A CASE STUDY OF DESIGN FOR AFFORDANCE: AFFORDANCE FEATURES OF A SIMPLE MEDICAL DEVICE

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ABSTRACT
People interact with artifacts, either products or services, in their lives. These interactions are based on two-way communication between people and artifacts. The characteristics of artifacts that induce natural activities of people, *affordances*, play critical roles in making interactions successful and meaningful. *Affordance features* are the structural elements of artifacts that provide affordances. In this paper, affordance features of a simple medical device are thoroughly studied. A task model has been developed based on the usage of a medical expert, and observation of activities of normal users has been conducted. Based on the structural elements of the device identified by state changes in user activity observation, affordance features have been identified. Then these features have been compared with functional features designed to provide the functions of the device. In this way, affordance features particularly designed to provide information- centered affordances were identified together with corresponding functional features.

Key words: Affordance, Design for Affordance, Affordance Features, Context-Based Activity Modeling

1 INTRODUCTION
People interact with artifacts, either products or services, in their lives. These interactions are based on two-way communication between people and artifacts. The characteristics of artifacts that induce natural activities of people, *affordances*, play critical roles in making interactions successful and meaningful. While many authors emphasized the importance of affordances [1], [2], not many systematic methodologies to design in such affordances have been developed.

A systematic method to identify affordances using the interaction between functions and tasks has been proposed by Galvao & Sato [3]. Maier et al. introduced affordance-structure-matrix for evaluating what affordances are embedded in each component of a product and thus grading. This matrix can illustrate correlations of affordances and also of components [4]

The notion of *affordance features*, structural elements of artifacts that provide affordances, has been proposed by Kim and his co-authors [5]. The subjective aspect of people in perceiving affordances, that is, the differences of the way affordance features are perceived by individual users has been discussed [6]. Three kinds of affordance feature classes have been introduced and some critical affordances for a typical household product as a toaster have been discussed [7]. Earlier, Murakami et al. tried formulation of affordance feature for product by showing relations between geometric attributes such as height, aspect ratio between width and length are strongly associated with human activities such as pushing, pulling, turning and tilting [8].

In this paper, affordance features of a simple medical device, a portable infrared crystal lamp, are thoroughly studied. A task model has been developed based on the usage of a medical expert, and observation of activities of normal users has been conducted. Affordances have been identified through the task-function interaction method of Galvao & Sato. Based on the structural elements of the device identified by state changes in user activity observation, affordance features have been identified. Then these features have been compared with functional features designed to provide the

functions of the device. In this way, affordance features particularly designed to provide information-centered affordances were identified together with corresponding functional features.

2 OBSERVATION OF USER BEHAVIOR

The Portable Infrared Crystal Lamp is used in curing and soothing various problems in small areas of body parts. This device is used so that individual people can easily speed up metabolism and help to promote the circulation of the blood. The devices could be used by professional medical service providers in clinics. The product is shown in Fig 1.

Figure 1. The Portable Infrared Crystal Lamp – MEDIBOY

For observation of user behavior of The Portable Infrared Crystal Lamp, we observed actual 18 patients from two hospitals of physical therapy. Furthermore we investigated behavior of a physical therapist for establishing a standard. We observed the use behavior of the specialist (female, thirty+, physical therapist), and defined the general task flow of The Portable Infrared Crystal Lamp. The user behavior of The Portable Infrared Crystal Lamp is divided in three levels, preparation, use and conclusion. However, we observed and analyzed the use part, excluding preparation and conclusion in task flow. Task flow of The Portable Infrared Crystal Lamp has been defined with 12 tasks; Task1: Grasping device, Task2: Moving device (after processing Task1), Task3: Aligning device, Task4: Re-grasping device (for operating lever/button), Task5: Controling lever, Task6: Time setting, Task7: Controling power, Task8: Re-grasping device (for treatment), Task9: Moving device (move to affected areas before Task 10), Task10: Treatment, Task11: Moving device (before Task 12), Task 12: Placing device, and shown in Fig. 2. The observed concrete behaviors by 18 users of The Portable Infrared Crystal Lamp are divided into two types and shown in Fig.3.

