# Three Case Studies of UX with Moving Products

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### ABSTRACT
Advances in ubicomp technology are enabling the development of products that move in affective ways. However, there is insufficient empirical knowledge to encourage such designs. As *research through design*, we built three prototypes of standing-type kinetic products to conduct user experience (UX) field studies with visceral, behavioral, and reflective perspectives. Tasks, the users' body reactions, and their feelings were measured and interpreted to uncover features of a desirable UX with moving products. The findings and discussions contribute to the ubicomp community by expanding the design space for moving products and inspiring the community with practical applications.

### Author Keywords
Moving product; user experience; research through design.

### ACM Classification Keywords
H.5.m [Information Interfaces and Presentation (e.g., HCI)]: Miscellaneous.

### INTRODUCTION
Most everyday products are stationary and do their jobs passively. What if they came to life and actively performed expressive movements? Imaginary products such as the anthropomorphized clock in *Beauty and Beast* (Disney) and the lifelike lamp in Pixar's prologue scene help demonstrate the affective potential of moving products.

So far, such products have been introduced to the market infrequently. For example, Clocky is an alarm clock that rolls back and forth to effectively wake up its users, and Rolly is a music player robot that can dance to the music. Thanks to the human tendency to personify products [33], such product movements can emotionally enhance the original functions of the products and provide a pleasurable user experience (UX) in everyday contexts.

The potential of designing movement as an affective medium for user-product interaction is being emphasized [9] and explored by many human-computer interaction (HCI) and human-robot interaction (HRI) researchers, made possible by recent advancements in physical computing technologies. Physically embodied movements of products can effectively attract users' attention [14,35], provide intuitive communication cues, and even change users' behaviors [7,16,30].

To realize the potentials mentioned above with everyday applications, a situated understanding of their realistic use is essential [3]. However, there have not been many consumer products or corresponding knowledge of affective UX. Thus, this study seeks to uncover possibilities for everyday UX with moving products. We start with *standing-type kinetic products without locomotion* as the most fundamental application of product movement design that can be supported by a relevant method [18].

*Research through design* is considered a useful approach to fulfill the explorative characteristics of ubicomp research [13,37], which predicts and examines UX that have not yet been defined through multiple field trials [11,24]. Prototyping plays an essential role in such research, by which pragmatic knowledge can be achieved in the field rather than constrained findings in laboratory conditions [6,8,11].

In this regard, we explore the daily values of UX with moving products by conducting three case studies with proper prototypes. More specifically, we measure and analyze how users react, interpret, and reconsider product movements as time passes. The findings and discussion of this paper present possible pros and cons of moving products, extend the body of ubicomp knowledge of daily UX, and encourage designers to create such products.

### RELATED WORK
Human sensitivity to perceive and interpret movements is an innate ability for survival [4]. Body movement is a major channel of human communication, along with verbal language [10,23,28]. Therefore, humans have mastered detecting others' movements and deriving meanings from them.

The communicative value of movements can be extended to simple geometric figures due to people's tendency to treat objects as their peers [33]. In other words, humans somehow attribute human meanings, such as intentions or emotions, even to objects' movements [2,15,29,35].

Such anthropomorphic sense-making is being actively studied in the HCI and HRI disciplines. For example, Roco is a robotic computer that can express emotions by moving its monitor like a head [1], Breakaway persuades its user to take a break by slouching its bar-type body down to the ground to represent the overworked user [16], the simple gestures of a

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standing TV can show attentive social cues to its users [30], and even a door with one degree of freedom (DOF) can deliver welcoming and reluctant messages to pedestrians by exhibiting simple patterns of movements [17]. Recently, a systematic design method has been introduced to support designers in creating expressive movements for simple standing products by translating human torso movements into combinations of X, Y, and Z axial movements of products and mapping them with general product messages [18].

Despite all these endeavors, there has not been much knowledge regarding the value of moving products in day-to-day life. A few long-term studies have examined the UX with specific moving products on a daily basis. Forlizzi and Disalvo observed how Roomba, a vacuum cleaning robot, can socially influence the family members to participate in a house-cleaning activity [12]. Lee et al. implemented the 'snackbot' system to serve snacks to office workers and discovered the robot's social effects on the community members [26]. Such long-term findings are critical in explaining the real world UX and in raising new points of discussion [19,20]. This study seeks to achieve the same value with a more generalized perspective rather than focusing on a specific type of product.

For this, we refer to Norman's view on UX [31]. He took the three-level framework of experience from psychology and applied it to UX design: *visceral* UX refers to the instantaneous influence of a design on a user; *behavioral* UX refers to the look and feel during usage; and *reflective* UX refers to the users' thoughts after use. With these lenses, we seek to predict and interpret the UX with moving products.

## FIELD STUDY DESIGN

Three field studies were designed with the aforementioned levels of UX to unfold the hidden dimensions of product movement design in the real world. Our main questions were:

- **Study 1 (visceral level):** How can a moving product effectively induce an instantaneous user response?
- **Study 2 (behavioral level):** How can a moving product promote changes in users' emotional behaviors?
- **Study 3 (reflective level):** How can the changed behaviors be retained after the movement stimuli are removed?

To tackle the above questions, three standing kinetic products were designed: for Study 1, a 'moving water-dock' was introduced to instantly promote users' water-drinking; for Study 2, a 'moving assignment-box' to emotionally refresh the experience of students' mandatory homework submission; and, for Study 3, a 'moving recycle bin' to support the effective education of children in dealing with trash.

The three conceptual products were implemented with Bioloid-kit [34], a robot prototyping tool that includes main processors, actuators, sensors, and programmable software.

We wanted the three products to express affective cues through kinetic movements. For this, we used a systematic movement design method [18] to find well-matched movements for each product's concept and user context.

