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HealthSit: Designing Posture-Based Interaction to Promote Exercise during Fitness Breaks

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ABSTRACT

This research was motivated by a desire to help office workers change their sedentary behavior because a prolonged sedentary posture increases the risks of developing musculoskeletal injuries and chronic diseases, thus threatening their physical and psychological well-being. Regular breaks involving low-effort physical activities are effective in reducing the adverse impacts of inactive behaviors. In this article, we present the design of a posture-based interactive system called HealthSit, which was developed to promote a short lower-back stretching exercise during work breaks. Through a within-subject study involving 30 office workers, the effectiveness of HealthSit in facilitating the stretching exercise was examined by making comparisons between an interaction-aided, a guided, and a self-directed exercise mode. We also used HealthSit as a research probe to investigate the interactivity of the system in enhancing user experience and the psychological benefits of the fitness breaks. Compared with the other two modes, the interaction-aided exercise mode significantly improved the quality of the stretching exercise and enhanced motivation and emotional state. These results confirm the effectiveness of HealthSit in supporting fitness breaks as a new workplace technology. Based on our study, a set of design implications have been derived for technology-assisted fitness work breaks.

KEYWORDS

Work breaks; lower-back stretch; posture-based interaction; workplace fitness-promoting technology

1. Introduction

The rapid penetration of labor-saving devices and task-oriented workplace norms have substantially reduced physical movement, while increasing mental stress in many jobs. A recent survey demonstrated that less than 20% of current jobs in the USA demand physical activity compared with almost 50% of jobs in the 1960s (Church et al., 2011). The prevalence of physical inactivity at work such as static sitting has been shown as the leading cause of muscular disorders and spine overload (Beach, Parkinson, Stothart, & Callaghan, 2005). Nowadays, over one-third of musculoskeletal back pains are related to sedentary activities in office work (Wynne-Jones et al., 2014). Moreover, the prolonged inactivity threatens metabolic health and leads to various chronic conditions, such as obesity, diabetes, and cardiovascular diseases (Owen, Healy, Matthews, & Dunstan, 2010).

To tackle such issues, there have been extensive discussions about how to increase physical activities and reduce sedentary time at work. One prioritized strategy is to encourage office workers to develop physically active behaviors during breaks in their work routine (Taylor, 2005). For example, regular breaks with some light-intensity physical activities at desk have proved beneficial to workers' physical (Healy et al., 2008) and mental health (Kim, Park, & Niu, 2017). Researchers have developed workplace interventions to promote fitness breaks by employing a variety of means, e.g. health programs (Falkenberg, 1987), sociocultural or environmental change (Yancey et al., 2004), and fitness-promoting technologies (Van Den Heuvel, De Looze, Hildebrandt, & Thé, 2003).

Fitness-promoting technologies designed to facilitate fitness breaks at work have been investigated extensively. For instance, early studies have focused on improving self-awareness of sedentary conditions and prompting breaks at work using, e.g. an ambient display (Jafarinaimi, Forlizzi, Hurst, & Zimmerman, 2005) and a mobile application (Van Dantzig, Geleijnse, & Van Halteren, 2013). Moreover, an emerging number of research prototypes and some commercial applications have been designed to provide guidance for physical activities that can support the exercise flow during work breaks using, e.g. animation (e.g., Wang, Jiang, & Chern, 2014), and a virtual coach (e.g. Workout Trainer[1]). The rapid advance of sensing techniques and Human–Computer Interaction (HCI) increases the interactivity of fitness-promoting technologies designed to improve the system's effectiveness and enhance the user experience. It has been shown that using motion-based interactions to mediate physical activities can boost the metabolism and improve psychological states (Gao & Mandryk, 2012), as well as provide enhanced exercise experience (Mueller et al., 2011). Previous research also indicated the potential of using motion-based interactions

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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/hihc.

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to promote low-effort fitness breaks (Mandryk, Gerling, & Stanley, 2014). However, how interactive technology can be designed to facilitate the light-intensity desk exercise during fitness breaks and what benefits it can provide to office workers remains an open question and is a worthy topic of study. This article offers insights into such questions, based on the design and evaluation of such technology.

In this article, we present HealthSit, an interactive posture-based system, that assists stretching exercises during fitness breaks at work. HealthSit senses the weight shifts of the subject as an indicator of sitting posture and it provides audio-visual interactions to support a lower-back stretching exercise. In this project, HealthSit serves as a research probe that can be used to investigate the effects of system interactivity and facilitating physical activities during fitness breaks. It was, therefore, implemented with three working modes: 1) an interaction-aided exercise mode with real-time feedback about users' performance and exercise results, 2) a guided exercise mode with pre-set exercise guidance, and 3) a self-directed exercise mode with neither feedback nor guidance. A within-subject study was conducted with 30 office workers. We compared the three working modes of HealthSit in terms of exercise quality, user experience, and psychological benefits. This user study was designed to answer three research questions:

(1) *To what extent does the interaction-aided exercise mode of HealthSit* ***enhance the effectiveness of the lower-back stretching exercise*** *compared with the other two modes?*
(2) *Whether and how does the interaction-aided exercise mode of HealthSit* ***enhance the user experience of fitness breaks*** *compared with the other two modes?*
(3) *Do fitness breaks combined with the interaction-aided exercise mode of HealthSit* ***enhance users' emotional status and cognitive performance*** *compared with fitness breaks based on the other two modes*?

