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Development of a usability evaluation method using natural product-use motion

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ABSTRACT

The present study developed and tested a new usability evaluation method which considers natural product-use motions. The proposed method measures both natural product-use motions (NMs) and actual product-use motions (AMs) for a product using an optical motion capture system and examines the usability of the product based on motion similarity (MS; %) between NMs and AMs. The proposed method was applied to a usability test of four vacuum cleaners (A, B, C, and D) with 15 participants and their MSs were compared with EMG measurements and subjective discomfort ratings. Cleaners A (44.6%) and C (44.2%) showed higher MSs than cleaners B (42.9%) and D (41.7%); the MSs mostly corresponded to the EMG measurements, which could indicate that AMs deviated from NMs may increase muscular efforts. However, the MSs were slightly different from the corresponding discomfort ratings. The proposed method demonstrated its usefulness in usability testing, but further research is needed with various products to generalize its effectiveness.

1. Introduction

Ergonomic analysis of product-use posture and motion plays a key role to improve the usability of a product. Product-use posture and motion influence users' satisfaction as well as task efficiency during physical interactions (Clamann et al., 2012). In general, product-use posture and motion are highly affected by the physical design factors (e.g. length, height, and weight) of a product. Thus, the product design based on the ergonomic relationships between users and a product under consideration may help users have more comfortable and convenient physical interactions with a product (Fostervold et al., 2006; Rempel and Horie, 1994; Rose, 1991; Smith et al., 1998; Qin et al., 2013). For example, Rempel et al. (2007) analyzed wrist and forearm postures while keyboarding at various keyboard angles, and found the optimal split (12°) and gable (14°) angles which could reduce the awkward motions of the wrist and forearm.

Most studies analyzing product-use posture and motion focused on the biomechanical load and motion efficiency while users interact with products. Nelson et al. (2000) measured keyboarding motions by an opto-electric finger monitor and analyzed finger/wrist postures and motions based on tendon excursion, angular velocity, and angular acceleration. Moffet et al. (2002) measured wrist postures while a laptop was used on the knees or table with a three-dimensional video system and quantified the deviation of wrist posture from the neutral wrist posture. Morag et al. (2005) measured shoulder, elbow, and wrist postures while operating a trackball at a standing posture using video cameras and identified uncomfortable postures (>30° deviation from the neutral posture). Moore et al. (2014) investigated upper body motions while wearing a spacesuit using an optical motion capture system with eight cameras to evaluate the compatibility between the spacesuit and the upper body movements. Lu et al. (2016) measured ingress and egress motions for the rear seat of minivans using an optical motion capture system and developed eight motion strategies for ingress and egress to propose the ergonomic door designs for minivans.

A few studies have analyzed natural product-use posture and motion which are determined by user preference and used the natural motion information as a reference to evaluate physical interactions between users and a product. This is because using a product with natural product-use posture and motion could

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increase the affordance of a product and the user satisfaction of the product (Chang, 2007). In addition, finding natural product-use posture and motion could provide a better understanding to improve the physical usability of a product. Nyberg and Kempic (2006) demonstrated the usefulness of this approach by examining users' natural drum washer-use motions; they found design directions to improve the physical interactions between users and a drum washer. However, existing studies on natural product-use posture and motion are limited for their qualitative approach in analysis (Allie et al., 1999; Nyberg and Kempic, 2006).

The present study defined natural product-use motion (NM) and developed a usability evaluation method based on quantitative measurement of NM. The usefulness of the proposed method in the study was investigated in usability evaluation of four canister-type vacuum cleaners having different design specifications. Also, the motion analysis results were compared with those of EMG and subjective discomfort to identify their association with muscular efforts and user satisfaction.

2. Usability evaluation method using natural product-use motion

2.1. Conceptual definition of natural product-use motion

It is assumed that all users have natural product-use motions (NMs) which they prefer in operating a product under consideration. In other words, the NMs can be considered as a user-preferred product-use motion for the product. The following three conditions were additionally assumed to the concept of NM for a product under consideration: (1) users already recognize the purpose of the product; (2) users already experienced how to use the product; and (3) users can determine their NMs.

