Breathe with Touch: A Tactile Interface for Breathing Assistance System

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Abstract. Breathing techniques have been widely used as an aid in stress-reduction and relaxation exercises. Most breathing assistance systems present breathing guidance in visual or auditory forms. In this study, we explored a tactile interface of a breathing assistance system by using a shape-changing airbag. We hypothesized that it would help users perform the breathing exercise more effectively and enhance their relaxing experience. The feasibility of the tactile interface was evaluated from three aspects: stress reduction, breathing training and interface usability. The results showed that for most participants, the overall heart rate variability were improved after breathing training. Moreover, "Breathe with Touch" brought users better satisfaction during the exercise. We discuss these results and future design implications for designing tactile interfaces for breathing guidance.

Keywords: Tactile interface · Biofeedback · Breathing assistance · Relaxation

1 Introduction

In modem society, the pace of life is fast and the competition is fierce. An increasing number of people are suffering from chronic stress in their daily life. Breathing techniques have been widely used in mind-body practices for stress reduction and relaxation [1]. Breathing techniques offer a simple tool to improve the balance of autonomic nervous system, strengthen its capability to adapt to stress and further mitigate the negative effects of stress on the health [2]. With a variety of breathing assistance devices, individuals learn to regulate their breathing into an optimal pattern with the aim of stress reduction. But this is not an easy task for most people to achieve a real relaxed state physically and mentally; because besides an improved breathing skills, the users' psycho-physiologic relaxing experience also affects the stress mitigation. To put it simply, users should also "feel good" during a breathing exercise. Therefore, the interface of breathing assistance device should not only offer an effective breathing guidance, but also a "feeling good" relaxing experience.

In medical applications, breathing guidance is usually presented in graphic or numeric forms, which tend to be technical and performance-oriented. In recent years, several new audiovisual interfaces with more aesthetic qualities have been created for daily use. For instance, Yongqiang Qin et al. developed an immersive breathing training game "Balloon" to train the user to improve breathing pattern [3]. In [4],

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the authors presented “Sonic Respiration” to provide breathing feedback by modifying the quality of musical interface. However, very little work has explored the feasibility of tactile interface for breathing guidance.

The sense of touch enables us to interact with real objects around us, meanwhile, to perceive these interactions. In [5], the authors suggested that the characteristic bidirectional property of touch sense provides a basis to further enhance motor learning and somatic experience. Studies in [6] revealed that tactile feedback could also reduce the perceived workload in learning tasks and enhance the user’s feeling of presence. Moreover, stimulating the tactile sense can give people strong relaxing experiences or even emotional experiences, which are beneficial for stress mitigation and health. Therefore, tactile stimuli are often used as a way to reduce stress and make people feel better, such as in massaging techniques and physiotherapy. Tactile feedback is often integrated into multimodal interfaces to enhance the user experience. For example in [7] the authors developed a breathing guidance system to provide the users with an immersive experience through a multimodal interface of auditory, vibratile and light stimuli.

In this study, we aim to investigate whether the tactile interface would help users perform breathing exercise more effectively and enhance user experience during the exercise. We present the concept of *“Breathe with Touch”*: a tactile interface of breathing assistance device that provides breathing guidance through a shape-changing airbag. The airbag inflates and deflates at a specific rhythm to simulate the targeted respiratory pattern. We assume that the changes in the shape of airbag can be mirrored by the user resulting in a better and more relaxing breathing pattern. The tactile interface was evaluated from three aspects: the effect on stress reduction, the efficacy of breathing guidance and the usability. We synthesized the results with valuable qualitative responses from users.

2 Design and Implementation

The concept *“Breathe with Touch”* entails a tactile interface for breathing exercises. By touching the interface, the user follows the shape change of the interface to receive the feedback information. To design the proper form of tactile feedback, we observe the nature of human’s breathing movement. Breathing is accompanied by diaphragm fluctuation activities. As an individual inhale, the diaphragm contracts and flattens, causing the expansion of the lungs. Conversely, on exhale, the diaphragm relaxes and moves upward to reduce the space in the chest cavity (see Fig. 1). The lungs are like two air balloons inside of our body. The changes in its shape depend on the airflow.

