Feedforward in Interaction: A Case Study of Feedforward for a Glimpse of its Potential in Interaction Design

KAIST, Daejon, Korea, Richard Chulwoo Park, rcpark@kaist.ac.kr
KAIST, Daejon, Korea, Woohun Lee, woohun.lee@kaist.ac.kr

Abstract

The mental model is a well-known subject discussed by Norman. But problems of everyday things continue to exist. In fact, it is almost impossible to provide a coherent conceptual model for individual users, especially when an increasing number of technology-embedded artifacts have created new interactivities nowadays. In this paper, the classical user interface problem of a gas stove's spatial mapping will be used to demonstrate how interactivity could be tamed by using the concept of feedforward. Feedforward is an important element to consider because it provides clear and instant affordance, leading to a mistake-free user experience.

This paper discusses feedforward based on the utilitarian perspective. The Previewable system will be introduced to compare the performance among conventional, touch-enabled, and hover-enabled gas stoves. Findings from a comparison analysis of its performance, its state of action, and the subjective experience will be shared. Furthermore, aspects of feedforward open up a venue in which to discuss its influence on the interpersonal and power relations that exist between artifacts and users with a design guide. The latent potential of feedforward leaves a lot to be discussed, but the findings in this paper strengthen the case for feedforward and lead to a glimpse of look at feedforward in context-aware.

feedforward; interaction design; micro-interaction; context-aware; experience;

Introduction

Have you ever been frustrated by a device when it doesn't work as you wanted it to? A set of identical looking light switches, for instance, it is hard to know which switch controls which light, and we make mistake turning off restroom when there is a person inside. Likewise, we often experience frustration and irritation when the conceptual model is incoherent, contradictory, and ambiguous in relation to our mental model. This is a well-known design problem discussed by Norman (2002). Consequently, designers and researchers have been hard at work trying to make a solid and coherent conceptual model. However, the problem of everyday things is still present, especially when it comes to computer-enhanced artifacts, which, with the connectivity of modern technology integrated with sensors, offer a new form of interaction that's sometimes immature.

This paper enquires into the problem of everyday interaction by giving a closer look at the classic gas-stove switch and its mapping issue. Furthermore, the paper looks into how should we look at modern technology and how we can deal with such complex interactions. We attempt to resolve the problem at a micro level of interaction by applying the concept of *feedforward* and the *micro level of context awareness* in everyday things. Feedforward is like a preview when we mouse over on icons in computer, and which reveals what the contents is without actually turning it on. It is an important element to be considered in the user interface design because it provides clear and instant information, which helps users to see what will occur next or what it will do.

Controlling a switch may not be considered a difficult or serious situation in normal life. As a matter of fact, it is a trivial and probably tiny moment that people typically experience only momentarily. However, it is important to look at this matter as a design issue of user psychology in a context-aware context. We believe it will help to understand developments in interaction design in the near future.

Background Research

Ever since Norman introduced daily life issues, empirical research on the subject has been conducted in various fields (e.g., cognitive sciences, human factors, ergonomics, design, and user experience; (Arthuret al., 1997; Downs & Stea, 1973). However, while designing appropriate affordance may sound ideal and simple, it is impractical in reality. A light switch and its mapping, for instance, resolves the issue with the affordance through spatial model, but it differs among people due to the fact that the cognitive map of a space is systematically distorted (Park et al., 2014; Tversky, 1992). Moreover, idiosyncratic differences among people, such as in culture (Oshlyansky et al., 2004), cannot be underestimated. And artifacts are becoming *smarter* and people are interacting with dynamic interactivity more frequently (Atzori et al., 2010; Cook et al., 2003). In other words, affordance is highly dependent on personal ability (Gibson, 1979). And universal design is indeed difficult.

As Djajadiningrat clarified (Djajadiningrat et al., 2004), feedforward is the information that communicates a possible action with an intrinsic functionality before a user performs an action. The aspect of feedforward is often employed in HCI such as *previews*. This has been typically used in the computing environment to prevent errors, improve task completion, reduce cognitive load (Sellen et al., 1992), and, in advance, gesture recognition (Cheng et al., 2013; Rekimoto, 2003). There are other examples of the use of feedforward in the form of a progressive gesture guide (Bau & Mackay, 2008; Freeman et al., 2009); furthermore, Ballendat (2010) propose proxemics interaction. The quality of understanding user's action could be further connected to Weiser's calm computing (1996). However, Weiser's vision arguably lacks the clarity of interaction as Bellotti (2001) described. When interacting with things in which information is veiled, feedforward can unveil information to people and create a more user-friendly experience. For this reason, we believe feedforward has great potential to create balance between automation and empowerment of users (Park et al., 2014; Vermeulen & Luyten, 2013).

We designed the study for a ubiquitous computing environment. A macro-level understanding of user behavior within the behavior's context is important; however, a micro-level understanding of behavior (Saffer, 2013) should also be studied in this context. We believe this micro-level understanding could be used to comprehend interaction design in a context-aware environment.