2.2. Development of a usability evaluation method using NM

The usability evaluation method proposed in the present study consists of three major steps (Fig. 1): (1) product characteristic analysis; (2) motion measurement; and (3) usability analysis. First, the product characteristic analysis identified the design characteristics, user characteristics, environment characteristics, and task characteristics of a product, which can affect users' posture and motion while using the product (Chang and You, 2006; HFES300 Committee, 2004). As for design characteristics, the dimensions (e.g. size, weight, shape) of the product are measured. As for user characteristics, user profiles (e.g. age, gender, and anthropometric attributes) and user requirements (e.g. explicit or implicit needs of users or design requirements for design problems perceived) are obtained through a user survey or a focus group interview. As for environment characteristics, use environments and their conditions such as floor materials, floor smoothness, and ambient temperature are identified. Lastly, as for task characteristics, major tasks and subsidiary tasks with the product are analyzed.

In the second step, an experimental protocol including measurement of both NMs and actual product-use motions (AMs) is planned. An experimental protocol is established based on product characteristics identified in the previous step; for example, participants can be selected using the user characteristics of the target product. Also, experimental tasks are designed by referring to the environment and task characteristics of the product. The NMs and AMs about the product are recorded using a motion capture system. Note that the NMs are users' voluntary motions (under the purpose of the product-use) when the product is not given. Meanwhile, the AMs are ordinary product-use motions while operating the product, so they are affected by the physical design of the product.

In the last step, the usability of the target product is evaluated by the motion similarity (MS; unit: %) between NMs and AMs. The NMs and AMs are operationally defined in the present study as the form of the range of motion (ROM) based on the average of 5th (lower bound) and 95th (upper bound) percentiles on each participant's ROMs because 90% accommodation of the target population is commonly employed in anthropometric studies (HFES300 Committee, 2004; Jung et al., 2009, 2010; Kwon et al., 2009). MS is defined as the ratio of AMs spent in the range of NMs as shown in Fig. 2 and Equation (1), where T is the total time of AMs, Tin is the time of AMs in the range of NMs, and MS is the proportion of Tin to T. For example, out 30 s of canister AMs, 24 s of canister AMs is in the range of corresponding NMs, its MS becomes 80% (= 24/30). Consequently, MS can be served as a usability index of the target product since it quantifies the similarity between ordinary product-use motion and natural product-use motion.

$$MS(\%) = \frac{T_{in}}{T} \times 100 \quad (1)$$

where:

T_{in} = time of actual product-use motion in the range of natural product-use motion
T = total time of actual product-use motion

3. Case study: canister-type vacuum cleaner

The usefulness of the proposed method was tested in usability evaluation of four canister-type vacuum cleaners the design specifications of which were shown in Table 1.

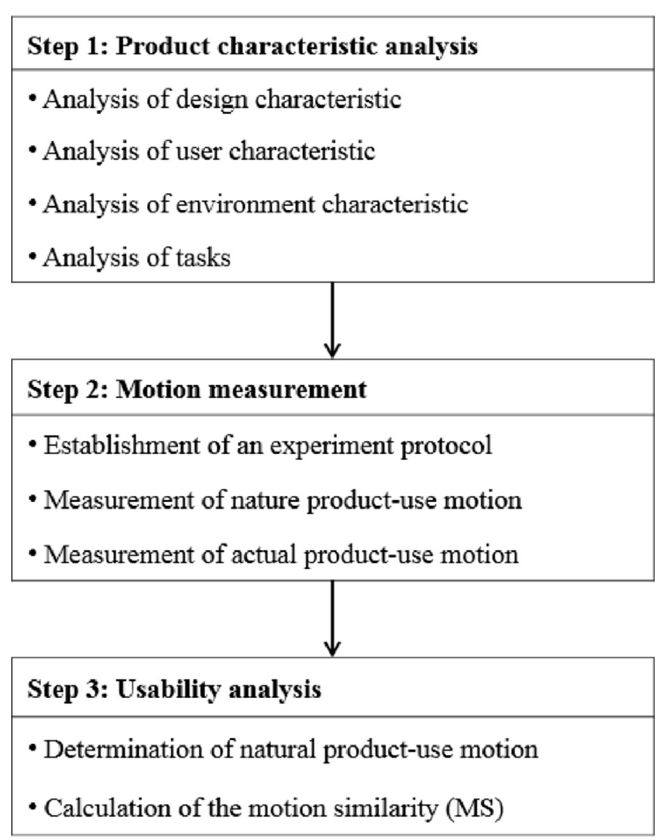

Fig. 1. Usability evaluation process using natural product-use motion.