“Breathe with Touch” simulates human’s breathing movements through the shape changes of an inflatable airbag. The expansion and contraction of the lungs are mirrored by the inflation and deflation of the airbag. We assume that this kind of natural mapping between the targeted behavior and the interface could minimize cognitive workload thanks to the intuitive interpretation of the interface. Besides, we think the gradual shape-changing process of airbag could render the breathing guidance in a more soothing way, which helps users slow down their breathing and calm down as well. A hand-sized ellipsoid airbag was made of thermoplastic textile covered by a

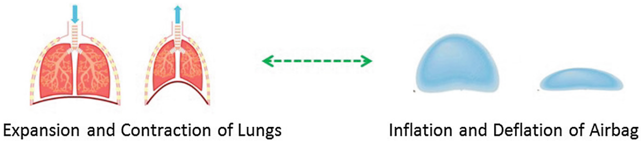

Fig. 1. The shape change of the airbag might be naturally associated with breathing movements

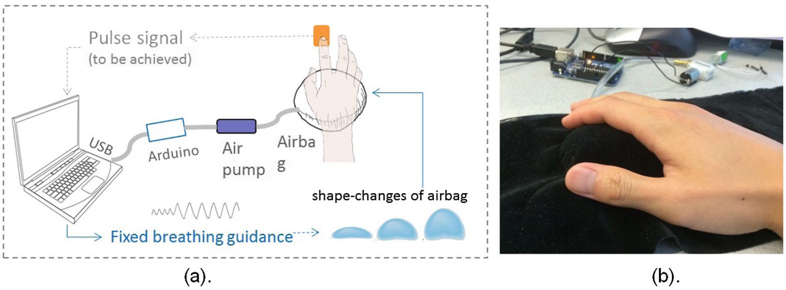

Fig. 2. (a). Touch Airbag schematic diagram. (b). The user's right hand on the airbag

layer of soft velvet. The user rests her hand on the airbag to "feel" the targeted breathing rhythm (see Fig. 2b).

The breathing guidance is mapped to the airbag in the following way: when the airbag inflates, an inhale activity is implied. When the airbag deflates, an exhale activity is implied. The maximum volume of airbag is around 120 ml that is the same size of a mouse approximately. This enables the user to identify subtle changes of the shape easily and accurately by hand. The sensitive tactile feelings from the hand and fingers ensure that users can receive the guidance precisely as well. An air pump and a solenoid vent valves implement the inflation and deflation of the airbag. During the inflation, the air-pump pumps air into the airbag and the valve is closed. During the deflation, the air-pump stops working and the valve turn opened. Then, with the hand own weight, the air will be pushed out of airbag gently.

In this study, we focus on the design and evaluation of the tactile interface. A feed forward system was built with a pre-set breathing rate of 6 breathing cycles per minute (c/min). According to literature [8], most people could achieve a high HRV level under a respiration of 6 c/min. The airbag starts from the deflated state to inflated state then return to deflated state again. The duration of this inflation/deflation process is 10 s and this process repeats for the whole training session. As shown in Fig. 2(a), the proposed tactile interface in this work can be embedded into a complete closed-loop biofeedback breathing assistance system in our future research.

3 Study One: Evaluation of the Effects on Stress Reduction

We administered the first user study to investigate whether the proposed tactile interface would enhance breathing training and reduce stress effectively. 12 subjects (six females and six males, age range: 25 to 35) participated in the study. Each participant performed two stress-induced tasks (mathematical test) before and after breathing training. For each task, the physiological data (pulse signals and respiration data) and subjective stress reports were collected (Fig. 3).