Finally, we meticulously selected the appropriate UX measurement methods. Due to the empirical and complex nature of UX, the measurement should be triangulated using multiple types of data [5,25,21]. First, *task measures* are the most objective indicator that numerically illuminates the usefulness of movement designs. Second, *subjective measures* can uncover users' feelings that are undiscoverable through external observation. Additionally, *body measures* are used to record the users' unconscious behaviors, such as proxemic reactions and dialogues [32]. We used appropriate combinations of these measurement methods according to the purpose of each field study.

## STUDY 1: MOVING WATER-DOCK

### Product Concept

Regular water-drinking is said to be important for health, as water is an indispensable element of the human body [36]. A moving water-dock may assist users' regular water-drinking with its movements as reminders.

### Prototyping

Our moving water-dock is composed of a bottle holder and its base (Figure 1). An infrared sensor on the holder is used to check whether a bottle is placed on the dock, and three actuators are used to generate three axial movements (in the X, Y, and Z directions) of the bottle. The actuator making the X axial movements reads torque to estimate the amount of water remaining in the bottle, based on which the main processor can decide which of the three levels of expression to perform to send the message 'please drink' (see Table 1).

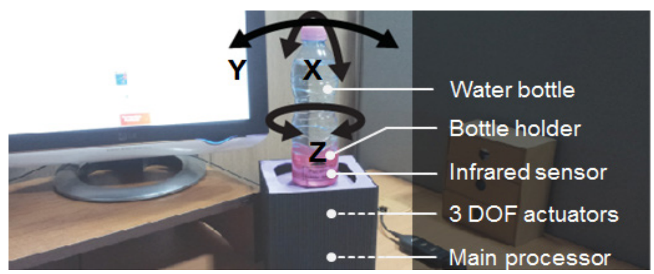



**Figure 1. The moving water-dock prototype.**

### Movement Design

We designed the water-dock's movements according to contexts of water-drinking activities. First, we listed seven possible messages for the water-dock (Table 1).

| User Context | Message |
|---|---|
| Turned on | Start |
| The dock is empty | Give me the bottle back |
| A bottle is loaded on the dock | Bottle checked in |
| No drink for 20 min. (water level $\geq$ 2/3) | Please drink 1 |
| No drink for 20 min. (2/3 > water level $\geq$ 1/3) | Please drink 2 |
| No drink for 20 min. (water level < 1/3) | Please drink 3 |
| A bottle of water has been finished | Bottle finished |

**Table 1. Contextual messages of the water-dock.**

Then we applied the systematic movement design method to assign appropriate movements to the intended messages (see the Appendix for details). As a result, seven movements were designed for the water-dock (Figure 2).

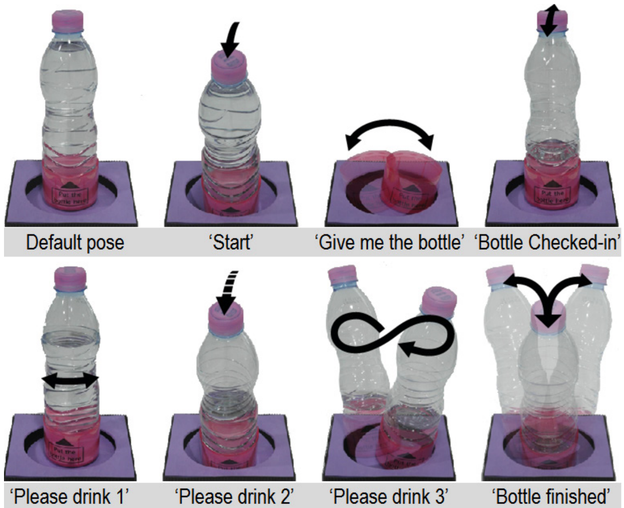



**Figure 2. Movements of the water-dock.**

### Participants and Conditions

To find out whether the water-dock's movements affected the users' drinking patterns or not, we designed a baseline experiment [27] spanning four weeks (4–5 days per week, from 10:00–18:00) with the following conditions: no-movement condition (baseline) for week 1 and 3 and moving condition for week 2 and 4. We recruited two participants (1 male, 1 female, both 29 years old) who spend most of their time sitting at their desks. Each participant used the water-dock somewhere within his/her sight.

### Measurements

To identify the changes, we measured the quantity and frequency of water consumption for four weeks and conducted semi-structured interviews before and after the four-week experiment.

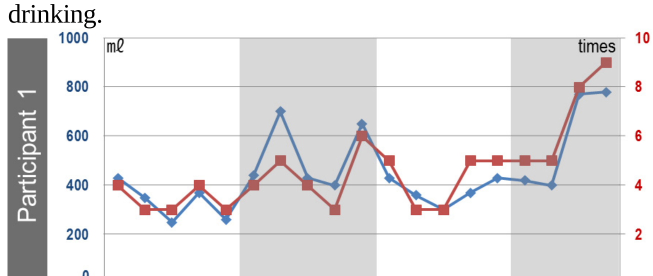
Each participant was provided with a sufficient number of 500 ml plastic water bottles and was asked to always keep a bottle in use on the water-dock except when drinking. They were also asked to take a front-view photo of the water bottle and send it through a smart-phone messenger every time they drank water, whether the water-dock was moving or not. Whenever they sent a photo, the time of drinking was automatically logged in the messenger. We measured the accumulated water quantity they drank with each photo by importing it into Adobe Photoshop under a transparent layer of 10 ml-unit scales.

In the pre-interview, the participants were asked about how they usually drink water. In the post-interview, they were asked about how their feelings toward the water-dock changed over the four weeks. In addition, the two participants were asked about how they interpreted the designed movements in different ways: participant 1 (P1) was asked to guess the meanings of the seven designed movements and was told about the design intention before the experiment, whereas participant 2 (P2) was asked the same questions after the experiment. This aim of this difference was to determine whether the designed movements would be correctly understood by P2 even without any explanation.

