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The Effect of Person and Thing Orientation on the Experience of Haptics

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The Effect of Person and Thing Orientation on the Experience of Haptics

Abstract

Learning by doing is an important pedagogical method. Haptic technologies support this mode of learning. However, selected individual differences may affect learner's ability to fully benefit from these technologies. This study investigates the effect of spatial rotation, thing orientation, person orientation, systemizing, and empathizing on the use of haptics. In this study 160 students with no prior experience using haptic technologies completed simple instruments measuring their ability to rotate objects in space, their interest in systems, and their differential orientation to objects and people in their environment. The students were then introduced to haptic devices, asked to use the haptic devices to complete a simple simulation, and asked to report on the forces they experienced, their ease of use of the devices, and the usefulness of the experience. They were also asked simple questions to test their ability to connect abstract concepts and haptic feedback. The study found that thing orientation and systemizing were connected to participants' experience of haptic technologies.

Introduction

Recent advances in the teaching and learning of science and engineering have demonstrated the effectiveness of learning by doing. One of the teaching and learning technologies currently being considered for more widespread adoption to support learning by doing are haptic technologies. These are technologies that allow the learner to experience both kinesthetic and tactile sensations by providing force feedback. A handful of studies have shown that these technologies may support learning by allowing students to physically engage with a range of phenomena. Several studies have also shown that individual learners experience and translate haptic feedback differently. However, very few studies have examined the individual differences within learners which may influence their experience of haptic technologies. This study examines the effects of selected individual differences on the experience of haptic feedback. Haptic devices can be classified as high mechanistic, technical objects. As such it is reasonable to assume that individual differences related to objects and their manipulation may influence the perception, translation, and information processing resulting from haptic feedback.

Haptics Technologies

Defining and creating an experience of touch and the corresponding control to interact with computer developed applications is called haptic technology. The science of applying touch sensation and control to interact with computer developed applications is the best definition given for haptic technology. The amalgamation of human intellect with the computer science field using haptics has grown rapidly with research areas such as communicating spatial information to the blind and visually impaired using maps and graphs [1] or teleoperated minimally invasive surgical robots [2].

With haptic technology, also known as kinesthetic communication or 3D touch, people get a sense of touch in a computer-generated environment, allowing them to interact with virtual objects in a more realistic way. This mechanical simulation aids the development and control of virtual objects and helps in the augmentation of remote operations on machines and devices. Haptics has brought biomechanics, psychology, neurology, engineering and computing together in an interdisciplinary study of human touch and force feedback [3].

In the real-world people act as both receptors and perceivers. We respond in order to maximize the quantity and quality of information obtained from the environment. The key difference between active and passive touch is the intentionality of our exploratory behaviors. Gibson [4,5] drew a clear distinction between active and passive touch. For Gibson, haptics was not limited to kinesthetic and cutaneous information when one experiences objects or patterns. Haptic experiences therefore include spatial perception which refers to the relative positioning of objects, kinesthetic perception which incorporates the movement of objects in space, tactile perception which refers to the feel of objects or sense of touch, and veridical perception which refers to the ability to interpret stimuli and correlate it to physical reality. Gibson thought that active touch was more likely to yield objective percepts and veridical perception, while passive touch tended towards subjectivity [6]. So in order to fully benefit from haptic technologies, a learner must be able to feel, perceive objects in space, relate objects to each other, translate the force feedback, and connect that force feedback to a physical object or appropriate representation. Learners must also be able to relate hand movements to these other perceptions. Direct associations between the desired knowledge about objects and hand movements plays a vital role during haptic object recognition. In [7], experiments were conducted to study the subject's reaction in free and constrained hand movement conditions. Hand movements can serve as "windows," through which it is possible to learn about the underlying representation of objects in memory and the processes by which such representations are derived and utilized.

