Make It Move: A Movement Design Method of Simple Standing Products Based on Systematic Mapping of Torso Movements & Product Messages

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ABSTRACT
Human communication significantly relies on the expressivity of their body movements. Based on these body language experiences, humans tend to extract meanings even from movements of objects. This paper begins with the above human tendencies to create a design method that can help product designers make their products move to communicate. As a research vehicle, we created a robotic torso prototype and utilized it to collaborate with movement experts, and listed up possible expressive movement components. We then built a mapping matrix that links these movements to general product messages. A method which utilizes this mapping matrix was developed to help designers determine a set of effective movements that can communicate specific product messages. Lastly, a design workshop was conducted to identify the usefulness of the proposed method. We expect the procedures and findings of this study to help researchers and designers approach affective user experience through product movement design.

Author Keywords
Product movement; design method.

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous.

INTRODUCTION
Ordinary products are usually stationary. However this does not stop people from imagining animate objects that come to life [27]. The anthropomorphized teapot and clock in the Disney animation 'Beauty and the Beast [38]' and the hopping lamp 'Luxo Jr. [28]' in the Pixar prologue clip make us envision everyday products interacting with us in a more intimate and human-like manner.

There are a number of commercialized products that incorporate emotional movements as design elements. The alarm clock 'Clocky [26]' rolls around and makes a fuss to wake people up; the robotic music player 'Rolly [34]' synchronously dances to the music; the concept car 'GINA [7]' blinks its headlights like a pair of eyes and spreads its doors like a pair of wings. Unlike routine movements of a toy, such movements have potential to add not only functional but also semantic values to products, enriching the overall user experience [9].

Unfortunately, only a handful of such products have been intermittently introduced to the market so far. It may be because their developments depend on inspiration, in the absence of a systematic design methodology that supports designers trying to give movements to products. With this background, this paper aims to establish a design method that can effectively help product movement design.

To begin with, we pay special attention to the fact that people tend to treat objects similar to humans [30]. According to Guthrie [13], anthropomorphism comforts people by allowing them to form relationship, and let them make a better understanding of the world around them. This anthropomorphic tendency also occurs naturally with moving objects [3, 16, 25, 37].

Thanks to this, we can imagine ordinary products coming to life. According to Takayama et al., users can better understand a robot's task when it expresses forethoughts and task-outcomes through movements [36]. We can expect similar application to products, that the user experience can be improved when the products express their internal status or feedback through such movements. For example, a webcam 'gazing' at us for a video-chat, or a phone 'dancing' for an incoming call can be amusing and even helpful.

This study focuses on simple standing products. Products such as a monitor, webcam, speaker, table alarm clock, lamp and trash bin have bodies made up of a single lump and do not have limbs, yet they might be frequently recognized as human figures by users. We expect users to easily interpret meanings from these products if we utilize such an anthropomorphic mapping in designing product movements.

However, giving plausible movements to a product is a difficult task for which the majority of product designers have no training. They often lack the necessary understanding of human's expressive movements. On the other hand, experts in human movements such as choreographers and actors have skills in human expressions that may help product designers, but these experts are not knowledgeable in product messages. To create product movements that successfully trigger the anthropomorphic interpretation of users, we need to draw expertise and insights from both fields complementarily and efficiently.

This paper presents a method to design movements of simple standing products, which effectively utilizes knowledge of body movement experts and product designers. While anthropomorphism may not necessarily be the best approach in every case [35], we intend to support designers who are willing to take advantage of anthropomorphism in product movement design.

RELATED WORK

There have been studies on application of this anthropomorphic tendency in Human Computer Interaction and Human Robot Interaction fields. 'Friendly Vending [4]' attracts attention by rotating its beverage cans towards pedestrians, which showes life-like movements can initiate user-product interaction in a friendlier manner. 'RoCo [1]' rotates and tilts its screen like a head and takes poses to correct a user's seating posture [8]. Similarly, 'Breakaway', a simple, flexible bar-shaped device, bends down as if it is tired, and encourages a long-hour seated worker to take a break [18]. These studies show that movements of objects can influence user behavior in natural and unobtrusive ways.

While sophisticated robots with high DOF (degrees of freedom) can effectively convey human expressions [31], it is notable that even products with extremely simple shapes can induce anthropomorphic cognition. For example, people could interpret welcoming or reluctant messages consistently from a 1-DOF door's movements [20]. The above studies show collectively that even simple movements of simple products can deliver certain meanings effectively.

Such anthropomorphic tendency depends on their experience of the body language. There are many types of body language using different body parts [10, 22, 24], but we focus on the central role of the human torso. The torso expresses four basic postures (approach, withdrawal, expansion and contraction) that set the tone of communication [19], and provides a reference against which to interpret movements of the limbs [6, 29]. In addition, dance studies often consider the head and limbs as supplementary extensions to the torso [17]. The torso has not only a strong influence in body language but also a simple form, so we regard it as a suitable model for product movement design.

After reviewing related studies, it became clear to us that modeling torso movements in product interface design has great potentials, but there were little systematic methods to do this. In 2005, DeSForM (Design and Semantics of Form and Movement) workshop was held to stress the necessity to formulate grammar of movements and develop suitable research approaches and techniques [12]. In this context, we aim to establish a pragmatic design method that will enable designers to apply the movements of the human torso to products in meaningful ways.