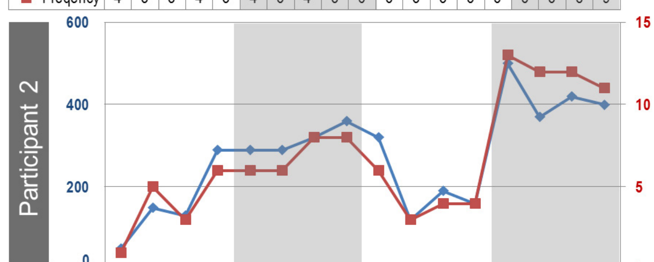
### Findings

*Changes in Water-Drinking Pattern*

As task measures, water-drinking quantity and frequency over the four-week period are shown in Figure 3. We observed significant rises and falls of the task measures in the two participants' water-drinking patterns. Independent-measures t-tests were conducted to verify the differences between week 1 and 2, 3 and 4, '1+3' and '2+4'. P1 drank 58% more water ($t(8)$=-2.296, $p<.05$) in week 2 than in week 1; 60% more frequently ($t(7)$, -2.401, $p<.05$) in week 4 than in week 3; 41% more water ($t(17)$=-3.493, $p<.01$) and 29% more frequently ($t(17)$=-2.399, $p<.05$) in week '2+4' than in week '1+3'. Similarly but more significantly, P2 drank 103% more water ($t(6)$=-3.042, $p<.05$) and 89% more frequently ($t(6)$=-2.6, $p<.05$) in week 2 than in week 1; 113% more water ($t(6)$=-4.374, $p<.01$) and 180% more frequently ($t(6)$=-10.333, $p<.01$) in week 4 than in week 3; 109% more water ($t(14)$=-4.758, $p<.01$) and 138% more frequently ($t(14)$=-4.721, $p<.01$) in week '2+4' than in '1+3'. In short, the movements of the water-dock seemed to effectively provide the users with a visceral level of experience, in response to which they exhibited an instantaneous response for healthy drinking.




| Week | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Quantity | 430 | 350 | 250 | 370 | 260 | 440 | 700 | 430 | 400 | 650 | 430 | 360 | 300 | 370 | 430 | 420 | 400 | 770 | 780 |
| Freqency | 4 | 3 | 3 | 4 | 3 | 4 | 5 | 4 | 3 | 6 | 5 | 3 | 3 | 5 | 5 | 5 | 5 | 8 | 9 |




| Week | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Quantity | 50 | 150 | 130 | 290 | 290 | 290 | 320 | 360 | 320 | 120 | 190 | 160 | 500 | 370 | 420 | 400 |
| Freqency | 1 | 5 | 3 | 6 | 6 | 6 | 8 | 8 | 6 | 3 | 4 | 4 | 13 | 12 | 12 | 11 |

**Figure 3. Water-drinking patterns with the water-dock. Gray shading: moving condition.**

*Changes in Feelings on the Water-Dock*

For week 1, both participants did not mention any specific feelings about the unmoving water-dock. They drank water as usual and got used to docking a bottle on it after drinking.

As the first impression of the moving water-dock in week 2, P1 said, "It was very funny," and P2 said, "It was surprising and cute." Regarding familiarization, P1 said, "Its presence became stronger compared to week 1…. It seemed to watch over me…. When it moved, I realized that I had not drunk water for a while," and P2 said, "I felt more responsibility to take care of it…. I liked its lifelikeness, so I started to use it more…. Sometimes when its movements hit against the wall, I felt sorry for it." On the other hand, P1 recalled, "Sometimes I was bothered by its aggressive movements when I needed to concentrate on my work," but P2 did not report any negative experience. It seemed that a certain level of behavioral UX—related to emotional behavior changes—started to take place as well as visceral UX.

In week 3, the movements were deactivated. P1 said, "I felt bad about it losing its lifelikeness … but I also appreciated the calmness when I was working hard." Similarly, P2 mentioned, "I was bored and felt sorry that it returned to become a non-life." The UX in week 3 could not fulfill the user expectations reflected in week 2 until the movements of the water-dock were reactivated in week 4.

To sum up the participants' comments, the movements of the water-dock represented lifelikeness and a stronger presence, so it was successful in drawing attention and instant reactions from users, which seemed to start a chain-reaction leading to behavioral and reflective levels of UX.

#### *Interpretations of the Water-Dock's Movements*
P1 was asked to guess the meanings of the seven movements of the water-dock before the experiment. His interpretations were aligned with the original design intensions for the following five movements (presented as: 'intended message (movement label for the aforementioned method)'→'interpreted message'): 'start (deep-bowing)'→'start,' 'bottle checked-in (yes)'→'nodding,' 'please drink 1 (acting cute)'→'acting cute,' 'please drink 3 (dizzy)'→'dizzy,' and 'bottle finished (dancing)'→'dancing.' However, his guesses were quite different for the other movements: 'please drink 2 (sleepy)'→'agonizing,' and 'give me the bottle back (raucous)'→'no.' Given that no contexts and no other modality were provided, such a misinterpretation is likely.

On the other hand, P2 interpreted most movements in relation to the water-drinking context: 'start (deep-bowing)'→'hello,' 'bottle checked-in (yes)'→'nodding,' 'please drink 1 (acting cute)'→'look at me,' 'please drink 3 (dizzy)'→'drink more,' 'bottle finished (dancing)'→'finish it,' and 'give me the bottle back (raucous)'→'drink more.' However, she could not guess any meaning from 'please drink 2.'

Based on the above results, it seems that the water-dock's movements stimulated the users to naturally associate them with human-like messages.