User Study

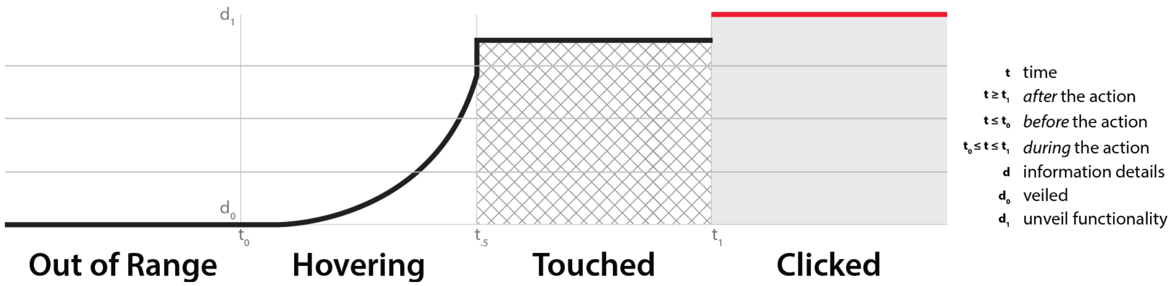


Figure 1: The states of the Previewable system: the illustration is based on Vermeulen's design space of time and level of information details (Vermeulen et al. 2014).

A gas stove involves with a classical yet complex interface problem. We wanted to assess different range of detection of a user behavior that could influence on a latent interaction issue during the performance and experience. We defined this different behavior based on the proximity. We designed the prototype to manipulate three modes of conventional, touch-detectable, and hover-detectable gas stoves. Each mode can understand different levels of users' action states. It recognizes whether a user is out of range, on the move (hovering), in the process of searching (touched or hovering), or in operation (clicked), as shown in Figure 1. A hover system provides continuous feedforward by gradual increments in brightness as the user's hand approaches the knob. The touch-able system provides instant feedforward when a knob is touched. We have proceeded in the order of prototype experience, main tasks, questionnaires, and an interview.

Implementation

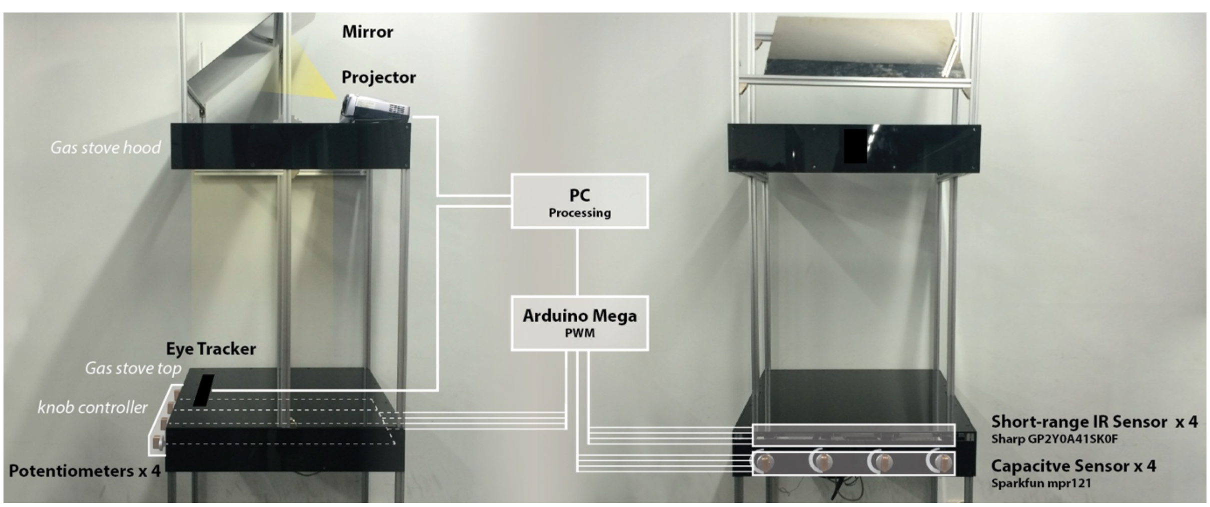


Figure 2. Implementation of the Previewable Gas Stove.

The prototype (see Figure 2) structure was built based on the commercial gas stoves. Potentiometers were used with the gas switch control knobs in order to reenact the haptic feedback of dialing and to detect when the knobs were turned on and off. To detect the distance from the knob to the user's hand, we used short-range (4–30 cm) infrared sensors. The sensors were embedded above each control knobs. For efficient prototyping, we used a projector to manipulate the visual effect, which worked in the form of gas-hood light fixtures, drawing a target indication for the tasks, and a visual effect of ignition. We recorded the user's eye behavior using the eye tracker (45–75cm, 0.5°–1° accuracy in 0.1° RMS). The specification of the tracker was reliable enough for our purpose of use. The prototype uses Arduino-Processing PWM serial communication.

The task completion time, eye behavior, and all the activity performed by the participants were logged. The logging time started when the target indicators were on and ended when the user located the targeted burner by turning the knob on. The whole performance was recorded with a camera for the purpose of behavioral study.

Experiment Setup

In reality, a user wouldn't operate a gas stove a number of times on the same spot repeatedly and simultaneously, which means the effect of perceived motor memory, learnability, and an increment of the physical load within the task should be considered in the analysis. To minimize the issues, the study sessions were scheduled with minimum three-hour intervals. The experiment was divided into two sets (see Table1), performance and experience within group study (A), and eye behavior for between group study (B). The order of the conventional and Previewable system were counterbalanced.