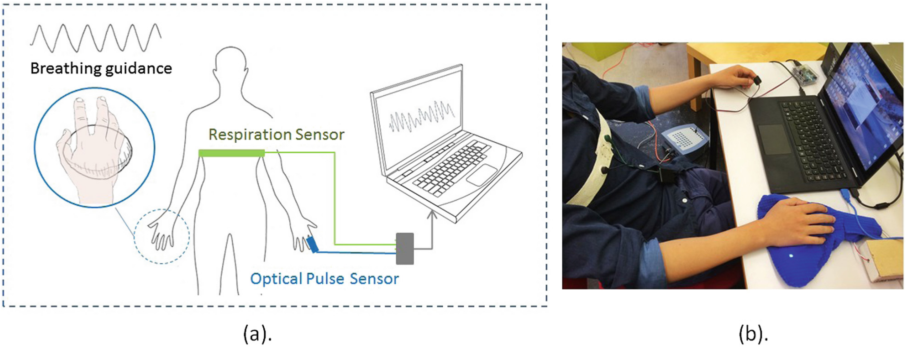

Fig. 3. (a). The experiment set up (b). Right hand on the airbag

For each participant, A PPG sensor was placed on the left index finger and a respiratory sensor was placed at the abdominal level. Pulse signals were measured by a data acquisition unit developed by our lab, and then beat-to-beat intervals (RR intervals) were calculated and transmitted to a Processing program for data storage. The standard deviation of the beat-to-beat intervals (*SDNN*) was calculated as the index of HRV. Respiration data was recorded by the ANT system[1] with a sampling rate of 256 Hz. The participant's stress level were measured by the state component of a Spielberger State-Trait Anxiety Inventory (STAIS) [9].

The experiment followed a procedure as shown in Fig. 4. On arrival at the laboratory, the participants were instructed how to use the breathing assistance system. The pulse sensor and respiration sensor were applied to the participants. Then participants were instructed to relax with their eyes closed for 5 min. After the resting period and without moving, participants were instructed to open their eyes and complete a pre-training mathematical task which lasted 10 min during which time measurements of HRV and respiratory rate were calculated. After the task, participants completed a pre-training STAIS questionnaire. After further 5-min rest with eyes closed, then participants completed a 10-min breathing training session with *"Breath with touch"*. The instructions given to participants were: *"Please follow the changes of the airbag to breathe, when the airbag inflates, you should breathe in. When airbag begins to deflate, you should breathe out. This session will last for 10 min."* After the training, participants completed a further 10-min mathematical task. Pulse signal and respiratory data were also recorded throughout this period. Then, a post-training STAIS questionnaire was completed.

The HRV, respiration rate and STAIS were calculated in Pre-training and Post-training periods separately. Differences were analyzed using an independent t-test.

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[1] ANT, the Netherlands, http://www.ant-neuro.com/.

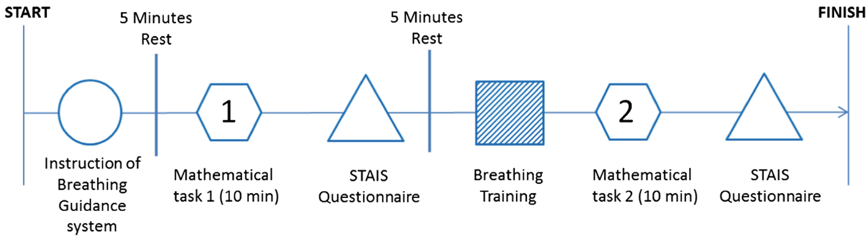

Fig. 4. The experiment procedure

All data are described as means ± standard deviation (SD). A p-value of < 0.05 was considered to be statistically significant.

Physiological data were missing from two participants because of technical problems. As the index of HRV, SDNN showed different degrees of increase among all participants after the breathing training, as shown in Fig. 5. The *SDNN* values of post-training period were significantly higher than pre-training period (49.5 ± 14.2 *vs*. 66.3 ± 20.4; Pre-training *vs*. Post-training, $p < 0.05$). Regarding the results of respiration data, seven participants showed a slower respiration rate during post-training task. However, there were no significant differences before or after training (18 ± 6 *vs*. 15 ± 2 circles; Pre-training *vs*. Post-training).

