Usability and Affordances: Examinations of Object-Naming and Object-Task Performance in Haptic Interfaces

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***Abstract*—**The introduction of haptic elements in a graphic user interfaces are becoming more widespread. Since haptics are being introduced rapidly into computational tools, investigating how these models affect Human-Computer Interaction would help define how to integrate and model new modes of interaction. The interest of this paper is to discuss and investigate the issues surrounding Haptic and Graphic User Interface designs (GUI) as separate systems, as well as understand how these work in tandem. The development of these systems is explored from a psychological perspective, based on how usability is addressed through learning and affordances, defined by J.J. Gibson. Haptic design can be a powerful tool, aiding in intuitive learning. The problems discussed within the text is how can haptic interfaces be integrated within a GUI without the sense of frivolity. Juxtaposing haptics and Graphic user interfaces has issues of motivation; GUI tends to have a performatory process, while Haptic Interfaces use affordances to learn tool use. In a deeper view, it is noted that two modes of perception, foveal and ambient, dictate perception. These two modes were once thought to work in tandem, however it has been discovered that these processes work independently from each other. Foveal modes interpret orientation is space which provide for posture, locomotion, and motor skills with variations of the sensory information, which instructs perceptions of object-task performance. It is contended, here, that object-task performance is a key element in the use of Haptic Interfaces because exploratory learning uses affordances in order to use an object, without meditating an experience cognitively. It is a direct experience that, through iteration, can lead to skill-sets. It is also indicated that object-task performance will not work as efficiently without the use of exploratory or kinesthetic learning practices. Therefore, object-task performance is not as congruently explored in GUI than it is practiced in Haptic interfaces.

***Keywords*—**Affordances, Graphic User Interface, Haptic Interfaces, Tool-Use, Object-Naming, Object-Task Performance

I. Introduction

HAPTIC based design approaches are better directed by understanding affordances and ways in which learning processes occur within the natural environment. Without knowledge of how affordances instruct learning processes, designing for haptic interfaces will fall short of its full potential of intuitive learning capabilities. Affordance based learning models inform how usability and functionality work especially for digital tools. By incorporating affordances in haptic models, it is suggested here, the process of form and symbol creation, and object-naming is causal to object-task performance.

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If we define these as separate systems; object-task (action-semantic) performance and object-naming (object-semantics) we can properly investigate causalities of learned behavior processes in haptic designs. If provided affordances, cues, or clues, the 'rules' will reveal themselves with use of the tool. Not only does the tool embody the physical constraints of the space but the digital constraints of the space, allowing a more fluid experience from the two interacting environments.

II. Design Ecology: How We Learn and Facilitate Learning

In haptic design, sensory perception is key in tool use. If we regard learning of interfaces from a psychological approach, we must understand the cognitive capacity that instructs both sensory perception and task performance, and how these are interpolated in tool use. What is important to investigate is the facilitation of learning and how this affects tool use in computational models. The question stipulated here: How do we learn, and how we learn to use tools? It is a much glossed over topic in Human Computer Interaction (HCI), particularly the psychological aspects of how we learn to use tools and learn with them.

> In the current information processing framework of cognitive science, knowledge is a set of representations that are stored in the mind, including symbols that represent concepts, properties, and relations as well as representations of procedures for manipulating symbolic expressions." [1]

However, these representations and concepts of our knowledge are subjectively known. We conceptualize symbols based on experiential data. So, the question brought forward is how can we experience and conceptualize representations of these symbols and come to a common understanding? The common denominator in conceptualizing representations happens through symbols (picture forms, text, spoken word). We communicate to understand the common objects we experience. Language and symbols are the semantic objects that are named. This is the definition of object- naming: the subjective process of naming graphic/function objects in an interface in order to communicate its use. Language and symbols are the common semantic objects that are accepted by cultural threads.

Harré describes the essence of quality, which is a wholly cognitive process, as a representation of an idea. Red, for example, is an abstract object that is defined as an idea, and therefore is a quality; quality of experience. Harré's example

uses the red of apple to discuss this terminology of Locke's "qualia" being a private experience that can not be quantifiable without language.