Twenty participants were recruited from the university (average age, 26.4; 13 males and 7 female). The participants were asked to turn on the targeted burner as accurately and quickly as possible. They executed 10 trials in each session. The target burner was randomized, and the mapping between the burner and the control knob was randomized with four types of mapping conditions.

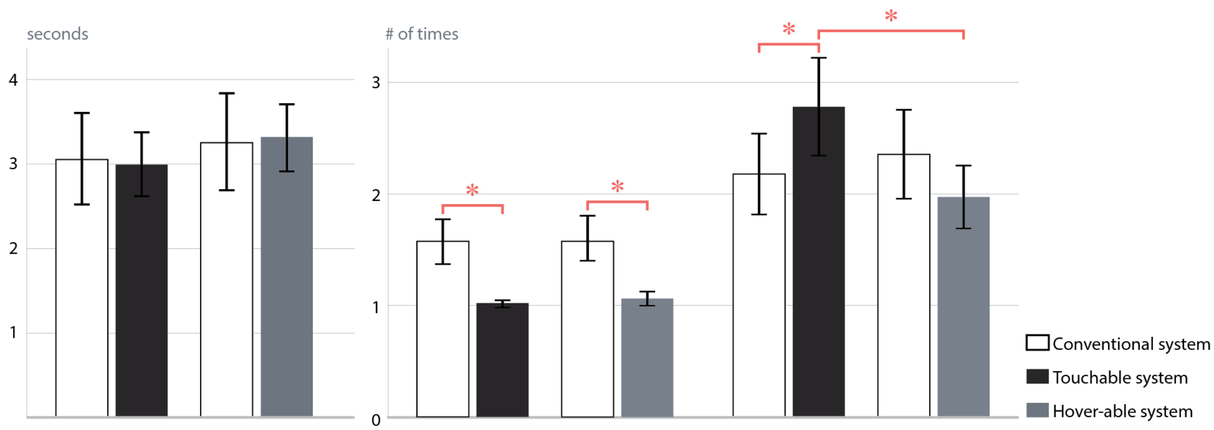
Table 1: Experiment setup. Task completion time and error (A). Attention and eye behavior (B).

	(A) Performance and Experience study Within Subject Test (20 participants)		(B) Eye Tracking study Between Group Test (10 participants)	
	TOUCH Session	HOVERING Session	TOUCH Group	HOVERING Group
Conventional gas stove	Conventional stove trial x 10	Conventional stove trial x 10	Conventional stove trial x 10	Conventional stove trial x 10
Previewable Gas Stove	Touch-able stove trial x 10	Hover-able stove trial x 10	Touch-able stove trial x 10	Hover-able stove trial x 10

An eye-tracking test was conducted with 10 additional participants (average age, 26.8; 8 males and 2 females) in order to understand the process of adjusting to the new system interface. The coordination and targeted burner in the study was randomized in every trial. Each session was carried out with a minimum 4-hour interval due to the learning effect. After each session, an interview and questionnaire survey were carried out with QUESI.

Performance Enhancement Result

All statistical results were based on a *t*-test. The performance was assessed with the task completion time and the number of missed clicks. Considering the fact that the user doesn't use the knob repeatedly in real life, we used the results of the first three trials for the main performance analysis. We analyzed with QUESI (subjective mental demand, perceived achievement of goals, perceived effort of learning, familiarity, and perceived error rate).



(a) task completion time (b) # of mean mistake (c) # of mean touched

Figure 3: Result of task completion time and error by means of mistakenly control and accidentally touched.

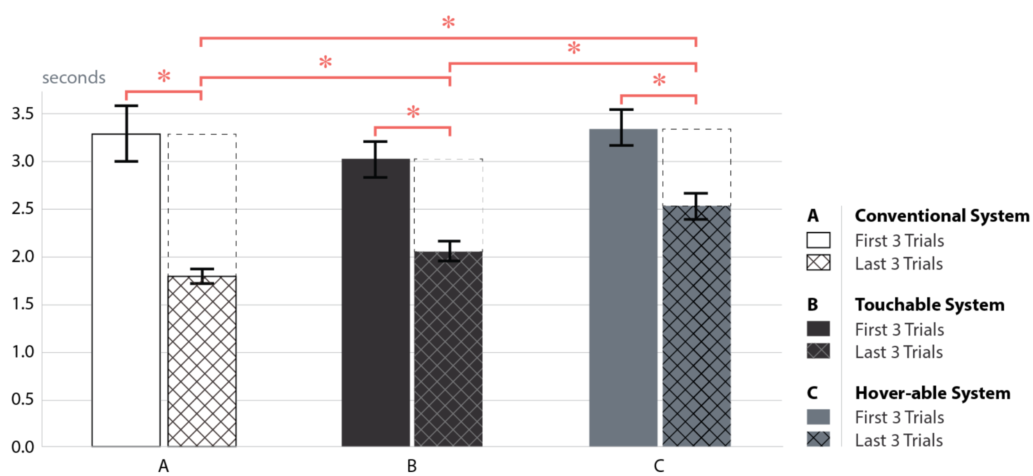
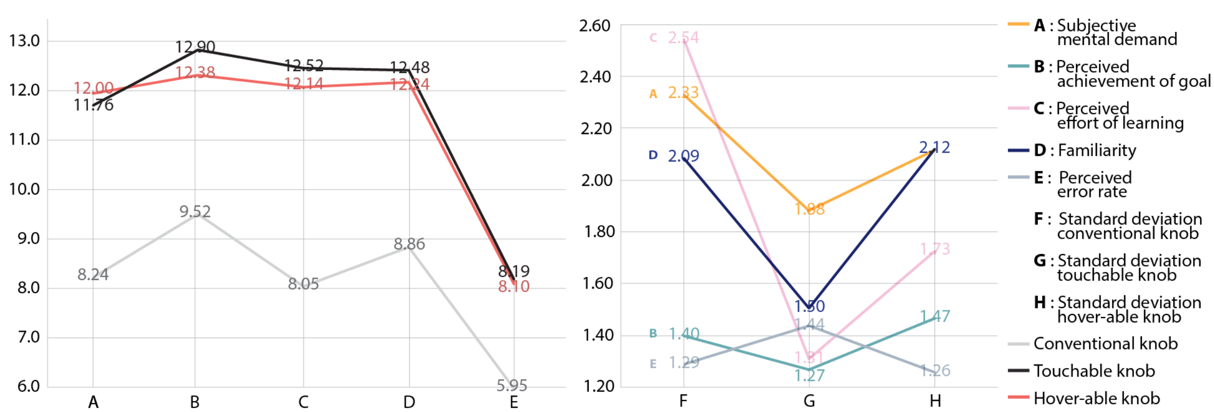


