

First Name	Samuel	Family Name	Ward	Student ID No	17004205
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COMP719 Applied Human Computer Interaction

Insert USB into Device Port

Samuel Ward 17004205

Using a USB device is a familiar concept to most human adults around the world, though not many would consider the level of cognitive processing involved in undertaking this menial task. The brain is utilising feedback from three of the five senses being sight, sound, and touch when carrying out this task, however, this essay will focus on only the first step of using a USB, *Step 1: Insert USB into device port*, and will explore this cognitive processing in relation to haptics. It will cover the different haptic processing required at the various stages of holding the USB in your fingers, orientation of the USB and device port, locating the device port with your index finger, moving the USB to the position of the device port, and finally inserting USB into the device port. These distinct stages and their corresponding haptic processing will be discussed in detail.

Haptics, also known as somesthesia (Reed & Ziat, 2018), relates to our perception of objects. The haptic system itself is made up of two afferent subsystems, cutaneous (touch) and kinaesthetic (proprioception or body position). These perceptual systems contain various sensory receptors: thermoreceptors and mechanoreceptors embedded in the skin for the cutaneous system, and mechanoreceptors in the muscles, tendons, and joints for the kinaesthetic system (Lederman & Klatzky, 2009). These systems and their receptors are part of the somatosensory system and can be categorised into one of four major somatic modalities being touch, temperature, proprioception, and pain (Strominger et al., 2012). It is the responsibility of the somatosensory system to receive tactile information from these sensory receptors and transmit this information via neurons to the central nervous system. Specifically, the part of the brain responsible for receiving and processing these signals is the somatosensory cortex (Strominger et al., 2012). This system and its receptors cover the entire body, but for the purpose of inserting a USB the relevant area of haptics is the glabrous skin of the hand, being the area innervated by the median nerve (Johansson & Vallbo, 1979).

To better understand the role of haptics when handling and feeling the USB in your hands, mechanoreceptors need to be explored further. Mechanoreceptors are encapsulated nerve endings and can be divided into four types: Merkel disks, Ruffini corpuscles, Meissner corpuscles, and Pacinian corpuscles (Strominger et al., 2012). The brain relies on feedback from these receptors to determine the position of the USB in the fingers, specifically the Merkel and Meissner receptors due to the increase in density of these types of mechanoreceptors at the fingertips (Johansson & Vallbo,

1979). Merkel disks and Meissner corpuscles both have small receptive fields, with Merkel being slowly adapting (known as type SA I) and Meissner rapidly adapting (known as type FA I) (Macefield & Birznieks, 2009). FA I afferents are more sensitive to mechanical forces such as slip or friction and contribute to maintaining and adjusting the grip, where SA I afferents are sensitive to edge contour and contribute to finer tactile discrimination such as texture and shape (Reed & Ziat, 2018).

As mentioned, SA I type receptors are highly sensitive to edge contour, this is because of greater spatial resolution compared to other receptors, especially at the fingertips (Strominger et al., 2012). Spatial resolution or two-point discrimination is the ability to distinguish between two points of contact and is directly linked to receptor density. It is this spatial discrimination of SA I receptors that lends their use in determining the orientation of a USB through edge detection. USBs are large enough that we can easily differentiate the longer flat side from the short side. While this is explicitly true for a square-edged USB due to SA I receptors being very responsive to rectilinear corners, it becomes increasingly difficult to determine exact orientation on a USB with curved edges (Wheat & Goodwin, 2001).

In most cases (such as this) the USB will have a plastic body and metal tip. In this situation thermoreceptors can be employed to assist in determining the USB orientation. Thermoreceptors are free nerve endings that sense changes in skin temperature (Strominger et al., 2012). Thermoreceptors do not measure absolute skin temperature, rather they sense relative adjustments to the environment, and this can be used to determine object material. The perception of coldness or hotness of an object at room temperature is not related to the temperature of the object itself, but rather due to the thermal properties of the material. The temperature of the skin is typically higher than room temperature and surrounding objects, therefore when an object comes in to contact with the skin, it is the objects material conducting heat away from the skin that causes the change in skin temperature. Different materials have different thermal conductivity (Ho, 2017), and it is the rate of change of skin temperature that allows us to identify object materials. This is how we can differentiate the plastic end of the USB from the metal end purely through haptics because the metal feels colder than the plastic due to a higher thermal conductivity.

While orientation of the USB itself is simple, determining the orientation of the pins can pose an issue to some. The size of the USB tip is small, and it will depend on the individual's level of

spatial discrimination as to whether they can accurately identify the side with the pins. Tactile spatial acuity is known to decline with an increase in age and finger size, due to either receptor loss or reduction in receptor density (Lederman & Klatzky, 2009; Peters & Goldreich, 2013), making it difficult for some to differentiate the solid side from the hollow side of the USB tip.