## STUDY 2: MOVING ASSIGNMENT-BOX

### Product Concept
Submitting an assignment can be stressful but is nevertheless unavoidable for all students. A moving assignment-box may alleviate the tense and the inhumane experience by inducing the students to carry out affective behaviors.

### Prototyping
The moving assignment-box is composed of an A3-paper box, a main processor, and a stand in which two actuators about the X and Z axes with an assembly of gears are covered by elastic fabric (Figure 4). A slot for submissions is located on the top of the front face of the box. Using a remote controller, the operator can control pre-programmed movements through the *Wizard of Oz* method [8].

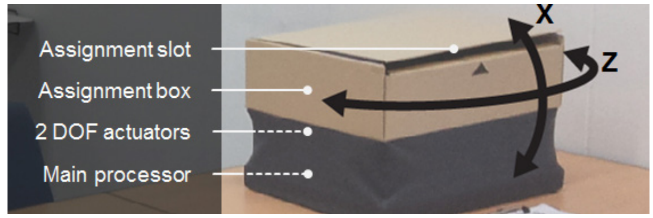



**Figure 4. The moving assignment-box prototype.**

### Movement Design
We listed seven possible messages for the moving assignment-box (Table 2). The first four messages were positive expressions to be shown before the due time, and the last three movements were negative ones to be shown after the due time. Then we applied the design method to create proper movements for the seven messages (see the Appendix). Figure 5 presents the resulting movements of the assignment-box.

| User Context | Message |
|---|---|
| The user enters the room | Waiting for you |
| The user approaches | Hello |
| The assignment is submitted | Submission in |
| For five earliest submissions | Ranked submission |
| Right after due time | Overdue 1 |
| For late submissions | Overdue 2 |
| The user goes out after late submission | Overdue 3 |

**Table 2. Contextual messages of the assignment-box.**

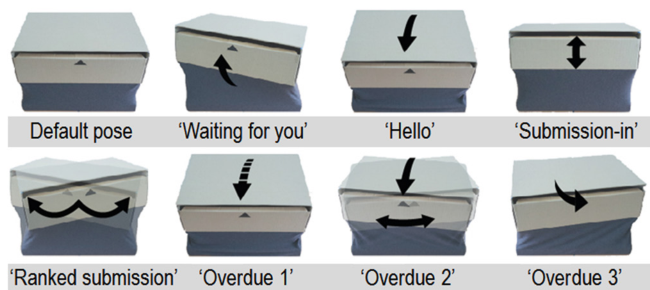



**Figure 5. Movements of the assignment-box.**

### Participants and Conditions
We contacted an undergraduate class with a weekly paper-based assignment to recruit our participants. Before starting our main observation, we tracked the submission-times of all 38 students for two weeks and then divided them into two groups for an evenly matched-groups design [27].

Group A, the control group, used the unmoving box (box A), and group B used the moving one (box B) for eight weeks of submissions (Figure 6). The students were asked to submit their assignments during the period from 17:00 to 18:59 on Tuesdays, but late submissions were also accepted from 19:00 to 20:00 with a penalty proportional to the amount of the delay. Thus, the negative expressions of box B were presented after the due time, 19:00.

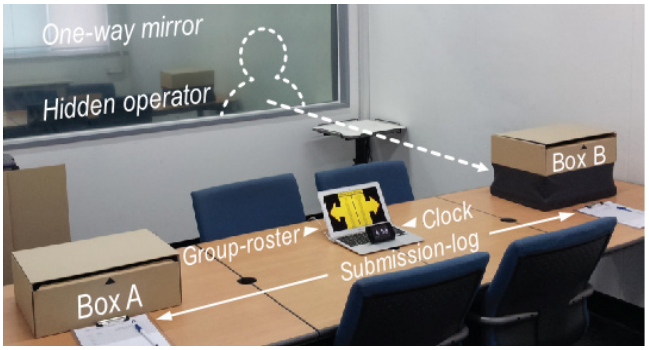



**Figure 6. Observation settings of Study 2.**

The two boxes were set up in a user test room where a one-way mirror and CCTVs were installed for hidden observation (Figure 6). An operator hid behind the mirror to remote-control the pre-programmed movements of box B and control CCTV. The students were not told about this detail of the observation until the end. They were debriefed and signed agreements during the post-questionnaire session.

### Measurements

To measure the UX with the moving assignment-box, interaction logs were extracted from the CCTV data. The submission times of every student were recorded as task measures; staying duration, number of eye contacts, dialogue, special behaviors (e.g. touch), and the presence of fellow students were considered a body measure. After the experiment, both groups participated in post-questionnaire sessions that included the following general inquiries: the first impression of the moving assignment-box and their reactions to it, the general feeling and reaction to it after the eight weeks, positive and negative effects of it, and suggestions to improve it. The answers were collected in paper documents.

### Findings

#### *Changes in Behaviors*

By analyzing patterns of user interactions with the moving assignment-box, the following were identified.

- **Submission time**: There was no significant difference in submission time between the two groups. It seemed to be influenced mainly by the assignment workload or individual schedules.
- **Staying duration**: We found no significant difference in staying duration between the two groups. The disclosure of box B to the control group's condition might have influenced this result.
- **Eye contact**: Paired t-tests showed different numbers of eye contacts between the conditions. As expected, group B students watched the moving box B more frequently than the stationary box A (box A: 0.128 times, box B: 2.028 times, $t(216)=-17.994$, $p<.01$). Meanwhile, group A students made eye contact with box B, not a lower frequency than with box A (box A: 1.196 times, box B: 1.422 times, $t(202)=-1.554$, $p=.110$). As time passed, the students of both groups naturally watched box B before it moved, expecting the movements from it.
- **Chain-reactive behaviors**: Pearson correlation analysis revealed the behavioral patterns of the participants. Students who used box B laughed more often ($r=.471$) and spoke more often about it ($r=.453$) when they were with other people. Even when they were alone, speaking behavior and other special behaviors such as touching and playing with it were correlated to each other ($r=.426$).
- **Care for the moving box**: Group A students regarded box A as a non-living object; for example, they sometimes tried to force it open for their convenience. On the other hand, group B students patiently waited until box B stopped moving to insert their assignments.