To physically implement human torso movements to simple standing products, it was necessary to create a prototype, because it would be difficult to estimate the feelings about expressive movements without experiencing it firsthand [2, 5, 41]. Therefore we built a robotic torso prototype as the main vehicle of this research.

ROBOTIC TORSO PROTOTYPING

The human torso is vastly more complex and flexible than any product can possibly implement, therefore it is necessary to simplify the torso for product design purposes. To analyze the torso movements, to screen for the ones that are universally applicable to a wide range of products, and to extract the essence of human torso expressions, we prototyped a robotic torso. The robotic torso contains four actuators arranged vertically, of which the movements are similar to that of Keepon [21]. Unlike Keepon, however, we rely on anthropomorphism at a higher level of abstraction by focusing only on the movements of the torso, and not on explicit anthropomorphic features such as eyes or nose. The top actuator generates rotation about the Z-axis, the second about the Y-axis, the third about the X-axis, and the bottom also about the Z-axis. The operating range of each actuator is from -90 to +90 degrees (Figure 1). The primary goal of such an arrangement was to implement the three human anatomical possibilities: flexion, rotation, and extension [17], through the X, Y and Z directional axial movements.

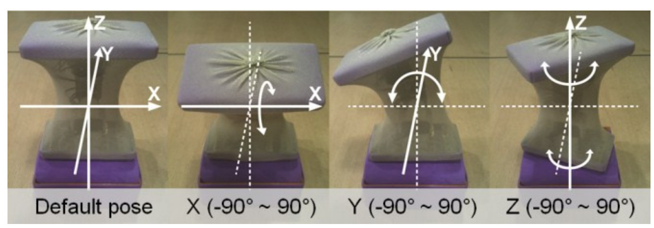

Figure 1. A robotic torso prototype

RESEARCH PROCEDURE

As expressive channels of products diversified with technological advancements, researchers have been attempting to map expressions to various meanings (Figure 2(a)). Modalities such as light, sound and haptic feedback have been explored [14, 23, 40]. In particular, Harrison, et al. investigated point light sources attached to various digital devices, and mapped different light patterns with the five most common product messages: notification, active, unable, low-energy, and turning on [14].

We intend to follow a similar path. However, the modality we deal with is movement in 3D space and time, which enables much more diverse 'expressions' and 'meanings' than modalities with fewer dimensions. Because of this, the expressions and meanings could not be mapped directly. So we instead devised a multi-step procedure explained below (Figure 2(b)). In addition, for our method to be applicable to different products in general, we avoided working with a particular product, and instead worked with the robotic torso prototype. The robotic torso served as a universal actuating body which can approximate a wide range of simple, standing products.

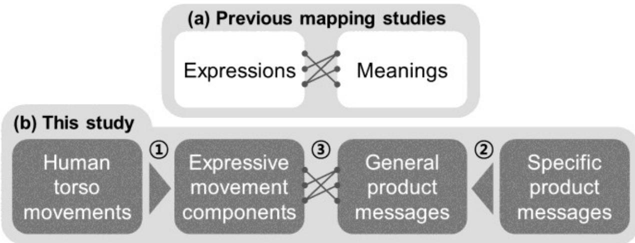

Figure 2. Comparison between previous expression-meaning mapping studies and our multi-step approach

① We assembled a group of experts on body movements, and asked them to recommend a list of expressive movements that can be performed by the robotic torso, by referring to human movements. These movements were categorized by actuation directions and could be combined as components to create a richer movement. Then we conducted a survey to ensure that even when human movements are simplified with low DOF, they are still understandable to ordinary observers. In addition, we hoped to build a reusable database by organizing the expressive movements according to 'product movement axes', instead of directly assigning them to specific 'product-level messages'

② We conducted a workshop, in which designers generated a list of messages that an interactive product may need to operationally express. Then the designers generalized and categorized these messages. We tried to make this list of product messages general and exhaustive, so that it covers any particular product messages that a particular product may need to express.

③ We investigated which expressive movement can distinctively represent which product message, and attained a movement-message mapping matrix. The movement experts were heavily involved in this step as they were in the first step. However, by separating step 1 from step 3 we hoped to avoid the situation where the movement experts would be required to directly come up with movements for specific product-level messages (e.g. out of memory storage, battery fully charged, etc.) of specific products, which is beyond the scope of their expertise.

With the knowledge gained from the above three procedures, we devised a method to apply the mapping matrix obtained in step 3 in real product design. This method is to assist designers in determining the optimal set of appropriate movements that correspond to the desired messages of a product. To verify the usefulness of this method, we facilitated another workshop, in which we observed and analyzed how designers use this method in an actual movement design task. At the end of this workshop, interviews were conducted to gather feedbacks.

ROBOTIC TORSO MOVEMENTS

Using the robotic torso as our test-bed, we wanted to attain meaningful expressive movement components that it is able to perform. For this purpose, we conducted an expert workshop and a user survey.

