse became an optional item. This is because laptops introduced a built-in trackpad, essentially a flat surface placed just below the keyboard and equipped with a tactile sensor that recognizes touch gestures. The trackpad is a very useful alternative where a flat desk surface is not optimum or is unavailable for mouse pointing. It executes the point-and-click metaphor by sensing the gliding motion of a user's fingers on the pad and translating it into fine horizontal, vertical or diagonal dragging movements of the cursor or mouse pointer on the screen.

Adopting a new GUI pointing approach is synonymous to overriding an already well-learned technique. With no recent practice, it can be cumbersome or even disruptive. However, with constant repetition, these actions become almost instantaneous responses. A good example of this is when one learns to use a mouse device. At first, the variety of skills largely occupy the mind, i.e. proper placement of the fingers on each button, the different motions and gestures of the hand as it grips the mouse, and the precision of pointing. Nevertheless, after a considerable period of using the mouse device and doing the same pattern of steps repeatedly, the associated sequence of actions can eventually be unconsciously carried out. In the case of adopting pointing modalities, we as users develop individual orientations as well as perceptions over time about the different modality options that are accessible to us. What influences our unconscious use of one modality over another is an inquiry worth conducting.

"To adopt", as defined by the Free Merriam-Webster online dictionary [2014], is "to begin to use or have a different manner, method, etc." From a technological perspective, adoption has been defined by Hall and Khan [2002] as "the choice to acquire and use a new invention or innovation". On a similar note, Rogers [as cited in Sahin, 2006] defines adoption as a "decision of full use of an innovation as the best course of action available". This thesis refers to the word 'automatic adoption' as a user's usage reflex in response to the presence of an alternate modality.

Modality choice is an observable fact that is typical in multimodal applications and devices in which there can be more than one alternate modality that can be used to perform similar tasks. What makes users feel motivated to use one over the other has been a topic of interest in multimodal research. One study whose goal is very much related to that of this thesis was an evaluation of factors that influence the choice of modality (e.g. GUI, voice control, and motion control) by Naumann *et al*. [2008]. Some interesting results from their study, which may have meaningful connection to the outcome of this adoption research, are that modality usage is influenced by the "type of tasks to be performed" and the "efficiency of modality" for accomplishing the task.

Today, although laptops are still predominantly operated with point-and-click modalities such as the mouse and trackpad, newer form factors are now also equipped with additional support for touch interaction, inviting users to adapt to a modified laptop usage orientation. It is relatively easy to predict the full use of touch on devices where it is the only modality that is perceivable and accessible (e.g. tablets and smartphones). However, as regards touchscreen laptops, users have not completely abandoned the use of point-and-click modality despite the added touch feature. The very existence of both the mouse and the trackpad could then potentially hinder the instantaneous adoption of touch modality.

This raises an interesting avenue of research pertaining to the automaticity of touch adoption on a touchscreen laptop, which has not received much attention in previous pointing modality studies. Users may consciously prefer the use of touch modality for certain interactions but their impulse might dictate the opposite. The mouse and trackpad devices are pointing modalities, which nearly all users have grown accustomed to. According to Wheatley and Wegner [2001], automaticity of thoughts and behaviours develops as a result of the continual practice of learned actions and skills. Hence, being a primary method on desktop computers and conventional laptops, users' habitual use of point-and-click therefore poses a clear challenge to the adoption of touch modality.

Building on existing literature governing touch usage, technology adoption and motivation as well as automaticity of action, this thesis hopes to diverge from previous pointing studies by focusing on the involuntary aspect of modality adoption and answering the following research questions:

1. Is there a difference between the frequencies of automatic touch usage when the laptop is used on top of the desk and away from the desk?
2. What are motivating and inhibiting perceptions, attitudes and expectations that may lead to the automatic adoption of touch modality on a touchscreen laptop?

Finally, this thesis reports findings from a user study that observed the users' impulsive use of touch on a touchscreen laptop as they performed common pointing tasks on a series of web pages. This study, investigates neither performance nor the adoption rate. Rather, it primarily aims to look into patterns of automatic touch usage, i.e. on which elements and in which pointing tasks it was chosen over point-and-click, as well as the frequency of automatic use after starting with touch modality.

After the introduction, Chapter 2 reviews literature on three essential concepts relating to the topic at hand: (1) touch usage, (2) technology adoption and motivation, and (3) automaticity of action. Chapter 3 explains the detailed conduct of the observation – the participants, procedure, and equipment. Chapter 4 categorizes and highlights the major findings of the study derived from both the pilot and actual observations. Finally, Chapter 5 gathers all gainful insights learned and uses them to draw conclusions regarding users' automatic response patterns pertaining to the use of touch modality on a touchscreen laptop.

2. Touch Modality and Adoption

While not entirely a new input modality - indeed its origins can be traced back as early as 1965 [Johnson, 1965] - touch has certainly gained popularity with the introduction of Apple's iPhone [Honan, 2007]. Today, smartphones and tablet, to a large extent, share the bulk of touch modality adoption, as evidenced by their rapid market penetration [Richter, 2013].

The attractiveness of using touch modality is quite evident since it merely utilises bare fingertips and direct pointing gestures that are inherent in humans. Apart from this, there are compelling reasons why touch modality would encourage automatic use: 1) Touch requires no additional mandatory time to attach, grab, and hold a pointing device such as the mouse or trackpad; (2) it eliminates the movement time needed to precisely focus a pointer cursor on an exact screen location or target object; (3) touching a touchscreen does not demand refined motor skills in order to successfully execute it; and (4) touch modality encourages a light and playful tone in user interface manipulation.

However, touch is also known for a number of difficulties. Particularly, its application on modern hybrid laptops has received numerous criticisms concerning its ergonomic qualities. One known problem resulting from using touchscreens on laptops has been metaphorically referred to as the "gorilla arm" [Carmody, 2010] where the human arm is subjected to stress and fatigue due to prolonged and repeated lifting of the arm to touch vertically positioned touchscreens. A white paper about touchscreen display ergonomics mentioned key ergonomic variables that must be taken into account [Bridge Design Inc., 2015], if a touchscreen is to be added to a product. Meanwhile, notorious user interface limitations such as the limited or absence of obvious visual feedback [Deron, 2000], and the small sizes of touchable targets [Schooley, 2013; T., 2012] detract from the attractiveness of touch pointing.

The following literature review takes a closer look into how touch usage has penetrated our interaction with computers so far, and how theories of technology adoption can help explain similar adoption phenomena in view of modality usage on a laptop.

2.1 Touch Usage Studies

Pointing modality studies have mostly focused on performance-based comparisons either of the user or of the device. Common themes include device performance on pointing tasks with varying complexities [Stollnberger *et al*., 2013]; movement times and error rates [MacKenzie *et al*.,1991]; information throughput and pointing accuracy [Norman and Norman, 2010]; effect on user performance when used with single finger, with the whole hand, and with both [Cao *et al*., 2010]; difference in age group performance [Hourcade *et al*., 2004]; suitability for different user groups [Althoff *et al*., 2001; Xu and Li, 2009]; postural demand [Brown *et al*., 2007], [Lee, 2005]; and suitability for specific display surfaces [Forlines *et al*., 2007], among others. Buxton *et al.* [1985, p.215], in their study of touch-sensitive tablet input, suggested that there are certain environments and applications where an input technology, such as a touch tablet, would be most appropriate [Buxton *et al*., 1985, p.222].

Performance studies commonly evaluate touch based on aspect of speed in selection-based tasks and selection strategy effectiveness, in comparison to mouse-based interaction [Karat *et al*., 1986; Sears and Shneiderman, 1989; Watson *et al.*, 2013; Zabramski, 2011]. Observational studies on the other hand, investigate the frequency of touch usage, the conditions within which it is used, the kind of touch gestures used, and the users' usage behaviour, among others [Agarwal, 2014; Ryall *et al*., 2006].

Factors affecting touch usage is a literature topic of particular interest to this thesis. A study worth noting, for instance, is the one conducted by Gilliot *et al*. [2014], which specifically examined the effects of a device's form factor and input conditions on touch pointing performance. They observed and analysed variables such as (1) the input device size (e.g. touchpad on an iPod vs. touchpad on an iPad), (2) the input condition (e.g. allowed to look and not allowed to look at the input surface), (3) the target position, and (4) the target size. Their findings suggest that being able to see the input surface occasionally assists in faster target acquisition. In addition, they discovered that the acquisition of smaller targets slowed down and lessened in accuracy as the input area size increased. Although the device's form factor and input conditions were variables considered in this study, Gilliot *et al.*'s work [2014] delved solely into users' success rate when acquiring targets (on first attempt) and not their touch usage tendencies and adoption-related behaviours. In addition, touch modality was applied in their study as an absolute-indirect pointing device. In absolute pointing [Norman and Norman, 2010], the finger's position on input (touch-sensing pad) space directly corresponds to the cursor's location on the output (screen) space. This means that pointing is not directly performed on the display screen's surface but with the use of a touch pad device to sense touch gestures and to control a remote cursor on the screen.

A study by Wigdor *et al.* [2006] covered both users' performance and subjective preferences for control space orientation (the rotation of control space area such as a mouse pad, on which the mouse operates) and display position (location of the screen relative to the position of the user and of the table where input is made). They conducted two sets of experiment: one where the participants could choose their preferred control space orientation, which they could adjust as they performed the tasks, and another where participants had to use a fixed orientation which they did not prefer.

They discovered that control space orientation significantly affects performance. They also found a significant interaction between control space orientation and display space, which was evidenced by the shortest interaction duration recorded under the condition wherein participants were able to manipulate the control space orientation at their will. Wigdor *et al.*'s study further concludes that preference is more closely associated to participant's physical comfort rather than performance, for the reason that participants did not necessarily prefer the control space orientation where they performed best but clearly favoured the condition that entailed the least effort. While their research only examined users' interaction with a mouse-controlled interface, their particular finding, concerning the relationship between preference and comfort may also be worth investigating in the adoption of touch on touchscreen laptops.

Using a computer away from the desk brings forth opportunities to try a variety of more casual ways to handle it, such as with the typical usage of tablets. Touch interaction on tablets is widely adopted because it fits the relaxed nature of personal and recreational activities (e.g. playing games, listening to music, shopping, checking emails, social networking, and searching information), which, for the most part, take place in more laid-back locations such as on the couch, on the bed, or in the kitchen [Gove and Webb, 2011]. The thinness and lightness of tablets essentially eradicate the need to maintain a particular posture, hence making the interaction experience feel a lot less restrictive.

The claims made by the above researches, wherein usage features such as comfort and the absence of postural restrictions have been mentioned, lead this thesis to form the first question: "*Is there a difference between the frequencies of automatic touch usage when the laptop is used on top of the desk and away from the desk*?"

An earlier study by Buxton *et al.* [1985] enumerated the properties of a touch tablet which distinguish it from other devices. Among the properties listed include its usability despite the absence of an external pointing device, its ability to support simultaneous use of more than one finger to indicate multiple points of contact, and its potential benefits in portable systems. These distinct characteristics underpin the suitability of touch tablets for mobile use and in environments that are subject to vibration or motion. Albeit this notion holds true, touch tablets can be inferior to mouse in certain aspects. For instance, their study stressed that the most prominent problem encountered with the use of touch tablet is the absence of kinaesthetic feedback inherent in the use of a mouse device. This imposes upon the user the need to pay close attention to visual and audio feedback instead.

Sears *et al*. [1991] stated that touchscreens were practical only for selecting large targets. Further, they presented a more thorough account of touchscreens' perceived advantages and disadvantages. Among the perceived advantages include:

1. *Directness*. Using touchscreens require just the fingertips to point. As soon as the fingertips get in contact with the display surface, the desired GUI object is instantly selected.
2. *Speed*. There is no need to locate and reach for a separate input device and to position a cursor on the screen before one can make a selection.
3. *Ease of learning*. There are no complicated steps to learn and skills to master such as spatial re-orientation and hand-eye coordination and precise mapping of cursor movements with hand movements, which is usually the case with point-and-click devices.
4. *Flexibility*. Touchscreen interfaces are varied and customisable according to their purpose for a particular task. For example, touchscreen devices can copy the look and feel of real-world objects while allowing interaction, i.e. photo frame or photo album, a virtual map, an electronic book, a board game, and several more. In other words, the interface can transform into any kind without the need to attach or detach physical parts.
5. *No moving parts*. Since touchscreens are often built-in, they do not need to be removed and replaced every time. This significantly reduces the wear-and-tear of the hardware.
6. *No additional desk space*. Another benefit of touchscreens being integrated into the physical make of a product is that there is no longer a need to allot a desk area for intermediary input devices such as keyboards or mouse devices. Nowadays, it is even possible to mount a touchscreen on a wall or to let it stand vertically, which therefore frees up some useful space.

Touchscreens of today have been enhanced to a great degree, compared to earlier touch technology 20 years ago. Nonetheless, some of their perceived disadvantages as enumerated by Sears *et al*. [1991] remain such as:

1. *Arm fatigue.* Frequent raising and retracting of the arm or holding it up for a while can eventually become tiresome to do. It is more convenient to keep the hand's wrist or palm rested on a horizontal position than it is to repeatedly lift it up.
2. *Parallax effect*. In geometric sense, it is the apparent displacement of a target object from its actual location when seen from a different viewpoint. This may lead to imprecise pointing.
3. *Glare and smudges*. Glares can be a problem depending on whether the touchscreen is made of a glossy or a matte finish. Matte finish is usually more favourable as they do not reflect light even when positioned against direct

light. Smudges caused by sweat, food, chemicals or dusts are very typical problems of touchscreens.

4. *Obscuring of the screen.* Smaller targets can easily disappear beneath the fingers. If the targets are too small, it will be difficult to notice whatever visual feedback there is.
5. *Limited tactile feedback*. Perhaps the most encountered example of this is when using touchscreen keyboards. Because virtual keyboards are merely displayed interfaces, we do not feel their edges the way we do physical keyboards'. Tactile feedback, if at all present, is usually just a faint vibration hinting that something has been touched.
6. *Undesired touches*. Accidental activation of unintended targets is a common event when touching on targets that are especially narrowly spaced. With multi-touch capable sensitive touchscreens, this happens even more frequently where the other fingers are quickly sensed and whose input signal is read by the touchscreen device.
7. *Price*. Although the price of touchscreen devices in general has gone down compared to earlier years, they are still comparatively more expensive than the non-touch display screens.

The enumerated perceived advantages and disadvantages of touchscreens are, of course, subjective in nature and may vary according to an individual's viewpoint and expectations.