The remainder of this article is organized as follows. In the next section, we provide a review of related literature on workplace technologies for fitness promotion, and state-of-the-art designs using interactivity to mediate fitness breaks. This is followed by a summary of how we developed HealthSit and a description of the three working modes. In Sections Four and Five, we report on the user study and its results, which lead to a discussion on the findings and limitations, with implications for future work, in Section Six. Section Seven contains our conclusions.

2. Related work

In this section, we present three kinds of related work. First, we provide an overview of health-related workplace technologies for fitness promotion, which cover active workstations and relevant HCI, as well as office management of personal informatics. Second, we describe the role of physical activity, especially the stretching exercise, during short work breaks in improving health and well-being for office workers. Third, we present some designs and applications of the interactive technology used during fitness breaks.

2.1. Technology for workplace fitness promotion

Regular physical activities that are incorporated into daily work routine have been shown to be effective in reducing the impact of a sedentary lifestyle for office workers (Owen et al., 2010), while improving health, productivity, and quality of life (Riedel, Lynch, Baase, Hymel, & Peterson, 2001). Recently, considerable efforts based on ergonomics and HCI have been devoted to the design of health intervention and promotion in the workplace. As a result, various types of active workstations have been developed to facilitate physical activities during work, including a treadmill,[2] a stationary bike,[3] and a balance chair.[4] Nowadays, active workstations are becoming increasingly common in the office environments of many large companies, e.g. Google and Microsoft (Choi, Song, Edge, Fukumoto, & Lee, 2016). Also, their effectiveness in balancing physical activities and work performance, as well as a positive user experience has also been demonstrated (Choi et al., 2016). However, active workstations also have disadvantages: a high price and large size, which makes it difficult for small companies to adopt them, especially in confined workspaces (Tudor-Locke, Schuna, Frensham, & Proenca, 2014).

Besides new types of active workstations, a growing number of HCI-mediated health interventions have been designed to promote physical activity by offering a new interaction model involving the use of a computer or collaboration with colleagues at work. Probst, Lindlbauer, Haller, Schwartz, and Schrempf (2014) developed a chair-based human-computer interface, which allows the user to control the computer with different sitting postures and finally achieve active sitting. Similarly, *Tap-Kick-Click* uses foot-based interaction for standing desks to improve standing postures and physical movements (Saunders & Vogel, 2016). Furthermore, new work modes with colleagues, such as walking meetings (Ahtinen, Andrejeff, Vuolle, & Väänänen, 2016), have been explored to promote physical activities in the social context. Compared with large-sized, high-priced workstations, these solutions may be easier to blend into a variety of office environments. However, the effectiveness of doing work and exercise simultaneously, especially weaving the exercise into interactions with computers at work, has often been questioned. It might easily turn out to be a lose–lose solution, which reduces both mental focus at work (Neuhaus et al., 2014) and exercise efficacy (Grooten, Conradsson, Äng, & Franzén, 2013).

Another research strand is to encourage active lifestyles by tracking and informing users about their physical status to improve self-awareness and encourage self-reflection. Extensive studies have investigated the application of personal informatics designed to enhance awareness of daily activeness and deficits. For instance, *Houston* tracks user's step data, visualizes walking history, and further adjusts daily step goals (Consolvo, Everitt, Smith, & Landay, 2006). *Fish'n'Steps* link users' level of daily activities with the growth and emotional state of virtual pets, which are displayed in an office kiosk to

reinforce users' fitness behaviors (Lin, Mamykina, Lindtner, Delajoux, & Strub, 2006). Foster, Linehan, Kirman, Lawson, and James (2010) have examined sharing activity data via social media and have suggested the positive impact of friendly competitive interventions in the workplace. Similarly, *HealthyTogether* uses cooperatively set goals to facilitate fitness-goal commitment and stimulate more physical activity in group settings (Chen & Pu, 2014). Although personal health informatics have become increasingly common in everyday life, it is still a challenge to incorporate a health informatics system into a daily routine or a busy work schedule without causing any interruption of work or an undue mental burden (Chung, Jensen, Shklovski, & Munson, 2017; Gorm & Shklovski, 2016). Unlike the technologies for workplace health promotion described above, in this study, we focus on a lightweight solution that was designed to promote fitness during a short work break.

2.2. Encourage physical activities during work breaks

Given the substantial benefits of regular work breaks (Healy et al., 2008), an increasing number of workplace technologies has been employed to monitor workers' sedentary time and remind them to take a break (e.g. WorkPace[5]). Research by Burkland (2013) has established that minute-short breaks with some light-intensity physical exercises could help avoid RSI, muscle fatigue, and prolonged inactivity among office-based employees. Prior research was dedicated to encouraging people to step away from the office for short breaks with technology-augmented walking (Cambo, Avrahami, & Lee, 2017) or physical leisure activities (Ren, Ma, Lu, & Brombacher, 2017).

Stretching is also a common physical exercise during short breaks, which has been shown to positively contribute to improved emotional state and muscular activation among office workers (Henning, Jacques, Kissel, Sullivan, & Alteras-Webb, 1997). Many fitness coach applications that instruct stretching and ergonomics training have been developed to prevent RSI (Janneck, Jent, Weber, & Nissen, 2017; Wang et al., 2014). Additionally, by tracking arm movements with a wearable sensor, an interactive application for arm-stretching has been designed and proven to be effective in increasing the number of stretches taken (Kim et al., 2017).