> This assimilation would suggest that there are two realms of the perceptible, the public realm in which there are beings perceivable by anyone, and many private realms, one for each person, in which there are beings perceivable only by the person whose private realm they inhabit. [2]

The importance of object-naming is that it, perceptually, is subjective, but publicly joined in standard language and symbolic forms. The use of 'standard' denotes specific cultural origins that share language or cultural commonalities, it does not intend to specify a particular dominant language. Subjectivity effects object-naming in the graphical world, especially in GUI because culture gaps, language gaps, and perceptual gaps must be reconciled for it to be understood.

> An information-processing analysis assumes that a person constructs a representation of the situation and her or his goal and reasons by manipulating the symbols in the representation. The person's knowledge includes information structures corresponding to concepts and propositions. [3]

The work of a designer is to create a form by which is reinterpreting an object-named representation of a symbol. It creates a further abstraction from the quality of the subjective experience, relying on a designer to call upon cultural dictations to determine new, culturally viable symbols. These new symbols are then steeped in their "rules." These rules are situated outside the natural environment and exhibit qualities engineered by the designer. Therefore, the user must take himself out of his cultural and environmental bounds to learn and adapt to a separate and foreign culture, created by designers in a subjective state. These 'rules' are a set of commands, symbols, keys, or, in the terms of haptic interfaces-- gestures, that are used to manipulate these symbols. This manipulation of symbols is referred to as object-task performance. The user is subjugated to learning these commands in order to use the tool. Object-task performance is therefore defined as the task the symbol is meant to represent. For example, the Wii uses buttons, wherein some games define as a kick, or a punch in others and provides vibration feedback accordingly. This is a more abstract application of object-task performance.

What is important about object-naming and object-task performance, from a psychological aspect? Hodges, Spatt, and Patterson suggest, through a study of patients with degenerative brain conditions, that there is evidence of two different categories of perception in object knowledge within the brain, showing that one class of patients may succeed in producing a normal conceptual explanation of a watering can, but be unable to organize appropriate actions to and with it, despite having no significant sensory impairment or limb weakness. [4] If, indeed, these two aspects of object knowledge are separate systems of interpretation, we must readily look at how this effects tool-use, object-naming, and 'way-finding'. Liebowitz and Post [5] as well as Neisser [6] have similar views in which visual systems process information into two categories: ambient mode and foveal mode. Foveal modes interpret orientation is space which provide for posture, locomotion, and motor skills with variations of the sensory information. Ambient mode, on the other hand, perceives of objects or symbols that are not deemed as visually important or provide direct stimulus to the brain.

> Information for spatial orientation is highly redundant, has an invariant mathematical structure, and is obtained most effectively by a person or animal moving in the environment, whereas information for object recognition has several dimensions that can vary independently, accumulates over time, and is obtained most effectively when the person and the object are stationary." [7]

It is suggested here, that object-naming and object-task performance, while seemingly operate in tandem, work tangentially and in the case of patients with brain injury, independently. Therefore, if we conclude that these are independent working systems, tool-use should be readily explored from object-task performance aspect in the foveal mode solely because object-naming is causal to object-performance.

III. AFFORDANCE AND LEARNING IN OBJECT-TASK PERFORMANCE

If it is understood that without conceptual or prior experiential sensory experience with tools, object-task performance is important in order to explore the function of any tool. J.J. Gibson uses the term affordance to discuss the exploratory nature that is used in object-task performance to create a sensory experience in order to complete object-naming. According to Krippendorf [8] and Norman [9], affordance indicates every and all possible behaviors which leads a user to identify what the user is expected to do with the object.