Figure 4: Comparison between the first three trials and the last three trials task completion time.



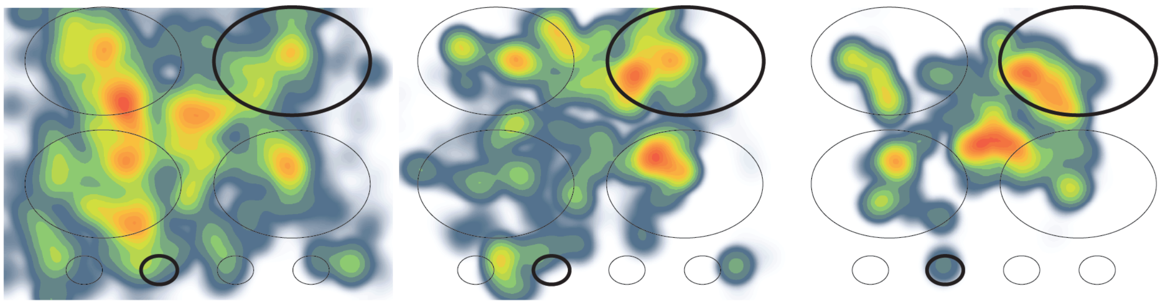
(a) Mean of QUESI subscale (b) Standard deviation of QUESI subscale

Figure 5. Score of each QUESI scales (a) and standard deviation (b). Higher the score the better the usability.

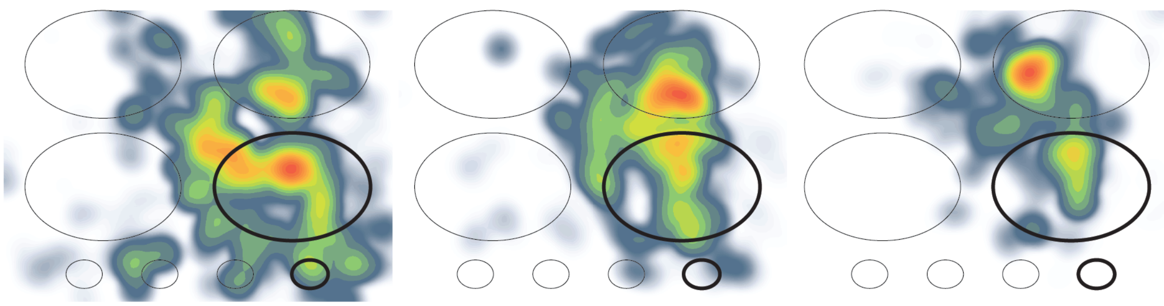
The Previewable system didn't differ in terms of the task completion time, but it had a considerable effect on the number of mistakes made ($t_{(124)}$= 5.462, $p < .05$; $t_{(124)}$ = 5.145, $p < .05$; Figure 3(b)).

The first and the last three trials reflected a performance comparison between the user in the *cognitive stage* and in the *autonomous stage*, as shown in Figure 4. The participants reduced the task completion time by 14.9% in the autonomous stage (conventional system; $t_{(124)}$= 5.338, p < .05); and they optimized their performance by 8% using the hover-able system (Figure 4, hover-able system; $t_{(124)}$ = 3.30, p < .05). Participants outperformed when they were in the autonomous stage using the conventional knob.

The QUESI results indicate that the Previewable system enhanced the overall satisfaction of the subjective user experience. The results also show that the system enhanced its intuitiveness ($t_{(40)}$ = -8.13, p < .05; $t_{(40)}$ = -6.47, p < .05; Figure 5). However, there is not much difference between the touchable and hover-able system.