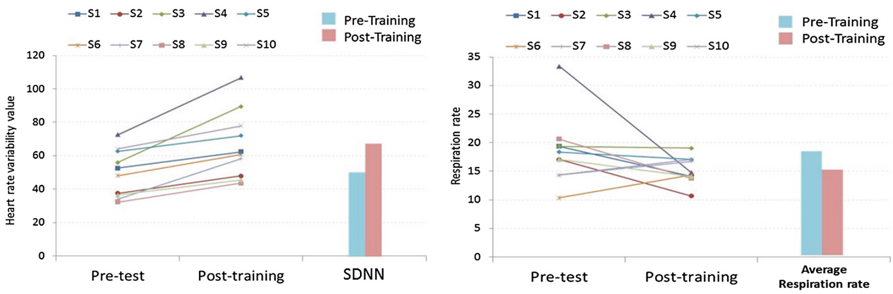

Fig. 5. HRV (*SDNN*) and respiration rate before and after the breathing training.

Psychometric data from the STAIS questionnaires are shown in Fig. 6. Nine participants reported a lower anxiety level during the post-training mathematics task; however, there were three participants showed a higher anxiety levels (subject #1, #4, and #5). The STAIS scores were not significantly different between Pre-training period and Post-training period (46 ± 11 *vs*. 39 ± 9 points; Pre-training *vs*. Post-training).

4 Study Two: Evaluation of Interface Usability

As tactile interfaces are seldom used in breathing assistance, we conducted another study to investigate the user's perception on the usability of tactile interface. To gain more insightful feedback and recommendations for further design, ten students with interaction design background (four females and six males, age range: 20 to 35) were

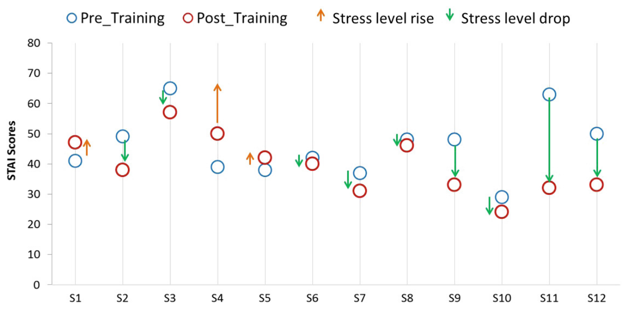

Fig. 6. Scores of STAIS questionnaires pre- and post- the breathing training (N = 12)

recruited for this study. All participants complete three 10-min breathing training sessions using the same breathing guidance, but with three different interfaces: visual, auditory and tactile interfaces. The experiment follows a within-subjects design with counter balancing to avoid carry-over effects.

We introduced visual and auditory interfaces for breathing assistance as shown in Fig. 7. In visual interface, an ellipse with varying radius represents the breathing guidance. When the ellipse grows, an inhale process is implied. In auditory feedback, we used the changes in sound volume to present breathing guidance. An increasing sound volume prompted user to breathe in, and the fading sound implied breathing out. The usability of the interface was measured using an adapted Lund's USE Questionnaire [10]. The questionnaire was designed for three dimensions: ease of use, ease of learning and satisfaction. All the questions used a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree).

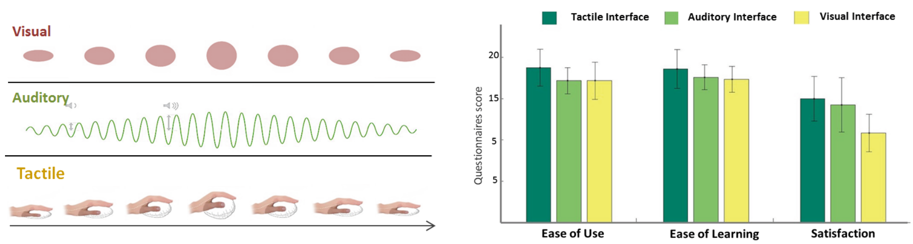

Fig. 7. The results of evaluation of interface usability

The results are shown in Fig. 7. In terms of "Ease of Use", all of three interfaces received high scores; there were no significant differences between tactile, auditory and visual interfaces (19 ± 2 *vs*. 17 ± 2 *vs*. 17 ± 2; Tactile *vs*. Auditory *vs*. Visual). In terms of "Ease of Learning", there were also no significant differences between three interfaces (19 ± 2 *vs*. 18 ± 2 *vs*. 17 ± 2; Tactile *vs*. Auditory *vs*. Visual). In terms of "Satisfaction", the score of visual interface was significant lower than tactile and auditory interfaces (15 ± 3, 14 ± 3 *vs*. 11 ± 2; Haptic, Auditory *vs*. Visual, respectively, $p < 0.05$). From the open-ended interview, we got more positive feedback about tactile interface. More than 70 % participants chose the tactile interface as their favorite interface. Specifically, they expressed a strong interest in working with the tactile interface and emphasized that it was more comfortable due to the touch experience.