> The process of perceiving affordances involves an important theoretical distinction between direct and mediated perception. J.J. Gibson (1966, 1986) argued that information that specifies affordances for orientation and locomotion in the spatial environment is perceived directly, rather than being constructed out of perceptions of more elementary cues.[10]

For example, a user can understand how to use a complex tool such as a bicycle based on visual cues such as size, weight, and depth of the object. We can understand how the pedals are used based on their design. The pedals for example, are small, indicating that it could be used by a smaller appendage of the body. We understand through locomotion of the pedals, the way in which it interacts with

the wheels to move it forward. From all of these "cues" we come to understand the way in which the body needs to use the bicycle in order for it to work and we learn from tactile "cues" the way the gears work, and the way the pedals move, and how these independent parts work in conjunction with the whole.

Adolph, Eppler, and Gibson [11] identify this point when testing with toddlers' perception of affordances in slopes. Children were placed on an platform attached to an incline slope and were tested to see how they learned to use the slope and what it affords to them. The research showed that the children 'tested' the slopes before taking action to descend or ascend, and that these 'tests' were goal-directed; as if the toddlers were looking for possible alternatives to achieve an outcome. "Although toddlers may have perceived affordances based solely on the height of the slopes rather than surface slant, it is likely that both properties were important."[12] Therefore, infants use a kinesthetic method and 'exploratory activity' to achieve perceptions of object-task performance. Though the children do not know the word for 'slope' or even have knowledge of the workings of a 'slope' they create their own perceptual representations of it by exploring it; using the body as a tool by which to understand how to best interact with it. Therefore, the experience of learning by action is more important that understand how it works. Therefore, Gibson's et. al., experiment shows that exploratory behavior is essential to perceptually learn affordances of locomotion. Further, Lockman [13] suggests that the attempt of tool use by children is the child's perceptual attempt to relate objects to other objects or surfaces. Further, it is known that children are able to construe the manual affordance of objects through sensory perception such as banging, textures, weight, and size. Surface combinations
and quality of those combinations inform children on how to use tools, and the best combinations to
use them.

> For instance, when presented with a surface that is entirely liquid, young children will attempt to use a paintbrush in it (and change the color of the liquid) but not a pencil. [14]

By providing affordances, cues, or clues, the 'rules' will reveal themselves with use of the tool. Not only does the tool embody the physical constraints of the space but the digital constraints of the space, allowing a more fluid experience from the two interacting environments.

> ...But also it is recognized that the actions of the perceiver have a significant impact on what is perceived. Even inert objects yield dynamic stimulus information when perceivers are permitted active perceptual exploration. I the case of social perception, the effect of an active perceiver on the information revealed is likely to be more significant. [15]

If child perceptual development uses affordances to understand object use, how can tool use turn to 'skill-set'? It is suggested that in the use of digital tools relies heavily on the concept of 'usability', which, for the most part, means how easily an interface is used and how a user can become skillful and adept through continuous use of the device. Zebrowitz [16] suggests that "tool use development may entail a more continuous and gradual process of discovery and exploration, not entirely dependent on some newly emerging form of relational or representational reasoning." In Gibson's et. al., experiment, fine-tuning the exploratory behavior was key. The children would use different senses in combination to fill understand any ambiguous information. For example, they would touch hills, which would combine ocular and tactile senses together in order to form a more complete perceptual interpretation of how the body can use the slope. After multiple iterations of using slopes, the children gained more facile movement to ascend or descend. [17] It is suggested here that once exploratory learning has taken place, that future interactions with the same objects are mentally perceived and actions pre-determined by a mental actualization. This is where we can differentiate between mediated and direct experience. It is through skill-set, which is learned through direct and exploratory behavior that instructs further mediated experience. Tool use and skill-set, therefore, rely heavily on iteration of use which leads to mediated agreements between the tool, body and space.

If we broaden the view to incorporate object-naming and object-task performance, we understand that the method to which is learned is fundamentally the same. However, the experience and the way in which the information is perceptually learned is subjectively situated. Therefore, what the user decides to facilitate with a particular tool based on its affordances, is subjectively known. However, skill, informs how the object can best be used over time, objectively. Krippendorf states...