#### *Changes in Feelings on the Moving Assignment-Box*

After the eight weeks of observation, a post-questionnaire was administered to the 38 participants. Because all of them experienced the moving assignment-box directly or indirectly, the entire answer-set was grouped and ranked by percentage without distinguishing between the groups.

- **First impressions and reactions**: When students saw the moving assignment-box for the first time, most of them received a 'novel' impression (56%), followed by 'surprising' (19%) and 'strange' (17%) impressions. Their first reactions to these impressions were 'to look into the box to figure out why it moves' (57%), and 'just being surprised' (30%). This could be explained in terms of the novelty effect such that unexpected movements of the box triggered the viewers' curiosity to examine it.
- **Overall feelings and typical reactions**: After many encounters with the moving assignment-box, they felt they had 'gotten used to it' (27%), or that it was 'friendly and fun' (24%), and 'still mysterious' (22%). Their typical reactions were to 'just keep watching it' (39%), to 'interact with it' (19%), and to 'expect it to be alive' (19%). We think that the novelty effect disappeared gradually and that the movements of the box were considered 'usual and friendly events' during submissions.
- **Positive thoughts**: Participants mentioned 'fun' (46%), 'novelty' (18%), 'trustworthiness' (18%), and 'usefulness' (11%) as the positive effects of the box's movements. Among those answers, trustworthiness was an unexpected value. Some of the participants explained that they felt safer about their submissions due to the lifelike feeling of the box and the 'yes' movement it performed to confirm a successful submission. If such positive values appeal continuously to users, the UX can also be gradually improved on the reflective level.
- **Negative thoughts**: Participants reported 'frightening' (20%), 'ambiguous' (20%), 'uneasy' (20%), and 'bothersome' (15%) experiences as negative UX. The frightening experience might have lessened after the first encounter, but the first impression would still matter. Ambiguity between simple expressions seemed to make the students feel unclear when using it. Uneasy and bothersome feelings might also be caused by the impending due time.

*Suggestions for the Moving Assignment-Box*

For ways to improve the moving assignment-box, participants mentioned 'talking ability' (36%), 'sound feedback' (12%), 'timer function' (12%), 'face recognition ability' (4%), 'voice recognition ability' (4%), and so on. These might imply that the users naturally expect high intelligence from moving products. Such high user expectations should be properly considered by the designers, to prevent a disappointing UX with moving products.

## STUDY 3: MOVING RECYCLE-BIN

### Product Concept

Reflective UX is strongly related to education. Specific knowledge can truly be acquired through iterative practices. A moving recycle-bin is an educational product that may help children form a good habit of picking up trash on the floor, even when nobody is around to tell them.

### Prototyping

Our moving recycle-bin comprises a standing structure and on the stand. Two actuators are placed in the standing structure: one for changing its body orientation (Z axis) and the other for opening a lid on the top (Figure 7). It also has three infrared sensors in a row at the bottom of the box to detect users' approaching directions. Additionally, an operator can manually activate some pre-programmed movements by using a remote controller.

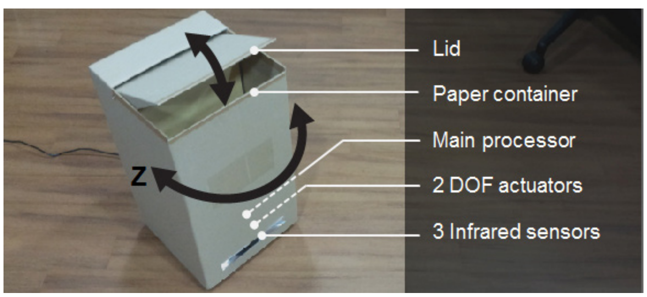



**Figure 7. The moving recycle-bin prototype.**

### Movement Design

We listed seven possible messages for the moving recycle-bin (Table 3) and then applied the design method (see the Appendix). Figure 8 shows the resulting movements. 'Searching trash' and 'have trash?' were sensor-driven movements, whereas the others were operator-driven.

### Participants and Conditions

We contacted a kindergarten, where four-year-old children were to be educated about environmental hygiene. The kindergarten let us work with two classes of four-year-old children, so we designed a between-subjects experiment; class A was the control group using a motionless recycle-bin, whereas class B used a moving one. The housings of the two recycle-bins were identical. The kindergarten already had a trash-can and a paper recycle-bin in each classroom, so we replaced the old paper recycle-bins with ours (Figure 9).

Each teacher of the two classes gave a brief explanation to the children by saying, "Please pick up the trash if you see any on the floor" at the beginning of each day. The teacher of class B, in particular, was requested to ask, "What do you think?" if any child asked about the moving recycle-bin.

| User Context | Message |
|---|---|
| A child approaches | Searching trash |
| The child stays in front | Have trash? |
| A wastepaper is dropped around | Feed me |
| The wastepaper is taken | Yummy |
| A child passes by | Use me |
| For wrong trash/careless use | Wrong use |
| No use for a while | Long time no use |