Advances in Haptics

Current advances in haptic feedback and pseudo-haptic feedback are widening the practical applications of haptic technology [8]. In [9], pseudo-haptic feedback uses vision to distort haptic perception and verges on haptic illusions. Pseudo-haptic feedback has been used to simulate various haptic properties such as the stiffness of a virtual spring, the texture of an image, or the mass of a virtual object. In [10], wearable sensing and haptic feedback platforms were used to re-establish health gait patterns resulting from diseases or injuries.

Utilizing contactless haptic feedback is another topic of recent advances and future research. In [11], two research methods establish haptic feedback – 1) air-jet haptic feedback using virtual tactile surfaces (by holding a receiver or with bare hands), 2) airborne ultrasonic haptic feedback. [12][13] described their first prototype implementation of an airborne ultrasonic tactile display that is designed to provide tactile feedback for 3D modeling software and video games. Their implementation does not require the user to wear anything.

Haptic Functionality

Haptic systems consist of two parts – the human and the machine. The human part senses and controls the position of the hand and the machine part exerts forces from the hand to simulate contact with a virtual object. Both systems are provided with necessary sensors, processors and actuators. In the case of the human system, nerve receptors perform sensing and the brain performs actuation of the motions performed by the hands. In the machine system the above-mentioned functions are performed using encoders, computers and motors respectively [14]. Specialized hardware serves the purpose of providing sensory feedback in haptics applications. A common haptic interface configuration uses mechanical linkages to link a person's finger to a computer interface. When the users' fingers move, the sensors translate those motions into actions on a screen [15]. Hence, motors transmit feedback through the linkages to the fingers of the user. The process used by software to perform this calculation is called haptic rendering.

Haptics for Learning

A major benefit of educational robots, of which haptics are a subset, is its practical implications. Haptic force feedback systems provide the unique ability to render physical representations with dynamism. This provides more hands on experiences and increases the connection between physical reality and science, technology, engineering, and math (STEM). Educational-based haptics take this connection a step further: haptic devices provide a sense of physical interactions. The effectiveness of haptic-supported learning environments and their implications for learning capacity and speed are an interesting avenue of research. Though currently much of the work primarily focuses on results pertaining to haptic-supported learning minus underlying learning structures, several educational haptics frameworks are being designed and tested in the fields of physics, biological, neuroscience and psychology. These include studies of representational fluency. In one such study [16], a haptic-supported learning environment was designed and analyzed. The primary use - to make connections between two different mathematical representations of sine and cosine: the unit circle, and their graph on the Cartesian plane - served the purpose of identifying moments where students made connections between the representations, and how the haptic feedback supported these moments of insight. The proposed theoretical framework captures four types of haptic representations, and focuses on one – the haptic bridge – that effectively scaffolds sense-making with multiple representations.

Another strand of haptic research investigates the development of mental models. Here the potential of haptic technologies to support conceptual understanding of difficult concepts in science, specifically concepts related to electricity and magnetism are explored. For these studies cognitive-affective theory of learning with media (CATLM) (Moreno & Mayer, 2007) serves as the primary theoretical framework [17]. The underlying idea is that effective learning occurs when there is a clear integration of prior knowledge with new knowledge leading to coherently structured mental models.

A third strand of research employs embodied cognition. Despite the impact visualization plays as the key mode of interaction in simulations, the most common way of interaction with physical objects is touch. An increase in immersion in a learning environment can be achieved if the user can feel and manipulate objects compared to audio/visual perception. Haptic augmented simulation allows the combination of both the force/kinesthetic and the purely visual simulations. These were found to be more effective than the equivalent non-haptic simulation in providing perceptual experiences and helping elementary students create multimodal representations of the movements [18]. Although, force feedback was needed to construct a fully loaded multimodal representation that helps students to comprehend later instruction with less sensory modalities. Haptic augmented simulation was effective in transferring knowledge to new learning situations.