(a) Target 2 Conventional System (b) Target 2 Touchable System (c) Target 2 Hover-able System



(d) Target 4 Conventional System (e) Target 4 Touchable System (f) Target 4 Hover-able System

Figure 6: Results for eye tracking. The figure illustrates the users' eye behaviors for the target Burner #2 (top row) and #4 (bottom row), and the differences between the conventional (a, d), the touch-able (b, e), and the hover-able system (c, f). We excluded the target Burner #1, and #3 results because the outcomes were similar.

We want to comment on the subjective mental workload and other subscales (see Figure 5 (a)-A ~ (a)-D). The hover-able system's subjective user satisfaction scores (12) on mental workload are higher than the touchable system's (11.75). The difference between the two scores are not significant. However, if we take standard deviation (touchable system = 1.85; hover-able system = 2.12), it addresses some design issues regarding mental demand and the complex interaction technique. In short, participants felt a smaller cognitive load of experience using the hover-able system but found it more difficult to pursue their goals.

This result could be explained by the participants' perceptual-skill-dependent behavior in the hover-able system which causes typical drawback of an absence of haptic feedback in the mid-air gesture interface. In the hover-able system, the participants don't have to memorize mapping (therefore, there is less of a cognitive load), but they have to respond to a visual aid. Occasionally they experienced being lost as a result of the discrepancy between motor and perceptual skills, which caused a delay at the end. Thus, the Previewable system may delay the task completion time, but it reduces the mental workload. Users seem to perceive mid-air gestures as an unfamiliar interface, which require a complex interaction technique, but the complex interaction could also sometimes be used to reduce the mental demand.

The Previewable system was distinctively more focused than the conventional system in the eye-tracking experiment. The participants' eyes were distinctively scattered all over the gas-stove surface and control knobs (see Figure 6(a)). The participants were busy paying simultaneous attention to the target, the actual burner, and the control knobs. They also tended to be more attuned to the manner of using the hover-able system. They slid their hands over the control knobs and immediately understood which knob controlled which burner. They were able to make a decision without looking very much. Participants had to activate the knob by means of physical contact in the touchable system. Therefore, they occasionally needed to check the location of the knob, their hand, and the target.

On the assumption of all the participants' equivalent short-term memory, the Previewable system is less demanding when it comes to memorizing, guessing, and evaluating, and perhaps, the hover-able system may not require these skills at all.

Observation and Interview Result

Compared to the participants' prior experience with the gas stove, they all agreed that they could naturally engage with both the touchable and hover-able system. They reported that the Previewable system is intuitive to use. Most of the users emphasized how the system helped to resolve their uncertainty in the course of their actions.

The participants mentioned they felt less work demand, reduced sensory time, and more comfort and confidence in their actions. They particularly mentioned that it was unnecessary to think about mapping. These responses support the results of the QUESI and eye-tracking experiment.

We observed that some participants did actually spend some initial time figuring out the mapping by pointing with their finger. It occurred to participants that this process of understanding and configuring the system was mentally demanded as a task. Most of the users descriptively used the word *annoyance* when they were describing their experience with the conventional system.

Participants felt that there wasn't much interaction difference between the conventional and touchable system. On the other hand, they reported that they perceived a hovering action as the pre-action state. We believe the participants' perceptions of their action states relate to the interface physicality.

There was a clear individual preference for the hover-able system in terms of interface familiarity and subjective mental workload. The hovering technique seemed to be associated with common mid-air-gesture drawbacks in that it caused cognitive awkwardness when the user's intended behavior differed from what was actually perceived. This finding supports the participants' comments on the stability of haptic feedback.

Most of the participants mentioned the word *mistake* and described the difference between the conventional and Previewable system. In addition, the subjective task completion time was much faster than in the conventional system, even though the actual task completion time contradicted this. Subjective mistakes were considered to be relevant to perceiving the action purpose rather than the action itself.

Participants who had experienced the Previewable system before experiencing the conventional system reported that they were confused and even embarrassed by the absence of feedforward. P12 mentioned, "*I am not being treated fairly; I feel like I am not asserting my right when the information before me is taken for granted*." Most participants, like P12, appreciated the information. They particularly mentioned that they felt that they were being taken care of by the system and could rely on it more. However, it also addressed the dichotomous interaction design issue that exists between intuitive usability and loss of control. Few participants raised this issue of losing controllability. They were skeptical and even feared becoming incapacitated.

Discussion

User perception of time and mistakes

The task completion time could be very crucial for some devices in terms of usability. However, in the case study, which is trivial and infrequently used like in a real life, time can be perceived differently. Csikszentmihalyi (1990) explained the optimal experience as follows: "*generally, after the experience we do not know where the time went; however, during the actual experience, time seems to stand still.*" Most of the participants reported that the actual task completion time (hover-able < touchable < conventional system) hadn't influenced their user experience; rather, the subjective quality of the time seemed to matter. Furthermore, the perception of time in the hover-able system is what caused this result in relation to subjective usability and satisfaction.

Considering the drawback aspects of the mid-air gesture (e.g., the absence of haptic feedback) and some negative comments made during the interview (e.g., losing controllability and unfamiliarity), it can be argued that the contradictory result related to the user satisfaction score reflected the possibility that a new or relatively difficult interaction technique could be tamed with appropriate use of feedforward in terms of the experience.

Table 2. Perceptual state of action, purpose of action, and mistake in the case study.