As regards the use of touch on vertical screens, a global survey of user experience (UX) about touch usage on clamshell form-factor devices was conducted by Intel's research team, led by Daria Loi [Baxter-Reynolds, 2012]. A clamshell form factor is a foldable hardware configuration, characterised by two equal parts that are divided and joined by hinges, which is widely applied in portable electronics such as laptops. The findings of the survey not only uncovered a surprisingly general positive attitude towards touch interaction on a clamshell device among users but also exposed interesting adoption behaviour. Their findings provide knowledge germane to the present topic this thesis attempts to inquire upon– how users adopt touch modality on a touchscreen laptop. Some observations worth noting are that: (1) participants touched the screen very lightly, (2) participants tilted the display screen backwards, (3) participants used their thumbs to touch the edges of the screen, (4) participants sat on a more relaxed posture, and (5) participants used both hands alternately to navigate the screen [Intel Free Press, 2012]. The unique ways how individual participants adopted touch modality for laptop interaction in this research clearly demonstrates an evolving perception about the usefulness of touch and its growing potential to be adopted. Nonetheless, participants were adamant about the idea of totally losing the functionality of a physical keyboard and exchanging it for a virtual keyboard. According to those who were interviewed, even though tablets fascinated them, they would not consider replacing their laptops with a tablet.

2.2 Technology Adoption Paradigms

While there are not too many published studies on the adoption of pointing modalities per se, there exist studies pertaining to the adoption of innovation in a more general sense. This review synthesises previously established principles governing the adoption of technology in order to obtain general inferences on what factors motivate and impede the automatic adoption of touch as pointing modality on a touchscreen laptop.

Some of the notable theories that explain how adoption of technology takes place include the Innovation Diffusion Theory (IDT) [Rogers, 1995] and the Technology Acceptance Model (TAM) [Davis *et al.,* 1989]. With a large number of related studies anchored to TAM and Rogers's IDT, these two are considered as the most influential among the frameworks used in understanding the adoption of technology.

TAM primarily predicts pre-adoption perceptions of individuals regarding the technology's usefulness and ease of use [Dillon and Morris, 1996]. Rogers's theory, on the other hand, has been cited many times for its extended view of technology adoption on a more collective level of analysis involving adopter groups.

Although these theories and frameworks are mostly applied in general information systems and instructional fields, they are neither limited nor exclusive to these domains.

2.2.1 Innovation-Diffusion Theory

In his Innovation Diffusion Theory, Rogers [1995] proposed that, in order to motivate the adoption of a certain innovation, individuals must be able to perceive its superior value in terms of relative advantage, compatibility, complexity, trialability, and observability. The following perceptions about innovation are summarised and applied to the context of touch adoption on a laptop device.

1. *Relative Advantage (Perceived Usefulness in TAM).* It is the perception that the innovation will be better than the existing practice or product it replaces.
   - For touch modality to gain relative advantage over other available modalities, users must be able to perceive that using touch modality significantly improves interaction with the user interface.
2. *Compatibility.* It is the perception that a particular innovation matches the individual's needs and values, and that it corresponds to expectations from a similar experience.

- Touch usage should easily fit into the users' habits and not interfere with their natural ways of doing things. This suggests that touch interaction must closely simulate the natural pointing gestures people do in the real world.

3. *Complexity (Perceived ease of use in TAM).* It is the perception of how difficult it is to understand how the innovation works and whether the required skills to use it are easy to learn and develop.
   - There should be adequate affordances to alleviate negative perceptions about the inefficacy of touchable interfaces. For instance, visual cues provide comfort to users, knowing that they are aware of what is going to happen next if they touch the interface elements in a particular way.
4. *Trialability.* It is the perception that the innovation can possibly be tried out before use, without the fear of committing irreversible errors by accident.
   - If touch interaction can be tested without uncertainties, it can encourage repeat usage until it is eventually adopted.

5. *Observability.* It is the perception that the occurrences in using the innovation are noticeable to other individual adopters. Having a shared experience facilitates evaluation and assists in the creation of positive acceptance of that innovation among a group of adopters.

2.2.2 Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) was first proposed by Davis [1986] and, later, developed with Bagozzi *et al.* [1992]. It illustrates the theory that adoption of an innovation is mainly influenced by individual attitudes and intentions which are either already existent prior to one's actual use of an innovation or are formed after the initial experience [Bagozzi *et al.*, 1992].

TAM fundamentally extends the Theory of Reasoned Action (TRA) [Fishbein and Ajzen, 1975] which is a widely used paradigm for predicting the likelihood that an individual will actually perform a specific behavior as dictated by his or her attitudes and conscious intention. The difference between the two is that, while the TRA framework is generally adapted for the social psychology context, TAM is more specifically directed towards the usage of technological systems and devices. Further, it relates to the fact that the learning of new technologies can quite easily be interfered by internal (e.g. unconscious habits) or external (e.g. environmental condition) limitations. Figure 1 shows the TAM's version by Davis *et al.* [1989] illustrating how external variables perceived usefulness (PU) and perceived ease of use (PEOU) interact to direct the formation of attitude and intention that influence the actual use of technology.

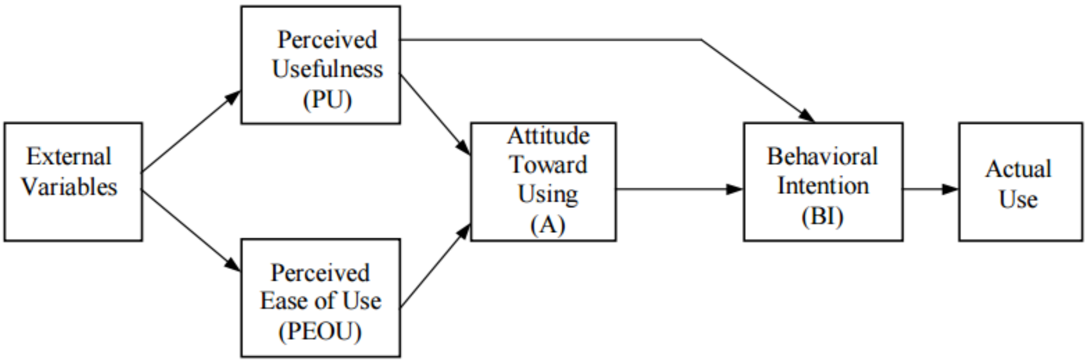

Figure 1. Technology Acceptance Model (TAM) [Davis et al., 1989]

TAM stems from the notion that technology usage is a consequence of intention and is notably known for the two technological acceptance measures it posits which determine the users' inclination to accept the use of an innovation. The following is a brief description of each component and a concise explanation of what it means within the perspective of this thesis:

1) *Perceived Usefulness (PU).* This perception was defined by Davis [1989] as "the degree to which a person believes that using a particular system would enhance his or her job performance". In order for touch usage to be accepted or adopted for use on a laptop device, the user must be able to readily perceive the added value of using touch modality over the point-and-click modality alternatives. That is, it must appeal to the user that, in comparison to using other alternative modalities, using touch modality will yield optimum results.

2) *Perceived Ease of Use (PEOU).* This refers to "the degree to which a person believes that using a particular system would be free from effort" [Davis, 1989]. An unproblematic and risk-free initial attempt to use any technological device is a highly-valued feature among users. It is important that users can proceed with their expected touch interaction as intuitively as possible.

Due to its extensive applicability, TAM has been cited in a number of research topics that discuss technology usage propensities of people. Yang [2005] used TAM to determine the factors affecting the attitudes of Singaporeans towards mobile commerce adoption and was able to validate the usefulness of the TAM model outside the U.S. context. Ducey [2013] studied the intention to use and the actual use of tablet computer among pediatricians by extending TAM and promoting the roles of three variables - subjective norms, compatibility, and reliability. Additionally, his research investigated the usage of tablet computer within the contexts of individual and team use. The findings suggest that intention has a significant effect to actual use but does not necessarily impact job satisfaction. Phan and Daim [2011] explored TAM and attested that both its constructs - PU and PEOU - emerge as key factors in the adoption of mobile services. Meanwhile, the prominent use of mobile phone cameras in an Arab region inspired the extension of TAM based on TAM, IDT and TRA - three theories also referred to in this thesis [Rouibah and Abbas, 2006].

Of the many approaches to understanding technology adoption, the application of TRA and TAM constructs in Davis *et al.*'s [1989] work especially bears a very close resemblance to the pattern of inquiry which this thesis hopes to tackle - how users behave (e.g. pattern of automatic touch use) towards a specific target of acceptance (e.g. touch modality on a laptop device) within a specified context (e.g. use on desktop and use away from desk). Basing on these adoption theories, this thesis attempts to answer the second research question (RQ2), "*What are the users' perceptions, attitudes and expectations that motivate and inhibit the automatic adoption of touch modality on a touchscreen laptop?*"

2.2.3 The Role of Motivation in Technology Adoption

Much research on technology acceptance has extended TAM by examining it in conjunction with the theories of motivation. As stated by Ryan and Deci [2000], "to be motivated means to be moved to do something". Motivation explains 'why' people behave or do things in a certain way, such as why they adopt or reject a technology. Oppenauer [2009] proposed the addition of the "Selection, Optimization and Compensation" (SOC) model and physical and psychological variables to TAM in order to explain what motivate older people to use technology. Ramayah *et al.* [2003] used TAM as theoretical basis in investigating the influencers of internet usage and proved that, besides perceived ease of use and perceived usefulness, a third factor - *perceived enjoyment* (an intrinsic motivator) - has a significant impact in the formation of motives towards using the internet technology. Prior work by Venkatesh [2000] has earlier established the importance of general computer playfulness and perceived enjoyment as enhancers to the perception of ease of use. Moon and Kim [2001], likewise, proposed an extended version of TAM to include 'perceived playfulness' specifically for analysing people's inclination to accept the use of the World Wide Web. They found evidence that 'perceived playfulness' improves individual motives to use WWW.

Motivation essentially originates from two sources: extrinsic and intrinsic [Vallerand, 1997]. Extrinsic motivation is driven by the expectation of reward similar to that which was received in the past, as a consequence for doing something [Sheldon, 2007] or by the desire to avoid an adverse outcome or punishment [Deci and Ryan, 1987]. Most experimental studies in HCI are anchored to the concept of extrinsic motivation. This follows Davis *et al*.'s assumption [as cited in Fagan et al., 2008] that "computer use will be primarily extrinsically motivated and that intrinsic motivation will have a smaller but still significant direct effect on intentions". Intrinsic motivation is induced by the perceived pleasure and satisfaction [Vallerand, 1997] or by the need to satisfy enjoyment, challenge and control. The very act of performing a specific behaviour is considered a reward in its own essence.

Venkatesh [2000] conceptualised intrinsic motivation as "computer playfulness", as being one of the determinants of perceived ease of use. "Playfulness" is a dimension found to be associated with a technology's acceptability [Rico and Brewster, 2010], patronage behavior [Song and Zinkhan, 2003], and satisfaction and intent to use [Lin *et al*., 2005], among others.

The vast majority of empirical research on motivation mainly involves users from North America, hence the findings are more representative of the American culture. In a desire to learn the extent of the validity of existing motivation theories, Igbaria *et al.* [1995] investigated the computer usage motivation within the cultural context of a Scandinavian country, particularly Finland. They found that Finnish users were motivated to use computers primarily as a result of perceived usefulness. Perceived enjoyment did not stand out as chief motivator as it did among American users. Igbaria *et al.*, did point out possible contributing factors that might explain this difference. One interesting explanation is that (at least at the time of the study) Finns generally treat a computer as a work tool, therefore they expect to maximise its usefulness instead of its playfulness. Another explanation is that Finns are intrinsically motivated to do their job and do not necessarily expect their job to be rewarding, as the first thing. The last and probably the most obvious explanation is that the study population used by Igbar *et al.* differed in usage goal from those of the study samples used by US-based studies. Finnish professionals and managers working in a real organizational setting are seen as naturally motivated to complete their task in the most efficient way possible, without really caring if it is pleasurable doing or not. On the other hand, university students may be inherently motivated to use a computer if it brings pleasant experience while accomplishing their tasks.

Inspired by Igbaria *et al*.'s previous work, Teo *et al*. [1999] embarked on a similar research that aimed to identify the extrinsic and intrinsic motivators that drive the usage of Internet in Singapore. Their findings indicate a very close similarity in that the idea of the Internet's usefulness comes as the first consideration for using it and that the thought of enjoyment and ease of use only come second. Their findings regarding Internet use is also consistent with the above-mentioned hypothesis set forth by Davis *et al*., with respect to computer use.

2.2.4 Technology Adoption Process

In their review of adoptive and post-adoptive behaviours in individuals' adoption of IT-enabled systems, Jasperson *et al.* [2005] observed that as the individuals were introduced to the idea of a new IT application feature, they began to form initial perceptions about the feature. Since experience of the feature of the new technology is yet to be had and current experience about the new feature is non-existent, these beliefs that are formed prior to adoption are assumed to be based on 'indirect experience (cognition)' [Karahanna *et al.*, 1999: 188].

Straub [2009] cites that there is not a single model, thus far, which definitively represents an understanding of what takes place before an individual decides to begin using a new innovation.

Nonetheless, Rogers [1995] had already previously proposed that the adoption phenomenon proceeds in five stages, as shown in his Diffusion of Innovation model in Figure 2 below.

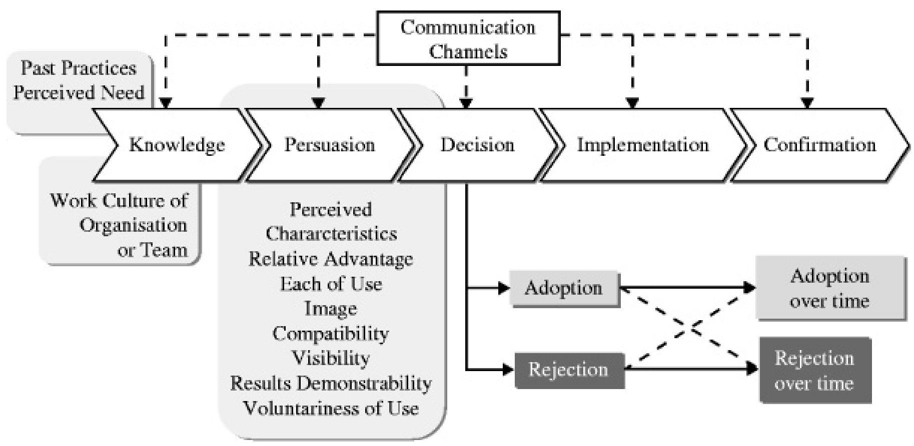

Figure 2. Diffusion of Innovation model, Rogers [as cited in Pundak *et al.*, 2014]

2.3 Automaticity of Action

In its simplest meaning, automaticity of action can be defined as 'doing something without really thinking'. Wheatley and Wegner [2001] explained that automaticity happens when the behaviour associated to a certain action has been overlearned as a result of repetition and practice.