A fourth strand examines the use of haptics for differently abled or impaired learners. Embossing serves as the technology currently most commonly used to display graphical content to visually impaired users. However, embossing generates only static images, requiring a new page to be printed for every new figure. Additionally, both the machines and output documents are quite expensive [19]. A further complication is introduced because impaired learners exhibit differences in brain organization and performance capabilities. In [20], they designed Canetroller, a haptic cane controller that simulates white cane interactions, enabling people with visual impairments to navigate a virtual environment by transferring their cane skills into the virtual world. Canetroller focuses on three types of feedback: physical resistance, vibrotactile feedback; and spatial 3D auditory feedback simulating. The inter-activeness of this technology allows learners to experience these environments in different ways and with greater richness.

The complexity of developing haptic virtual learning simulation systems increases as the subjective content increases. In [21], in order to identify the impact of the project – hapTEL (developing and evaluating a virtual learning system within an HE healthcare education setting), two theoretical frameworks (Entwistle, (1987) and Webb and Cox (2004)) have been used. A range of quantitative and qualitative methods were designed, piloted and evaluated in order to measure the impact of TEL on teaching and learning. The results from using these frameworks show that institutional and departmental factors should be considered when evaluating the impact of TEL in higher education and that these had a major influence on the design and curriculum integration of the hapTEL systems.

Familiarity and engagement of students with two-dimensional (2-D) representations is significant as opposed to three-dimensional (3-D) in terms of depth of articulation and comprehension. In [22], "haptico-visual observation and drawing" (HVOD) method was deployed in a qualitative assessment to understand the development of a "mental picture" of the object as being central to "deep learning."

Haptics and Individual Differences

A further potential complication of haptics is the individual variation in interactions with the technology. A range of individual differences may be expected to affect the experience and interpretation of the haptic experience. One of these individual differences could be person-environment adaptations [27]. Empirical studies have demonstrated that people respond differently to the things in their environment and the people in their environment. These differences can be characterized in terms of a differential interest in things or the objects in an environment (TO); and in people or the social interactions in an environment (PO). These orientations can be thought of as adaptations that govern how successfully individuals can exploit and adapt to their environment. Because of these adaptations, people high in TO have a greater capacity to identify, manipulate, understand, and respond to things in their environment while people high in PO are better placed to seek out and have successful social interactions.

This ability to manipulate things in one's environment can be assumed to be related to another cluster of similar abilities and individual differences around the ability to manipulate objects. These are commonly referred to as spatial visualization. These include the ability to rotate and manipulate two dimensional and three dimensional objects in two/three dimensional space; the ability to fit shapes together; the ability to fold and unfold shapes and predict their final position and structure; the ability to recognize patterns within and among shapes; the ability to relate spatial relationships to each other and the orientation of fixed and moving bodies; and the ability to abstract or breakdown shapes into component parts.

A third set of individual differences revolves around empirically determined measures of ability to identify and respond to others' emotions (empathizing) and ability to analyze and construct systems (systemizing) [23]. These individual differences relate to individuals' ability to navigate rule governed social or physical systems. These sets of tendencies manifest as both behaviors and cognitive styles and therefore can be expected to impact the perception, interpretation, and encoding of physical and visual stimuli.

Methods

Data for this study were collected from 161 students in an engineering technology statics course. These students attended lab sessions in groups of 10-20 over the course of one week. Each of these labs lasted approximately two hours. During each lab the students were introduced to the haptic technology (*Figure 1*) using a simple exercise. In this case the students were walked through a simple density exercise by the lab technician. This exercise was designed to allow the students to experience force feedback from objects of different weights and sizes. The exercise also allowed students to experience different affordances of the particular haptic system e.g. heaviness, pushing/pulling. They then completed a simple statics exercise using the haptic technology. The exercise involved them pushing rectangular objects (cubes) along surfaces with varying levels of friction.

Figure 1: The haptic device (Novint Falcon)

Finally, they completed an online survey which included questions on demographics, person-thing orientation, systemizing/empathizing [23], spatial rotation, and their experience of the haptic technologies. The person-thing orientation scale [24, 25,26] was created based on the original Little [27] scale. The empathizing/systemizing scale was adapted from Baron-Cohen's original measure [28]. The Purdue Spatial Visualization Test was used to measure spatial rotation [29].