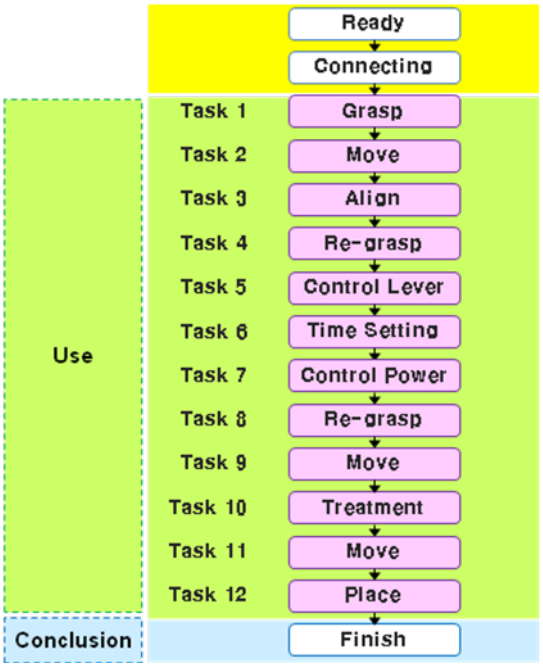

Figure 2. Task Flow of Specialist using behavior of The Portable Infrared Crystal Lamp

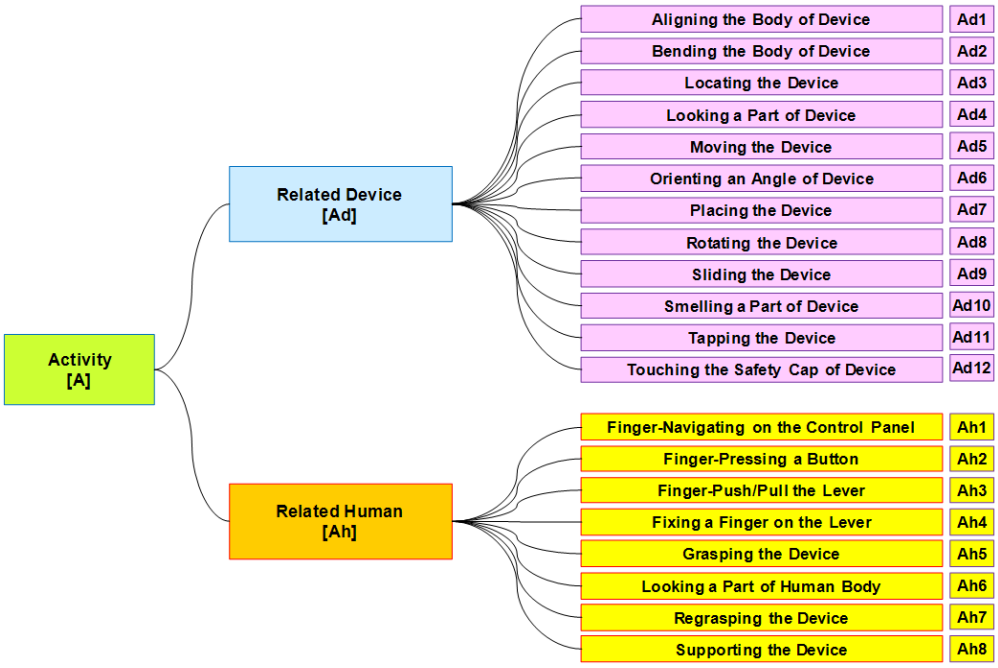

Figure 3. List and categorization of User Behavior of The Portable Infrared Crystal Lamp

3. ACTIVITY ANALYSIS USING CONTEXT-BASED ACTIVITY MODELING

To analyze user activities observed in a systematic manner, the context-based activity modeling method [9] has been used. Its schematic diagram is given in Fig. 4. Especially in the case of this device, the context part has been categorized as follows:

- The goal context has four classes: preparation, treatment, validation/safety and conclusion.
- The relevant structures are the structural elements specifically related to the activities. Thus the body parts to be treated and their geometric characteristics are the relevant structures. These are the back of neck, elbow, palm, back, knee, foot etc.
- Physical context includes location, temperature, lighting condition, sound condition, visibility and posture.
- Psychological context includes occupant context; affective context such as relieved, curious, attentive; and cognitive context, hot feeling and skin-touch feeling; and motivation context, relieving pain and requested.

A specific activity is shown as an example in Fig. 5.