5 General Discussion

During a breathing training, users need to recognize the breathing guidance and follow it to regulate their breathing. In other words, the breathing training is a learning process, in which the users should take an active role, rather than just being exposed to it. Therefore, in breathing training, although the learning tasks are very simple (i.e. to regulate breathing to a specific rate), some participants still regard it as a serious task, which keep them away from a pure relaxation. We think this might be an interesting "paradox" in the design of self-training system for relaxation. It appeals to us and drive us to think about the interaction design in these products or systems that aim to promote relaxation. The training session requires user's mental effort to achieve optimal training effect, such as improved breathing skills, positive imagination or more concentration. However, such mental effort of learning might leads to new stress.

In this design, we tried to lower the workload and enhance the relaxing experience by using a tactile interface. The touch airbag was used as a tangible communication media between the training system and the user. It is assumed that the user can adapt her breathing movements to an optimal pattern more effortlessly by mirroring the shape changes of the tangible interface. The results of user study confirm that the proposed "natural-mapping" interface could help the users perform breathing exercise more spontaneously. The users do not need to put much effort into understanding the instructions, and the transition between inflation and deflation of airbag might naturally trigger a slow and smooth transition between inhalation and exhalation.

The effectiveness of tactile breathing guidance in aiding relaxation and reducing stress was shown by the results of SAITS self-report. However, there is no significant reduction of stress level during the post-training mathematics task. There might be two possible explanations. For most participants, it was their first time to use breathing assistance system; the unfamiliarity with the system brings about new stresses. We also have reservations about the acute effect of 10-min breathing exercise on stress reduction. Although in some clinical use [11], the minimum time of each training session could be 5 min; a short-period exercise may be repeated several times throughout a day to achieve a greater effect on stress mitigation. From physiological measurements, the results suggested that there was a significant improvement in HRV during the post-training task, which suggests that tactile breathing training could enhance the users'physical ability to adapt to stress.

The users' ratings on the usability of visual, auditory and lighting interface were shown in Fig. 7. The tactile interface shows the potential in improving user experience during the relaxation exercise as seen from significantly higher user ratings on satisfaction. Improvements in user experience were also evidenced by the participants' feedback from the interviews at the end of the experiment. During a breathing training process, repeated breathing instructions become boring easily. This is a major problem of most breathing guidance systems for long-term use. To some extent, the touch airbag shifts the focus from the superficial interface to users' own regulating behavior, which helps to relieve users of tedium. Besides, the users thought tactile feedback offers a condition for them to perform breathing training with eyes closed, which also helped relax. They also gave us a lot of insightful recommendations for further design of the interface, for instance, changing the size or position of airbag, integrating the airbag into regular items, and combining tactile and auditory feedback.

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Foreword

The 15th IFIP TC.13 International Conference on Human–Computer Interaction, INTERACT 2015, was held during September 14–18, 2015, in Bamberg, Germany, organized by the University of Bamberg. The city of Bamberg is proud of its more than 1,000-year-old center. It has more than 2,400 historically listed buildings and became a UNESCO World Cultural Heritage Site in 1993. With 70,000 inhabitants, Bamberg is a small town in the heart of Europe.

The theme of the 2015 edition was "Connection, tradition, innovation." In its relatively short history, the human–computer interaction (HCI) area has experienced impressive development. Theories, methodologies, procedures, guidelines, and tools have been progressively proposed, discussed, tested, and frequently adopted by academia and industry. The protagonists of this development created in a short period of time a scientific and technological tradition able to produce high-quality interaction systems. However, the evolution of the computers and networks pose new challenges to all stakeholders. Innovation, based on tradition, is the only way to face these challenges, even if innovation often requires breaking the tradition. In order to make this process possible, INTERACT 2015 provides diverse and abundant connection opportunities. A multidisciplinary approach is characteristic of the HCI field. INTERACT 2015 aimed to connect all the matters able to contribute to the quality of the future interactions among people and computers.