In this study, we propose an interactive fitness system that supports a lower-back stretching exercise during work breaks. Exercise mechanisms designed for seated lower-back stretch training have been shown to be efficient in reducing the risk of musculoskeletal back disorders (Da Costa & Vieira, 2008). However, to our knowledge, few studies have leveraged interactive technology to support such stretching exercises during fitness breaks and investigated office workers' physical and psychological outcomes as part of an empirical approach.

2.3. Interaction design for promoting fitness breaks

HCI technology can have a positive impact on fitness-promotion during work breaks. An increasing number of interactive fitness-promoting systems have been developed to facilitate physical activity by utilizing motion data and game mechanics (Mandryk et al., 2014). Motion-based interactions are essential in fitness-promotion systems designed to facilitate physical movement. In the office environment, various types of sensors can be employed to capture motion data as input to the system. For instance, *Limber* uses a workstation-mounted Kinect sensor to track the user's posture data (Reilly et al., 2013). *SuperBreak* uses computer vision via a webcam to detect a user's hand movements for vision-based activity (Morris, Brush, & Meyers, 2008). *Exerseat* installs a proximity sensing toolkit on office chairs to monitor whether users are sitting on or near the seat (Braun, & Clarke, 2006).

Given the advantages of attracting people to engage in long-term physical activities, various exergames have been designed to encourage seniors to be more physically active (Gerling, Livingston, Nacke, & Mandryk, 2012), increase individual fitness levels (Mueller et al., 2011), and encourage an active lifestyle (Gao & Mandryk, 2011). For workplace fitness-promoting technology, moreover, gamification has also been increasingly applied to support fitness break. For example, a casual exergame called *GrabApple* has been designed with simple rules and easy access for a 10 min of play. This has proven to be effective in increasing young adults' physical efforts during the game and generating psychological benefits (Gao & Mandryk, 2012). *BreakSense* uses a mobile application to propose short indoor-location-based challenges for office workers to increase their physical movements at work (Cambo et al., 2017).

In this article, we present the design of HealthSit, which employs a set of force-sensing resistors (FSR) to sense sitting posture and has a lightweight game-like interaction design, which facilitates a lower-back stretching exercise during work breaks. The aim of HealthSit is to offer users a low-effort yet engaging fitness break. We elaborate on the design considerations and the system implementation of HealthSit in the next section.

3 Design of HealthSit

3.1. HealthSit hardware used to sense sitting postures

HealthSit was designed to detect the user's sitting posture by sensing weight distribution on a sit pad. The size of the HealthSit sit pad (40x40 cm^2) ensures that it fits regular office chairs. As shown in Figure 1, six square-type FSR are embedded in a fabric pad at specific positions. The FSRs are symmetrically distributed on the left and right sides of the pad, based on references from a sedentary pressure map (Commissaris & Reijneveld, 2005). The combination of multiple FSRs on each side improves the accuracy of motion detection, given different sitting positions.

The raw data sensed by the FSRs are transmitted to an Arduino PCB, which contains an ATmega 328 microcontroller. The collected motion data were then transmitted to the HealthSit through an AT-09 Bluetooth 4.0 module. In the software, the motion data were processed by a specialized artificial neuron network (Ren et al., 2016) designed to recognize the user's sitting postures and variances. After that, the software archived and presented the posture-related information to the user with animated musical feedback to encourage posture dynamics and avoidance of excessive sitting.

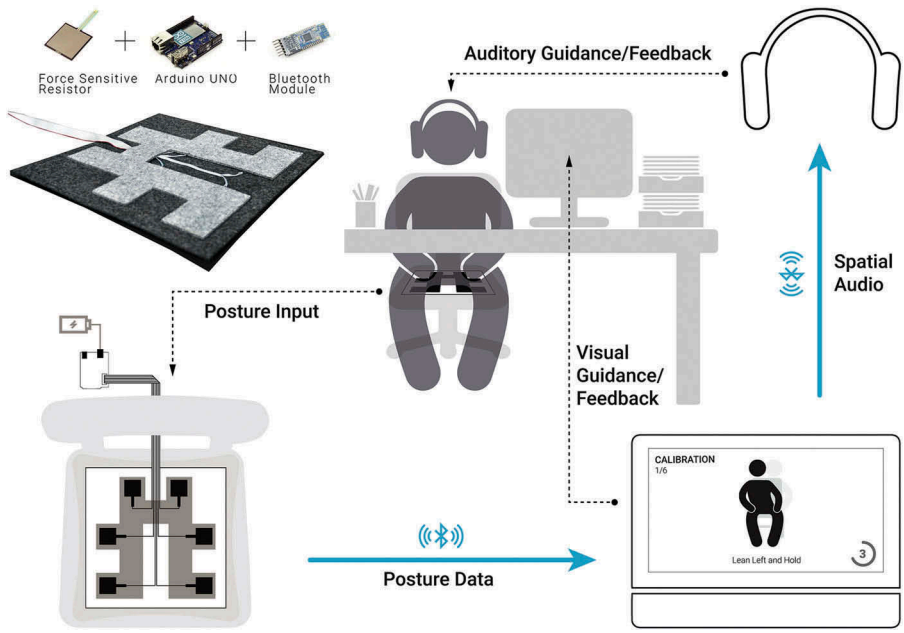

Figure 1. Technical implementation of HealthSit.