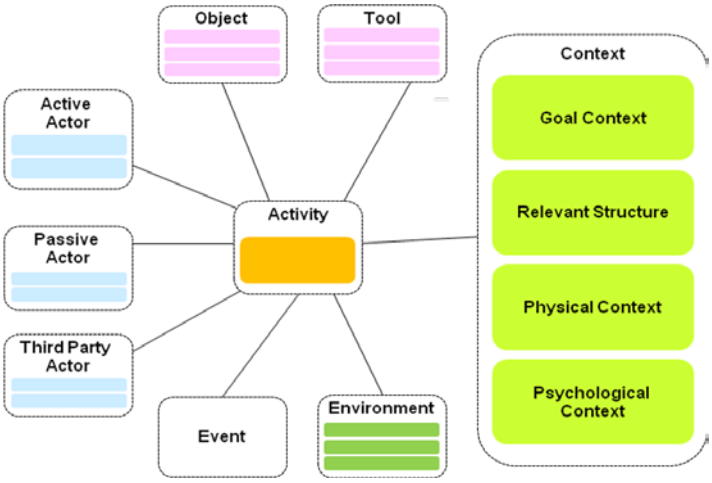

Figure 4. Context-Based Activity Modeling

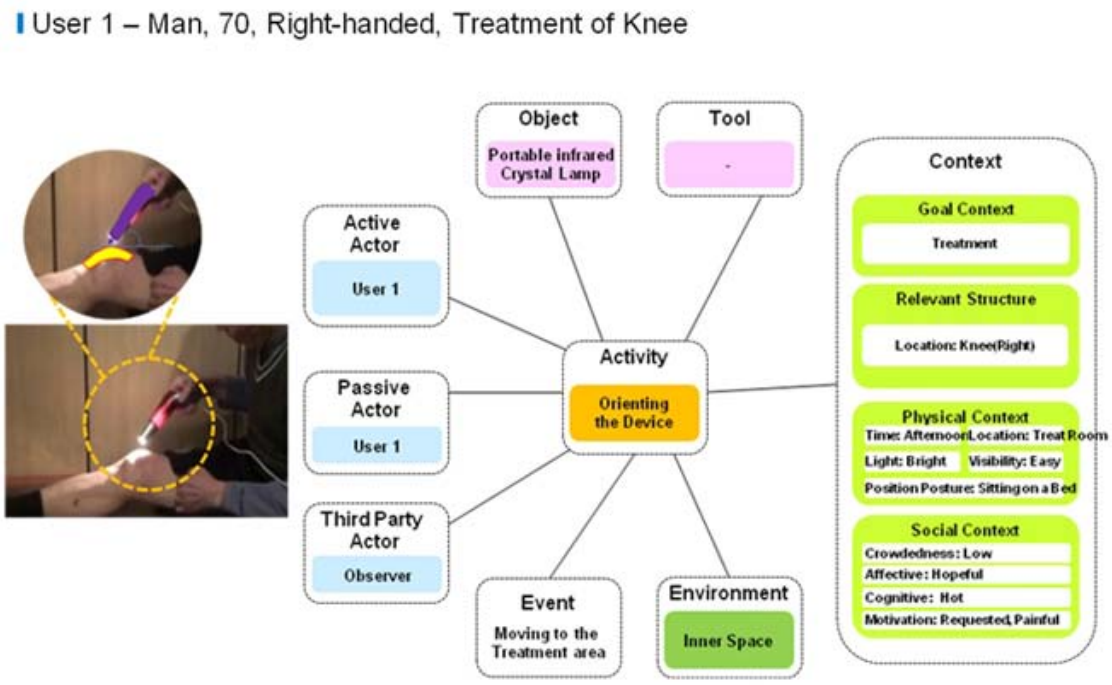

Figure 5. Context-Based Activity Modeling Example

4. AFFORDANCES

Through the observation of use of the Portable Infrared Crystal Lamp, 13 tasks and 20 specific activities were observed. Because there exist affordance features, which induce activities of users, in the Portable Infrared Crystal Lamp, all 18 users did similar activities. When user behavior is changed, state of user is changed, and through such change of state, an affordance is identified [5].

In the process of identification of affordance by observing state change of user, affordances related with hands are identified as follows, and shown in Fig 6.

- 1>2: Grasping device with two hands for holding > Bending the device
  Grasp-ability, Support-ability, Bend-ability
- 2>3: Grasp type change of left-hand holding the body of device:
  Vertical-Upside & Adducted Thumb Grasp > Vertical-Downside & Thumb-3 Finger Grasp
  Regrasp-ability
- 3>4: Right-hand holding the grip > Finding and pushing buttons by the thumb
  Finger Navigate-ability, Finger Press-ability
- 4>5: Controling and Pushing lever with thumb of right-hand.
  Finger Navigate-ability, Fix-ability, Finger Push/Pull-ability

Furthermore, four examples of affordance related with the device are identified as follows, and shown in Fig 7.