The series of INTERACT international conferences (started in 1984) is supported by Technical Committee 13 on Human–Computer Interaction of the International Federation for Information Processing (IFIP). This committee aims at developing the science and technology of the interaction between humans and computing devices.

IFIP was created in 1960 under the auspices of UNESCO with the aim of balancing worldwide the development of computer technology and Science. Technical Committee 13 is fully conscious of the social importance of information and communication technologies for our world, today and in the future. Therefore, INTERACT 2015 made efforts to attract and host people from all over the world, and to pay attention to the constraints imposed on HCI by differences in culture, language, technological availability, physical, as well as sensory and cognitive differences, among other dimensions of interest.

INTERACT 2015 gathered a stimulating collection of research papers and reports of development and practice that acknowledge the diverse disciplines, abilities, cultures, and societies, and that address all the aspects of HCI, including technical, human, social, and esthetic.

Like its predecessors, INTERACT 2015 aimed to be an exciting forum for communication with people of similar interests, to foster collaboration and learning. Being by nature a multidisciplinary field, HCI requires interaction and discussion among diverse people with different interests and backgrounds. INTERACT 2015 was directed both to the academic and industrial world, always highlighting the latest developments in the discipline of HCI and its current applications. Experienced HCI researchers and professionals, as well as newcomers to the HCI field, interested in the design or evaluation of interactive software, development of new technologies for interaction, and research on general theories of HCI met in Bamberg.

We thank all the authors who chose INTERACT 2015 as the venue to publish their research. This was again an outstanding year for the conference in terms of submissions in all the technical categories.

We received 651 submissions. Of these, the following were accepted: 93 full research papers; 74 short research papers; eight demos; 30 interactive posters; four organizational overviews; three panels; six tutorials; 11 workshops; and 13 doctoral consortium papers.

The acceptance rate for the full papers was 29.6 % and 26.8 % for short papers.

In order to select the highest-quality contributions, an elaborate review system was organized including shepherding of 38 full research papers that went through a second and sometimes a third round of review. That process was primarily handled by the 32 meta-reviewers who willingly assisted and ensured the selection of high-quality full research papers to be presented at INTERACT 2015.

The final decision on acceptance or rejection of papers was taken in a plenary Program Committee meeting held in Tampere (Finland) in February 2015, aimed to discuss a consistent set of criteria to deal with inevitable differences among the large number of reviewers who were recruited and supported by the meta-reviewers. The technical program chairs and the track chairs, the general chairs, and the members of IFIP Technical Committee 13 participated in the meeting.

Special thanks must go to the track chairs and all the reviewers, who put in an enormous amount of work to ensure that quality criteria were maintained throughout the selection process. We also want to acknowledge the excellent work of the co-chairs of the different sections of the conference and the meta-reviewers of the full research paper track.

We also thank the members of the Organizing Committee, especially Mirko Fetter, local organization chair, who provided us with all the necessary resources to facilitate our work. Finally, we wish to express a special thank you to the proceedings publication chair, Marco Winckler, who did extraordinary work to put this volume together.

September 2015

Tom Gross
Julio Abascal
Simone Barbosa
Philippe Palanque

IFIP TC13

Established in 1989, the International Federation for Information Processing Technical Committee on Human–Computer Interaction (IFIP TC13) is an international committee of 37 national societies and nine working groups, representing specialists in human factors, ergonomics, cognitive science, computer science, design, and related disciplines. INTERACT is its flagship conference, staged biennially in different countries in the world. From 2017 the conference series will become an annual conference.

IFIP TC13 aims to develop the science and technology of human–computer interaction (HCI) by: encouraging empirical research, promoting the use of knowledge and methods from the human sciences in design and evaluation of computer systems; promoting better understanding of the relation between formal design methods and system usability and acceptability; developing guidelines, models, and methods by which designers may provide better human-oriented computer systems; and, cooperating with other groups, inside and outside IFIP, to promote user orientation and humanization in system design. Thus, TC13 seeks to improve interactions between people and computers, encourage the growth of HCI research and disseminate these benefits worldwide.