Many activities in real life are governed by automaticity, which makes it easy for us to perform complex actions without the need to consciously watch every movement involved. As we learn new actions, we focus much of our attention to the specifics of how the action is done [Vallacher and Wegner, 1987]. For example, riding a bicycle consists of various steps (e.g. turning the handles, kicking the pedals, and engaging the breaks), which a beginner has to mindfully execute in order to keep the needed balance, to be able to keep the wheels moving, and come to a halt. On the other hand, a skilled bicyclist can perform these actions as existing habits that no longer require conscious attention.

Automaticity allows us to think and act effortlessly. Through experience, we develop familiarity with the environment, hence, we feel comfortable knowing that things will go as they are supposed to [Wheatley and Wegner, 2001]. Interestingly, even though the word automaticity may denote general involuntariness of an action, the concept of automaticity is, in fact, divided into two categories - unconscious and conscious. The former describes an automatic action which is primarily initiated by a perceptible stimuli from the environment and the latter describes an automatic action that results as an “act of will” or thoughtful intention of the individual.

Unconscious automaticity takes place when the person is unaware of the meaning or of the effect of a particular stimulus to his or her subsequent actions. Conscious automaticity, on the other hand, emphasises the indication of conscious attention only at the onset of an action. For instance, driving a car starts with a conscious intention to get on the car and start the engine. After the action has been initiated, the subsequent behaviours and actions such as releasing the handbrake, holding the steering wheel, kicking the foot pedals, and so on can proceed automatically. On his adaptation of automaticity, Bargh [1994] elaborated on the concept by defining four common characteristics of automatic behaviours:

1. *Awareness*. An automatic behavior may occur without the person’s awareness of the stimulus or its influence on his or her judgments.
2. *Intentionality*. An automatic behavior may be initiated without a deliberate goal in mind.
3. *Efficiency*. An automatic behavior requires little to no effort.
4. *Controllability*. After it has been initiated, an automatic behavior may not be ceased or counteracted.

In the same vein as Wheatley’s and Wegner’s [2001] classification of automaticity (consciously or unconsciously triggered), Bargh [1994] classed automaticity based on conditional requirements – awareness (preconscious automaticity), attention (postconscious automaticity), and intention (goal-dependent automaticity). *Preconscious automaticity*, according to Bargh [1989] occurs ‘involuntarily and uncontrollably’. It requires only that the person notice the presence of the triggering stimulus in the environment. This means that a person is not consciously aware of the action he or she is about to do and therefore does not need to have a goal for performing such action. *Postconscious automaticity* is said to be functionally the same as preconscious automaticity, except that it carries the effect of recent conscious experience. For instance, although a person is not consciously aware of the actions he or she is about to do, but is primed to react to a specific condition which activates the conscious thoughts, he or she will likely unconsciously think and act based on that recent experience. *Goal-dependent automaticity* starts with a conscious intent to initiate an action. Once it has been started, however, it can proceed without conscious guidance.

Based on these classifications, the automatic adoption of touch modality for pointing on a touchscreen laptop may also be manifested prior to conscious awareness (user does not expect to do tasks using touch), during a conscious encounter (user is made aware of the possibility of using touch), and during the completion of a goal-driven task (user is stimulated to reach an intended outcome).

For the majority of users, touch input is a familiar way of interacting with a wide range of devices nowadays, especially with smartphones and tablets. They already have an idea of how to operate a touchscreen using touch gestures and they know the consequences of those gestures. The effect of postconcious automaticity on the adoption of touch usage on a laptop is activated with the preconditionings (e.g. recent use of other touchscreen devices and awareness of the touchscreen's accessibility) applied. For a user who has never used a touchscreen device, has never watched one use it before, or has not been informed of its accessibility, the adoption of touch modality will merely rely on the perception of readily noticeable visual stimulations – such as the graphic design of an interface – to trigger one's impulse to use touch on a laptop device (preconscious).

2.4 Touch Affordances: Touchability and Touch Worthiness

Statistical surveys on the phenomenal rise in smartphone and tablet usage and adoption for web browsing [Bosomworth, 2015; Richter, 2013; Sterling, 2014] may help explain why touch-responsiveness has become an important consideration in designing modern web user interfaces. Web layouts that used to be perfected for PCs are now being re-modelled to fit smaller screens, and elements are magnified so that they can easily be activated by the touch of a fingertip.

As the global market begins to witness the expansion of touch capability to laptop PCs, it becomes an even more important task for designers and developers to not only produce web contents and layouts that would suit various touchscreen sizes but also to create a touchable look-and-feel to elements that would entice users to adopt the touch modality on these devices whose main interaction modality remains to be point-and-click.

In the context of interaction design, a concept called ‘affordance’ was introduced to refer to the discoverable feature of an object, which guides a user to the usage potentials and possibilities of that object. There have been varied explanations of affordance by different theorists. Two most cited elucidations of affordance came from Gibson [1979] and Norman [1988]. Gibson was the first to coin the word ‘affordance’, which he described from an ecological point of view as that which the environment “offers the animal, what it provides or furnishes, either for good or ill”. Gibson's theory stresses that affordances need not be perceived. Contrary to this idea, Norman [1988] defines ‘affordance’ as both “perceived and actual properties” which suggest possible ways how a thing can be operated or used. Further, he pointed out the importance of an affordance's detectability, observability, and understandability for it to serve its purpose. Ten years later, Norman [1999] made strong emphasis on the distinction between real affordance and *perceived affordance* - the former being applicable to real world physical objects and the latter, a primary feature of screen-based interfaces where objects are purely metaphorical depictions of real objects. Moreover, displays, according to Norman, are not affordances but, rather, perceived affordances, which are "visual feedback that advertise the affordances". Hartson [2003] draws upon the affordances (real affordance for physical objects and perceived affordance for graphical objects) laid out by Norman and arrived at four complementary types of affordance which he fitted within the context of interaction design. He proposed a third kind of affordance, as an extension to the concept of physical affordance, which he labelled as 'sensory affordance'. Sensory affordances are design features that serve as cues which can easily be seen, felt, or heard by the user. Common issues associated with this type of affordance, as enumerated by Hartson [2003] are "noticeability, discernibility, legibility (in the case of text), and audibility (in the case of sound)". Hartson further attempted to distinguish between 'sensing' and 'perception', stating that unlike sensing, perception includes a cognition component. He argues that a successful HCI design uses sensory affordances which convey discernible messages to the user, without the need for cognitive processing. This notion supports Norman's theory of perceived affordance for graphical screen objects.

Due to the inherent cognitive load involved in HCI activities, users rely on the perceivability and discoverability of objects they interact upon. Web browsing is an example of this activity. Common interactions such as pressing buttons, swiping images, moving scrollbars, panning an image, and dragging-and-dropping objects, each has characteristics that trigger us to act towards them in a certain way. The tools that are accessible to us so that we can manipulate these objects also determine how we can subsequently act on them. However, Hartson and Pyla [2012] argue that users' actions (e.g. clicking on the screen) are driven by a certain goal and not merely by the feasibility of those actions. This could mean, for example, that an element designed to be touched may not be touched at all. It holds a parallel meaning to Norman's [1999] reasoning, in which he states that all screens afford touching regardless of whether the display has the capacity to respond to touch or not. On the other hand, if a displayed element is automatically touched despite the user's uncertainty of the screen's responsiveness, there is reason to believe that this particular element possesses such a strong touch affordance to trigger an automatic usage impulse. In this thesis, touch affordance relates to either the touchability of a display element or to the worthiness (referring to trade-off or benefit in accuracy, speed, and effort) of touching that element.

Touchability and *touch worthiness* are the equivalent of TAM's perceived usefulness (PU) and perceived ease of use (PEOU), in the realm of automatic adoption. As PU and PEOU influence the individual's behavioural intention to accept the use of a certain technology, touchability and touch worthiness prompt the automatic adoption of touch modality through the compelling characteristics perceived of the screen stimuli. Touchability - 'being touchable' - means that the virtual screen element is perceived by the user as something that, without a doubt, will respond to a touch gesture. Sears *et al.* [1991] describe the visual representation of a touchable area: realistic button shapes, rounded rectangles, shadowed boxes, distinctive color text, tabs, or standard icons. But, over the last 20 years, UI graphics have advanced greatly so that they are no longer mere static images, rather are now composed of smooth transitions and little movements that make them even more eye-catching. A heightened interest has been directed towards the touch-friendliness of web elements, in particular, as tablets' sales and usage traffic progressively surpass that of smartphones' and PCs'. There is definitely a clear move to transform websites to become tablet-ready, hence touch friendly.

Some commonly used techniques nowadays that have been applied to send out a 'Touch me!' message to a prospective touch user include the use of explicit call-to-action invitations such as in the form of wiggling elements every few seconds, 3D buttons with bevels and drop-shadows, flashing button, progressively blinking dotted lines, or even simple explicit texts such as 'Touch here'.

Touch worthiness of an element specifically points to the advantage or disadvantage associated with using touch instead of conventional pointing modalities. When a user touches an element, be it unconsciously or consciously, there comes a certain amount of expectation that is waiting to be fulfilled. From dozens of user studies on preferential use of devices, expectation usually points to either efficiency or convenience. Given a task, users naturally choose a way that is easier and quicker.

Were the steps taken worth the time and energy it took to execute them? Similarly, does touching an element offer good reason for defying the risk of deviating from conventional clicking?

Touchability and touch worthiness may not be detected by the user at the same time. For example, in the case of zooming, panning or scrolling a document on a web page, where there may not always be visible controls, i.e. arrows and scrollbars, to precisely point on, the user may just simply think that the display is worthy of touch manipulation rather than spend time figuring out where the controls are. Alternatively, depending on the user's learned habit and attitude towards touch, a display that does not have a strong touchable characteristic to it may still be deemed worth touching. Characteristics inherent to the type of pointing task such as perceived accuracy, speed, and effort are typical benchmarks of an element's touch worthiness.

In summary, both technology adoption paradigms IDT and TAM offer a good point of reference for understanding the conscious use of touch modality based on user perceptions. On the other hand, the theory of motivation and automaticity present meaningful explanations about the occurrence of unthought-of actions as a result of stimulants from experience and the environment. Lastly, the concept of affordances puts forward the importance of touch-suggestive features on interfaces that appeal to the users' senses, which drive users to involuntarily touch an interface even without knowing whether it will respond or not.

3. Observation: Beginners' Automatic Adoption of Touch on a Touchscreen Laptop

This chapter discusses the conduct of a lab-based observation of touch modality usage on touchscreen laptop among beginners. It also describes the pointing tasks, pointing targets, and usage setting that typically applies to real-world usage of touchscreen laptops.

3.1 Method

This study uses descriptive statistics for analysing the data gathered from the observation. The frequency of 'touch-first' pointing was counted on single and continuous pointing task categories, on each type of element, and on two use modes, from each participant.

The observation was conducted in a laboratory setting, using a 15-inch touchscreen laptop with a trackpad, pointing stick, and an optional mouse device for pointing and selecting. The user interface designed for this user study emulates common touch user interfaces found on web pages (see Appendix 3).

3.2 Participants

Four students from the University of Tampere participated in the pilot test and nine in the actual test. They each received course credits for participating. All participants have had adequate exposure on computers and were familiar with touch interfaces. Before coming to the laboratory, all participants answered an online questionnaire assessing their prior experience with computers, internet, and pointing devices, among others. Although some of the participants have had brief experience using a touchscreen laptop in the past, none of them used it on a regular basis. However, they all have used laptops and they were all equally familiar with both point-and-click and touch gestures. During the brief orientation in the laboratory, they were each given an informed consent document containing the detailed activities of the experiment, their rights as participants, and the confidentiality of results. By signing, they had given permission to record the session and to be interviewed after the observation. Each participant carried out three phases of pointing tasks. Table 1 shows the overall demographics of the participants who participated in the actual observation.

Participant ***n=9***	**Gender**	**Age**	**Owns or used other touchscreen devices**	**Has experience with a touchscreen laptop**
P1	Female	37	No	Yes
P2	Male	24	Yes	None
P3	Male	36	Yes	None
P4	Male	40	Yes	Yes
P5	Male	27	Yes	Yes
P6	Female	27	Yes	Yes
P7	Female	44	Yes	Yes
P8	Male	25	Yes	Yes
P9	Female	35	Yes	None

Table 1. Participant Demographics

3.3 Procedure of Observation

There was only one participant in a given session that lasted approximately 45 minutes to about an hour. During the first five minutes, the participant was introduced to the activity and the equipment to be used. The purpose of the observation was not revealed to the participant until after the interview part. An informed consent document (see Appendix 2) was also handed out to the participant. The observation was divided into four phases. The following are the detailed descriptions of each phase.

1. *Casual web browsing (2 minutes).* As a starter, participants were asked to freely browse some of their favourite websites for two minutes. There were no special instructions given as to which pointing device to use at this stage. This activity aimed to get a quick glimpse of the participants' natural way of pointing and selecting on web pages, without being aware of what kind of actions they were expected to make.
2. *Practice task (3 minutes).* As the next step, the participants were introduced to the nature of the pointing tasks they would be doing for the most part of the experiment. This short exercise was primarily meant to acquaint the participants with the availability of the touchscreen on the laptop device as well as to let them try each of the pointing devices. The familiarity with the devices that this activity hoped to create among participants was important in order to eliminate the effect of infrequent use or non-use of either of the pointing devices. This way, participants gained recent experience on all these devices prior to evaluating their primary impulses in pointing.

3. *Actual pointing tasks (15-20 minutes)*. In this phase, there were two nearly identical activity sets to be performed under different conditions, i.e. desktop mode and laptop mode. Before each set began, the participants were asked to choose at random an input device as their starting modality. However, after the first use of the starting modality, switching to another input device was allowed if they so preferred. No further instructions were given to the participants, except that they should interact with the displayed elements as they would normally. The main purpose was to elicit the participant's most natural pointing reflex on a touchscreen laptop. The process was then repeated another time in the second use scenario.
4. *Goal-oriented web browsing (7 minutes).* Lastly, participants were given links to three websites wherein they were provided with goals to accomplish, using any or all of the input devices, whichever they preferred to use at any point. The purpose of this phase was to observe on which pointing tasks or elements participants would first be motivated to adopt the touch modality. The participants were allowed to begin with any of the websites.