- 1>2: Confirming or checking device by looking at the front part after orienting
  Look-ability, Orient-ability

- 2>3: Move device to locate the device to the troubled areas for treating
  Move-ability, Locate-ability
- 3>4: Treating right leg > moving device to left leg and rotating device
  Move-ability, Rotate-ability

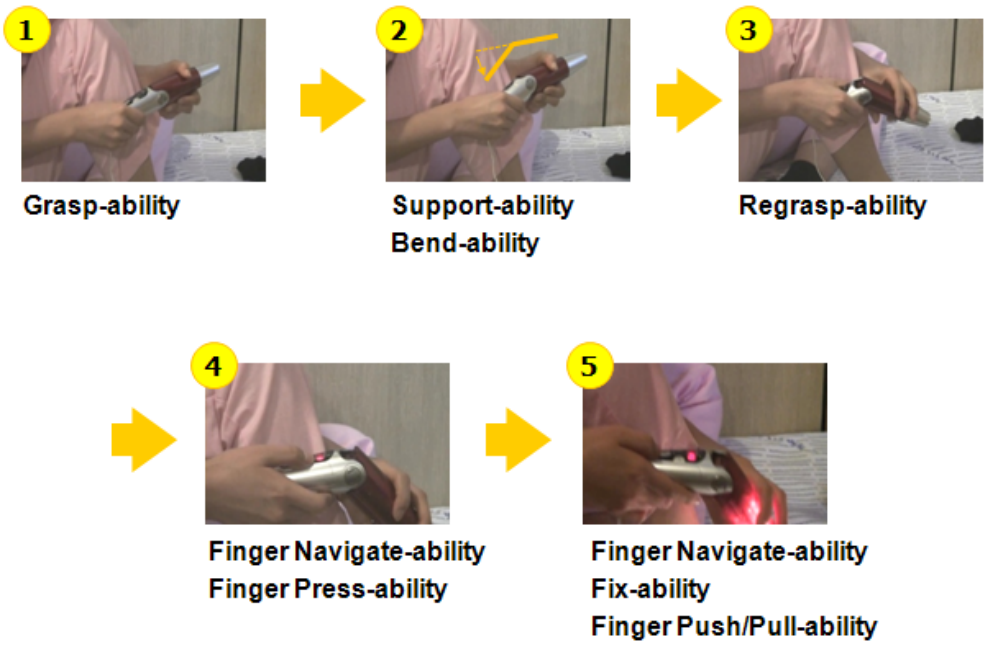

Figure 6. Affordance Identified by State Change

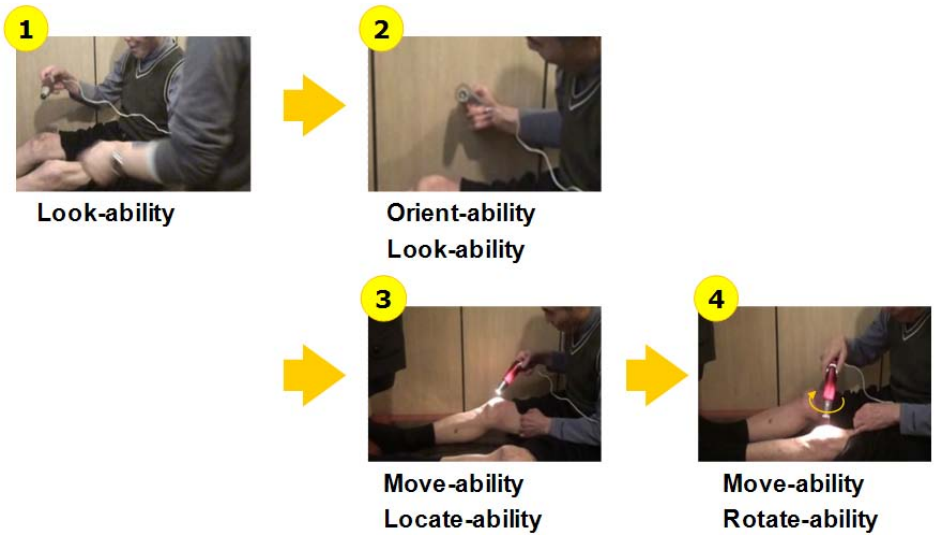

Figure 7. Affordance Identified by State Change

In this way, 18 affordances have been identified by observing user behavior of The Portable Infrared Crystal Lamp and the list is as follows.