Recommendation of Expressive Torso Movements

We wanted to investigate the expressive capability of the robotic torso. So we organized a workshop and invited an actor and two choreographers, experts who are knowledgeable in communicating through body movements, because we judged that a small number of movement experts would be more beneficial than a crowd of novices or product designers who lack both the experience and the insight in movement-based expressions.

In the first phase of the workshop, we asked the experts to have an action-brainstorming in which they performed with their own bodies to demonstrate as many kinds of body expressions as possible. Through this activity, 64 different kinds of human torso movements were listed up in total. Among these, 41 were stand-alone expressions which could be performed without contacting other people or objects, for example picking up, pushing or riding something.

In the second phase, the experts were given the robotic torso prototype, and were asked to translate these expressions via puppetry. Puppetry is a handy technique with which movements can be quickly simulated without the need of programming or other time-consuming preparations [41]. During this investigation, the experts determined that the robotic torso was capable of performing 28 expressive movements of the 41 human torso movements (Figure 3). To recreate these recommended movements, temporal data such as speed and rhythm were necessary and were provided by the experts through visual and verbal instructions.

A close look at the recommended movements reveals distinct characteristics of movements about each axis. First, the X-axis movements were the most versatile. These communicated positive intentions such as 'bowing', 'yes' and 'listening', and levels of consciousness such as 'fainting', 'sleepy' or 'surprised'. Second, the Y-axis movements were useful in communicating 'thinking' and 'dubious'. Third, the Z-axis movements conveyed 'looking around', 'no' and 'shuddering', among others. Furthermore, multiple-axes movements expressed richer and more nuanced meanings such as 'in a sulk' and 'despairing'.

The experts provided a number of comments on the limitations of the robotic torso. First, they agreed on that facial expression is the primary channel of emotional communication and found it difficult to express some emotions only through movements [11]. Second, some movements such as crouching and vertical extensions were impossible to perform due to the limited number of actuators in the robotic torso. Despite these shortcomings, the experts noted that a diverse range of intricate human body expressions could be translated into a mere 4-DOF robotic torso, and that this

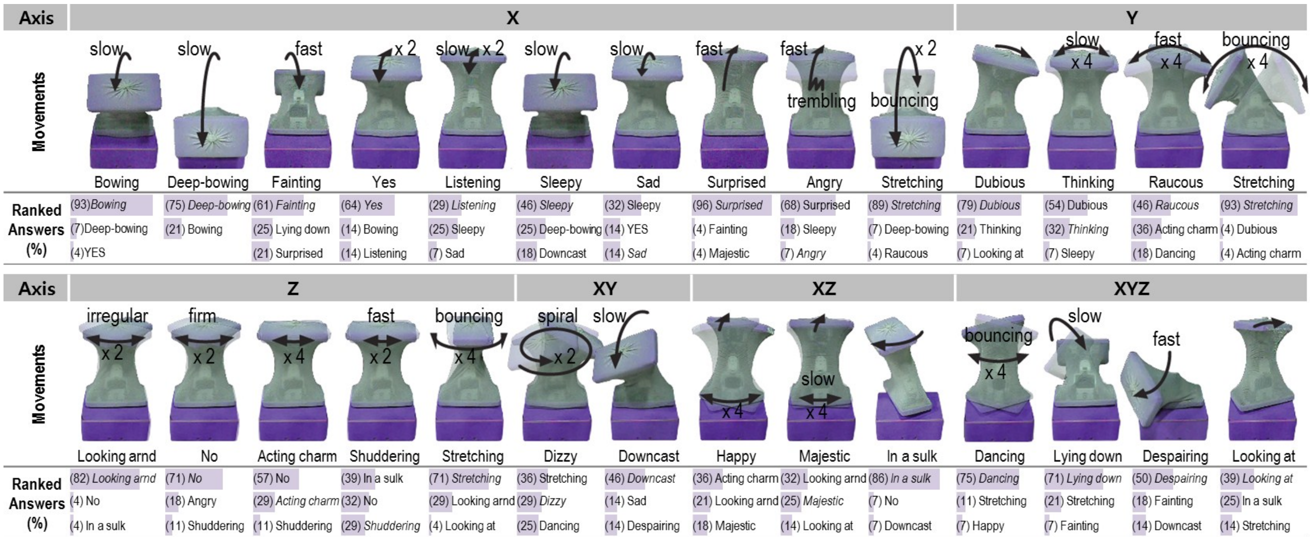

Figure 3. 28 recommended movements and their ranks of recognition

was unexpected from such a simple device. However it was necessary to carry out further investigation in order to identify how well an unsuspecting observer can understand the meanings behind the movement of the robotic torso.

Recognition of the Recommended Torso Movements

After using the data from the experts to program the robotic torso, a survey was carried out to make sure if the recreated movements can be recognized as originally intended. We asked participants to watch movements of the robotic torso placed in front of them and guess their meanings. Because some expressions differed only slightly (e.g. 'yes' and 'listening'), we were concerned that the answers might be affected by the order in which the movements were presented. To counter balance this bias, we used a 28 × 28 Latin square and gathered 28 participants (14 male & 14 female; aged between 18 & 31). Like contemporary dance presented on an empty stage, movements presented without any context could be difficult to interpret meanings from it. So each participant was given a scrambled list of 28 descriptions as a referential vocabulary to guess from, but was not confined to it, and was free to make up answers or even omit an answer. During the survey mimicking behaviors were frequently observed among many participants, which means they used their own movements as references.