Action in the system / User Perception	Hovering	Touching	Turning knob
Perceptual state of action	Before the action	Action	
Perceptual purpose of action	Exploring system		Executing system
Perceptual mistake after trial	Not mistake		Mistake

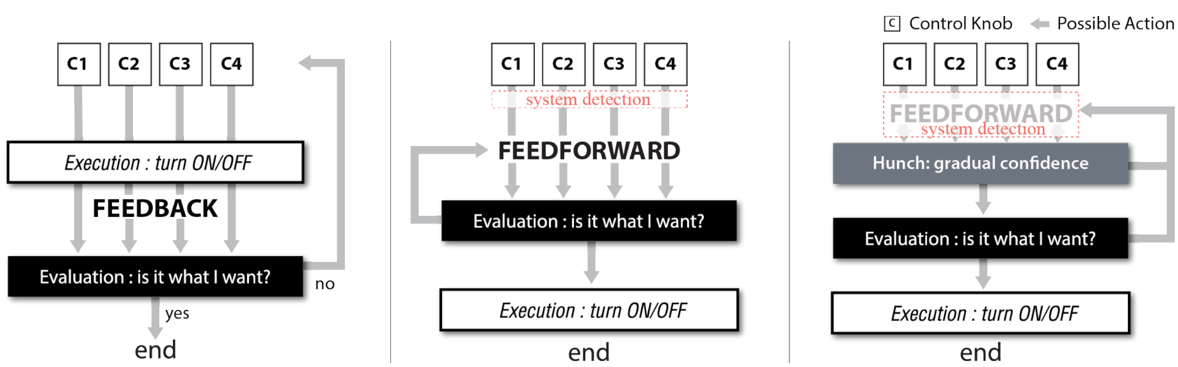
Generally speaking, mistakes are a decision or an action that we fear we will come to regret, and which arise from conscious deliberations (Norman, 2002). This is one reason why people become stressed or blame themselves when they fail in a simple choice they've made.

The participants were asked to describe a state of action and a purpose of action for each system in order to understand mistakes with regard to the state of action. The results show some aspects of an individual's tolerance for making a mistake. We found that making a mistake in micro-interactions is relevant to *perceptual action purpose* and that participants' knowledge of their actions is relevant for serving the purpose. For example, the user perceives a touching action behavior as an action in the touchable system, but the purpose of the action is to explore the system, as shown in Table 2. The same state of action, turning a knob, on the other hand, is perceived as executing the system. The participants perceive their action as a mistake when executing the knob if it fails to meet their goals. This is quite an important finding in interaction design because it implies that the same error made by different people could cause a different user experience.

It is almost impossible to create an absolutely error-free interaction design. However, we can make a perceivable system without mistakes. The interaction design strategy lies in the question of how to perceptually sublimate the purpose of executing the action. One suggestion is to have an implicit tutorial session for complicated functions by providing feedforward. This would lead users to build trust in a reliable system.

Action states

Figure 7 illustrates the action states' difference among the (a) conventional, (b) touchable, and (c) hover-able system. The conventional system begins by following the execution, and the users evaluate their goals in relation to the outcome. The users repeat the steps until they achieve their goal. Therefore, the user experiences trials and errors, which are accrued as the number of possible actions increases. On the other hand, Feedforward shortened the process of action states by minimizing the physical steps in the trial-and-error process. Users start with the evaluation process. They would slide their hands over the knob and immediately see which one controls which burner. This would lead users toward a more error-free user experience (which differs from a mistake-free one).



(a) Conventional System (b) Touchable System (c) Hove-able System

Figure 7. States of action cycle.

We named the loop of the perceptual process before the action as the state of *hunch.* In the hunch state, the system could detect the users' behavior before the user perceives an action. It then progressively attains the user's confidence as it gradually carries out the user's actions by feedforward. Eventually, it leads the user to make a confident decision. This aspect was also revealed in the interview where the participants reported that they gained confidence as they approached the control. The downside of hunch, on the other hand, is that it causes a delay in the task completion time as the users keep evaluating the perceived information using their perceptual skills. A few participants pointed out that they often got stuck on the hunch state due to a discrepancy between their motor and perceptual skills.

Manipulation techniques

The participants tended to adapt to the system in which they actively used hovering and touch gestures as a means of searching. Buxton (1995) and Hinckley (2005) described it as *foreground* interaction, which refers to activities that are at the forefront of human consciousness. This interaction only lasts for a few trials in the process of learning during the cognitive stage. Once they became accustomed to the system, they tended to passively engage with feedforward. The interaction passes on to the periphery where feedforward information works as an assurance of the choice of their action (i.e., feedforward becomes feedback). This interaction occurs in the autonomous stage in which people usually control the artifact or system without thinking. This transition of states allows participants to undergo a process of adaption.

One potential benefit of feedforward is that it could induce users to adjust to a new environment or an unfamiliar interface and optimize their performance by adapting their behavior to the system. In other words, feedforward creates an opportunity for users to adjust their behavior in their own optimized way using the context of the system's interactivity.