**Table 3. Contextual messages of the recycle-bin.**


**Figure 8. Movements of the recycle-bin.**

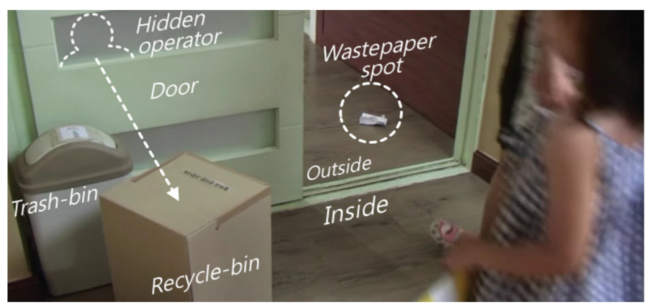



**Figure 9. Observation setting of the moving recycle bin.**

To examine the reflective level of UX, we used a nonequivalent control group design with an interrupted time series [27] for 11 days (Table 4). On the first two days, both bins had no movements to check the two groups' equivalence. The moving recycle-bin in class B was activated on days 3, 5, and 7. Such intermittence aimed first to provide the children with iterative chances of fun practice, second to make them believe that it was not 'dead' even when it is not moving, and third to gradually remove the novelty effect. On the last four days, we removed all the movements again to observe whether the reflective behaviors of children would take place.

| Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Class A | - | - | - | - | - | - | - | - | - | - | - |
| Class B | - | - | M | - | M | - | M | - | - | - | - |

**Table 4. Nonequivalent control group design with interrupted time-series quasi-experiment design. Class A: a nonequivalent control group. M: moving condition.**

### Measurements

Task measures of the moving recycle-bin are indicated by how effectively it induced children to find wastepaper and bring it to the bin. To verify this in an objective way, we secretly placed 'designed' wastepaper at the entrance of each classroom every 30 minutes. We counted the number of times children ignored the wastepaper and passed over it until it was finally brought to the recycle-bin. Fewer occasions of ignorance means that children were dealing with trash in a more responsible manner. In addition, we counted the total number of bin usages, including unexpected trash throwaways. We believed that this artificial setting would not be discerned by the four-year-old children, unlike adults.

A video analysis was used to qualitatively investigate how the children interacted with the recycle-bin along with the changes in the moving conditions. From a viewpoint of body measure, we reviewed 11 days' worth of video data.

After 11 days of observation, we had a group-interview with the children of class B as a subjective measure, with help from their teacher. Children were asked to guess the meanings of the seven recycle-bin movements while watching them one by one. An additional interview of the teacher of class B was conducted to ask about changes in the children's behaviors, the teacher's role in the exercise.

### Findings

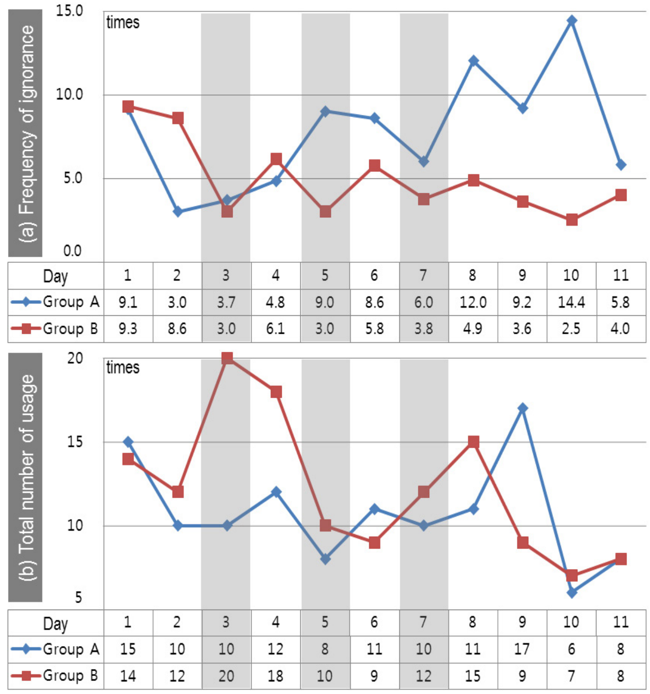
*Changes in Trash-Sensitivity*

The results of task measures are presented in Figure 10: (a) how many times a piece of wastepaper was ignored by children until it was finally brought in and (b) how many times the children used the recycle-bin in total.

- **First two days**: Both classes showed a similar amount of ignorance (A: 9.1, B: 9.3) and total usage (A: 15, B: 14) on day 1. However, class A showed a drop in the amount of ignorance (A: 3.0) on day 2, unlike class B. Based on video analysis, we found that one 'good' child of class A was diligently taking care of the intended wastepaper on day 2 and that this tendency continued for a couple of days, but not for a long time.

- **Movement days**: It seemed clear that the amount of ignorance in class B dropped (8.6→3.0) and the amount of total usage increased (12→20) on day 3, the first day of the moving condition. We observed the same tendency in the amount of ignorance on days 5 and 7 as well. On the other hand, the number of total usages was the highest on day 3, which can be attributed to the novelty effect, and then it decreased throughout the remaining period. From the videos, we even noticed some of the class B children intentionally generating paper trash so that they could use the moving recycle-bin on day 3.

- **No movement days**: On days 4, 6, and 8, which were the days right after the movement days, the amount of ignorance in class B was slightly increased relative to the days right before, but this tendency diminished as time passed. Surprisingly, the ignorance frequency of class B kept decreasing for the remaining days, even without the movements of the bin, whereas that of class A kept increasing overall. A significant difference in the amount of ignorance was revealed based on independent T-tests; Class A vs. B (A: 10.43, B: 3.83, $t(45)=2.533$, $p<.05$); Class B's day '1+2' vs. '8+9+10+11' (day '1+2': 8.93, day '8+9+10+11': 3.83, $t(36)=1.666$, $p<.05$). This result can indicate that the effects of the bin's movements had an impact on the children in a positive way.




| Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Group A | 9.1 | 3.0 | 3.7 | 4.8 | 9.0 | 8.6 | 6.0 | 12.0 | 9.2 | 14.4 | 5.8 |
| Group B | 9.3 | 8.6 | 3.0 | 6.1 | 3.0 | 5.8 | 3.8 | 4.9 | 3.6 | 2.5 | 4.0 |

| Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Group A | 15 | 10 | 10 | 12 | 8 | 11 | 10 | 11 | 17 | 6 | 8 |
| Group B | 14 | 12 | 20 | 18 | 10 | 9 | 12 | 15 | 9 | 7 | 8 |

**Figure 10. Frequency of ignorance on trash and total number of recycle-bin uses. Gray shading: moving condition.**

*Changes in Behaviors*

Video analysis provided a practical way to observe changes in the children's experiences with the moving recycle-bin, reinforcing the findings of the task measures.