The main orientation is toward users, especially non-computer professional users, and how to improve human–computer relations. Areas of study include: the problems people have with computers; the impact on people in individual and organizational contexts; the determinants of utility, usability, and acceptability; the appropriate allocation of tasks between computers and users; modeling the user to aid better system design; and harmonizing the computer to user characteristics and needs.

While the scope is thus set wide, with a tendency toward general principles rather than particular systems, it is recognized that progress will only be achieved through both general studies to advance theoretical understanding and specific studies on practical issues (e.g., interface design standards, software system consistency, documentation, appropriateness of alternative communication media, human factors guidelines for dialogue design, the problems of integrating multimedia systems to match system needs and organizational practices, etc.).

In 1999, TC13 initiated a special IFIP Award, the Brian Shackel Award, for the most outstanding contribution in the form of a refereed paper submitted to and delivered at each INTERACT. The award draws attention to the need for a comprehensive human-centered approach in the design and use of information technology in which the human and social implications have been taken into account. 2007 IFIP TC 13 also launched an accessibility award to recognize an outstanding contribution with international impact in the field of accessibility for disabled users in HCI. In 2013, IFIP TC 13 launched the Interaction Design for International Development (IDID) Award, which recognizes the most outstanding contribution to the application of interactive systems for social and economic development of people in developing countries. Since the process to decide the award takes place after papers are submitted for publication, the awards are not identified in the proceedings.

IFIP TC 13 also recognizes pioneers in the area of HCI. An IFIP TC 13 pioneer is one who, through active participation in IFIP Technical Committees or related IFIP groups, has made outstanding contributions to the educational, theoretical, technical, commercial, or professional aspects of analysis, design, construction, evaluation, and use of interactive systems. IFIP TC 13 pioneers are appointed annually and awards are handed over at the INTERACT conference.

IFIP TC13 stimulates working events and activities through its working groups (WGs). WGs consist of HCI experts from many countries, who seek to expand knowledge and find solutions to HCI issues and concerns within their domains, as outlined here.

WG13.1 (Education in HCI and HCI Curricula) aims to improve HCI education at all levels of higher education, coordinate and unite efforts to develop HCI curricula and promote HCI teaching.

WG13.2 (Methodology for User-Centered System Design) aims to foster research, dissemination of information and good practice in the methodical application of HCI to software engineering.

WG13.3 (HCI and Disability) aims to make HCI designers aware of the needs of people with disabilities and encourage development of information systems and tools permitting adaptation of interfaces to specific users.

WG13.4 (also WG2.7; User Interface Engineering) investigates the nature, concepts, and construction of user interfaces for software systems, using a framework for reasoning about interactive systems and an engineering model for developing user interfaces.

WG 13.5 (Resilience, Reliability, Safety, and Human Error in System Development) seeks a framework for studying human factors relating to systems failure, develops leading-edge techniques in hazard analysis and safety engineering of computer-based systems, and guides international accreditation activities for safety-critical systems.

WG13.6 (Human–Work Interaction Design) aims at establishing relationships between extensive empirical work-domain studies and HCI design. It will promote the use of knowledge, concepts, methods, and techniques that enable user studies to procure a better apprehension of the complex interplay between individual, social, and organizational contexts and thereby a better understanding of how and why people work in the ways that they do.

WG13.7 (Human–Computer Interaction and Visualization) aims to establish a study and research program that will combine both scientific work and practical applications in the fields of HCI and visualization. It will integrate several additional aspects of further research areas, such as scientific visualization, data mining, information design, computer graphics, cognition sciences, perception theory, or psychology, into this approach.

WG13.8 (Interaction Design and International Development) are currently working to reformulate their aims and scope.

WG13.9 (Interaction Design and Children) aims to support practitioners, regulators, and researchers to develop the study of interaction design and children across international contexts.

New Working Groups are formed as areas of significance to HCI arise. Further information is available on the IFIP TC13 website: http://ifip-tc13.org/

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