Design Implication

Design guide for using feedforward

First, designers must consider the context of interaction and usage frequency. Some artifacts may be used hourly or even more frequently, such as the use of smartphones. In this case, users can learn and adapt new features and remember how to use the system model without much effort. On the other hand, some artifacts may not be in use as often, such as a case study, in which users may consistently forget or be unwilling to remember. In this circumstance, using feedforward could be a powerful guide for the initial state of the artifact when the user is in the cognitive stage. Therefore, feedforward could be useful for guiding the novice by means of a more intuitive experience. However, we want to note that feedforward could also cause a delay in the autonomous stage, and some artifacts or expert users might perform best with a strong coinciding bond between the user's mental model and the system model. Experts may not benefit when it comes to the task completion time, but they may benefit in the course of their action choice when they need to choose action carefully.

Second, a designer could transform feedforward as a different manipulation technique. Feedforward could even make different impressions in terms of user experience. We have demonstrated an intertwined interaction controllability between the foreground and background. In the hover-able system, the participants used feedforward as a foreground interaction to explore mapping of the system in the cognitive stage, and it was also used as a background interaction for users to confirm their choice of action in the autonomous stage. The system could also provide confidence to users during the action process. This aspect of feedforward could be useful for designing artifacts that have to do with dangerous contexts involving highly uncertain controls that require insurance of the action.

Third, designers should be aware of the benefits and drawbacks of using feedforward. One of the benefits of feedforward is that it could provide confidence to users' actions. Findings from the case study indicate that the participants used the information to make sure that their own action was appropriate, using the information as feedback regarding the results of their action. However, this particular interaction process caused delays in users' performance because they tended to rely more on perceptual skills than cognitive skills. Perceptual skill dependency may significantly reduce the mental workload, but it also increases the task completion time. This is a crucial issue for design artifacts using feedforward.

Power Relation and Interactive Complexity

The case study reflects the important aspects of a power relation (i.e., the user is in control or is being controlled). Detecting a particular level of a user's intended action is a prerequisite for feedforward to provide information before the actual action takes place. It helps users to trial-and-error-less control. However, some of the participants were afraid of losing controllability. They mentioned that the system helps them to achieve their goal without difficulty, but being in control makes them feel lethargic. They particularly mentioned that they fear losing skills as a result of system dependency. The skills they once had would become obsolete as a result of using this system. This issue of power relations addresses some questions. How much should the system take control and in what way can designers balance the comfort of being control free and the feeling of being in control?

The problem with digital artifacts lies in their short lifespan with the overloaded new features. People tend to maintain behavior they are accustomed from prior experience when they are confront with new digital devices. They seldom go through manuals and instructions even if this would save time in the long run by allowing them to take the initial time to optimize the system (Carroll & Rosson, 1987). This may be a problem related to the paradoxical nature of users. However, if we think about all the artifacts that require users to learn and study them, it's clear that acquiring new artifacts is indeed a stressful experience.

Users are eventually going to adapt the interface and new features for their own good. Helping people in this way, however, lacks the ability to accommodate idiosyncratic differences among people. Using feedforward could be used as an explicit guide for the new interface. This instructive aspect of feedforward could lead users to achieve more intuitive usability in the feature, thereby overcoming their complicated lives.

Context-aware and Interpersonal Relation with Artifacts

If designers provide appropriate feedforward, it can build interpersonal relationship while interacting with the system. P18 stated during the experiment, "it (technology) didn't make much difference (between conventional and the prototype), but I felt that I could manipulate it with entire dependency on the system with trust."

In psychology, trust involves believing that the person who is trusted will do what is expected. According to Erikson (1950), trust is the first state of psychosocial development where it can lead to feelings of security and optimism. Building relationships with artifacts can be seen as a similar process as the above. Furthermore, numerous empirical studies have demonstrated how the experience of the product influences attachment and fidelity (Fenko et al., 2010; Schifferstein et al., 2008) interacting with it.

Although it cannot be conclusively stated, and many further studies may require, we believe that taking advantage of the concept of feedforward and context-awareness in micro-interactions could lead to the building of interpersonal relations with artifacts. Therefore, feedforward requires careful attention to the aspect of interpersonal relations in interaction design.

Conclusion

We have looked at the concept of feedforward as part of the process of usability. It provides explicit affordance to users, especially when a number of possible interactivities are uncertain. Nevertheless, products related to everyday things continue to miss these advantages. In particular, technology has become increasingly pervasive nowadays, and designers have to somehow mediate between technology and the physical world. Thus, feedforward should be addressed more in interactive design. The findings of this paper strengthen the case for feedforward and demonstrate why it is a prerequisite for user interfaces.

Feedforward can connect broken links in the cognitive process between intention and execution by *disclosing latent action possibilities* and explicitly *revealing an action possibility*. This quality of interaction strategy can: 1) prevent users from making mistakes, 2) support intended user behavior by revealing hidden information, 3) lead to confidence in the choice of an action, 4) help users perform tasks in a more concentrated manner, 5) lessen the demands of the mental workload, and 6) enhance the user's cognitive stage. These particular attributes of the concept lead to natural behavior and help people accommodate to everyday things, which outlines the importance of human-centric interactive design.

We have demonstrated the potential for feedforward to influence a user's subjective time, perception of mistakes, and *trust* in the end. However, the latent potential of feedforward hasn't been fully realized in the physical world. Much more research should be done to apply feedforward as an interaction design strategy. We should discuss power relations, the interpersonal relations between users and artifacts, the dynamic range of perspectives on feedforward and finally, how it shapes the experience.