- **First two days**: Since there was no movement, there was no special interaction between the children and the recycle-bins for both classes. Instead, the usual behavioral patterns of children regarding wastepaper were observed. Although each teacher gave instructions to pick up trash every morning, most children ignored the intended wastepaper, passed over it, stepped on it, or kicked it but did not pick it up. Wastepaper was properly dealt with by only a few responsible children in both classes.

- **Movement days**: Many kinds of novelty effects of the recycle-bin's movements were observed on day 3. Children in class B talked to the teacher and friends about their surprises. They asked questions of and answered each other about why and how it moved. Similar to the findings of Study 2, the movements induced them to participate in more active engagements with their friends. Most children approached and used the moving recycle-bin more carefully than before. Even though they did not have any wastepaper, they enjoyed calling it, clapping their hands for it, tapping on it, and looking at its interior to understand more about it during breaks. Such behavioral patterns were observed on days 5 and 7, albeit with less frequency. Interestingly, children started to consider separate collections of trash more seriously by sorting them out (or asking the teacher to sort them out) to dispose of them using the correct container, either the trash-can or the recycle-bin. On the other hand, the children of class A showed no improvement.

- **No movement days**: The movements were deactivated for the first time on day 4. Most children used the recycle-bin as usual. Some children tried to interact with it by touching it, opening its lid, looking into it, or just waiting in front of it. The overall sensitivity and motivation of the children toward trash were temporarily dampened. For example, many children came back to ignore the trash again, and some even complained about the regularly appearing wastepaper, which did not occur on day 3. We observed similar behavioral patterns on days 6 and 8. Then they intermittently expressed their hope that the recycle-bin might 'come back to life' again soon.

*Interpretations of the Recycle-Bin Movements*

According to the interviews, children showed a tendency to interpret the movements of the recycle-bin in relation to the 'picking up trash' education. They tended to personify the recycle-bin to identify its emotions. All such interpretations were within our design intentions. The replies of the children are organized in Table 5.

| Movements | Interpretations by Children |
|---|---|
| Searching trash | It follows me/It is watching me |
| Have trash? | Ah ah [with his mouth open]/<br>It asks me to give it some trash |
| Feed me | Ah ah [with his mouth open]/<br>It looks hungry/It wants my trash |
| Yummy | It talks/It eats |
| Use me | It seems to be looking at me/It bows to me/<br>It makes fun of me |
| Wrong use | It says no |
| Long time no trash | It dances/It asks me to dance together/<br>It is looking for trash |

**Table 5. Children's interpretations of recycle-bin movements.**

## DISCUSSION

### Source of Movement Design for Products

The design source of the movements of the three standing kinetic products used in this study was human movements. Even though the prototypes were implemented with two or three DOF for movement-based expressions, participants successfully made sense of anthropomorphic meanings from the movements. Their interpretations varied in detail, but the main nuances were well-received. Participants sometimes referred to animals to explain their interpretations of the designed movements; nevertheless, the messages could not be interpreted by animals but by humans. In this line of thought, applying the essence of human body language to product movements can be a useful approach for movement design, as suggested by Jung et al. [18].

### Three Levels of Strength of Moving Products

*Inducing Sensitive Perception (Visceral Level)*

As observed in the three studies, the physical movements of products invited the users to interact thanks to the innate human sensibility to others' movements. The users kept responding to the movements even after they were familiarized with them. A product using its movements to instantaneously grab the user's attention belongs to the lowest level of interaction design; nonetheless, it will still be critical for further interaction possibilities.

This visceral-level potential can be applied to any object that needs to gain the strong attention of users quickly. For example, urgent product messages such as errors, loss of network, or filling up of trash can be effectively expressed with physical movements. Advertisements can also take advantage of this property for display shelves in shopping malls or for interactive sculptures in public spaces.

*Promoting Affective Interaction (Behavioral Level)*

The human tendency to derive human meanings from movements of a product can be extended to induce users to perform emotional behaviors with the product. In Study 1, the water-dock's movements induced its users to take more responsibility for maintaining it and also to drink more water. In Study 2, facing the moving assignment-box, the students greeted it, talked to it, touched it, and played with it. Similarly, the children in Study 3 also showed socio-emotional attitudes toward the moving recycle-bin. Carefully designed product movements will have the potential to effectively trigger the emotional sense-making of users, inducing them to perform reactive behaviors and respond to the product according to their interpretations.

Product movements seemed to provide users with pleasure, persuasiveness, and empathy and can be built into future interactive products. Such a possibility can be strategically exploited if a designer intends to offer experiences beyond mere functionalities. For example, a mirror can make movements to greet and then adjust its angle toward a user's face, and a vase can tilt down to express a sad emotion to ask for water to replenish the plant inside it.

*Assisting Long-term Adoption (Reflective Level)*

A moving product can be seen as a kind of robot, which means that it excels at repetitive tasks. From a short-term perspective, product movements influenced users in visceral ways. Then, as interactions occurred repeatedly, the users affectively behaved as if the moving product was a life form, whether they could consciously recognize it or not. From a long-term perspective, we envision that living with moving products would help users dynamically change or adjust their habits in positive ways.