Results and Discussion

The data were analyzed using statistical methods in SPSS. The results were clustered around two primary questions. First did male and female students demonstrate different levels on the key variables? Second were there individual differences that had a significant impact on students' ability to experience and therefore learn from the haptic devices?

To answer the first question, we examined the means across the individual differences measured i.e. person orientation, thing orientation, empathizing, systemizing, and spatial rotation. We also examined the measures of students' interaction with the haptic devices viz. how easy it was for them to use the haptic devices (Ease of Use), how much they enjoyed using the haptic devices (Enjoyment), whether the haptic devices helped them understand the concept of friction (Aided Understanding), and how well they felt the force feedback (Feel Force Feedback). The last variable was included because some learners report that they have a hard time differentiating the feeling of, for example, a heavy and a light object, while others can easily feel the difference between different levels and types of forces. The data were then differentiated by male and female respondents and the average scores compared across the individual differences and haptic experience variables (*Table 1*).

Table 1: Means and significant differences between males and females on key variables

	Ease of Use	**Enjoyment**	**Aided Understanding**	**Feel Force Feedback**	**Person Orientation***	**Thing Orientation****	**Empathizing+**	**Systemizing+**	**Spatial Rotation+****
Female	4.0	4.39	3.37	2.96	3.42	2.05	40.87	35.22	42.91
Male	4.25	4.57	3.70	2.70	3.16	3.19	37.40	39.60	61.03
All	4.15	4.50	3.59	2.82	3.25	2.77	38.64	37.99	54.75

+Scored on a 1-100 scale, all other variables scored on a 1-5 scale; *significant difference between males and females p+0.01, **significant difference between males and females $p < 0.001$

Independent samples t-tests were conducted to compare the males and females across different conditions. A significant difference was found between males and females in person orientation, thing orientation, and spatial rotation. Females scored significantly higher in person orientation ($M_f = 3.42$, $SD_f = 0.69$, $M_m = 3.16$, $SD_m = 0.59$; t(156) = , p = 0.013). Males scored significantly higher in thing orientation ($M_m = 3.19$, $SD_m = 1.18$, $M_f = 2.05$, $SD_f = 1.03$; t(157) = , $p < 0.0001$). Males scored significantly higher in spatial rotation ($M_m = 61.03$, $SD_m = 20.50$, $M_f = 42.91$, $SD_f = 21.04$; t(91) = , $p < 0.0001$).

To answer the second question, do certain individual differences impact the experience of haptics, we examined correlations among the variables (*Table 2*). Empathizing and systemizing were found to have a positive association, (r(127) = .32, p<.001) with males scoring slightly high on systemizing and females scoring slightly higher on empathizing. These results were consistent with prior studies. As expected empathizing correlated positively with person orientation (r(143) = .42, p<.001) and systemizing correlated positively with thing orientation (r(139) = .56, p<.001). This is consistent with the expectation that people who display greater differential interest in people in their environment are more able to recognize and respond to the emotions of those people. By the same token, people more inclined towards the things in their environment are better able to understand the rules governing the existence and interaction of those things within the space.

Spatial rotation correlated positively thing orientation (r(93) = .35, p<.001) and systemizing (r(81) = .34, p=.002). This would suggest that people more interested in identifying and interacting with the things in their environment are also more able to understand the rules governing these things and therefore more able to manipulate, rotate, and judge these things.