3.4 Observation Parameters

The focus of the observation was directed towards the roles of the pointing task, pointing targets, and use context in motivating and inhibiting the adoption of touch modality on touchscreen laptops. The following texts explain how each parameter was conceptualised to have as close representation as possible to the real world usage scenarios.

3.4.1 Pointing Tasks

Pointing almost always occurs with the intent to perform a subsequent action. For the purpose of this observation, a pointing event is said to have occurred the moment the pointing device has made a definite contact with the pointing target. For example, a hovering finger or mouse cursor can't be considered to have pointed on the target element until it actually triggered the element's interactive properties.

Two types of pointing tasks – single and continuous – were considered in this observation, according to the duration it took from the moment the pointing modality triggered the pointing target until it left that target. 'Single pointing' tasks are pointing tasks that typically require split-second contact with the pointing target to accomplish the pointing goal. It is characterised by either a 'first contact' or a swift single succession of the 'land' and the 'lift-off' selection strategies [Sears *et al*., 1991, p. 12-13]. The 'first contact' strategy activates the target element instantly as soon as it is touched. The 'continuous pointing' tasks suspend the lift-off phase to a later time to proceed with either a slow (e.g. dragging) or swift (e.g. swiping) persistent motion.

The following pointing tasks designed for this observation emulate the pointing tasks typically performed when browsing a web page. These kinds of tasks were chosen because they are atomic, short, realistic, and suitable for both point-and-click and touch approaches.

- *Pointing to activate* – placing focus on a textbox; opening a cascading menu; pressing a 'Search' or 'Submit' button;
- *Pointing to select* – picking from multiple-choice checkboxes or radio buttons
- *Pointing to drag* – moving scrollbars; pulling sliders (e.g. volume control)
- *Pointing to pan* – viewing a map or a large photo that does not fit into the screen
- *Pointing to swipe* – browsing through image galleries
- *Pointing to draw* – drawing lines and shapes

Examples within the categories of pointing tasks used in the experiment:

- *Single-pointing task* – activating focus on a textbox; pressing a 'Submit' button; selecting from adjacent sets of options, i.e. checkboxes; activating menu tabs
- *Continuous pointing task* – panning, swiping, dragging, and drawing

3.4.2 Pointing targets

The pointing targets used in this observation were mainly interactive controls, which are alternately referred to in this text as 'web elements'. These elements are interactive because they exhibit the characteristic of an active object, in that they respond to activation and manipulation as well as send feedback to the interface once triggered [Bates, 2006]. The interactive elements used in this observation were either static (e.g. submit buttons, checkboxes, text boxes, etc.) or movable (e.g. draggable objects, 'pannable' and scrollable documents, 'swipe-able' images, or something else that can be drawn such as lines and curves) in nature.

In attempting to make this pointing experiment more realistic, pointing targets or web elements were obtained from PixelKit [2014] website, which has a selection of demo previews to UI templates designed for touch-first usage. A couple more demos were derived from the following sites: jQuery plugins for drawing from ThreeDubMedia [2014], gallery slide from SlidesJS [Searles, 2014], jQuery for mobile from Demos.jquerymobile.com [2014] and scrollbar from Tympanus.net [2014]. The goal behind choosing touch-optimised elements was to encourage users to use touch and to neutralize the aged impression of the laptop model used in this experiment. The interactive elements were picked following the guidelines [Hoober, 2013; Davis, 2010; Nielsen, 2004] on the recommended size, appearance, and their proximity relative to other screen elements as well as the distance from the edge of the screen display.

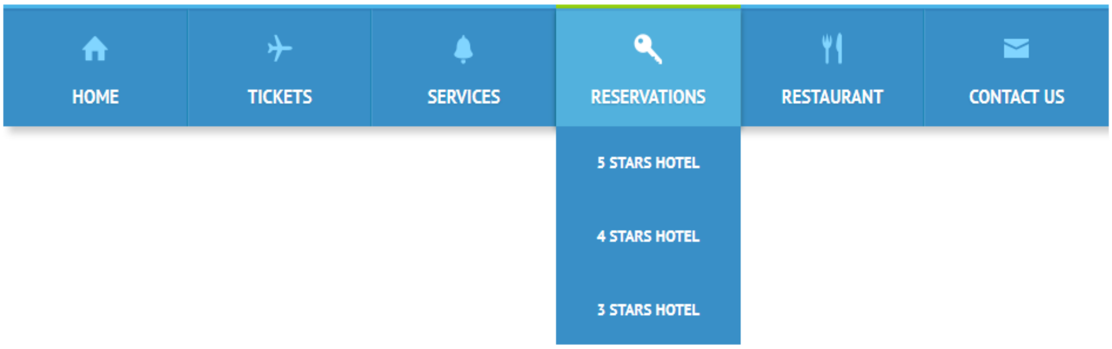

Figure 3. Example of touch-optimised web [menu bar] element, PixelKit [2014]

3.4.3 Use Context

The laptop's foldable form factor was intentionally designed for easy transitioning from stationary table-top use to an on-the-go work style. When a laptop is placed on a hard flat and steady surface, it is naturally used like a regular desktop PC, almost always with a mouse attached to it. Once it is placed on an unstable or irregularly shaped surface such as a person's lap or is used in a shaky condition, a laptop takes on its ultimate purpose – a fully functional mouse-less computer. These two use contexts (Figure 4 and Figure 5) reveal opportunities to change input devices as deemed appropriate by a user.

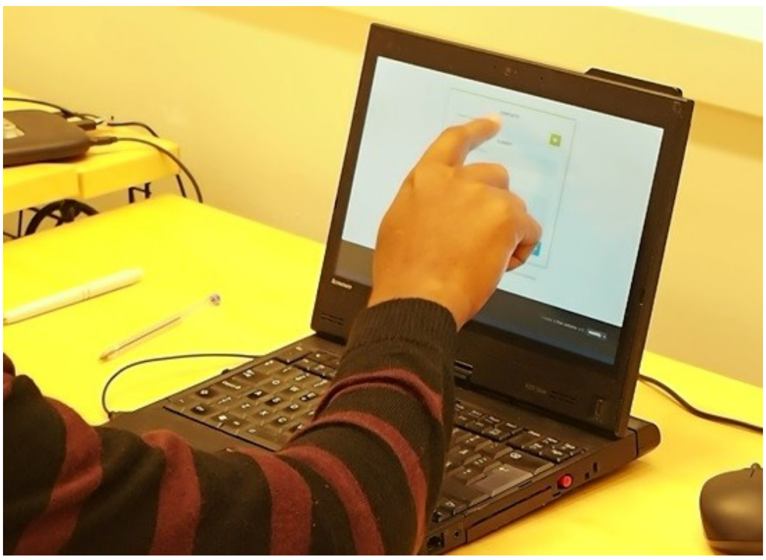

Figure 4. Touch modality adoption in desktop mode context

It is important to test possible use scenarios, in order to find out whether participants would retain the same adopted pointing modality for each pointing task regardless of the use context or whether they would adopt a different one according to the change in use context.

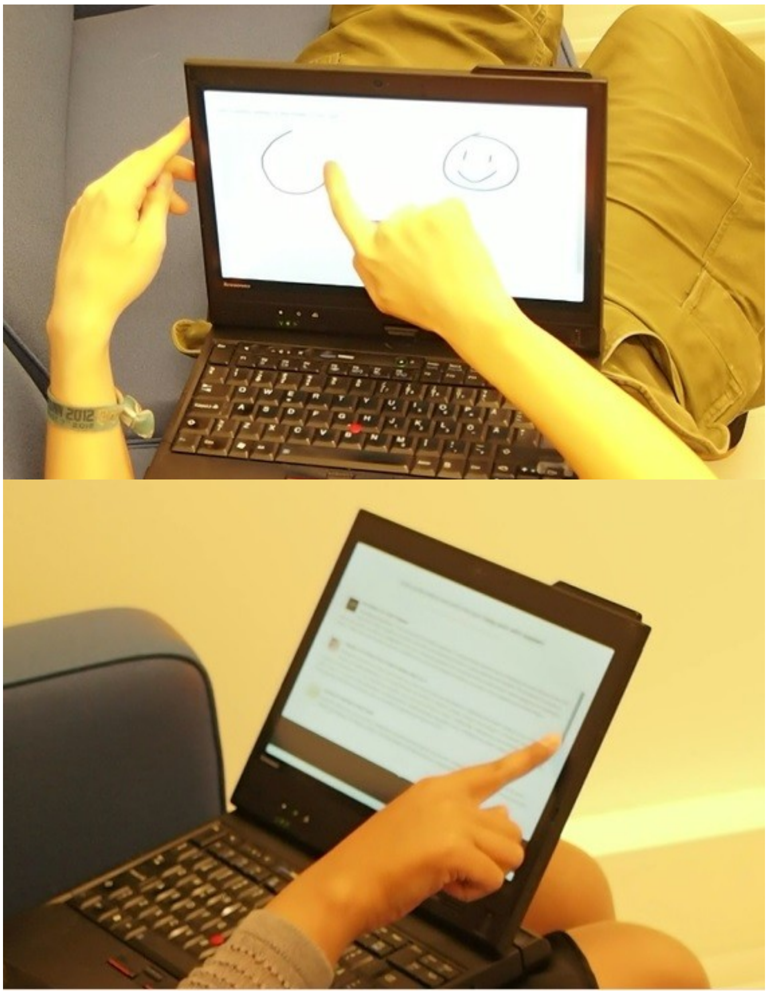

Figure 5. Touch modality adoption in laptop mode context

3.5 Web Page Setup

The test bed for this observation was a website created with Weebly's [2014] drag-and-drop online web builder. Two separate sets of a 17-page website were prepared for this observation. Each set contained similar elements but in reordered arrangement. Each of the pages was linked to the next, either by activating the element that was pointed to or by clicking a separate hyperlink such as a 'Next' button. In every page, there was one specific kind of interactive web element which required one or more pointing actions. Figure 6 shows an example of an interactive object that contains more than one target (e.g. text field, drop-down button, and Send Message button) to point at.

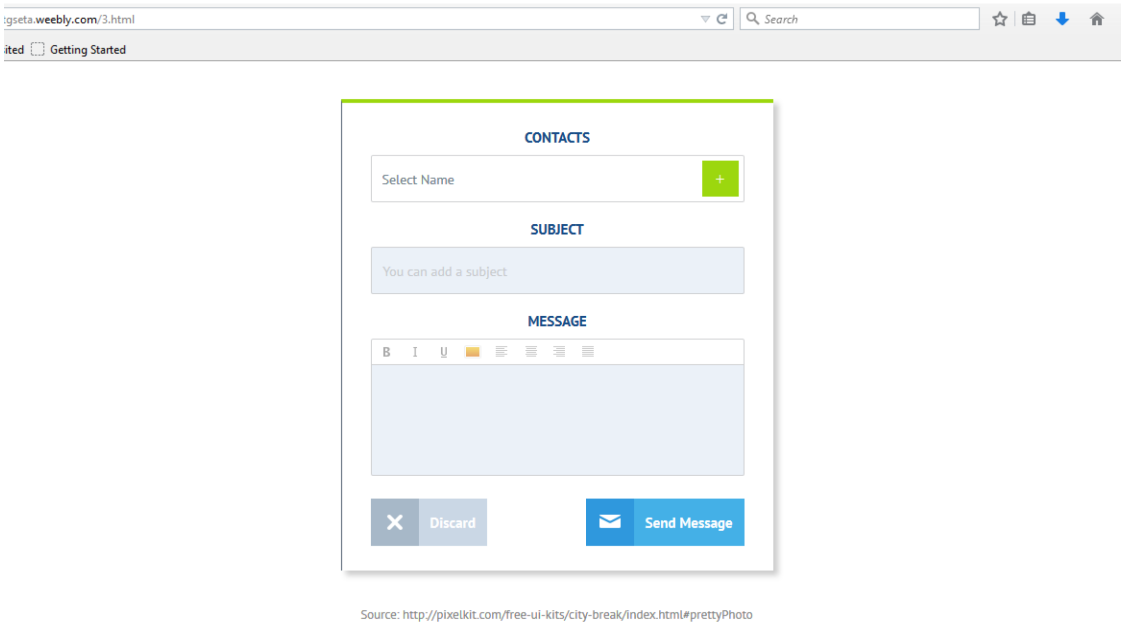

Figure 6. Web interface displaying an interactive web element containing multiple controls, , PixelKit [2014]

3.6 Data Collection and Analysis

This section discusses the tools used for collecting observation data and, in particular, the type of data that were gathered.

3.6.1 Background Questionnaire

Prior to the observation, participants were asked to remotely fill out an online questionnaire that included questions (see Appendix 1), which asked about their familiarity with common computing devices as well as their experience with both point-and-click and touch pointing modalities. The answers they had provided were used for designing the observation setup.

3.6.2 Video Recording

A video of the whole observation was recorded, including the preliminaries and post-task interview sessions. Particularly, the participants' hand movements, their touches on the screen, and their usage mode were recorded.

3.6.3 Frequency Tallying

Since automatic touch adoption of touch modality can be either an unconscious or conscious at the onset, both frequencies for conscious and unconscious automatic touches during the postconscious stage were tallied. Frequencies were not recorded during the presconscious (casual browsing) and goal-dependent stages.

Frequency of automatic touch adoption by use mode

The frequency count begins after using the starting modality. For the four participants who had selected touch as their starting modality, their interaction on the first element was excluded from the count.

Moreover, regardless of how many times the participant repeats using the first used modality on an interactive element (e.g. used touch modality a few times because the element would not quickly respond), it still counts as a single frequency for that modality. What accumulates in the frequency of touch adoption on each use mode is the number of different interactive elements each participant had automatically touched unconsciously.

Frequency of automatic touch adoption by pointing task and element type

If an element contains more than one control as in the case of a web form which has a text field and a submit button, and the participant used two different modalities to point on the different controls (e.g. mouse to point on text field and touch on a Submit button) or likewise redid the pointing task using a different modality, the frequency of automatic adoption is counted towards both modalities. Each modality can only receive a maximum of one count for every element. A count is basically similar to a 'Yes' answer if the question had been "Was this modality used?"