The first to the third most frequent answers and their percentages for each of the 28 expressive movements are presented in Figure 3. (Participants could submit multiple answers, so the sum of percentages can be higher than 100% for each movement). For 21 out of 28 movements, the most frequent answer matched the experts' intention. Expressions corresponding to verbs such as 'bowing' (93%), 'deep-bowing' (75%), 'fainting' (61%), 'X-stretching' (89%), 'Y-stretching' (93%), 'looking around' (82%), 'Z-stretching' (71%), 'dancing' (75%), 'lying down' (71%), and simple symbolic expressions such as 'yes' (64%), 'no' (71%) were well-received without any contextual clues.

On the other hand, expressions corresponding to emotional adjectives such as 'sad' (14%), 'angry' (7%) and 'happy' (4%) were ill-received as predicted by the experts. Nevertheless there were the special cases of emotional expressions that recorded high percentages of agreement. 'Surprised' (96%) showed a sudden movement which could not be mistaken for any other expression, and 'in a sulk' (86%) and 'despairing' (50%) made use of multiple axes and accurately described the original movements.

In addition, similar movements with slightly different tempos or angles were not sufficiently differentiated. For example, participants found it hard to distinguish between 'bowing' and 'deep-bowing'; 'listening', 'sleepy' and 'sad'; 'surprised' and 'angry'; 'dubious' and 'thinking'. Nevertheless, most of such ambiguities occurred only over the same axis combinations, and this was especially so for movements with similar nuances. This was expected considering the fact that these movements were presented without any contextual clues. We expect that the meanings may be clearer for the users in the real context.

MESSAGES OF PRODUCTS

We aimed to apply the expressiveness of the torso prototype to many different products, with different messages to convey to the user. Therefore it was necessary to investigate a wide range of interactive product messages. For this we organized a workshop and recruited three Ph.D. students who had experiences in real product design projects. The workshop was divided into two parts: the first being a brainstorming session, and the second a grouping session. A mind-map software was used to organize ideas.

As a result we could come up with two overall categories. The first category is 'informing, absent of user's intention', which describes messages a product sends to the user when he/she is not directly using the product. In it, there are two sub-categories: the first is ‘general status informing’ which passively provides information as to the general operational status of the product; and the second is ‘urgent status informing’ which actively alarms in emergencies and other problematic situations that require user intervention. The second category is ‘feedback on user’s intention’, which provides feedback when the user is interacting with the product. There are four sub-categories: ‘positive feedback’ and ‘negative feedback’ are triggered immediately after a user input; ‘neutral feedback’ sends the user useful and functional information which was anticipated by him/her; and ‘processing feedback’ shows the status of a task being processed. The categories, sub-categories and messages are depicted with a tree chart in Figure 4.

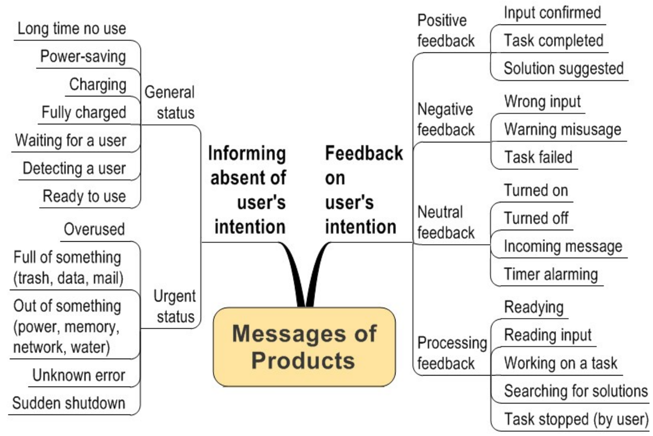

Figure 4. Messages of general interactive products

MAPPING MOVEMENTS TO MESSAGES

At this stage, we had the expressive movements that convey human meanings and the product messages designers generally want their products to express, but did not have knowledge as to which movement can deliver which product message in a meaningful way. So in the next step, we consulted the same three experts who recommended us the expressive movements, as they had the skills and expertise in communicating abstract messages through concrete movements. After reaching an understanding as to the product design goals of this research, the experts evaluated each of the 28 movements’ appropriateness in expressing each product message, and gave a score from 0 to 3. The result has been tabulated in Table 1, which contains arithmetic sums of the scores assigned by the three experts. The score, therefore, ranged from 0 to 9, with 9 meaning the highest agreement among the experts.

We also provide the percentage of agreement for each movement presented without context attained in the user survey so as to assist a product designer in making informed decisions regarding choice of movement in different situations. For example, movements with high percentages of agreement are relatively context-independent and thus they can be selected in any situation, whereas even context-dependent ones may still be selected if the designer expects that the situation in which the movement will be presented will provide enough contextual cues.