> ...that [a] chair and telephone and their affordances refer to cognitive models or constructions that users identify as things of a particular kind, not what they "objectively" are. Whatever an artifact's form, if it is capable of performing according to a particular user model, it can be said to afford it. [18]

IV. AFFORDANCE BASED MODELING IN HAPTIC INTERFACES

Therefore a tool in design, should be capable of use without instruction. If object- naming precedes object-task performance by users, the object has issues of usability. If we take in account the Graphic User Interface (GUI), it is modeled in reverse; allowing object-naming to precede object-task performance. The symbols represented in a GUI are graphical icons that represent an application or function of the application. These symbols represent commands, which are meant to aid a user in cognitive offloads. However, understanding graphic icons and symbols requires a cognitive learning process involving memory to use these applications. Normally digital models, in theory, are constructed for humans to offload burdensome cognitive processes. However, this is generally accepted *quid pro quo*: the user benefits only from engaging in a learnable behavioral process, to make offloading easily and readily possible. This is defined as a skill set, and, depending on software, will have multiple learnable processes rather than a universal constant. [19] Therefore,

skill in these computational modes is like remembering a recipe in order to use an application for a desired outcome. [20] The newer generations of haptic interfaces (e.g., multi-touch screens, gesticulative gaming, tactile keybords), allow cognitive processes to be carried out on a basic physical level, but the level of the physicality is still inherently learned and not wholly intuitive. The model still lies on a think-first-and-

Fig. 1 momo with casing

then-do-later approach, rather than the ability to just act. This is the challenge for designer in creating haptic interfaces to expunge the object-naming process, and allow physicality and affordance to dictate object-task performance, as well as unifying this method within the constructs of GUIs. However, if the object of designing for haptic interfaces is not to re-represent symbols and cognitive offloads, and is shifted to a more direct experience; learning by trial-and-error, or exploratory learning, the subjective perceptual experience will enhance further learning and create skill sets.

One example of a haptic interface that uses an affordance based technique is navigation system called Momo (fig.1 & 2), created by Che-Wei Wang and Kristin O'Friel. Momo is a haptic navigation device that uses only the sense of touch. It does not use any language, or symbolic representation to instruct users on how to use it. [21] Momo is like a little creature and it's big enough to sit in the palm of the user's hands. It guides using movement and vibration to "cue" the user to either the right or wrong direction. It is up to the user to learn how to use the device in order to navigate to coordinates that are programmed. They believe Momo frees a user to be able to explore, while still being able to be "pointed in the right direction." [22] Momo tilts its 'head' forward if the user is going in the right direction, and points back to the user if the user is walking in the wrong direction. It will tilt it's head depending on which way the user needs to go, and forward means to go onward. The interface allows the user to learn by experience, and creates new opportunities to experience the 'natural' environment without being held to rules or instructions. This haptic interface frees a user from having to understand reading maps, or using GPS navigations systems, or go through lengthy manual learning of the symbols represented by maps and other navigation systems. [23]

Pulse Presence is another haptic interface that allows users to understand the affordances of the device to create a wholly valuable experience. *(fig. 3)* Pulse Presence is a modular structure that hangs on either side of a wall. Attached

Fig. 2 momo interior

to the wall are hand molds where users put their hands to read their pulse. Pulse readings from either side of the wall gives off haptic feedback in the form of a vibration based on the users heartbeat. An LCD screen on either side of the wall gives visual feedback about the interaction of the pulses and generates graphic animations. [24] According to Morowati et. al., Pulse Presence "creates an intimate moment, sharing heartbeats, exploring intimacy, and bringing to life our hidden frequencies"[25] The piece is simple in what it affords, however, the idea of affordance and object-task performance is simple. For a user, the response to placing hands on a wall, is a heartbeat. The heartbeat is a variation of their own heartbeat. It creates a very subjective quality that is only expressed by those who view it, and it is an extension of their human biological capacity. There is no need here to understand how it works, it is constructed in a way to give a non-mediated and direct experience.