3.6.4 Post-observation Questionnaire

Following the pointing tasks, the participants were asked to briefly respond to questions relating to the pointing modalities they had used when operating the touchscreen laptop (see Appendix 5).

3.6.5 Interview

Since motivation, as described by Touré-Tillery and Fishbach [2014] "*cannot be observed and recorded directly*", interview (see Appendix 6) was used to capture a retrospective explanation of the participants' instantaneous use of touch modality and the reasons for using or not using touch modality in each of the use modes. Particularly, they were asked about the reasons which motivated or did not motivate them to use touch and why they stopped using it at certain times. To gain an understanding of users' current perceptions on the use of touch on a laptop, they were also asked to give their opinions about the suitability of touch for use in a laptop.

The participants' answers to the interview were transcribed and grouped into three categories: (1) participants' perceptions of the usage, (2) participants' attitudes and expectations about using touch modality and, lastly, (3) participants' intentions for actual use of touch modality on a touchscreen laptop. Although not of particular focus in this thesis, capturing the expressed intentions concerning the use of touch modality gave useful information about the participants' conscious automaticity.

As mentioned above, the interview was also recorded on video to document the participants' meaningful facial expressions and gestures as they expressed their thoughts about the set of activities they had just performed. These provided useful cues to determine whether a participant's attitude towards the idea of touch modality in a specific context was positive, neutral or negative.

4. Results and Discussion

This section presents the findings drawn from both the pilot and actual observations. The pilot results are in narrative format while results from the actual observation are presented and explained with the aid of tables and graphs.

4.1 Pilot Observation Results and Implications

The following observations and interview results from the four participants who participated in the pilot experiment helped direct the design of pointing activities that would be most appropriate for the actual observation, so that the study could elicit the most observable aspects of touch modality usage on a touchscreen laptop.

Environment and Usage Setup

All participants reported that they normally used laptop while placed on a desk. One participant commented that the laptop looked old and therefore it did not occur to him that he could use touch interaction. Another participant said that the angle of the laptop screen was not ergonomic, particularly for typing. Lastly, one participant felt that the laptop's keyboard was preventing him from being as close as possible to the touchscreen display. These impressions were later taken into consideration when designing the actual study setup.

Pre-Meditated Use of Touch

Two users grabbed the mouse instantly, in spite of being out of reach, as soon as they began the pointing activity. Without a concrete instruction to use one specific pointing modality, participants used the modality they were already accustomed to - in this case, the mouse or trackpad. In retrospect, participants admitted to have thought about using or switching to touch. According to one participant, the reason he did not use it was because he was not convinced that the interface would be responsive to touch gestures. One participant stated that although he wondered that touch could have been better to use for browsing a photo gallery, he, uncontrollably, still used the trackpad. After having been made aware that touchscreen gestures could be used, still one applicant clarified whether she could have the freedom to use any modality she preferred. One participant said that he did not expect multi-touch features from the laptop device because it looked old.

Opportunities to Use Touch

One participant said that if there were no buttons, she would have used finger to flick a page. The buttons were small, according to one participant. Another commented that when he encountered problems using the trackpad, he realized he could have done the same thing with touch. There was also one who expressed disappointment by saying that writing something using touch was problematic, especially if the onscreen keyboard does not pop up automatically. One participant also mentioned that the interface elements were not suited for touch interaction. Lastly, one participant said that he felt that 'pdf' viewing or dragging are the kinds of tasks that respond well to touch gestures.

Switching To and From Touch

Participants carried on in using the pointing modality they had first picked throughout the series of pointing tasks. Majority did not consider it necessary to change to another modality as long as the first choice continued to work. One participant stated that when he found that he had not done the task properly with the point-and-click modality, he wondered if it would have been better if he used touch. According to another participant, he did not consider switching to touch modality at any point because the trackpad was already working and he knew how to use it.

Based on the learnings from the pilot observation, the following pointers were used to guide the design of the actual observation such that the tasks would ultimately entice the adoption of touch in the succeeding pointing activities.

1. To remove the limitations for touch adoption when using the laptop on a desktop, provide an opportunity to use the laptop away from the desk such as on the couch.
2. To eliminate the premature impression of the laptop not being able to support touch because of its outside appearance, offer an equal opportunity to practice touch, alongside other pointing modalities available on the laptop.
3. To neutralize the dominant appeal of mouse, place it away from the right hand's reach.
4. To reduce the effect of the participant's tendency to stick with the use of habitual modality in the beginning, have the participant randomly choose a starting modality and, after its first use, allow switching to another.
5. Design an interface that is primarily optimized (both in appearance and responsiveness) for touch interaction.
6. Exclude typing tasks using the virtual keyboard but instead, focus on tasks that activate controls.
7. In order to find out how far participants are willing to forgo touch interaction, create pointing tasks that predominantly invite touch gesture such as dragging, swiping, and panning, drawing.

4.2 Actual Observation Results

This section presents the findings about the participants' usage, particularly their unconscious automatic adoption behaviour during a pointing activity performed on a touchscreen laptop. The reasons behind these observations are then explained by a follow-on interview.

The results are grouped according to the three proposed types of automatic action in the literature: *preconscious, postconscious,* and *goal-oriented*. In this thesis, these types of automatic actions were assumed to manifest at specific phases - each phase reflecting the participants' full awareness of the accessibility of touch on a laptop device.

4.2.1 Preconscious Use of Touch on a Touchscreen Laptop

The casual web browsing task in the beginning of the observation revealed an overall picture of the participants' usage tendencies on a touchscreen laptop, after they had been introduced to the laptop device and its features. At this point, the participants were neither particularly aware of what actions were expected of them nor were they conscious of which pointing devices to begin with. Without practice and instructions specified as to how to go about the task, their usage tendencies were assumed to be mostly influenced by their previous experience.

Of the eight participants who own touch devices, only one (P9) used touch on the casual browsing activity. This participant also claimed to not have prior experience with touchscreen laptops. Ironically, most of the participants who have had experience with touchscreen laptop did not, at any point in this activity, automatically adopt touch.

In summary, regardless of participants' familiarity with a touchscreen laptop or ownership of other touch-enabled devices, touch modality did not dominate as the instant choice for pointing interaction.

4.2.2 Postconscious Use of Touch on a Touchscreen Laptop

Figure 7 presents the frequencies of touch usage after the participants had had recent experience of touching a laptop screen during the practice stage and answers the question: **RQ1**: "*Is there a difference between the frequencies of automatic touch usage when the laptop is used on top of the desk and away from the desk*?"

According to an independent-samples *t*-test of the sample's automatic touch usages, there is no significant difference in the frequency when using the laptop on top of the desk (M = 5.33, SD = 6.42) and when using the laptop away from the desk (M = 9.44, SD = 7.12); $t(15) = -1.28$, $p = 0.217$.

But, as derived from the combined tally of conscious and unconscious automatic touch pointing, there are more automatically touched elements, during the *laptop mode* than during the *desktop mode*. In laptop mode, according to element type, the 'movables', 'menu', and 'drawing canvas' were the top three favourite categories for touch pointing. In desktop use context, the 'drawing canvas' garnered the highest touch modality usage, followed by the 'image slider'.

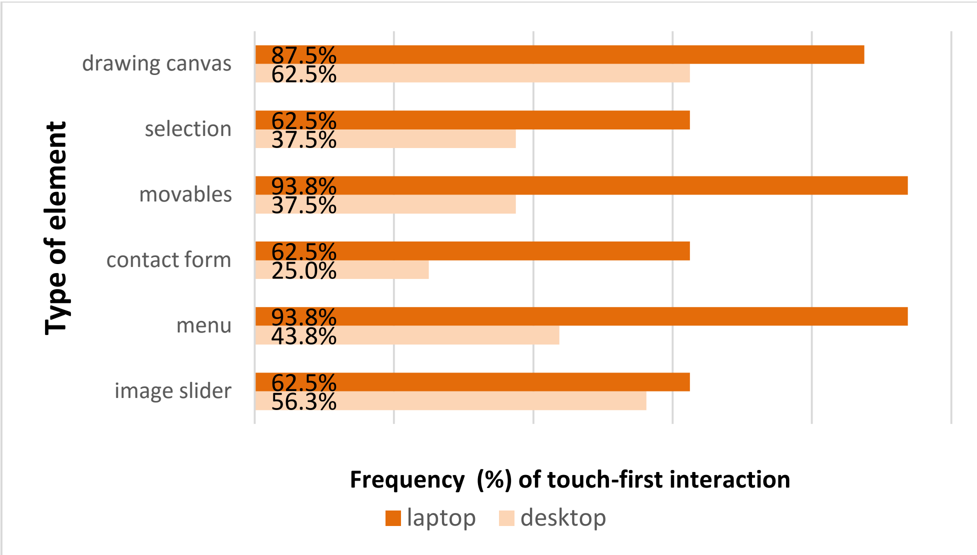

Figure 7. Frequency of automatic touch modality usage according to element types in laptop and desktop modes

A closer inspection of automatic touch usage in each of the two use modes is shown in Figure 8 and Figure 9.

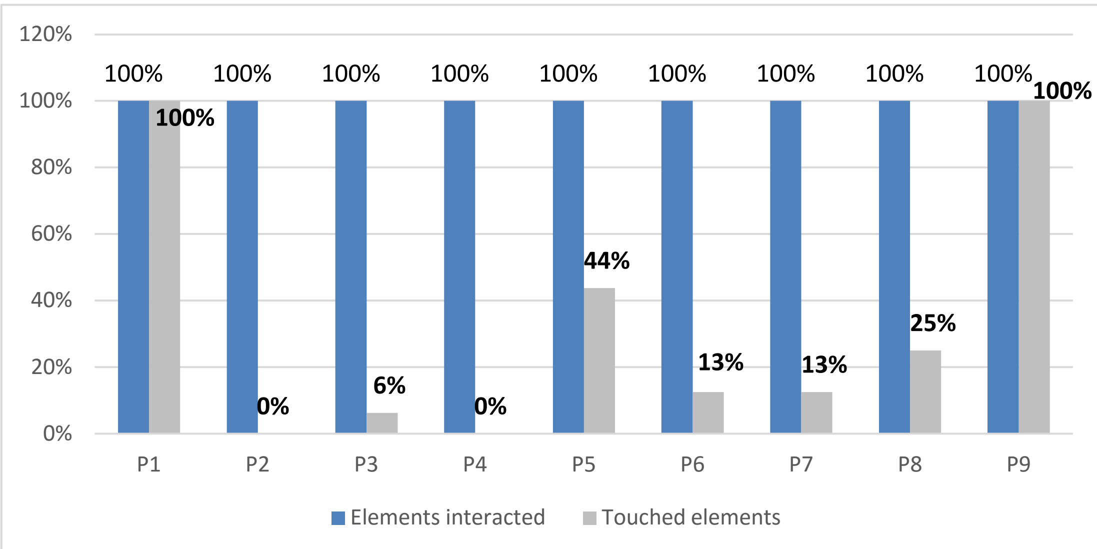

Figure 8. Percentage of automatically touched elements as compared to interacted elements in desktop mode for each participant

In desktop mode (Figure 8), two participants P2 and P4 skipped using touch modality completely. Participants P1 and P9 touched all the elements in desktop mode. Referring back to their contrasting backgrounds, P1 does not own a touch device but has experience using a touchscreen laptop. Conversely, P9 owns a touch device but has no experience using a touchscreen laptop.

In laptop mode (Figure 9), two participants (P1 and P4) did not automatically use touch modality in all the pointing tasks. Quite the opposite, P1 previously touched all elements in desktop mode. P4, however, consciously switched to touch modality on the first target (drawing element) after using the mouse as a starting modality. It is also interesting to note that, participants who had the least touch usage frequency in the desktop mode, P3, P6 and P7, had evidently adopted touch modality on every single element in laptop mode.

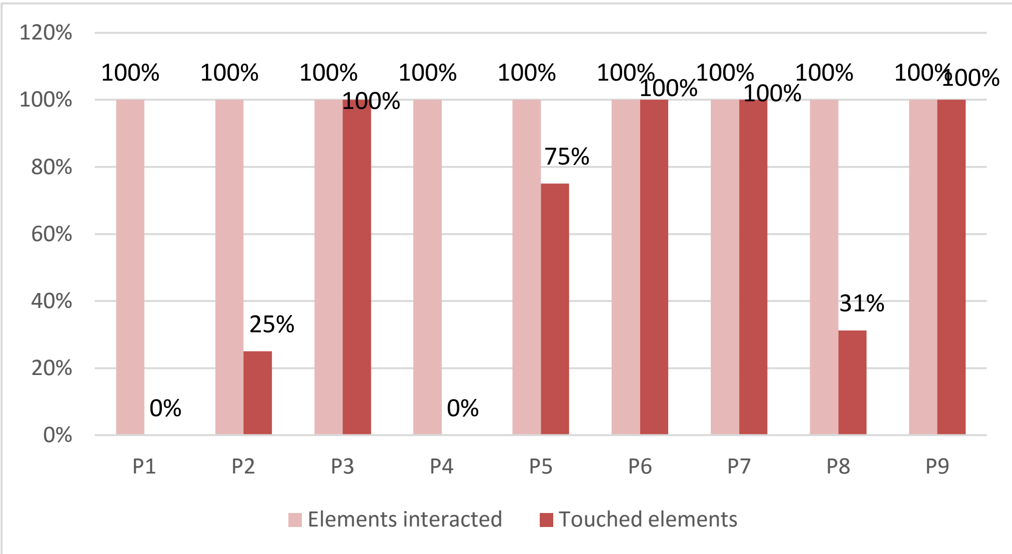

Figure 9. Percentage of automatically touched elements as compared to interacted elements in laptop mode for each participant

Table 2 shows a closer look into the element or pointing task's order of appearance, when each participant first **automatically** adopted the touch modality. Among three participants (P5, P6, and P7), it can be noticed that their first touch usages occurred toward the middle or later part of the pointing activity in desktop mode, in which the checkboxes and drawing canvas were encountered. Evidently, two participants (P6 and P7) postponed using touch modality until the appearance of drawing canvas element (a 'continuous' type of pointing task) in desktop mode. On the other hand, image slider and map-panning elements (also examples of continuous pointing tasks) were touched as soon as they appeared in the beginning of the pointing activity in laptop mode.