3.2. Healthsit software for assisting in a stretching exercise

The feasibility of the HealthSit sit pad has been validated in our previous work (Ren et al., 2016; Ren, Lu, Visser, Le, & van den Burg, 2017), in this study, we focus on investigating the posture-based interaction of the HealthSit system for facilitating a seated lower-back stretching exercise during work breaks. The lower-back stretching exercise is adapted from dynamic weight-shifting (see Figure 2), which involves trunk movements on the pelvis designed to shift the body weight laterally with a few seconds of stretch hold on each side (Au-Yeung, 2003). During weight-shifting, the movements should be performed slowly and repeated about 20 to 40 times. In all working modes of HealthSit, we pre-set equivalent repetitions of 36 times (18 each side) for each exercise. This physical activity was chosen because Cheng and colleagues (2001) found that dynamic weight-shifting is beneficial for individual's balance, core muscle, and back support training. Due to such benefits, it can be applied to support the prevention of musculoskeletal back pains, one of the most critical health issues related to excessive physical inactivity during office work (Wynne-Jones et al., 2014).

3.3. Interaction design of HealthSit

With the combined aim of physical activity and relaxation, we identified a typical scenario for HealthSit-assisted fitness breaks: *Listening to relaxing music while doing the stretching*

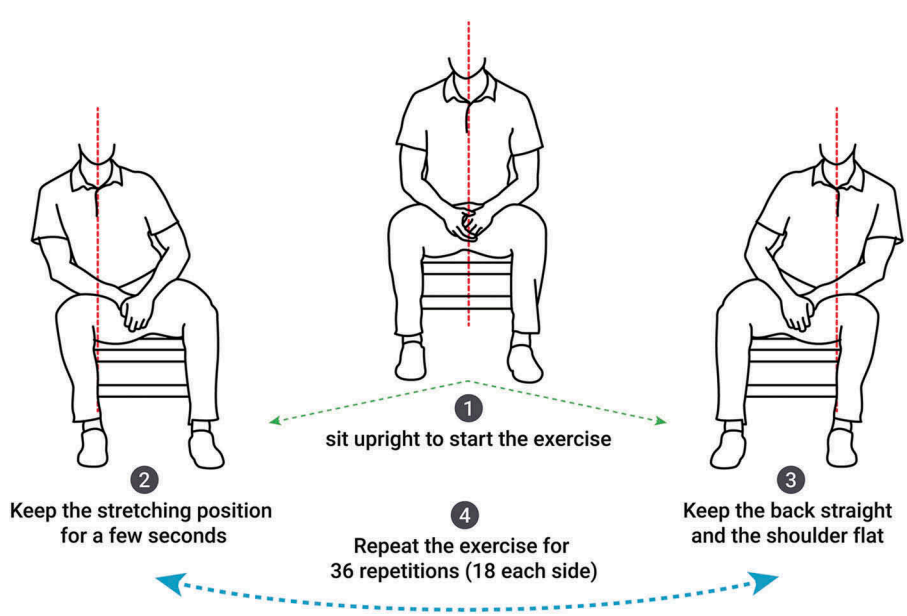

Figure 2. HealthSit facilitate a lower-back stretching exercise that is adapted from dynamic weight-shifting.

exercise. The HealthSit software was mainly implemented with an interaction-aided exercise mode (IEM) to facilitate lower-back stretches using real-time audio-visual feedback on the user's exercise performance and results. Following the design guidelines of exertion games (Mandryk et al., 2014) and lessons learned from studies of workplace fitness technologies (Cambo et al., 2017; Singh et al., 2014), we developed the IEM (Figure 3 (a)) of HealthSit with two main features.

- **Audio-visual feedback**. The primary strategies for ensuring the interactivity of HealthSit were to provide references for target postures, guidance for the exercise flow, and appropriate feedback on the exercise effort (Mandryk et al., 2014; Singh et al., 2014). Specifically, in the graphical interface of HealthSit, a visual avatar serves as a virtual coach who mirrors the correct stretch postures. Meanwhile, the music of HealthSit was manipulated with pan-control (Hodgson, 2010, p.162), which shifts the audio output between left and right channels to give spatial cues (Burgess, 1992) to the lateral movement. When the user swayed the body trunk toward the instructed side, the sound would gradually move back to the center according to the extent of the posture. Once the user arrived at the target position, the music would be panned back to the center. At the same time, the visual avatar would change to the color black from light grey. After a few seconds of stretching, the system would indicate the next position on the opposite side.
- **Exercise challenges and game rewards**. According to Mandryk et al. (2014), interactive technology for non-sedentary behavior should apply persuasive strategies (Ren, Lu, Oinas-Kukkonen, & Brombacher, 2017), e.g. short-term challenges and rewards to foster the user's long-term motivation to engage in repeated practice. Besides the audio-visual feedback, the interaction design also addresses the following features. First, the software requires the user to hold the stretching positions for different durations, ranging from two to four seconds. The aim here is to establish a flow experience during the stretching exercise by keeping the balance between the task challenges and skills. Second, by accomplishing challenges continuously, the user can receive virtual rewards, which can be upgraded by awarding badges at various levels. Specifically, during the exercise, the user could earn a 'star' badge by completing six stretching exercises and a 'heart' badge by conducting lateral movements eight times. After the exercise, the badges that had been earned would be converted into 'crown' rewards, based on the following rationale: 1× crown = 4× star = 2× heart = 2× star + 1× heart. Moreover, the user receives a positive message after each exercise to sustain adherence to the game.