Reference

Arthur, E. J., Hancock, P. a, & Chrysler, S. T. (1997). The perception of spatial layout in real and virtual worlds. *Ergonomics*, *40*(1), 69–77.

Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of Things: A survey. *Computer Networks*, *54*(15), 2787–2805.

Ballendat, T., Marquardt, N., & Greenberg, S. (2010). Proxemic Interaction : Designing for a Proximity and Orientation-Aware Environment. In *UIST '11* (pp. 315–326). ACM.

Bau, O., & Mackay, W. E. (2008). OctoPocus: A Dynamic Guide for Learning Gesture-Based Command Sets. In *UIST '08* (pp. 37–46). ACM.

Bellotti, V., & Edwards, K. (2001). Intelligibility and Accountability: Human Considerations in Context-Aware Systems. *Human-Computer Interaction*, *16*(2), 193–212.

Buxton, B. (1995). Integrating the Periphery and Context : A New Taxonomy of Telematics. In *Proceedings of Graphics Interface '95* (pp. 239–246).

Carroll, J. M., & Rosson, M. B. (1987). *Paradox of the active user, Interfacing thought: cognitive aspects of human-computer interaction*. MIT Press.

Cheng, L., Lee, M., Wu, C., Hsiao, F., Liu, Y., Liang, H., Chen, M. Y. (2013). iRotateGrasp : Automatic Screen Rotation based on Grasp of Mobile Devices. In *UIST Adjunct Proceedings '12* (pp. 15–16). ACM.

Cook, D. J., Youngblood, M., Heierman, E. O., Gopalratnam, K., Rao, S., Litvin, A., & Khawaja, F. (2003). MavHome : An Agent-Based Smart Home. In *2013 IEEE International Conference on Pervasive Computing and Communications* (p. 521). EEE Computer Society.

Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal performance*. Cambridge University Press.

Djajadiningrat, T., Wensveen, S., Frens, J., & Overbeeke, K. (2004). Tangible products: Redressing the balance between appearance and action. *Personal and Ubiquitous Computing*, *8*, 294–309.

Downs, R. M., & Stea, D. (1973). Cognitive Maps and Spatial Behaviour : Process and Products.

Erikson, Erik, H. (1950). *Childhood and society*. New York: WW Norton & Company.

Fenko, A., Schifferstein, H. N. J., & Hekkert, P. (2010). Shifts in sensory dominance between various stages of user-product interactions. *Applied Ergonomics*, *41*(1), 34–40.

Freeman, D., Benko, H., Morris, M. R., & Wigdor, D. (2009). ShadowGuides. In *Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces - ITS '09* (p. 165). New York, New York, USA: ACM Press.

Gibson, J. J. (1979). *The Ecological Approach To Visual Perception*. Psychology Press.

Hinckley, K., Pierce, J., Horvitz, E., & Sinclair, M. (2005). Foreground and background interaction with sensor-enhanced mobile devices. *ACM Transactions on Computer-Human Interaction*, *12*(1), 31–52.

Norman, D. A. (2002). *The Design of Everyday Things*. *Human Factors and Ergonomics in*

Manufacturing (Vol. 16). New York: First Basic Paperback.

Oshlyansky, L., Thimbleby, H., & Cairns, P. (2004). Breaking Affordance : Culture as Context. In *NordiCHI '04* (pp. 81–84).

Park, R. C., Lee, H., Kim, H., & Lee, W. (2014). The previewable switch. In *Proceedings of the 2014 conference on Designing interactive systems - DIS '14* (pp. 191–194). New York, New York, USA: ACM Press.

Rekimoto, J. (2003). PreSense : Interaction Techniques for Finger Sensing Input, *5*(2), 203–212.

Saffer, D. (2013). *Microinteractions: Designing with Details*. Sebastopol, CA: O'Reilly Media, Inc.

Schifferstein, H. N. J., & Zwartkruis, Pelgrim, E. P. H. (2008). Consumer-Product Attachment: Measurement and Design Implications. *International Journal of Design*, *2*(No.3), 1–13.

Sellen, A. J., Kurtenbach, G. P., & Buxton, W. A. S. (1992). The Prevention of Mode Errors Through Sensory Feedback, *7*, 141–164.

Tversky, B. (1992). Distortions in Cognitive Maps, *23*(2).

Vermeulen, J., & Luyten, K. (2013). Crossing the bridge over Norman's gulf of execution: revealing feedforward's true identity. *CHI '13*.

Weiser, M., & Brown, J. S. (1996). *The coming age of calm technolgy*. *Beyond Calculation*. Springer New York.

Author Biography

Richard Chulwoo Park

Richard is currently Ph.d. candidate at KAIST (Korea Advanced Institute of Science and Technology) in Korea. He is researching on 'smart' interactivity that deals with not only artifacts' functionality but also holistic user experience regarding with active role of technology. He has been published several papers regarding with the concept feedforward and its functional values. His recent interest is how the agent plays role in interactivity of aesthetic experience. http://wonderlab.kaist.ac.kr

Woohun Lee

Woohun is currently professor at KAIST (Korea Advanced Institute of Science and Technology) and running Wonder lab in Korea. He has been devoted his career to humanize technology and create 'wonderful' user experiences through experimental ways which blur traditional boundaries between design, art, and engineering. http://wonderlab.kaist.ac.kr