Expressive Movements with % of Agreement	Product Messages:	ON	Long time no use	Power-saving mode	Charging	Fully charged	Waiting for a user	Detecting a user	Readying	Ready to use	Overused	Unknown error	Sudden shutdown	Full of something	Out of something	Reading input	Searching for solutions	Task stopped	Input confirmed	Working well	Completed the task	Suggesting solutions	Warning of misusage	Failed the task	Wrong input	Incoming message	Timer alarming	OFF
X- Bowing	93%	4		2		2		3		4					3					3	4							5
X- Deep-bowing	75%	5	2	4				3							1									1				6
X- Fainting	61%		3	2			3				5		8		5			3					2	4	3			2
X- Yes	64%	5				3		3		3						2		1	4	2	5	1					1	
X- Listening	29%	2	1		5		5	1	2							2	4			3								
X- Sleepy	46%		3	3			3					1			5									1				6
X- Sad	14%											1		3										6	2			
X- Surprised	96%		3			3	3	4		2		3	5										4	1	4	3	2	
X- Angry	7%							2		3	3	1	2	2							3		8		3	2	1	
X- Stretching	89%	1	3		3		4		6							1	1			1								
Y- Dubious	79%		1				1		1			9	2			3	3	1					1		3	2		
Y- Thinking	32%	1	1	1	1		1		6	1		2				5	6			3								
Y- Raucous	46%	1				3	1	2		1	9	1	1	6	4								8	2	4	3	6	
Y- Stretching	93%		3		8		3		5									1		2								
Z- Looking arnd	82%	3	1				5	3	3							5	4			3								1
Z- No	71%										1	4		1				2					5	2	6	2	2	
Z- Acting cute	29%						3	4							2						1	2	3	1	2	1		3
Z- Shuddering	29%		2			2		1		1	3	2		1				2	1				5	2	5	3		
Z- Stretching	71%	3	5	2	5		2	3	3	3							2			3							1	
XY- Dizzy	29%	2	3			1	2		4		9	2		4	5	3	3						2	2	1			
XY- Downcast	46%		9	3	1		1				6	1	4		6			1						7	1			5
XZ- Happy	4%	2				9		4		2	3			2		1	1				6	1	2			3	2	
XZ- Majestic	25%	3				3	2	3	2							1	1		2	2	5							
XZ- In a sulk	86%		4								3		1	2				2					3		3			
XYZ- Dancing	75%	2			3	7		3		1						1	3		2	3	9	3	3			6	6	
XYZ- Lying down	71%	1	6	3		1	2			3	6	1	2	1	5					3	3							3
XYZ- Despairing	50%	1	2								7	6	6	1	5			1					2	4	3			2
XYZ- Looking at	39%	1					3	3		1							2											

Table 1. Mapping matrix from expressive movements to product messages

PRODUCT MOVEMENT DESIGN METHOD

This section is to generalize knowledge we have attained thus far to devise a practical movement design method, which allows ordinary product designers to create meaningful movements for simple standing products without having to consult movement experts on case-by-case basis.

In a practical design process, designers need to identify which axes of a product can be actuated. They also need to identify messages this particular product should deliver, and determine movements that can convey these messages. At this stage, the designers can utilize a corresponding subset of the mapping matrix. But this does not necessarily have to be a linear process. The following three steps can be iterated to assist designers to reach an optimal solution (Figure 5).

Step 1: Identify Available Movements.

Different standing products may have different dynamic structures. Products such as a PC monitor and electric fan may already have one to two DOF for actuating, about the X-axis and/or Z-axis. The designer can also consider adding a structure capable of actuating about the X, Y and/or Z-axis for products with no DOF. A designer should identify and determine available axes of movements and consider movements pertaining to these axes only (Figure 5-1).

Step 2: Select Desirable Messages.

The designer should scan through the matrix with reduced rows and select messages that need to be expressed by the product, preferably among messages that have high scores. This operation will reduce the number of columns (Figure 5-2). In addition, the designer may set a zero padding value so as to eliminate all scores below this particular value. Selecting a high zero padding value may help reduce the number of combinations to choose from. The number of desirable messages here should not exceed the number of available movements, so that at least one unique movement can be assigned to each product message.

Step 3: Determine the Optimal Movement Combination.

The previous two steps reduce the original matrix down to a subset-matrix. All movement combinations from this subset-matrix should be compared against one another in terms of total sum of scores. By this stage, the subset-matrix is significantly smaller than the original mapping matrix, so the designer can choose over several plausible combinations without having to deal with a complex optimization problem (Figure 5-3).

DESIGN WORKSHOP

The purpose of this workshop was to verify the usefulness of our design method, by answering the below 4 questions:

- Do designers without the method still design product movements based on human body movements?
- How does our method influence design process?
- What values does our method provide to designers?
- How can our method be improved?

Design Task

Target Product

We selected a household humidifier as our target product. Because it is simple standing product, it does not require complex interactivity, and there has been no example of a moving humidifier so far. We limited its actuation axes to X and Z directions to simulate the engineering constraint that designers may have to work with in practice.

Target Messages

Designers were required to design movements for the following seven messages of the humidifier: 'on', 'off', 'out of water', 'water fully charged', 'humidification necessary', 'humidification sufficient', and 'change filter'. While a humidifier does not usually express the latter four messages, we added these messages to make the design task more challenging and to explore the potential of our method.