To investigate the benefits of system interactivity for the fitness break, we removed the two interactive features of HealthSit. Instead, the system then provided standard exercise guidance to lead the exercise flow. This was used as a guided exercise mode (GEM) for the user study. Specifically, the GEM uses the audio-visual interface to present the instructions without giving feedback on the user's exercise performance. Moreover, the exercise challenge is not adapted and therefore no rewards are provided during the exercise. To investigate the effectiveness of the system in facilitating the lower-back stretch, we further removed the exercise guidance from HealthSit as a self-directed exercise mode (SEM), where the user performs the exercise at his or her own pace without either real-time feedback or standard guidance. (Figure 3 (c)).

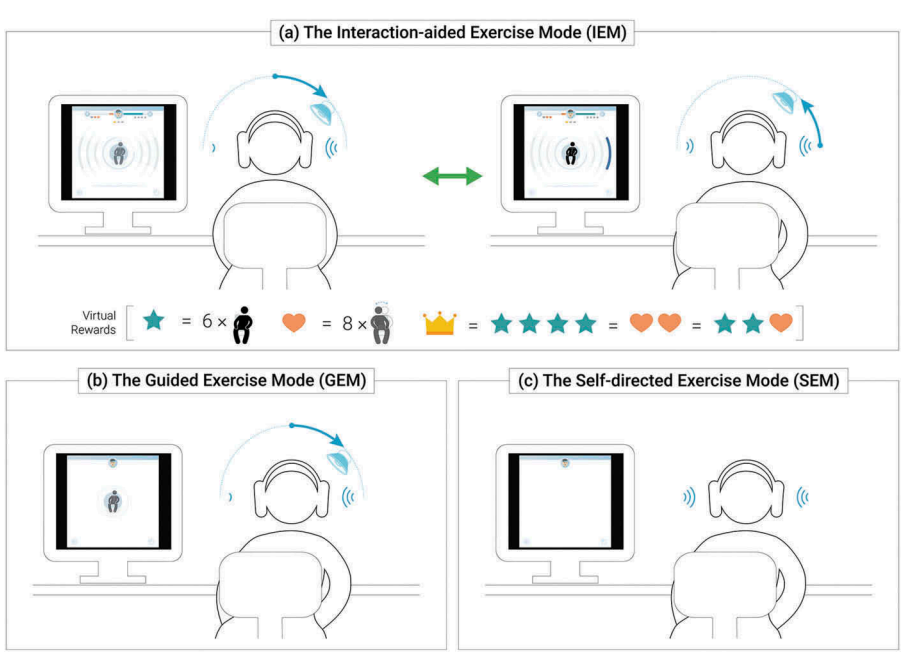

Figure 3. Interaction design in the three working modes of HealthSit: (a) audio-visual interaction to guide the flow of the exercise and provide feedback on the user's performance; (b) audio-visual guidance to lead the flow of the exercise; (c) exercising with background music without exposing the user to audio-visual guidance and feedback.

Table 1. Interaction elements included in each exercise mode of HealthSit.

Interaction elements	Self-directed exercise mode (SEM)	Guided exercise mode (GEM)	Interaction-aided exercise mode (IEM)
standard exercise guidance		√	√
exercise feedback, challenges and rewards			√

The differences among the three working modes of HealthSit are summarized in Table 1.

4. The study

In response to the research questions, the aim of the user study was to investigate 1) the effectiveness of HealthSit in facilitating the lower-back stretching exercise; 2) the role of system interactivity in enhancing the user experience with HealthSit; 3) the effects of HealthSit-assisted fitness break on the user's emotional status and cognitive performance. We used a within-subject repeated measure design, with participants performing the stretch exercises in the three working modes (IEM, GEM, and SEM) of HealthSit mentioned above, respectively. We compared three conditions relating to exercise quality, user experience, and psychological benefits. Our primary hypotheses are as follows:

- **H01**: The IEM of HealthSit will be more effective in improving the stretching exercise than the GEM and SEM, in terms of exercise performance and perceived exertion.
- **H02**: The IEM of HealthSit will enhance user experience in the stretching exercise more than the GEM and SEM, in terms of heightened exercise motivation and reduced mental workload.
- **H03**: Short stretching exercises with the IEM of HealthSit will increase office workers' emotional state (pleasure, arousal, dominance) and mental focus more than with the GEM and SEM.

The following section describes the experiment setup, the characteristics of the participants, the study procedure, and data collection and analysis.

4.1. Setup

The study was carried out in an office-like living lab (see Figure 4). We placed the sensor pad of HealthSit on the seat of an armless office chair, and all the other electronics were located under the seat. The HealthSit hardware is easy to deploy on most office chairs and it remains unobtrusive in real office surroundings. The HealthSit software was installed on a 15-inch laptop, which was placed flat on the desk. When the HealthSit software runs, its graphical interface is presented on the laptop's screen, and the auditory feedback is delivered via a Bluetooth wireless headphone.

4.2. Participants

A total of 30 participants (14 males, 16 females) aged from 26 to 60 (M = 32.1, SD = 7.7) were recruited for the study. We recruited participants by spreading information via word of mouth. During recruiting, the participants for whom it might be risky to perform the stretching exercise were excluded (e.g. pregnant women and people with physical complaints). All participants were knowledge workers who perform sedentary work for at least 6 hrs per day. The selected participants worked in the same building where the living lab was situated, for ease of attendance. Before the study, the participants did not know about either our research prototype or the stretching exercise. They were fully informed of the study procedure without discussing its hypotheses and were given the opportunity to withdraw at any point. Each participant was compensated with €15 in the form of a gift voucher after completion of the study.