A more complex approach to affordance modeled haptic interface design is the Haptic Radar Project. Developed in the Ishikawa Komuro Laboratory at University of Tokyo, it is a wearable device that allows user to perceive and respond to spatial information via haptic clues. *(fig. 4)* It is coined as a type of 'double skin', that seeks to enhance sensory perception either for the disabled or while using machines such as cars. It is comprised of 'optical modules' that sense range information and provide feedback accordingly. Its target application is in creating interfaces in visual prosthetics for the blind, enhancing obstacle awareness, and hazardous working environments. [26] One example that is given states that the sensory information of range would allow for users to get haptic feedback if they are about to have a collision with another vehicle or object.

The mission statement denotes that it will allow "users to perceive and respond to spatial information using haptic cues in an intuitive and unobtrusive way"[27] By increasing awareness to perception, it seamlessly allows users to be hyper aware in assessing affordances in situations. The Haptic Radar project not only provides for extra-sensory perceptions, but provides feedback in order for the user to understand what actions to take before an injury might occur. This is a system that helps manipulate the current psychological learning state that humans face and allows for humans to learn before the

trial-and-error process begins, in order to make appropriate object-task performances. This interface creates object-task performance efficiently, while integrating into an exploratory learning process. It creates
a link between direct and mediated perception and, itself, is actualizing direct perception while in use. In Koffka's words "Each thing says what it is....a fruit says 'eat me'; water says 'drink me'; thunder says 'fear me'; and woman says 'love me'"[28] Therefore, by creating digital affordances and allowing users to interact using exploratory learning, it provides a significant way of achieving extended usability while enabling natural extensions of the environment.

On the other hand, Apple Inc. is creating a multi-touch display with localized haptic feedback, which incorporates Graphic User Interfaces (GUIs) with haptic technologies. The interface is covered with piezoelectric actuators that will give off vibratory feedback when the screen is touched. [29] As stated earlier, there are slight issues when integrating haptic

Fig. 3 Pulse Presence

ideas in GUI. GUI tends to blur the lines between use and skill because it only triggers a select number of senses, without any exploratory learning before incurring a cognitive process. Simply put, GUI models are performatory by nature, rather than exploratory, based upon the senses they use. GUIs are, at heart, a purely cognitive process divorced from any physical application in the world. Although advances have been made to create a gesticulative GUI to bring into a physical domain, this model still acts under a cognitive constraint. GUI necessitates a certain skill set, steeped in memory and recall on the part of the user.[30]

Because, inherently, GUI is built on the foundations of a performatory, cognitive offloading device, incorporating haptic design into the fold tends to render it as 'additive' quality rather than bending the system to incorporate affordance based models. Apple is no exception. In GUIs, the modeling process is converse to that of haptic interfaces. Object-naming is accepted first and object-task performance follows, whereas in Haptic Interfaces object-task performance is necessary in order to use the interface. From there, object-naming takes place. It is contended that this ordering takes place in GUI because it is both a cognitive process and a mediated process. Haptic interfaces, on the other hand, are directly perceived and require action for use. It is the physicality versus cognitive offload that separates GUI and Haptic Interfaces. So the question here lies, if these two systems require opposing models for usability, how can the systems be rectified if they are used co-operatively? Nortd has developed a project called Touchkit which is a multi-touch interface. One application it has developed for it's Touchkit is a set of Dj turntables which allows users to manipulate graphic representations of turntables to mix and scratch their records. *(fig. 5)* What is interesting about this application is two-fold. It provides a GUI which has the ability to act as a Haptic interface, insofar as it provides digital affordances that allows users to learn how to use the turntables, while working inside the confines of GUI. What can be learned from Nortd is how to construct meaningful affordance based interfaces through GUI methodology. The turntables are designed for what they do, and they do what they are intended, therefore there is no