Design Medium

We provided a humidifier prop that can be actuated about the X- and Z-axes, so that the designers can design movements through puppetry (Figure 6). Designers could directly manipulate such a tangible medium to visualize movements. The prop had a simple, lumped shape, to avoid the form of the prop biasing the design activity in any way. We asked the designers to 'think aloud [33]' and note down the movement characteristics and the rationales for the movements, so they could present their designs through puppetry and oral explanation in the presentation session.

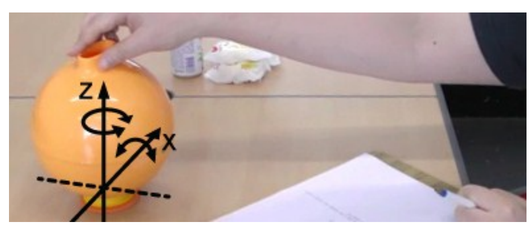

Figure 6. A humidifier prop for design via puppetry

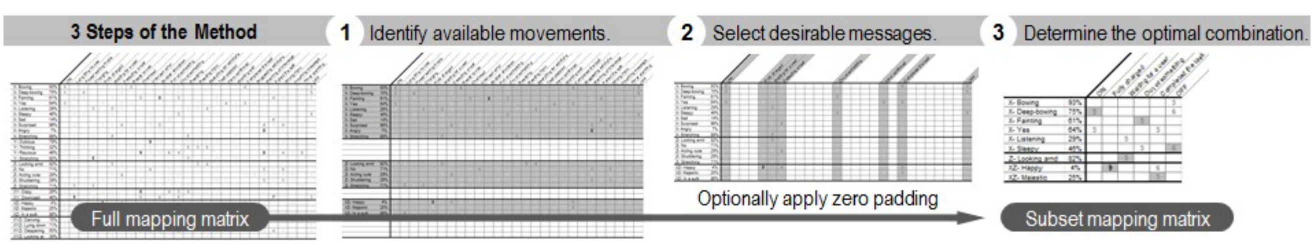

Figure 5. Three-step procedure of our movement design method

Workshop Setting

Participants

Nine participants with industrial design major took part (3 male & 6 female; 3 master's & 6 doctor's course; aged between 21 & 32). These designers all had training in product design, user-centered design, and interaction design, so we expected them to be capable of understanding and performing the required interaction design task.

Conditions

Nine designers were assigned to three different conditions. In each condition, there were equal number of male and female participants, and also doctor's and master's course students. The workshop, however, was not a group activity. It was conducted separately for individual designers.

- **NO** (no-method): Designers were provided with no method and were free to design as they wished. This was the control group condition, against which to verify the usefulness of our method.
- **ONLY** (only-with-method): Designers were required to follow the proposed method thoroughly. This condition enabled us to observe how designers use our method.
- **ALSO** (also-with-method): This is a hybrid of the NO and the ONLY conditions. At the beginning, designers created movements freely without the method, and later, they were introduced to our method, and used it. By this, we wanted to observe if the method can influence the designers' initial designs.

For convenience, we denote the nine designers assigned to three conditions as follows: NO1, NO2, NO3, ONLY1, ONLY2, ONLY3, ALSO1, ALSO2, ALSO3.

Procedures

A maximum of 40 minutes was allowed for all three conditions. We instructed the designers about our method at the beginning of the design session for the ONLY condition, and at the middle of the session for the ALSO condition (Table 2). We instructed the ONLY and ALSO designers about our method once with a MS PowerPoint document. After the instruction, the designers used the provided laptop to access the instruction document and the 28 video clips of the robotic torso's movements. The mapping matrix was provided in the form of a MS Excel spreadsheet, with which the designers could create their own sub-matrices. After the design session, the designers presented and explained their movement designs. And then we interviewed them to ask about the interesting aspects, difficulties, and suggestions for the movement design activity. The entire workshop was video-recorded for qualitative analysis.

NO	Max 40 min.			Presentation	Questions
ONLY	M	Max 40 min.			
ALSO	Max 20 min.	M	Max 20 min.		

M = Method Introduction; grey = Design Activities

Table 2. Three conditions and procedures of the workshop

Design Results

Each of nine designers presented seven movement designs of the humidifier through puppetry and also explained their design rationales. As a result, nine sets of seven movements were produced. Figure 7 is the final movement set designed by ALSO3, given as a visualized example of the results.

Findings

Source of Design

When we analyzed the interviews with the designers and their rationales for their movement designs, all designers used human movements as their source, with one exceptional movement for which the source was movement of a turtle (NO3, 'out of water'). The NO designers personified, for example, 'on' was often designed to assimilate waking up from sleep, and 'off' to assimilate going into sleep. The ONLY designers had no other option but to use the movements from the mapping matrix, where all the movements were derived from human movements. Before the method instruction, the ALSO designers were similar to the NO designers in personifying. From these observations, we judge that our method based on human torso movements, is consistent with designers' common line of thinking.

Patterns of Design

We discovered some interesting differences in design patterns under the three conditions by observing the design activities and design outcomes.

The NO designers took considerably less time (18 minutes) compared to the ONLY (31 minutes) and ALSO designers (36 minutes) on average. This may be because the NO designers performed the design task in a simpler way. After the initial idea regarding movement for each target message was generated by puppetry, they moved on without thorough comparison with other possible movements.