The most natural way to hold the USB when relying solely on sense of touch is between the thumb and middle finger, using the forefinger as a guide to locate the device port. The reason that this differs from when assisted by vision, is due to the increased reliance on haptic sensitivity. On top of the abrupt increase in mechanoreceptor density of the hand in the proximodistal direction mentioned earlier, there is also an increase in the transverse direction, with the index fingertip being most sensitive (Johansson & Vallbo, 1979).

Discovery of the port is directly related to the texture of the surrounding area. Again, it is the fine spatial discrimination of the SA I receptors that lend themselves to the perception of texture, caused by small changes in pressure on the skin (Strominger et al., 2012). There is a tangible difference between the smooth surface of the device surrounding the port and the port itself, allowing us to quickly identify the sudden change in pressure when transitioning from this smooth surface to the edge of the port. If the surrounding surface were rough, it would be a lot harder to differentiate the edge of the port from the surface texture. Once an edge is detected, the user will then use edge tracing to determine the orientation of the port in a similar manner that was employed with the USB, with the same difficulty encountered when determining the orientation of the pins.

Once location and orientation of port is determined, moving the USB stick to that position uses what is known as proprioception. Proprioception is the sense of position; it refers to our ability to detect the position and movement of body parts relative to each other in space based on the judgment of forces exerted by muscles (Gandevia, 2009). Known as the "sixth sense", it is this sense that allows us to move and perceive body position without visual feedback, such as touching our face in the dark.

Proprioception uses proprioceptors to gather and send information about body position. Proprioceptors are receptors of the somatosensory system concerned with the kinaesthetic subsystem of haptics. These proprioceptors consist of mechanoreceptors in the tendons known as Golgi tendon organs which sense changes in muscle tension, and mechanoreceptors in the muscles known as Neuromuscular spindles which sense changes in muscle length (Strominger et al., 2012). The Kinaesthetic system also has some coupling with the cutaneous system, specifically the SA II and RA II receptors responding to nearby joint movement (Walsh et al., 2014). It is the feedback from these receptors that allow us to depict quite accurately, how far, and what direction we have moved the USB in free space.

Now that direct contact with the device port is removed, the act of inserting the USB into the port introduces a new concept known as extended physiological proprioception, which is essentially extending the proprioception process through the hand to the object being held. Extended physiological proprioception is the concept of the somatosensory system extending beyond the body, to include the tools we use, and is what gives us the ability to feel through the USB even though there are no receptors in the USB itself, perceiving it as part of the body (Heed, 2019). A good example of this is a blind person using a cane to understand their surroundings through touch, the cane essentially becomes an extension of the arm.

This phenomenon of tool embodiment does not utilise the same haptic processing found with direct contact with the skin, but rather relies on vibration through the object to interpret the tool touch (Heed, 2019; Walsh et al., 2014). This can be explained because the grip of the object does not change, therefore the SA I and FA I receptors that are highly dense in the fingertips, become less effective at providing this feedback. Instead, it is the Ruffini corpuscles (type SA II) and Pacinian corpuscles (type FA II) receptors which have larger receptive fields and are spread relatively uniform over the hand (Johansson & Vallbo, 1979) that take up this role. The FA II receptors are the most sensitive to vibration (Strominger et al., 2012) and are the main contributors in extended physiological proprioception.

The feedback cues experienced with extended physiological proprioception are of a similar nature to direct contact, albeit with a lesser degree of accuracy. As you attempt to insert the USB into the device port a number of feedback cues are presented indicating different results. An

increase in friction means the USB is orientated correctly and is going in, followed by a sudden increase in pressure as it touches the bottom indicating correct seating. The pressure increase cue of bottoming out without the initial increase in friction would indicate either misalignment of the USB itself, or the pins are around the wrong way in which case it becomes trial-and-error. Luckily, these feedback cues are so fast that the brain is able to quickly send adjustment signals to the hands to correct this.

The somatosensory system is a vast and complex system, with the human body requiring an enormous number of perceptual processes just to carry out the seemingly menial task of inserting a USB into a device port. While vision, sound, and haptics are all employed in this task, the focus has been on haptics and the expansive number of sensory receptors as part of this system, covering the relevant somatic modalities of touch, temperature, and proprioception. Temperature employs the use of thermoreceptors that allow us to determine object material for orientation of the USB. Touch entails the different types of mechanoreceptors such as FA I mechanoreceptors for grip and handling the USB, and SA I mechanoreceptors for various functions including edge detection and tactile discrimination for locating the device port. Touch also includes the SA II and FA II mechanoreceptors involved in extended physiological proprioception giving us feedback cues through the USB, essentially treating it as an extension of our hand. Proprioceptors provide us with the sense of body position allowing us to perceive the position of our hand and the USB in space. It is the interaction between this somatosensory systems feedback and the resulting signals sent to the motor neurons of the muscles that enables us to seamlessly carry out these everyday tasks as second nature, such as using a USB.

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