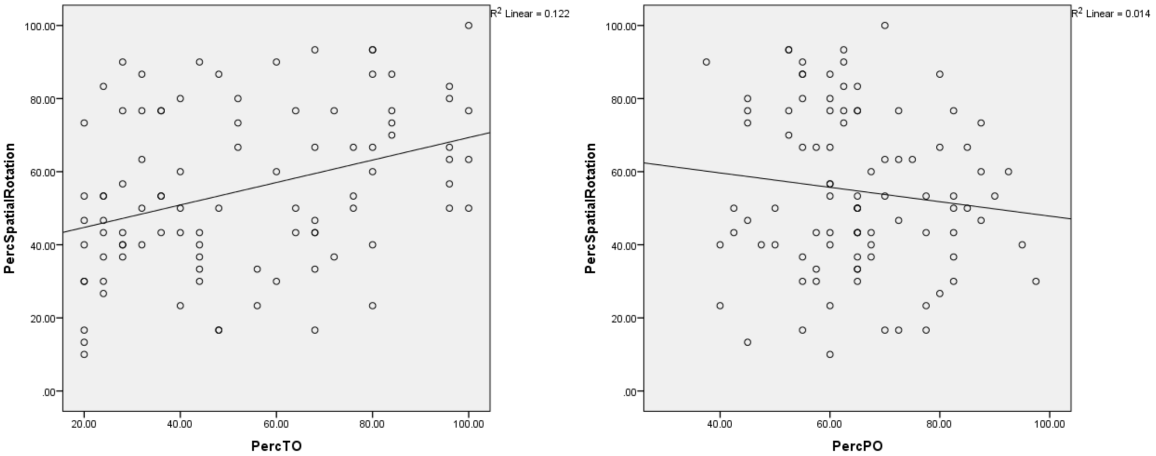

Figure 2: Variation of spatial rotation with TO and PO

In terms of the haptic feedback variables enjoyment of the haptic devices was positively correlated with ease of use (r(159) = .37, p<.001) suggesting that people who enjoyed the haptic devices found them easier to manipulate. Or conversely people who found the devices easy to manipulate were less stressed about using them and therefore enjoyed the experience more. Enjoyment of the haptic devices was also positively correlated with the extent to which the haptic devices helped them understand the forces at play(r(159) =.41, p<.001). The understanding of the forces from the haptic devices was also positively correlated with the ease of use of the haptic devices (r(159) =.26, p=.001). Interestingly, the ability to feel the haptic force feedback was negatively correlated with the experienced ease of use of the devices (r(159) = -.25, p=.001) and the extent to which the haptic devices aided understanding of the statics concepts (r(159) = -.30, p<.001). This would suggest that students who had a hard time differentiating among the forces or actually feeling the force feedback provided by the haptic devices found the devices more difficult to use and did not learn as much from using them. This would sense since the utility of the haptic devices is in providing a sensation which can be translated as representing visual objects. Without the ability to feel the sensations, the aid to learning provided by the additional affordance is negated.

Table 2: Correlations among variables

	Empathizing	Systemizing	Spatial Rotation	Person Orientation	Thing Orientation	Ease of use	Enjoyment	Force feedback	Aided Understanding
Empathizing	1	.320**	.052	.415**	-.036	.115	.049	-.153	.102
Systemizing		1	.344**	.270**	.563**	.141	.091	-.169*	.262**
Spatial Rotation			1	-.120	.350**	.130	.186	-.189	.073
Person Orientation				1	-.016	.108	.056	.026	.107
Thing Orientation					1	.230**	.167*	-.019	.279**
Ease of use						1	.367**	-.252**	.260**
Enjoyment							1	-.133	.406**
Force Feedback								1	-.300**
Aided Understanding									1

** Correlation is significant at the 0.01 level; *Correlation is significant at the 0.05 level

In terms of individual differences that affected the experience of haptics, thing orientation was positively correlated with the ease of use (r(158) = .23, p = .004) This would suggest that being high in thing orientation made the haptic devices easier to use and made it easier to understand the force feedback. Perhaps one of the most important experiences of the haptic devices, the ability to feel the force feedback, was slightly negatively correlated with systemizing (r(137) = -.18, p = .05).

Conclusion

This study examined the impacts of selected individual differences on students’ experience with haptic devices. The study found that there are individual differences which affect students’ experiences with and therefore ability to learn using haptic devices. Specifically, students higher in thing orientation and systemizing were more able to use haptic devices. Students scoring higher in these individual differences also scored higher on spatial rotation skills. The study found that while there are not differences in male and female students’ experience of haptic devices, there are differences along gender lines in many of the individual differences related to the manipulation and visualization of objects.

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