- [Af01] Align-ability: Aligning the parallel axis in the device
- [Af02] Bend-ability: changing the parallel axis in the device
- [Af03] Finger_Navigate-ability: Use the fingers, which grasp device, to move
- [Af04] Finger_Press-ability: Use the fingers, which grasp device, to press the button
- [Af05] Finger_Push/Pull-ability: Use the fingers, which grasp device, to push/ pull
- [Af06] Fix-ability: Fixing the fingers to the part of device
- [Af07] Grasp-ability: Use the hand to grasp device
- [Af08] Locate-ability: The device is kept on fixed location.
- [Af09] Look-ability: Looking the device or physical body
- [Af10] Move-ability: Try to change location of the device
- [Af11] Orient-ability: Resetting direction
- [Af12] Place-ability: Relreading device from hand and placing on the other object
- [Af13] Regrasp-ability: Changing position of hand
- [Af14] Rotate-ability: Rotating device
- [Af15] Slide-ability: Repeatation of moving
- [Af16] Support-ability: Maintaining safety condition about power from outside
- [Af17] Tap-ability: Repeatation of tapped actions of device to physical body or other objects
- [Af18] Touch-ability: Touching device with some part of physical body

5. AFFORDANCE FEATURES

The overall function of the device is to radiate infrared light as shown in Fig. 8. To understand how the function is realized, the bill of material, that is, structural decomposition, can be done as shown in Fig. 9. The device is composed of 8 components. To further understand the function-structure relation, the function decomposition has been obtained as shown in Fig. 10 where the relevant structural entities are shown near their functions.

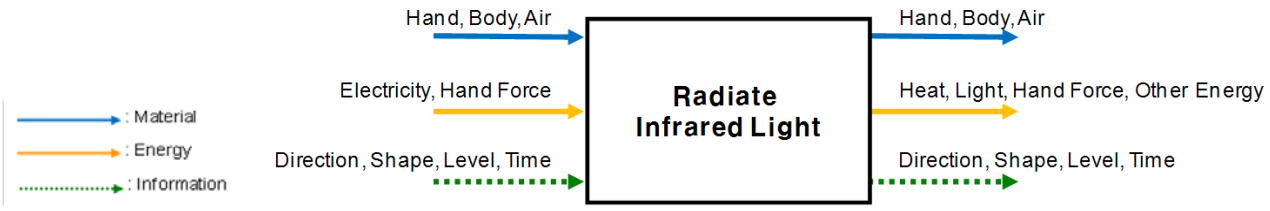

Figure 8. Overall Function

Figure 9. Structural Decomposition

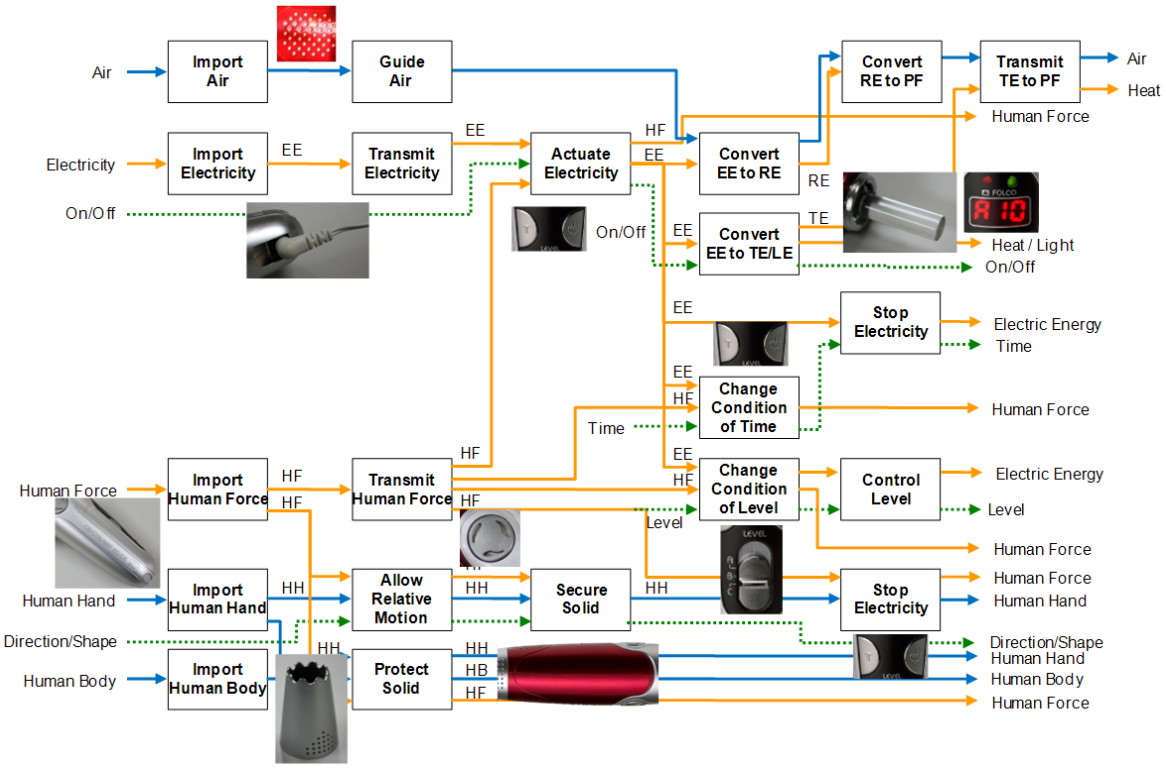

Figure 10. Function Decomposition

Affordance feature (AF) and functional features (FF) have been identified by relating those 18 affordances with components and functions of the device based from the activities of users. The activities of a man who treated knee are shown in Fig.11 together with relevant context aspects.