4.3. Procedure

The study was conducted on three separate working days, so that the participants experienced one of the three modes each

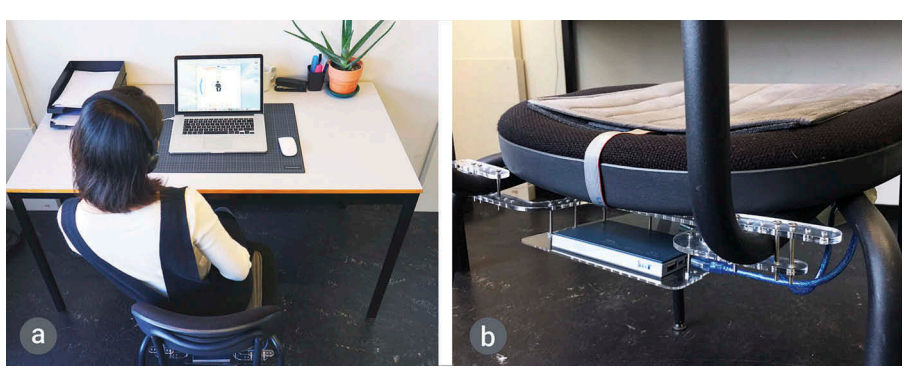

Figure 4. (a) The setup of the laboratory; (b) The HealthSit sit pad is mounted on the chair.

day. The exposure to three modes was fully counterbalanced. For each working mode, the participants performed two stretching exercises during their work breaks. There was a time interval between the two exercises of about 3 hrs, during which the participants carried on with their daily work. In total, each participant did six stretching exercises over three working days. The data collected from two exercises in each mode were averaged to moderate the impacts of break time and work status, and this information was further used for comparative analyses.

Before the experiment, the participant watched a tutorial video to get familiar with the stretching exercise. At the beginning of each experimental session, the participant completed a mental arithmetic challenge for two min. Then, the participant was asked to fill out the self-assessment manikin (SAM) (Bradley & Lang, 1994). Next, we left the participant alone to complete the stretching exercise, assisted by HealthSit in the working mode of that day. During the exercise, the sit pad collected the participant's performance data and this was stored locally in the HealthSit software. After completing the exercise, the participant filled out the SAM and the Borg rating of perceived exertion (Borg RPE) (Borg, 1998). At the end of each session, the participant completed a 2-minute mental arithmetic challenge again. The arithmetic challenge was used as a mental task whose score can be used as an indicator of participants' cognitive performance. Similar to Gao and Mandryk (2012), we also used the pre-post comparison to reveal the cognitive benefits of exercising with HealthSit. After the second session (in the afternoon) for each mode, the participant completed an Intrinsic Motivation Inventory (IMI) (McAuley, Duncan, & Tammen, 1989) and the NASA task load index (NASA-TLX) (Hart & Staveland, 1988). When the participant had completed all six experimental sessions, an exit interview was conducted in person.

4.4. Measurements

As shown in Table 2, we collected both quantitative and qualitative data for three main purposes. First, to evaluate participants' exercise performance, we collected the motion data from the sensor pad and participants' self-perceived exertion using Borg RPE (Borg, 1998). The force data from the FRSs on the left and right side were averaged respectively to indicate the weight distribution on each side. Then, the difference between the weight distribution on the left and right sides was calculated as the motion data. Borg RPE is a reasonably good single linear scale that has been widely applied in sport studies as an alternative to estimating the actual heart rate during the physical activity (Borg, 1998). In this study, we used the revised version of Borg RPE, the scale that ranges from 0 (no exertion at all) to 11 (maximal exertion), with 2, 3, and 5 standing for "light," "moderate," and "strong," respectively (Borg, 1998).

Second, the evaluation of user experience mainly focuses on intrinsic motivation (Miller, Deci, & Ryan, 1988) and mental workload. The participant's intrinsic motivation to carry out the stretch exercise is measured by IMI, which contains a total of 45 items across seven subscales, thus assessing self-desire for a specific activity (McAuley et al., 1989). We selected the first five subscales due to their high relevance to the fitness exercises in this study, including *interest/enjoyment, perceived competence, pressure/tension, effort/importance*, and *value/usefulness*. We used NASA-TLX (Hart & Staveland, 1988) to assess the cognitive workload of the short stretching exercise. As we mainly focused on examining how mentally demanding the stretch exercise was, three subscales of NASA-TLX were used in this study—*mental demands, performance*, and *frustration*—to indicate how burdensome the participants felt the exercise was, which might negatively influence engagement in the exercise. For all subscales, a lower rating represents a lower workload, although in the case of *performance*, it represents being more satisfied with the performed task.

Third, we examined the immediate impacts of the short stretching exercises on emotional states by means of a pre- and post-intervention survey using SAM. SAM (Bradley & Lang, 1994) is an emotion assessment tool that has nine-point graphic scales, depicting cartoon characters expressing three emotions: *pleasure* (from 1-negative to 9-positive), *arousal* (from 1-low to 9-high levels), and dominance (from 1-low to 9-high levels). We also assessed the impacts of the exercises on participants' mental focus as indicated by changes in the scores in a 2-minute mental arithmetic test before and after each exercise. In the study, all arithmetic tests were at equivalent levels of difficulty, consisted of multiplication and division involving 2- and 3-digit numbers and decimals.