In the three studies, many participants asked themselves why the products moved, and routinized their behaviors and feelings based on the answers they found in their given contexts. Later, they naturally expected and enjoyed the lifelikeness of the products and even felt sorry for them when they went back to non-life. This might imply that people will readily accept the presence of moving products and find everyday value in the moving products in their own, unique ways. Designers might be able to guide users in certain directions in terms of various health, economic, or safety issues by meticulously designing appropriate messages and effective movements to convey them. Deriving the intended types of responses from the users through product movements will require the highest level of design considerations, covering possibilities in the visceral, behavioral, and reflective UX domains.

### Considerations for Better Product Movement Design

*Provide Pre-Cues of Movement Not to Frighten Users*
People can be startled by sudden and unexpected movements of a product. In Study 2, several students were frightened by some sudden movements of the box. If surprising people is not a design intention, designers are advised to provide predictable cues, such as structural appearance or sound, to allow users naturally foresee upcoming events. Another possible way is to minimize the energy of the initial movement to make careful presentations to users.

*Consider User Contexts; Do Not Disturb Them*
Movements of a product can physically help users, but there are also possibilities that they will simply bother users. The 'hello' (bowing) movement of the assignment-box was sometimes annoying, especially when the students were inserting the assignment sheets in a hurry. Similarly, the slowly opening lid of the recycle-bin made children wait for a while when they used it. Therefore, the movement design of a product should be reconsidered to avoid distracting or bothering its users in using the product for its purpose. Technologies of situational awareness using various sensors may help products flexibly control their expressions to suit the user's circumstances.

*Strike a Balance with Other Modalities*
Our case studies have concentrated on the effects of pure movements. However, many digital products are complemented with other modalities, such as point light, sound, vibration, or text, for unambiguous communication with users. Our participants' suggestions for the moving assignment-box included adding talking ability, sound recognition, and so on, which shows that the expectation level of users can be quite high when it comes to products moving to communicate. Therefore, to avoid disappointing the users, movements would better be used with other input and output modalities of a product in a well-balanced and supplementary manner. Having said that, this is a great research topic in its own right.

## CONCLUSION AND FUTURE WORK

There is no doubt that the number of moving products will grow in the future. However, there is not enough knowledge regarding the UX of such products in general. In this study, the visceral, behavioral, and reflective levels of UX were initially explored with a research through design approach. We designed three standing kinetic products and brought them to real-world users and empirically observed the corresponding UX. Multi-layered measurements revealed significant potentials of moving products in everyday settings. The discussions in this paper may inspire product designers creating new moving products. Moreover, the procedures and the findings of this study may also promote commercial ubicomp applications.

For future work, we aim to: 1) study more about the interweaved connections between the three levels of UX with moving products from a longer-term perspective, 2) confirm that the lessons learned from our three moving products in this study can be generalized to apply to other moving products, 3) explore synergetic effects of combining the movement modality with other modalities, and 4) find how cultural differences influence users' interpretation of product movements, noting that this study was carried out in South Korea.

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## APPENDIX: THREE MOVEMENT DESIGNS

Jung et al.'s movement design method [18] provides a list of simplified human torso movements with combinations of X, Y, and Z axial components, a list of general messages of interactive products, and a mapping matrix between the two lists. Three steps need to be followed to take advantage of the matrix: 1) identify the available axes of a target product; 2) select the necessary product messages; and 3) determine a mapping with the highest score within the sub-set matrix. We faithfully followed the three steps to design product movements for the three studies in this paper. Figure 11–Figure 13 are the corresponding sub-set matrices we made.

| Expressive Movements | | ON | Detecting a user | Out of something | Input confirmed | Completed the task | Warning of misusage | Water-dock Messages |
|---|---|---|---|---|---|---|---|---|
| X- Deep-bowing | 75% | 5 | | | | | | ► Start |
| X- Yes | 64% | 5 | | | 4 | 5 | | ► Bottle checked-in |
| X- Sleepy | 46% | | | 5 | | | | ► Please drink 2 |
| Y- Raucous | 46% | | | 4 | | | 8 | ► Give me the bottle back |
| Z- Acting cute | 29% | | 4 | | | | | ► Please drink 1 |
| XY- Dizzy | 29% | | | 5 | | | | ► Please drink 3 |
| XYZ- Dancing | 75% | | | | | 9 | | ► Bottle finished |

**Figure 11. Movement design for our water-dock (Study 1).**

| Expressive Movements | | Long time no use | Waiting for a user | Ready to use | Input confirmed | Completed the task | Failed the task | Wrong input | Assignment-box Messages |
|---|---|---|---|---|---|---|---|---|---|
| X- Bowing | 93% | | | 4 | | 4 | | | ► Hello |
| X- Yes | 64% | | | | 4 | 5 | | | ► Submission-in |
| X- Sad | 14% | | | | | | 6 | | ► Overdue 1 |
| Z- Looking arnd | 82% | | 5 | | | | | | ► Waiting for you |
| Z- No | 71% | | | | | | | 6 | ► Overdue 2 |
| XZ- In a sulk | 86% | 4 | | | | | | | ► Overdue 3 |
| X Z- Dancing | 75% | | | | | 9 | | | ► Ranked submission |

**Figure 12. Movement design for our assignment-box (Study 2).**

| Expressive Movements | | Long time no use | Waiting for a user | Detecting a user | Warning of misusage | Recycle-bin Messages |
|---|---|---|---|---|---|---|
| Z- Looking arnd | 82% | | 5 | | | ► Searching trash |
| Z- No | 71% | | | | 5 | ► Wrong use |
| Z- Acting cute | 29% | | | 4 | | ► Use me |
| Z- Stretching | 71% | 5 | | | | ► Long time no trash |

**Figure 13. Movement design for our recycle-bin (Study 3). The movements of the recycle-bin's lid are not shown here, as we mapped them to 'mouth' movements of humans**