In the activity of Grasp, goal context (GC) is to get ready and easy visibility of physical context (PC) is noted. Light-emitting part points front, and the diameter and the length of back part are suitable to grasp, thus they are functional features. The position of the air vent on safety cap provided information on top and bottom side of the device, and the triangular shape of the air vent provided information on front and back. These are affordance features.

In the activity of Move, where the physical context has changed to the tilted sitting position, size and weight of device was suitable to move, thus they are functional features. Furthermore, the shapes of grooves and adapter cord in the power part, which can be rotated 360-degree, are functional features.

In the activity of Finger-Navigate and Finger-Press, difference of colors between button and the control panel provides information about the two different parts, and thus it is an affordance feature. The inward button, rather than protruding control panel, supports action of pressing button, and this is a functional feature.

In the activity of Orient, where the goal context is to treat the rear knee, the rear knee is a relevant structure (RS) and the visibility of physical context becomes difficult, the long length of the body due to the long length of the lamp for radiating is a functional feature. The symmetric shape of the body allowing same orientation is an affordance feature as this is not needed in the basic function of the device.

Male, 60+, Right-handed, Treatment of Knee

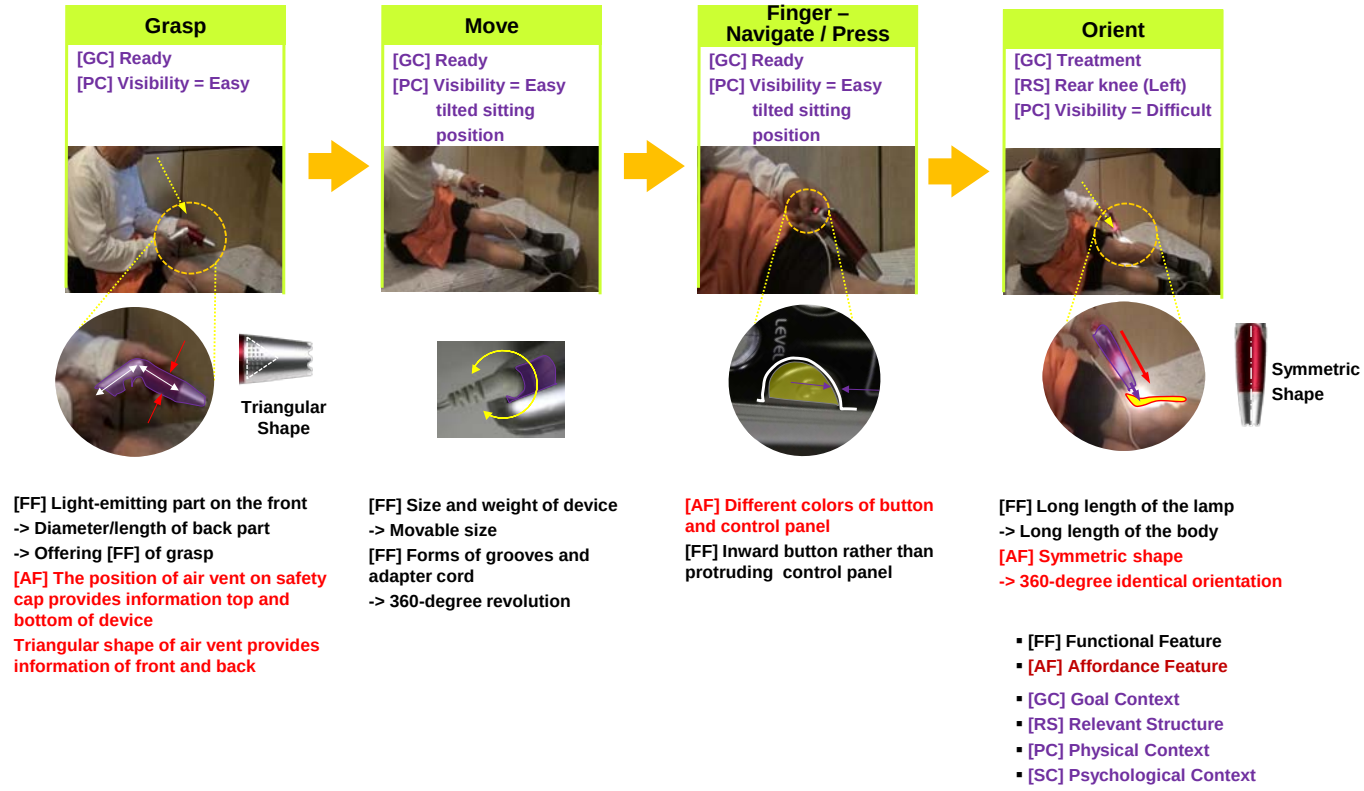

Figure 11. Functional Feature and Affordance Feature 1

The activities of a man who treated rear neck are shown in Fig.11 together with relevant context aspects. In the activity of Regrasp, the shape of cylinder type allows that it can be re-grasped from every direction, thus it is an affordance feature. In the activity of Bend, the difference of colors between body and grip shows that it is composed of two parts, and thus it is an affordance feature. The open space between body and grip shows that it can be bent down, thus it is a functional feature. The circular shape of hinge between body and grip provides information of being rotatable, and is an affordance feature. In the Orient activity with rear neck as relevant structure and difficulty of visibility as physical context, the same functional feature and affordance feature are identified with the case of the first patient.

The activities of a woman who treated arm are shown in Fig.13. In the Grasp, the difference of level of transparency between body and grip allows grasp on the part of grip, not on hot body, thus it is a functional feature. In the first Orient activity, because lamp was entered into safety cap, light directly shed to affected areas, therefore it is a functional feature. In the activity of the second Orient, the wavy shape of edge of safety cap supports safety due to possibility of releasing heat even when touching the skin is a functional feature.