To conclude the experiment, a semi-structured interview was conducted for approximately 30 min per participant to collect qualitative data regarding their experience and opinions on the different modes of HealthSit. During the interview, we asked participants a series of three questions: "Which working mode of HealthSit would you mostly consider using for a work break?," "Please describe the reason you like or dislike each

Table 2. Data collected from the study.

	IEM		GEM		SEM		
Measures	Session1	Session2	Session1	Session2	Session1	Session2	Post study
Exercise quality							
Motion data	√	√	√	√	√	√	
Borg RPE	√	√	√	√	√	√	
User experience							
IMI		√		√		√	
NATA-TLX		√		√		√	
Psychological benefits							
SAM	√	√	√	√	√	√	
Arithmetic test	√	√	√	√	√	√	
Follow-up interview							√

exercise mode and share your ideas for improvement." and "Do you have any suggestions concerning the use of the HealthSit system to aid fitness breaks in your everyday work?" There was enough space for participants to freely provide feedback on their experience. All interviews were audio-recorded and transcribed later for analysis. The interview data were used to support the interpretation of the quantitative data.

4.5. Data analysis

4.5.1. Quantitative data

The collected force data were analyzed in Matlab software. First, the raw data were smoothed using a median filter to remove noise. Next, two indices of stretching exercise quality (Au-Yeung, 2003): *Time of stretch hold* and *Amplitude of stretch motion* were calculated. The length of each dataset was screened further for valid lateral postures and calculated to arrive at the *time of stretch hold* (in seconds) by dividing the sampling frequency. The median of each dataset was identified as the *amplitude of stretch motion*.

The processed motion data, questionnaire responses, and arithmetic test results were analyzed using SPSS software. We initiated the quantitative analysis with the descriptive statistics, in which we checked the distribution of all data using a Shapiro–Wilk test. For data with normality across all conditions, we first conducted repeated measures ANOVA with exercise mode as a factor (IEM, GEM, and SEM). When the sphericity could not be assumed, degrees of freedom were adjusted. Post-hoc analyses were conducted using Bonferroni correction for pairwise comparisons. For data that were not normally distributed, we first conducted a non-parametric Friedman test to measure the differences among conditions. Where Friedman was significant, we conducted non-parametric paired Wilcoxon tests to identify which condition differed significantly.

4.5.2. Qualitative data

All interview transcripts were imported into NVivo software for thematic analysis (Braun & Clarke, 2006). The qualitative analysis began with the segmentation of the interview transcripts into quote statements and these were labeled. We then measured the labeled statements using inductive coding (Thomas, 2006) to identify recurring clusters suggesting emergent themes. Additionally, the frequency of statements attributed to themes was counted to indicate the importance and relevance to our quantitative data.

5. Results

5.1. System interactivity improved the effectiveness of the exercise

5.1.1. Motion Data

Time of stretch hold. Figure 5(a) shows the results of stretch hold time for each of the three modes. A Friedman test revealed that the interactivity of the HealthSit system had a significant effect on the duration of stretch holds during the exercises, X^2 (2) = 41.600, $p < 0.001$. Pairwise non-parametric comparisons showed that the duration of stretching in the IEM (M = 125.33, SE = 2.14) was significantly longer than that under the GEM (M = 71.75, SE = 3.85), Z = 4.782, $p < 0.001$, and the SEM (M = 56.54, SE = 6.40), Z = 4.721, $p < 0.001$. No statistical difference was found between the GEM and SEM, Z = 1.944, p = 0.052.

Amplitude of stretch motion. Figure 5(b) shows the difference in stretch amplitude during the stretching exercises under three conditions. A Friedman test demonstrated that the differences were statistically significant, X^2 (2) = 8.867, $p < 0.05$. The post-hoc Wilcoxon tests showed that the stretch amplitude with the IEM was significantly higher (M = 788.93, SE = 92.08) than with the SEM (M = 587.31, SE = 102.42), Z = 3.198, $p < 0.01$. The stretch amplitude in the IEM was also larger than in the GEM (M = 696.47, SE = 102.13), but the difference was not significant, Z = 1.594, p = 0.111. No significant difference was shown between the GEM and SEM, Z = 1.121, p = 0.262.

Motion patterns in stretching exercises. Figure 6 shows examples of participants' motion data in a stretching exercise with HealthSit in each of the three modes. In the SEM (see Figure 6(a)), the amplitude of the stretch exercise seemed small and irregular (e.g. P29) and the time of the stretch seemed short (e.g. P19). In the GEM (see Figure 6(b)), the amplitude of stretch was improved, and the stretch motion became more regular with extended hold time. In the IEM (see Figure 6(c)), the stretch amplitude and the stretch hold time were both improved to a higher level. It is also interesting to observe the difference in stretch performance between the GEM and IEM, which reveals that the IEM requires only a short time for participants to become familiar with the feedback and perform well (e.g. P8, P19, P29).