Participant	1st element touched (desktop)	Order of appearance	1st element touched (laptop)	Order of appearance
P1	Menu bar	1	-	-
P2	Image slider	2	Menu tab	1
P3	Image slider	1	Image slider	1
P4	-	-	-	-
P5	Checkbox and radio	6	Menu bar	1
P6	Drawing canvas	5	Menu tab	2
P7	Drawing canvas	11	Image slider	1
P8	Search bar	1	Map panning	3
P9	Search bar	1	Menu bar	2

Table 2. Summary of first element touched by participant on each use mode

Further inspection of differences in observed instances of automatic touch modality adoption in each use mode (Table 3) reveals that there is no considerable gap in the number of automatic touch occurrences regardless of the type of pointing task performed, although, the 'browsing' and 'drawing' tasks do show slightly higher counts than others.

Pointing Task	Number of observed touches (desktop mode)	Number of observed touches (laptop mode)
Selecting text fields to start typing	3	3
Marking/ unmarking checkbox and radio buttons	3	3
Selecting a menu from a menu bar or menu tab	4	3
Browsing image galleries	4	6
Dragging objects	4	2
Drawing on a canvas	5	6
Scrolling a page	2	3
Panning an image	2	3
Totals	**27**	**29**

Table 3. Touch modality adoption according to the type of pointing task

Table 4 shows the frequency of automatic touch adoption by each participant according to the starting modality they used in laptop mode. Instances of repeat touch usage were counted only after the participant's interaction with the first element wherein touch, as the starting modality, was used. Attempts to use touch modality on the same element, after another modality had been already used, were considered conscious automatic touches. It can be noticed that there were more instances of automatic touch use observed among those who started the pointing activity with touch modality. Four participants started with the non-touch modality and five with touch modality during the laptop use mode session. Among the participants, complete non-usage of touch (0%) was observed between P1 and P4. Both started with non-touch modality (P1 on laptop as 1st use context and P4 on laptop as 2nd use context). P9, on the other hand, was observed to have touched all elements after the first element, despite starting also with a non-touch modality.

Participant	Starting Modality	Laptop mode usage order	Frequency of automatic touch use	Percentage (%)
P1	NON-Touch	1	0	0
P4	NON-Touch	2	0	0
P8	NON-Touch	2	5	19
P9	NON-Touch	2	16	100
P2	TOUCH	1	4	25
P3	TOUCH	1	16	100
P5	TOUCH	2	12	63
P6	TOUCH	1	16	94
P7	TOUCH	2	16	100

Table 4. Frequency of automatic touch usage per participant in laptop mode, according to starting modality

Statistically, an independent-samples *t*-test shows no significant difference in the observed frequencies of automatic touch modality use among those who have used *touch* (M = 12.8, SD = 5.21) and *non-touch* (M = 5.25, SD = 7.54) starting modalities in laptop mode; $t(5) = -1.70$, $p = 0.147$.

4.2.3 Goal-dependent Use of Touch on a Touchscreen Laptop

The succeeding results are based on the last web browsing activity wherein participants were asked to perform specific tasks on websites that have been optimised for touch interaction.

Table 5 presents the events of touch usage (occurring for the first time) while browsing a website with the intent to accomplish certain tasks. Included are the types of web element or pointing task as well as the participants' reasons in retrospect.

Six out of nine participants automatically adopted the touch modality when browsing to execute the stated objectives (see Appendix 4). Of the six automatic touch events, four were directed at movable type of elements or continuous pointing tasks (e.g. scrolling, panning, and zooming). Two of the three participants who did not use touch at all implied that it was a matter of which method they have gotten used to when it comes to laptop usage.

Participant	Used touch modality?	First task or element where touch is used	Reasons for using / not using touch modality
P1	Yes	Scrolling	"I tried if it's easier; the pictures are easy to touch"
P2	No	--	--
P3	Yes	Scrolling	"When I need to scroll and I do not see the scrollbar.."
P4	Yes	Video playback	"I use touch to complement the mouse."
P5	Yes	Map panning	"Images - to swipe them is very easy; and to draw something, I don't prefer using the trackpad or the mouse"
P6	No	--	"It's not difficult but it depends on the habit; it didn't come to mind"
P7	No	--	"It still has this thing for me that if I had a laptop...I'll use the mouse"
P8	Yes	Zooming	"Touch is more intuitive"
P9	Yes	Selecting menu	"Some buttons were designed for touch. They're easy to select"

Table 5. Participants' first automatic adoption of touch modality on a goal-driven web browsing activity

4.2.4 Interview Results

Appendix 7 shows the participants' varied opinions about their touch modality adoption during the whole observation session. It answers the following question that is based on the constructs of the Innovation Diffusion Theory:

RQ2: **"***What are motivating and inhibiting perceptions, attitudes and expectations that may lead to the automatic adoption of touch modality on a touchscreen laptop?"*

The perception-based characteristics that motivated the participants to automatically adopt touch include the beliefs that this modality is easy, comfortable, fast and fun to use. Specifically, these perceptions mainly pertain to picture elements and activities that suggest worthiness of using touch such as drawing, scrolling, and panning. One participant also thought that the element was big enough to be touched, which relates to touchability. On the other hand, the perceptions that inhibited the participants from adopting touch comprise of the established bias towards the familiar mouse, the size of the laptop screen, and the difficulty in acquiring an exact position on the screen.

The motivators and inhibitors of touch adoption related to participants' attitudes and expectations are mostly based on their experience of touch on other devices and of certain task and usage scenarios. For instance, one participant readily expected to use touch where drawing task was concerned because he has been accustomed to such practice at work. Once again, participants stated that tasks like swiping, scrolling, drawing, and dragging would encourage them to adopt touch. One participant specifically pointed out that the orientation of the laptop screen (if it is tilted horizontally) should be conducive to touch for him to adopt this modality. An interesting comment made by one participant is that he expected to find a button where he would press using a pointer. But when he did not see it, it made him use touch. Although some participants demonstrated openness to adopting touch, majority of the participants showed conscious avoidance to use touch on a touchscreen laptop for the reason that they are satisfied to use the laptop in a classic manner.

During the actual pointing modality usage, some participants confirmed that they had intended to adopt the touch modality at some point during the pointing interactions if certain conditions were met while others admitted doing the tasks following their habits of thinking and acting. At least three participants, i.e. P4, P5, P6 admitted to being inclined to use the touch modality whenever they needed to scroll, swipe or draw. As examples of intended adoption (conscious automaticity), one participant only adopted touch as a supplementary method to point-and-click. Another participant stated that he would adopt touch when there is no mouse and when the touchscreen laptop is being used away from the desk. Other participants also reserved adopting touch for bigger target areas, for drawing tasks, and for more realistic interactions such as horizontally browsing an image gallery. Another participant thought about adopting touch but automatically went with the trackpoint.

Finally, Table 7 shows the participants' general opinions towards having a touchscreen capability on a laptop device. Four out of nine participants (44%) openly accepted the addition of touch screen to a laptop device and expressed interest in using it. Three participants believed that touch screen on a laptop is not entirely useless but its usefulness would depend on other factors such as screen size, operating system and if the laptop's monitor screen could be used alone as a tablet. The remaining two participants see no added value from having a touchscreen on a laptop device.

Participant	Opinions about touchscreen on laptops
P1	"It's modern; I would try it"
P2	"I feel like it's [touch on touchscreen laptop] just a gimmick"
P3	"I'm looking forward to getting one"
P4	"Depends on the operating system. With traditional interface, it's not handy"
P5	"Having a touchscreen on a laptop is an advantage"
P6	"Touchscreen is better for small screen"
P7	"I love it. I will definitely buy a touchscreen laptop"
P8	"I kinda don't like the idea that the screen is slightly far away and you do this kind of interaction (motions both arms reaching for the screen)"
P9	"It depends if I can take it out and use it as a tablet"

Table 6. General attitude of participants toward touchscreen integration into a laptop

4.2.5 Summary

During the preconscious adoption of touch (casual browsing activity) – when participants did not have a clue of what kind of tasks they would be doing – none of the participants reached for the screen as the first thing. The only participant (P9) who touched the screen in this phase only did so after having used the trackpad and the mouse respectively. After switching to touch, this participant continued to use the same pointing modality towards the end of the task. When asked why she kept using the modality despite the fact that she thought it did not work well, she answered plainly that it was mainly due to curiosity.

The second (post-conscious adoption) phase, after participants had been made aware of the kinds of tasks they would be performing, image browsing, drawing and panning – all continuous types of pointing activities – seemed to strongly prompt the adoption of touch. In desktop mode, there was a noticeable difference between the frequencies of touch usage on the 'drawing' and 'contact form' elements. In the laptop mode, the elements of the 'menu' type were the only non-continuous pointing tasks, alongside 'drawing' and 'movables', which were automatically pointed at.

Finally, during the observation of the goal-driven adoption (when participants were instructed to achieve specific browsing objectives on touch-optimised websites), the motivators and inhibitors for adopting touch modality became mostly triggered by a combination of the participants' recent conscious experience and conscious intent, since, at this stage, participants had already gained idea about the nature of the activity and how the laptop device would respond to the recently tried pointing modalities.

4.3 Discussion

The results of the concluded observation revealed informative facts about the automatic adoption of touch as a pointing modality on a touchscreen laptop. The following discussion aims to delve deeper into the meaning of the above findings.

Throughout the pointing activity session, it can be generally observed that neither the ownership of touchscreen devices nor the previous usage of a touchscreen laptop readily indicated the automatic adoption of touch modality on any given opportunity to use a touchscreen laptop. A user without prior use experience with touchscreen laptop or who has not owned a touchscreen device may, nevertheless, feel excited and therefore be curious to adopt touch modality on a laptop, as was the case with P9.

However, although prior experience with touchscreen laptop and other touch-enabled devices did not motivate the automatic use of touch modality when participants were not aware of the tasks and of the fact that the touchscreen actually worked, its effect was clearly manifested when participants were confronted with specific goals to carry out and after they had been oriented to the user interface as well as tasks they were about to do.

Laptop mode received more automatic pointing in favour of touch modality. Possibly, this was because using the laptop device away from the desk relieved the user of movement restrictions and offered more possibilities for a more intimate or comfortable interaction.

As regards the touchability of the elements as they appeared on the screen interface, one significant finding worth noting was that while the visibility and size of the buttons (being big enough to accommodate the fingers) had led to the use of touch, the absence of buttons, likewise, did the same. It is interesting to know that not only is touch modality adoption motivated by the appearance of visible elements but as well as by the absence of such.

The touch-worthiness of a pointing task was also observed to encourage the usage of touch modality. Generally, continuous pointing tasks such as drawing, swiping, panning or scrolling were more touch worthy than were single pointing tasks, possibly because continuous pointing requires steady control and consistency of movement while, at the same time, it evokes playfulness due to the freedom of movement it allows. As in previous research by Sears *et al.* [1990], dragging and outlining tasks were more efficiently performed using touch. Moreover, touch effectively avoids the problem of spatial limitations inherent to trackpad and mouse use. The ‘drawing’ and ‘contact form’ element types very well illustrate the worth of using touch modality, especially in laptop mode. For the most part, contact forms contain a series of controls for receiving textual input which is mainly a keyboard-aided task. Therefore, instead of touch, the user is more inclined to use the tab or trackpad or mouse to navigate between text fields. In contrary to this, drawing mainly involves creating strokes, which is not ideally done with a keyboard. Although drawing with a trackpad is feasible, the trackpad's spatial restriction can make it a bit difficult (which may even require repeated attempts) to do this task as fast as when using a touch.

Concerning the significance of the difference in touch usage frequencies between the laptop mode and desktop mode, it may be largely attributed to the size of the sample and the number of interactive elements each participant has either repeatedly pointed at (using different modality each time), or has accidentally skipped pointing at (no modality used at all). In addition, the number of participants who used touch modality completely in laptop mode is offset by the number of those participants who did exactly the same in desktop mode, which roughly evened out the count of automatic touch usage for both use modes.

Nevertheless, since the laptop mode generally encouraged more instances of alternate usage between touch modality and point-and-click than did the desktop mode, a closer look into what motivating or inhibiting qualities of the usage context could prompt a user to break from or return to a habitual pointing modality proved to be an interesting subtopic in this discussion. In an artificial usage scenario setup applying the notion of 'conscious automaticity' (requiring participants to use the specified modality on their first pointing interactions), it was noticed that participants who started the series of pointing tasks with touch modality continued to adopt touch more as the activity progressed than did those who started with non-touch or point-and-click. Similarly, not starting the task with touch modality invited the chance of complete non-usage, as in the case of two participants who did not start with touch and, consequently, did not adopt the modality throughout the task. This can be explained from several perspectives. One plausible reason is that, because it is realistically more convenient to keep using the same method than it is to change to another too frequently, participants continued to adopt touch automatically until: a) they felt curious to try the alternative; b) they got tired; or c) their usage habit took over. Another possible explanation for this consequence is that the use of touch as compulsory modality in the beginning of the task confirmed the participants' positive perceptions or, similarly, denied their negative perceptions about the modality, hence it stimulated continued use. However, this motivation could also be linked to the laptop mode of usage, wherein users did not really have strong preference for using the trackpad in the absence of a mouse. Therefore, instead of using the trackpad, touch modality might have appeared more convenient to use.

As what emerged in the interviews concerning the participants' real world usage of touchscreen laptops, they admitted to being still inclined to favour point-and-click over touch modality. Many times during the observation, it was revealed that a frustrating or failed first attempt to use touch – being unresponsive (having lack of or slow feedback) thereby causing delay in the instant activation of the element – inhibited further automatic adoption of touch modality.

Among many seasoned laptop users of today, the traditional way of using a laptop (with touch pad or mouse) remains to be the norm. In this observation study, the sample participants belong to a generation of users that has grown very much accustomed to point-and-click modality that they automatically reached for the mouse during 'desktop mode' or immediately tapped their forefingers on the trackpad during 'laptop mode'. These uncontrolled usage impulses occurred despite their professed approval of touch modality. Specifically, one participant intended to use touch but realised in the middle of the task that he was already using the alternate modality he was accustomed to. This example clearly suggests that it is possible that what is consciously intended is not, at all times, what is automatically adopted. Likewise, what is prompted by conscious automaticity can be overridden by unconscious automaticity.

4.4 Limitations

Although this thesis was able to uncover behavioural information about touch modality adoption on a touchscreen laptop through a concrete observation study, the presented results may only be considered within the context mentioned and may not warrant generalizability due to the following known limitations:

The first limitation is the small number of available participants toward the end of the school term when the observation was conducted. As a result, participants' ages were not spread out to come up with a good picture of a heterogeneous generation of laptop users. Although this does not impact the results since the study concerns beginners to touchscreen laptops regardless of age, it would have been interesting to compare how varied age groups (e.g. pre-teens, users in their 20's, and the elderly) differ in the way they adopt touch modality on a touchscreen laptop device.