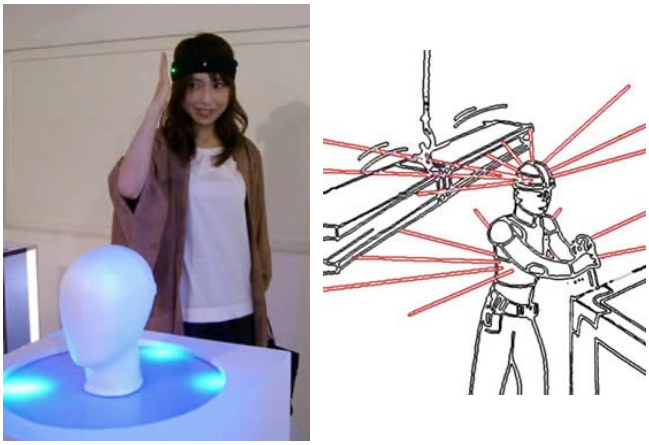

Fig. 4 Haptic Radar Prototype Demo

need for a human to extract himself from his physical environment to adapt to the features of the interface. GUI intends that humans must adapt to the working environment of the tool in order for it to function. Its rules are separate from the physical world. However, Nortd's Touchkit turntables are a GUI with affordance based capability that extend past adaptation and allow GUI to truly be an extension of the 'natural' environment.

V. Conclusion

The interest of this paper, is to rectify design anomalies between Haptic and Graphic User interfaces and to discuss these discrepancies in relation to interfaces that exist or are in development. Because there are differentiating motivations between Haptic and Graphic User Interfaces, it is necessary to understand the psychological processes that are used in the facilitation of learning, tool use, and skill-sets. What has been discussed here is that the learning processes are aided by affordances. Affordances are the conceived possibilities of use determined by a user through exploratory and trial-and-error learning. In a deeper view, it is noted that two modes of

perception, foveal and ambient, dictate perception. These two modes were once thought to work in tandem, however it has been discovered that these processes work independently from each other. Foveal modes interpret orientation in space which provides for posture, locomotion, and motor skills with variations of the sensory information, which instructs perceptions of object-task performance. It is contended, here, that object-task performance is a key element in the use of Haptic Interfaces because exploratory learning uses affordances in order to use an object, without meditating an experience cognitively. It is a direct experience that, through iteration, can lead to skill-sets. It is also indicated that object-task performance will not work as efficiently without the use of exploratory or kinesthetic learning practices. Therefore, object-task performance is not as congruently explored in GUI than it is practiced in Haptic interfaces.

Further discussion is required in developing more practical ways of integrating affordance models, object-task performance, and exploratory learning processes within GUI.

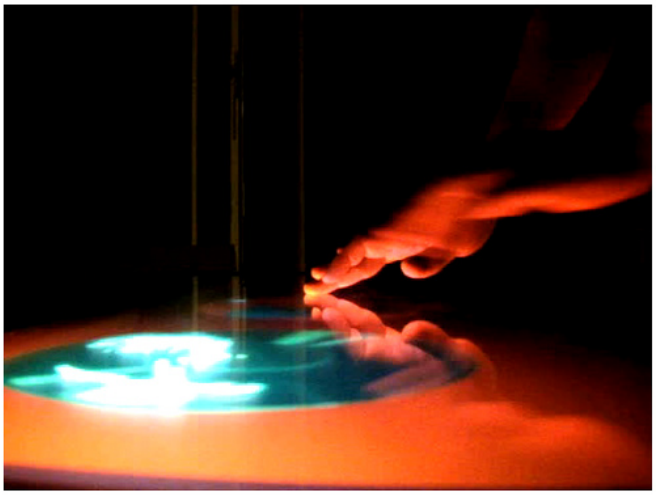

Fig. 5 TouchKit Turntable

It would be useful to further explore the opportunity that exists to expand haptic interfaces beyond commercial additions to classic GUI, and incorporate inherent haptic processes within the scope of GUI, to determine the usability benefits that could arise from the incorporation of these techniques. Finally, it is suggested to continue the exploratory process of affordances and discussing usability and design possibilities from a psychological perspective, as it benefits not only the dissemination of better modeling systems and techniques, but gives a better understanding of interaction on the whole.

Acknowledgment

Thanks goes to J.J. Gibson, and Tikva Morowati, and Rodrigo Salles Peirera Dos Santos.

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