The ONLY designers faithfully followed the method, and their design outcomes were also organized in the given

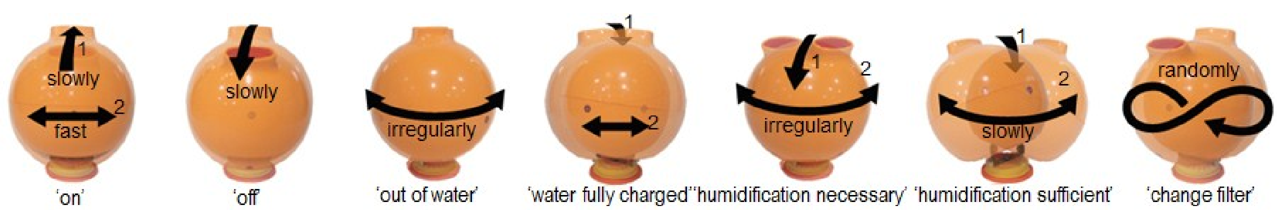

Figure 7. An example set of design result by ALSO3

format. Each of them followed the three steps to extract a subset matrix, and determined a set of seven movements-message pairs based on the highest scores (Table 3). The ONLY designers were interested with the fact that discrete options for movement-message pairs could be provided and that they could select with ease. On the other hand, they thought that this procedure was somewhat mechanical. However, even with the same procedural method, the design outcomes of the ONLY designers significantly differed, reflecting each designer's insights. The designers considered different aspects of the user context, and selected among different movement-message pairs with high scores. For example, ONLY1 thought that the humidifier would be filled with water, so the actuating range of the 'bowing' movement for 'on' should be limited to 30% of that of the original movement. She also selected the 'sleepy' movement instead of 'fainting' not to spill water.

Expressive Movements \ Product Messages	ON	Fully charged	Waiting for a user	Out of something	Task completed	Warning of misusage	OFF	Humidifier Messages
X- Bowing	4	2		3	4		5	▶ Off
X- Deep-bowing	5			1			6	▶ On
X- Fainting			3	5		2	2	▶ Out of water
X- Yes	5	3			5			▶ Humidification sufficient
Z- Looking around	3		5				1	▶ Humidification necessary
Z- No						5		▶ Change filter
XZ- Happy	2	9			6	2		▶ Water fully charged

Table 3. An example of subset-matrix made by ONLY3

The ALSO designers freely designed movements initially, and then later compared their initial ideas with the suggestions by the method. They sometimes chose one over the other, and sometimes fused the movements together. The ALSO designers exhibited the following four patterns.

- **Identical**: The initial movement design and the one suggested by the method were identical (e.g. ALSO3's 'on' and 'off' were expressed by the 'bowing' and 'sleepy' movements both by the initial design and the method).
- **Method selected**: The movement suggested by the method was considered better than the initial idea, and was therefore selected (e.g. initially, the three ONLY designers had different movements for 'humidification sufficient', but later they all chose the 'majestic' movement from the method over their initial ideas).
- **Initial idea selected**: The initial movement design was deemed better than the one suggested by the method, and was therefore selected (e.g. ALSO3 thought that the 'bowing' movement was less interesting than the movement he had originally devised for 'on').
- **Fused**: The initial movement the designer had devised and the movement suggested by the method were fused together to make a more expressive movement (e.g. ALSO2's original movement for 'water sufficient' was spinning once about the Z-axis, but she later added the 'happy' movement suggested by the method).

Of the 21 design outputs of the ALSO group (3 participants × 7 movements), the frequencies were as follows: Identical × 2; Method selected × 9; Initial idea selected × 6; Fused × 4. In other words, 13 (= 9 + 4) out of 21 movement designs were influenced by our method. The designers told us that the method was a useful source of inspiration in developing their ideas. They also said that fusing their own ideas with the suggested ideas was an interesting way of development.

Confidence with Design Results

Designers under the three conditions had different levels of confidence with their design results. We did not originally intend to measure the designers' level of confidence (e.g. with a Likert scale). However, we could qualitatively identify how some designers felt 'unconfident' about their output, when we asked about difficulties of the design task during debriefing interviews.

The NO designers devised their movement designs relatively quickly in a straightforward manner (NO1: 24 minutes, NO2: 11 minutes, NO3: 18 minutes), but as a result, all three of them were not very confident with their results. They suspected that their movements may not be able to deliver the right messages to the majority of users, and some of them were unable to explain the rationale for the movement (e.g. NO3: "I just felt this way").

The ONLY designers, on the other hand, had undergone a comparison process where they reviewed and selected from many different movement-message pairs, and they were less doubtful about their results. However, they felt uncertain about eliminating some movements during the mechanical procedure of the design method.

The ALSO designers were the least doubtful, because they had the opportunity to generate their own ideas, to compare these ideas against the ones suggested by the method, and to fuse the ideas. The method, therefore, may have had the most positive influence on design activities under the ALSO condition.