The second limitation lies within the method, tool, and procedure. Since the observation was done in a laboratory setting, the conditions were restricted to only few usage scenarios and it is possible that adoption tendencies may vary in an outdoor setup or in a more spacious area where more factors may come into play while using a touchscreen laptop such as the screen's angle against the source of light, the cramped space when using laptop while sitting in a vehicle, or using the laptop while placed on the floor and lying on one's chest.

Another limitation is the ambiguity of when to treat touches as either conscious or unconscious. The speed of the participant's response may somewhat be linked to the level of consciousness of the user in order to be certain that the touch action was not partly a conscious choice. However, the speed of response was not recorded.

As regards the touchscreen laptop that was used, the device's old-fashioned design did not clearly give the impression to the participants that it was responsive to touch. It looked like just a basic laptop, which was not exactly comparable to the trendy touchscreen laptop models sold in stores nowadays. It would have been interesting to see how participants would have used the modern touchscreen laptop.

The next limitation, is the inconsistency of administering the use contexts throughout the three stages of the observation. During the preconscious (first stage) and goal-driven pointing tasks (third stage), participants were not expressly given the option to try using the laptop away from the desk. Therefore, there was clearly no opportunity to use the touchscreen laptop without the mouse in these cases and it would not have been possible to observe how their adoption behaviour differed.

Nevertheless, each stage in the observation was treated separately and no analysis was conducted correlating neither the element of conscious automatic touches with the unconscious automatic touches nor the relationship between the identified motivators and inhibitors for using touch as automatic pointing modality.

5. Conclusion

This thesis has attempted to identify and classify the motivators and inhibitors for automatically adopting touch as pointing modality on a touchscreen laptop, specifically for activating interactive web elements.

A laboratory observation was conducted among beginners of touchscreen laptop use, who were asked to perform pointing tasks in three stages (preconscious, post-conscious, and goal-driven). Five observation parameters were considered: *participants' background in touch usage, use context, pointing targets (touchability), pointing tasks (touch worthiness),* and *starting modality*.

As an overall assessment, touchscreen laptop beginners were not inherently compelled to use the touch modality. With the keyboard still being present and a mouse device being accessible, touch modality appeared to be an extra accessory that required unnecessary effort. Moreover, the observation showed that beginners automatically reached for point-and-click instead of touch when they encountered pointing targets in the form of primitive controls such as scrollbars, arrow buttons, and text hyperlinks. Automaticity of adoption due to regular usage of touch modality on other devices (as evidenced by ownership of such) also did not seem to reflect on usage behaviour when tasks are unknown.

Since there are no obligatory reasons to use touch modality on a laptop, particularly because conventional pointing modalities still apply, the unconscious habit of using point-and-click over touch modality prevailed. Nevertheless previous experience and familiarity with touch-enabled devices can prompt curiosity and can make a user more receptive to adopting touch modality on certain situations such as when a task reminds of a positive outcome in the past with the use of touch.

The frequency of automatic touch adoption began to increase, albeit very slightly, when touch was used as the first modality during the laptop use mode. However, automatic touch adoption declined once again as goals were incorporated in the pointing tasks as beginners focused on the execution of familiar tasks with a habitual modality. It seems that users develop tendencies to be more purposeful of their actions when they need to perform tasks that are accompanied by instructions. Having an idea what pointing actions the browsing activity might entail, adoption behaviour becomes occasionally driven by 'conscious automaticity' instead of 'unconscious automaticity'. That is, users either mindfully avoid using touch on certain tasks or they wait for the next opportunity to use it.

Sitting on a sofa or doing a continuous type of pointing task such as drawing were shown to attract frequent automatic touch usage. As was previously found out by Sears *et al*. [1990], tasks that have very little to no spatial restrictions are more significantly easier to use particularly with a touchscreen.

Based on the motivating properties of the observation parameters considered, inhibitors were found to come from formed negative perceptions in past usage; slow feedback or lack thereof; weak or missing touch affordances (touchability and touch worthiness); and, most noticeably, from using the laptop in a desktop PC fashion.

In conclusion, while there are not too many interactions on a touchscreen laptop which would necessitate the use of touch, its automatic adoption is, nevertheless, possible and has the potential to become widespread if user interfaces convey discoverable features of 'touchability' and if perceived worthiness of using touch overrides existing habitual usage of non-touch modalities.

Now that touchscreen laptops are becoming highly marketed, more research needs to be carried out on how touch experience can be improved on this form factor. Website interface designers must work to ensure that user interfaces, including websites, are not just built to respond to touch but also to have interface elements that convey discoverable 'touchability' features and that boosts perceived worthiness of using touch. When it comes to interactive elements, it seems that users have the intuition of what kind of natural gestures they can make when no controls are visible, i.e. absence of scrollbar, or arrow buttons on image galleries. Designers can, therefore, seize this opportunity to create user interfaces that stimulate and make the best use of the human's tendency to touch and navigate the screen's surface when no obvious indication of conventional point-and-click elements is found. As Sears *et al*. [1991] suggested, interface designs may not always have obvious cues of where to point. This will allow the natural impulse to use touch to be stimulated.

The UI's display properties can also be explored. Much us adjusting the orientation of a page view, i.e. landscape or portrait, to suit the screen's width, a flexible visual dimension which adjusts according to the leaning angle of the laptop's screen may be explored as well to strengthen the 3D virtual look of elements as they appear to the user - that is, if the interface is meant to evocatively entice the use of touch. Designing user interfaces so that neither right nor left handed are discriminated can also focus on replacing primitive UI controls with touch-driven surfaces, i.e. pannable and swipeable areas.

One particular topic of discussion that may arise from this research is which motivation (extrinsic or intrinsic) will prevail if pointing tasks must be accomplished with time constraint. As far as extension studies are concerned, it would be interesting to conduct an experimental research on the rate of touch modality adoption among non-users when mixed in a group of touch users as compared to those adopting the modality alone. It would be fascinating to know the effect of a group's motivation, as compared to individual motivation, to the rate of adoption.

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Appendix 1

Device Usage Background Questionnaire

1. Age
2. Gender
3. Educational level
4. Which of the following device(s) do you own or use (check all that apply)
    - Laptop (14-18 inches screen size)
    - Touchscreen laptop
    - Tablet
    - Smartphone
5. Select the device(s), which you do not own, but which you have tried or experienced using before (check all that apply)
    - Desktop computer
    - Laptop (14-18 inches screen size)
    - Touchscreen laptop
    - Netbook (7-10 inches screen size)
    - Tablet
    - Smartphone
    - Other
6. Which input devices have you used on mobile handheld devices? (check all that apply) *
    - Mouse
    - Stylus pen
    - Trackpad
    - Joystick
    - Trackpoint
    - Touchscreen
7. Which input devices have you used on desktop or laptop devices? (check all that apply) *
    - Mouse
    - Stylus pen
    - Trackpad
    - Joystick
    - Trackpoint
    - Touchscreen

8. Name your top 3 browsers used to browse the web
9. Which device (s) do you use to browse web pages?
   Desktop computer
   Laptop (14-18 inches screen size)
   Touchscreen laptop
   Netbook (7-10 inches screen size)
   Tablet
   Smartphone
10. Please list at most three (3) websites you like to visit often (with addresses, if you know them). *
11. Indicate how frequent you do the following tasks when browsing web pages *
    - *All the time, Most of the time, Occasionally, Rarely, Never*

    Using the search bar on the browser window (e.g. Google, Firefox)
    Using the website's 'search' feature
    Filling in forms (login, contact, feedback forms)
    Browsing image galleries
    Selecting options from a menu bar (or menu tab)
    Selecting options from multiple-choice
    Dragging files to be uploaded
    Scrolling pages

Appendix 2

Information Sheet and Consent to Participate in a Research Study

USERS' INTERACTION STEPS FOR BROWSING WEBPAGE ELEMENTS ON A MULTIMODAL DEVICE

Researcher: Kimberly Brown, HTI

Background Questionnaire and Data Treatment
Before coming to this activity, you filled in a background questionnaire online. The data you had given will be completely anonymous and your personal identity will not be revealed in any publication resulting from this study.

Description of the research
This research aims to investigate the interaction moves users take according to the type of element viewed on a touch-enabled multimodal device. Particularly in this study, the subject device is a touchscreen laptop.

Audio & Video Recording
This whole session will be recorded on video so that the conduct of this test and the valuable setup information can be reviewed by the researcher later. Also, the screen activity will be recorded in the background to capture a more precise view of the interactions.

Device to be used
The main device, which will be used for the hands-on activity is the ThinkPad X220 Tablet by Lenovo. The input devices available in this device are: mouse, trackpad / touchpad, trackpoint, and touchscreen.

Procedure
Your participation in this research involves browsing web contents and web pages as well as answering questions related to the activity you have just completed.

You will use or interact with webpage elements that will be displayed on the screen. After which, you will be automatically redirected to the next page or will be prompted to select a link, in order to proceed to the next page. The researcher will not interrupt or guide you during this process (unless there are errors on the web pages), but you may raise a question at any point. Responses you indicate will not be processed and no feedback will be issued. Moreover, **Speed and accuracy are not important!**

The instructions for this activity will be given as you proceed from phase to phase.

Voluntary Participation
Participating in this study is completely voluntary. Even if you decide to participate now, you may change your mind and stop at any time.

By affixing your signature. You agree to all the conditions stated herein.

Consent
I have read this consent form and have been given the opportunity to ask questions. I give my consent to participate in this study.
Participant's signature________________________________ Date:_________________

Detailed procedure:

1st Phase. Web browsing (2 mins)
For a period of three minutes, you will visit one of the websites you have listed in the background questionnaire and browse its contents shortly.

2nd Phase. Practice (max 3 mins)
In this phase, you will be familiarized with web element examples and browsing tasks, which you will encounter in the actual activity.

3rd Phase. Web element interaction (max 20 mins)
In this phase, there are two activity sets to be performed under different conditions (desktop mode, laptop mode). The mode order will be drawn randomly (desktop first or laptop first).

Then, you will pick the input device, which you will use at the start of the activity (mouse, touchpad, touchscreen). After the first use of the starting input device, switching to another input device is allowed anytime during the activity.

To launch the web interface, you may open it using the designated browser shortcuts on the desktop. As soon as you launch the browser, the web interface for this activity will be displayed in full screen. You will act upon the elements that you see as you normally would when you encounter them in websites. Disregard the source links and weebly.com footer at the bottom of the page

For each set, you will interact with one type of element on each page, at your own pace, unguided and uninterrupted. Note that, **Speed and accuracy are not important!** Simply respond to the webpage elements as you normally would as when browsing web pages. Responses you indicate will not be processed and no feedback will be issued.

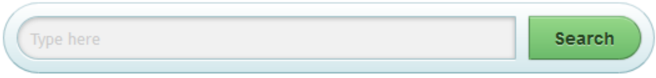
You will repeat the process for the second time, but this time, under the second use mode condition, in which the elements have also been reordered.

4th Phase. Perform a task on a website (max 7 mins)
In this phase, you will perform short web element interaction on real websites, using any or all of the input devices, whichever you feel like using at any given time.

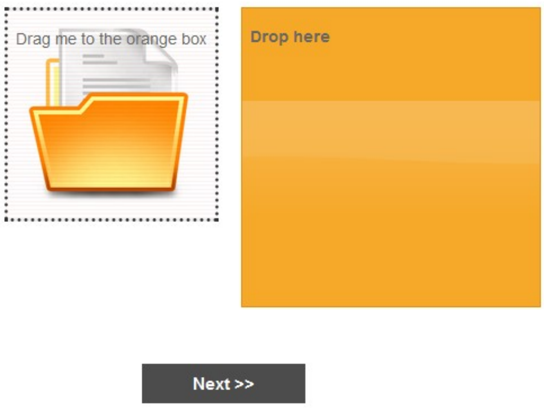
5th Phase. Questionnaire & Interview (15 mins)
As the last part of this activity, you will be filling out a questionnaire about your overall experience. Then, I will ask a few questions to clarify your answers.

Appendix 3

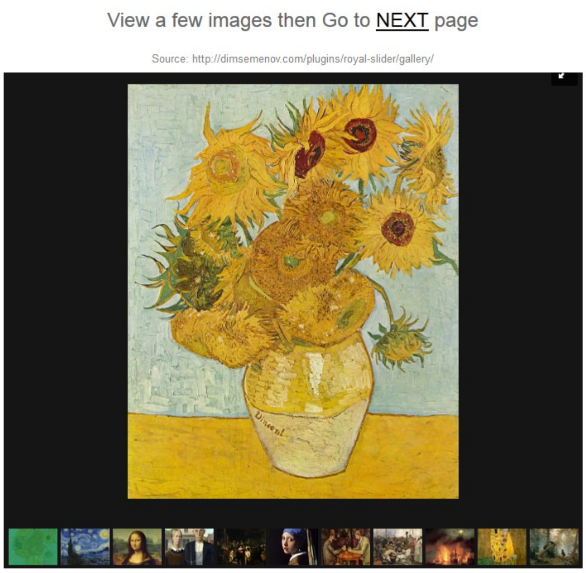
Examples of Pointing Targets (Interactive Web Elements)



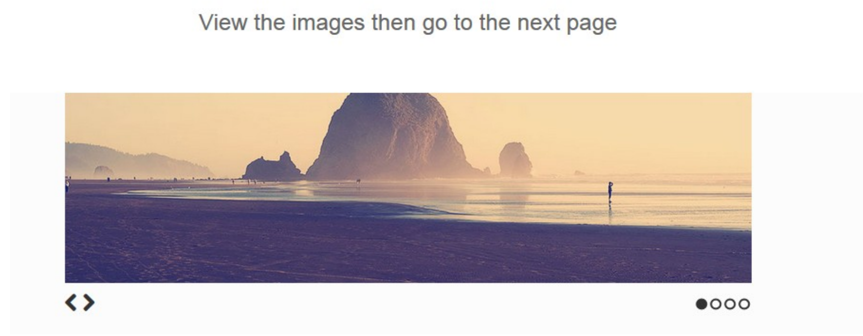
Source: http://www.awcore.com/url/aHR0cDovL3d3dy5yZWQtdGVhbS1kZXNpZ24uY29tL3dwLWNvbnRlbnQvdXBsb2Fkcy8yMDExLzAyL2NzczMtc2VhcmNoLWJveC5odG1s