Male, 70+, Right-handed, Treatment of Rear Neck

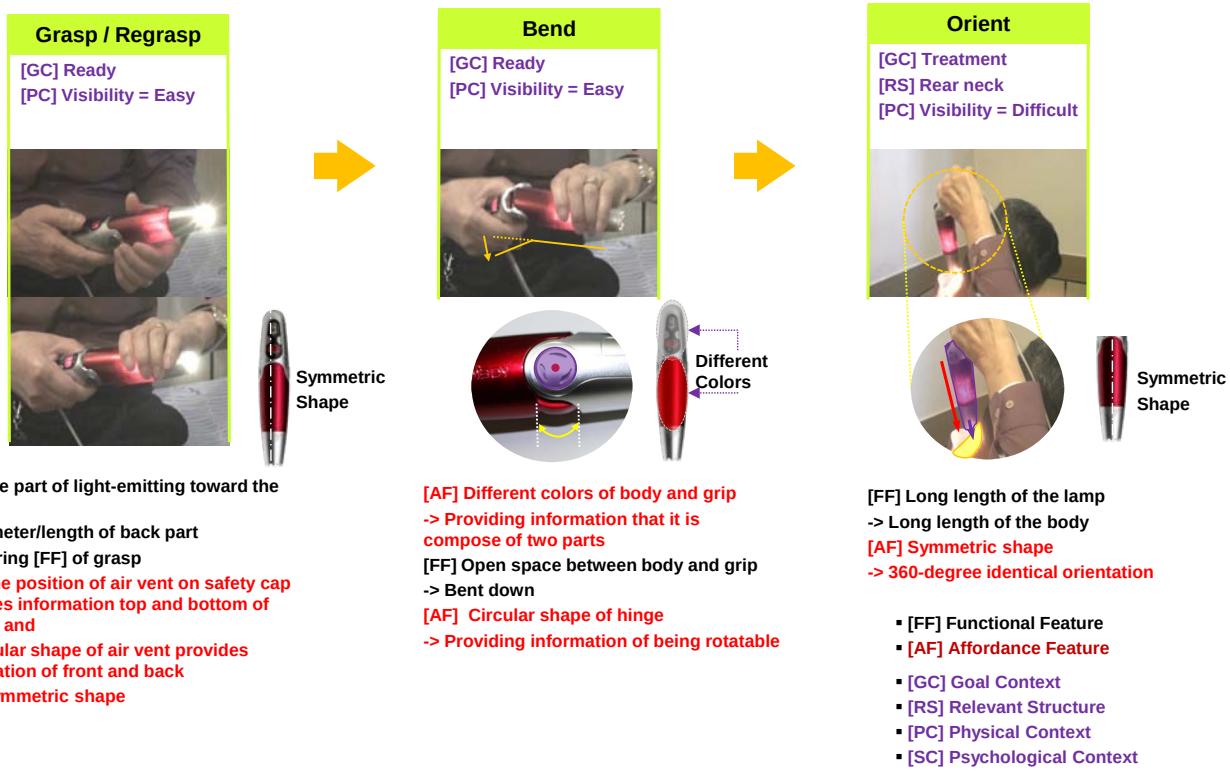

Figure 12. Functional Feature and Affordance Feature 2

Female, 40+, Right-handed, Treatment of an Arm

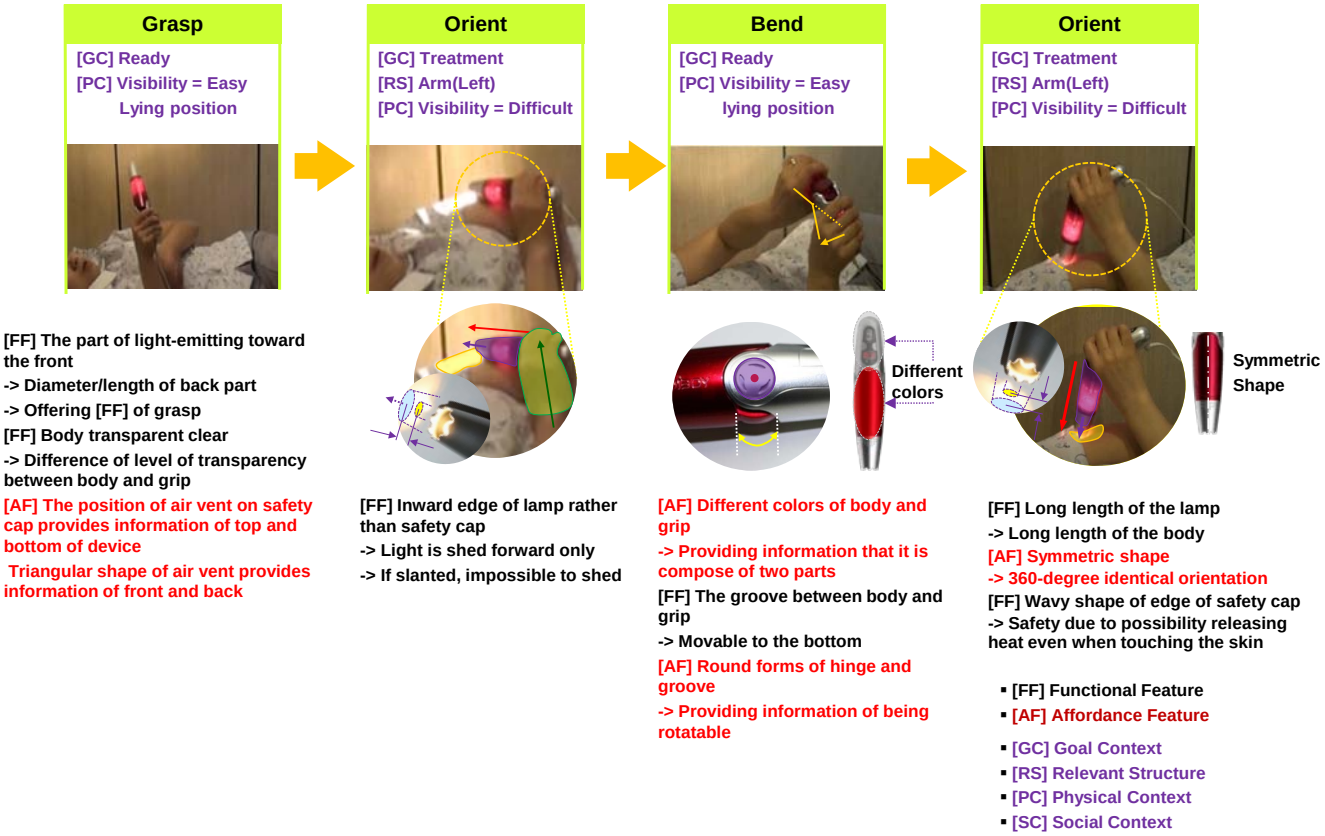

Figure 13. Functional Feature and Affordance Feature 3

6. CONCLUSION

In this paper, affordances of a simple medical device, a portable infrared crystal lamp, have been identified through observation of user activities by noting the state change. Based on the structural elements of the device identified by state changes in user activity observation, affordance features have been identified. Then these features have been compared with functional features designed to provide the functions of the device. In this way, affordance features particularly designed to provide information-centered affordances were identified together with corresponding functional features. The result could be used in providing guidance on activity elements, affordances and affordance features in designing other products similar to this device. Repositories obtained in this way could enable design for affordances.

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