Suggestions for the Method

The difficulties experienced by the ONLY and ALSO designers who have used our method, and their suggestions to overcome these difficulties are summarized as follows:

- **Improvement of the mapping matrix**: The designers felt difficult when there were no suitable movements for the selected product message in the subset matrix. For example, ONLY2 selected the 'out of something' product message to express 'out of water'. However, many of the movements that could express 'out of something' involved actuation about the Y-axis and were therefore eliminated, leaving him with only a few options with low scores on the final subset matrix. An update of our full matrix can add more expressive movements with higher scores, and may solve this problem. Such an update can be performed by referring to the research procedure of this study.

- **Necessity of software interface**: In the movement design workshop, we utilized the MS Excel to provide the mapping matrix to designers and for them to construct their subset matrices. The designers told us that manipulating the matrix to eliminate irrelevant DOF and product messages were complicated on Excel. We may create dedicated software that supports the followings: easier matrix manipulation; visualization and comparison of expressive movement candidates; interactive interface for giving priorities to some messages or movements; calculation of the sum of all mapping scores, useful for comparison between mapping sets.
- **Simulation with the actual form**: Designers noted the difference in the nuances between the movements of the provided torso video clips and the movements simulated with the humidifier prop. This was due to the differences in form. A software system that can simulate the expressive movements with the user-provided 3D CAD model of the product may help design decision-making.

DISCUSSIONS

The scope of this paper is to devise a movement design method and to verify the usefulness of this method to product designers. In this section, we discuss how users may interpret and accept the product movements produced with the help from our method. Four relevant issues are addressed:

- **Intended messages vs. received messages**: One important issue in interaction design is if users correctly understand messages as the designer had intended. In reality, each user may interpret designed messages differently, so a designer should embrace this multitude of interpretations and not force 1:1 mapping [15, 32]. In this regard, designers should understand that precise communication can be difficult only with movements, and instead take advantage of the fact that movements can be effective in conveying the intensity of expression (intense or subtle) and symbolic gestures ('yes', 'no', 'bowing', etc.).
- **Help of context**: Even humans experience difficulties in communicating through body movements without the aid of context, however delicate and expressive the movements may be. Movements of simple products tend to be less effective than that of humans. Nevertheless, we expect these movements to be understandable in the context of product usage. For example, the confirmatory movement for 'water fully charged' will be easy to understand when it is performed instantly after the user fills the humidifier with water.
- **Help of other modalities**: Real electronic devices nowadays utilize combinations of multiple modalities such as point light, sound, text and graphics to convey messages precisely. Designers should regard product movement as one additional modality, rather than as a stand-alone modality, and design movements in accordance with expressions of other modalities. For example, movements for 'out of water' and 'change filter' were often similarly designed in the workshop, as they both required user reaction. So the ideal interaction scenario would be these movements attracting the user's attention, followed by labeled LED lights indicating the precise information required for user reaction.
- **Role of the design method**: No design methods can guarantee the design quality for certainty. This is primarily because the process of creativity required for design activities is a black box not to be fully explained with science and mathematics [39]. Therefore, for now, each individual designer's capability is still the decisive factor for the quality of the design outputs. Some designers may not be able to attain satisfactory results even with a method, and some more talented designers may be able to do so without a method. The proposed method in this paper aims to provide a framework for infusing expert knowledge from different fields, for a procedure of exhaustive exploration, and for metric comparison between different designs, so that designers can more easily generate ideas, select among them with proper rationale, and have more confidence about their designs.

CONCLUSION AND FUTURE WORK

We start from the assumption that in the near future, product movement design will play an important role in affective user experience. This research applies people's anthropomorphic tendency to movement design, and differentiates from conventional, stationary product design by taking a step towards semantic movements.

The overall contribution of this paper is that it brought human movement expertise and product design expertise together through a step-by-step research procedure. By doing so, we could study movements as exhaustively as possible, without preconception about the messages they are to represent. Likewise, we studied the general product messages as exhaustively as possible. Then we bridged the two systematically to derive the full 'movement-message' matrix which is generally applicable to simple standing products. Without such separated procedures, we believe the mapping would have been difficult, coupled, arbitrary, and unable to take advantage of the richness of full 3D and temporal movements. As a result, we could devise a design method to systematically apply the matrix to produce a desirable movement solution set for a simple standing product.

Specifically, the contributions are: 1) simplification of the human torso to a robotic torso capable of rotating around the X-, Y- and Z-axes and accumulation of expressive movements, 2) generalization and categorization of product messages, 3) construction of a mapping matrix linking expressive movements to product messages, 4) formulation of a step-by-step method for movement design, 5) identification of usefulness of the proposed method by conducting a design workshop. These demonstrate a systematic way to extract quantitative and qualitative information from somatic human expressions and apply it to communicate specific product messages.

For future work, to reflect the feedback from the design workshop and discussions, we will test whether the users correctly interpret the internal status of a product when they recognize its movement, and thus validate our current movement-product message relationship matrix. Long-term user studies involving product designers using our method and end users using the moving products will allow us to update the matrix, as it now relies on the expertise of the three movement experts. While our current matrix served as a useful initial framework, it is not conclusive, and continued validations and updates are needed. Beyond the scope of this paper, exploring the role of arms and legs in expressive movements will provide a plausible extension of the torso model, allowing movement design of various kinds of virtual agents and robots. A more systematic way to manage, analyze and control tempo and speed of movements is needed.

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