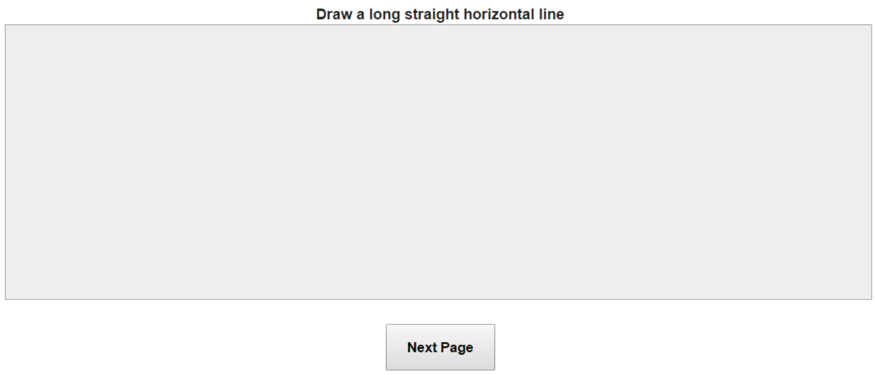
Source: https://jqueryui.com/droppable/



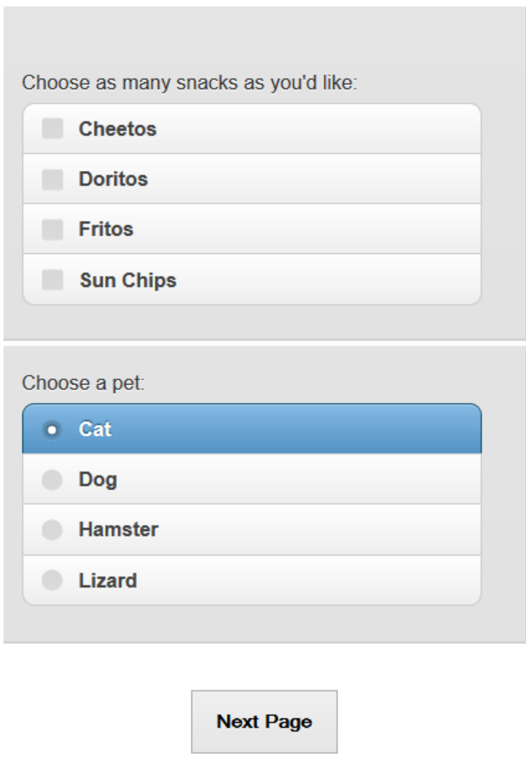
Source: http://dimsemenov.com/plugins/royal-slider/gallery/



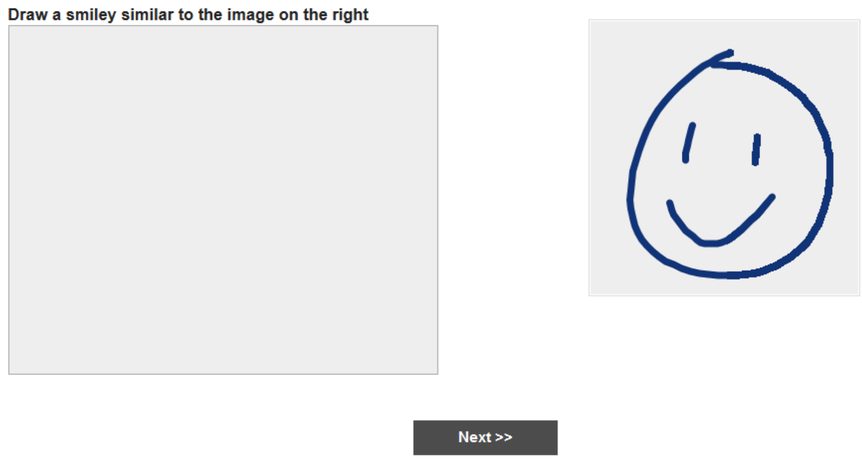
Source: http://slidesjs.com/



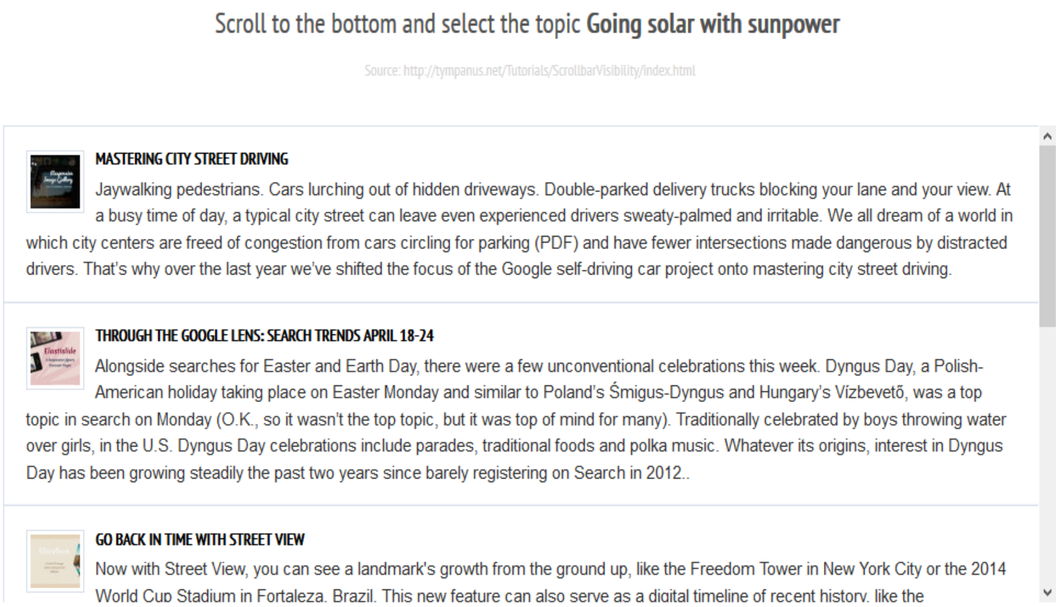
Source: http://threedubmedia.com/code/event/drag/demo/draw



Sources: http://demos.jquerymobile.com/1.0a4.1/docs/forms/forms-checkboxes.html;
http://demos.jquerymobile.com/1.0a4.1/docs/forms/#forms-radiobuttons.html



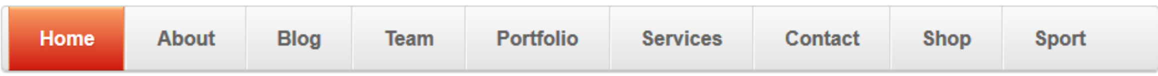
Source: http://threedubmedia.com/code/event/drag/demo/draw



Source: http://tympanus.net/Tutorials/ScrollbarVisibility/index.html

View the bottom of the map then Go to **NEXT** page

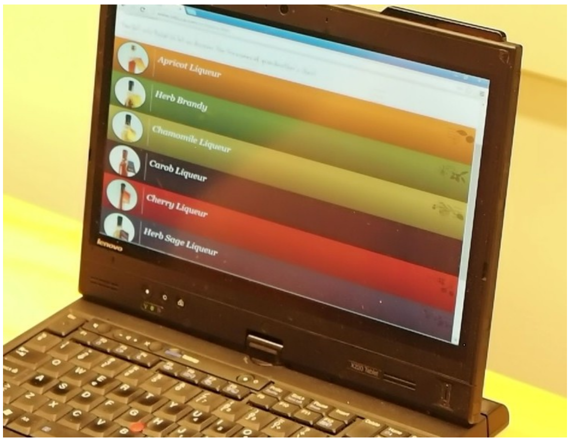
Source: http://www.jqueryscript.net/zoom/jQuery-Plugin-For-Panning-Zooming-Any-Elements-panzoom.html
Image: http://www.tampereconventionbureau.fi/@Bin/176116/Kartta_uusi.jpeg



Source: http://pixelkit.com/free-ui-kits/arctic-sunset/index.html

Appendix 4

Goal-dependent Browsing Tasks



http://www.inbuza.com/m/home.htm

1. Browse their products
2. View the whole map

http://www.icehousempts.com

1. Browse the FOOD and DRINKS menus
2. View Photos
3. Fill in the contact form but DON'T send
4. Reserve a table

http://www.cbsnews.com

1. Pick a news article to browse
2. Select a video clip to watch

Appendix 5

Postconscious Touch Usage Questionnaire

LAPTOP MODE (mouse-less)

1. Check the input / pointing device(s) you used in this activity.
   Explain briefly why you used them:

   - I used the TRACKPAD because ____
   - I used TOUCHSCREEN because ____
   - I used TRACKPOINT because____

2. Check the input / pointing device(s) that you DID NOT use in this activity.
   Explain briefly why you did not use them:

   - I **did not** use the TRACKPAD because _______________________________________
   - I **did not** use the TRACKPOINT because _____________________________________
   - I **did not** use TOUCHSCREEN because ______________________________________

3. Did you change the input /pointing device any time during the activity in LAPTOP MODE?
   YES ___ NO __

If you answered YES, Explain briefly when you changed from one input device to another:

- I changed from ______________ to TOUCH when _____________________________
- I changed from TOUCH to ___________________ when _________________________

- I did not change input device but I briefly thought about changing it when
  ____

4. What will be a motivation to use touch in this mode?

DESKTOP MODE

1. Check the input / pointing device(s) you used in this activity.
   Explain briefly why you used them:

- I used the TRACKPAD because ____
- I used MOUSE because ____
- I used TOUCHSCREEN because ____
- I used TRACKPOINT because ____

2. Check input / pointing device(s) that you DID NOT use in this activity.
   Explain briefly why you did not use them:

- I **did not** use the TRACKPAD because ________________________________
- I **did not** use the TRACKPOINT because ______________________________
- I **did not** use TOUCHSCREEN because ________________________________
- I **did not** use MOUSE because _____________________________________

3. Did you change input / pointing device during the activity in DESKTOP MODE?
   YES ___ NO __

   If you answered YES, Explain briefly when you changed from one input device to another:

   - I changed from ____________ to TOUCH when ___________________________
   - I changed from TOUCH to ________________ when _________________________

4. What will be a motivation to use touch in this mode?

Appendix 6

INTERVIEW QUESTIONS

Automatic Preference Before Touch Usage

On the website you chose to browse at the beginning of the activity, which pointing device(s) do you recall using?

Do you recall switching between devices? If yes, what was the reason?

Explain briefly why you used / did not use touch.

Perception on Elements and Pointing Tasks

Tell about an experience you remember while interacting with the 17 elements during the laptop mode.

- How will you describe the elements' responsiveness using the pointing device you had chosen?
- Describe how you felt while pointing , selecting, moving the elements

Tell about an experience you remember while interacting with the 17 elements during the desktop mode.

- How will you describe the elements' responsiveness using the pointing device you had chosen?
- Describe how you felt while pointing , selecting, moving the elements

Goal Dependent Browsing

On the last three websites that you browsed, which input device (s) do you recall using?

Do you recall switching between devices? If yes, what was the reason?

Explain briefly why you used / did not use touch.

Opinions About Touch Modality

What is your personal opinion about the addition of touchscreens on laptops?

What are your thoughts about using touch on a laptop, while browsing in desktop mode?

What are your thoughts about using touch on a laptop, while browsing in laptop mode?

Appendix 7

Interview Highlights: Motivating and inhibiting reasons for automatic touch modality adoption on touchscreen laptop

Perceptions	- Maybe the pictures are easy to touch (P1)**M** - Touchscreen is fast (P1) **M** - I find it really easy to use the mouse because of familiarity (P7)**I** - Machine is closer so it might be nice for scrolling – if there is no equivalent gesture in trackpad (P2)**M** - I am comfortable using touch when sitting down on sofa (P7)**M** - I think everything is easy with touch (P7)**M** - This is a small screen so touch is not very good, at least for my hands(P4)**I** - This touchscreen is kind of crappy, not responsive but slow (P4)**I** - It is not comfortable operating it with touch only (P4)**I** - [with touchscreen] it can get messy to go to exact position (P5)**I** - Touch is handy for panning and maybe scrolling (P4)**M** - [sitting on] Sofa means *relax* mode (P7) **M** - Doodling with the smiley is easier that [touch] way (P2) **M** - Drawing and swiping images across screen is fun through touchscreen (P5) **M** - I used touch because the buttons were large enough to use my fingers on (P9) **M**
Attitudes and expectations	- I'd like to keep my hands close to the cursor (P3)**I** - With laptop, it's always the mouse even though there is a trackpad (P7)**I** - I was missing the scrolling on trackpad (P3)**I** - For doing heavy tasks like writing long documents, I can do with trackpad alone (P6)**I** - I draw on a touchscreen device. I instinctively know there's a touchscreen so just go with that (P5)**M** - I go to the same [interaction] routine that I normally do (P5)**I** - I am used to a laptop with a trackpad (P5) **I** - If I get used to it, I most probably use touch (P7)**M**

	- [while sitting] I was like "hey, this is touchscreen, I can use touchscreen, but no, I like the mouse" (P7)**I** - I could use touch in scrolling or swiping (P4)**M** - I should have the screen like this (horizontally tilted) (P5)**M** **-** Drawing, swiping, dragging – I would love to have touchscreen for that (P5) **M** - I used touch because the buttons were large enough to use my fingers on (P9) **M** If you use trackpad, you expect to find button where you can press. With touch, they are not there (P3) **M** I think some devices are more suited for some elements, especially tiny radio button. (P8)**M** If the touchscreen was working and has Win8 (P4) **I**
Intentions for Actual Use	- I just compliment the use of mouse with touch (P4)**M** - I forgot about this (picking up mouse). I had not used it in 10 years. (P3)**M** - [I] automatically went with trackpoint (P2)**I** - I wanted to use touch (on horizontal line drawing) but I already used trackpad. I don't want to do it again (P6)**I** - I definitely use touch when lying down, sitting down, or if I can't find the mouse (P7)**M** - I was planning to use touch to make the figure but for some reason, it [touch] did not work (P8)**I** - I will not use mouse just to scroll. I'll use finger instead (P3)**M** - I would always use touchscreen because it's handy and easy to use for any mobile devices (P6) **M** - Whenever I have to draw something, I prefer to touch the screen (P6)**M** - If it has a big area I can touch, then touch (P8)**M** - If horizontal-like browsing gallery, I might have done it with touch (P8)**M**