5.1.2. Borg RPE

Figure 7 shows the results of the Borg RPE survey. In general, three conditions produced perceived exertion value at light-to-moderate intensity, which improves aerobic capacity. A

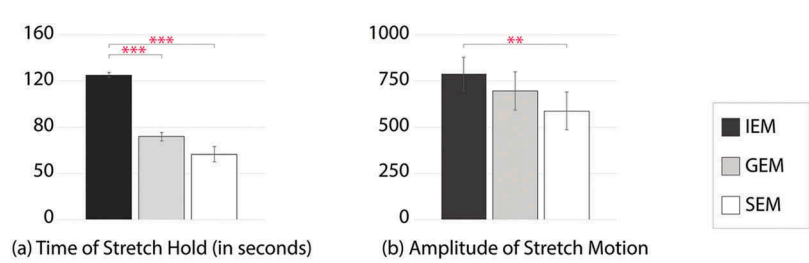

Figure 5. Mean and SE of motion data.

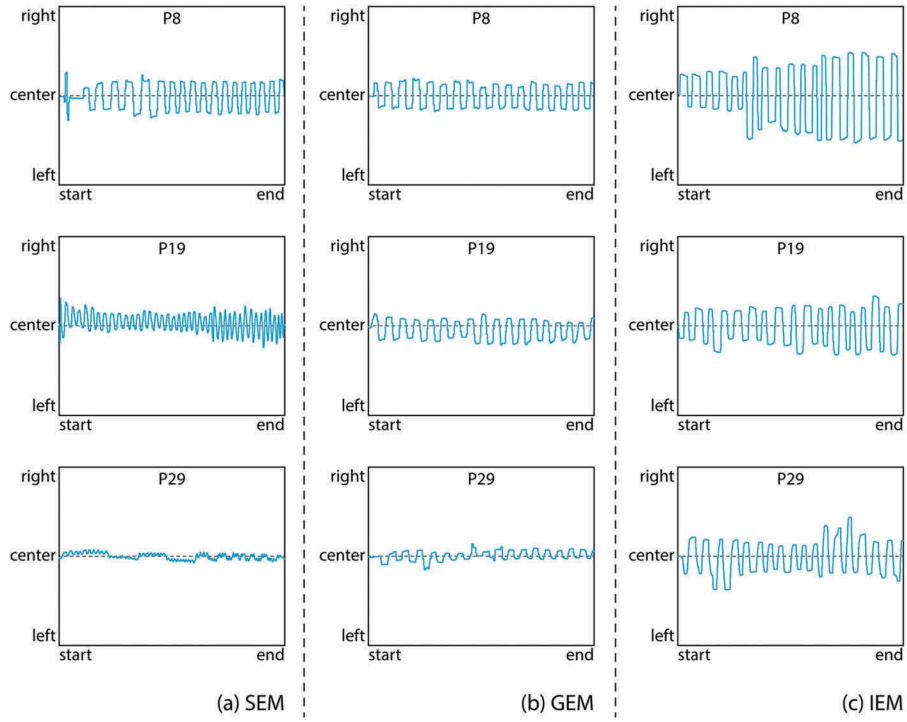

Figure 6. Examples of participants' motion patterns during the exercise with (a) SEM, (b) GEM, (c) IEM.

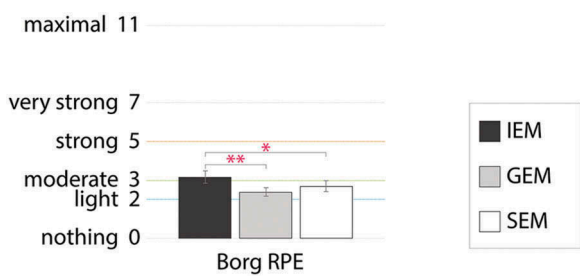

Figure 7. Mean and SE of Borg RPE.

Friedman test revealed that there were significant differences among the conditions in terms of perceived exertion, X^2 (2) = 9.415, p < 0.01. A Wilcoxon non-parametric tests showed that the intensity of the exercise was perceived to be significantly stronger in the IEM (M = 3.17, SE = 0.31) than in the GEM (M = 2.39, SE = 0.22), Z = 3.406, p = 0.01, and in the SEM (M = 2.70, SE = 0.27), Z = 1.962, p = 0.05. For perceived exertion, there was no significant difference between the GEM and the SEM, Z = 1.545, p = 0.122.

5.1.3. Summary

First, a comparison between the motion data in the IEM and the SEM confirmed our first hypothesis that the HealthSit system can effectively improve the quality of the stretching exercise, which was reflected by the extended time of stretch hold and the increased amplitude of postural sway. Second, the comparison between the IEM and the GEM also revealed the impact of system interactivity on promoting the stretching exercise, especially for the duration of stretch hold, which also increased the perceived exertion without leading to excessive levels of physical activity. To summarize, the results suggest that the interactive HealthSit system could facilitate the stretching exercise both in terms of physical performance and the perceived intensity of the exercise.

5.2. System interactivity improved the intrinsic motivation to carry out the exercise

5.2.1. Intrinsic motivation

Figure 8 shows the results of the IMI. Overall, we found that participants were positively motivated to perform the stretching exercise during work breaks, with reasonably high scores on the subscales of *interest/enjoyment, perceived competence*, and *value/usefulness*. Additionally, ratings for all conditions were moderate for *effort/importance* and low for *pressure/tension*, which indicated that the exercise was not very demanding for our participants. A repeated measure ANOVA showed that there were significant differences on the *enjoyment, perceived competence, and effort* subscales among the three modes of HealthSit.

Interest/enjoyment. As shown in Figure 8(a), there were significant differences when it came to enjoying the fitness among the modes, $F(2)$ = 10.401, p < 0.001. Enjoyment was rated significantly higher for the IEM (M = 5.50, SE = 0.18) than for the GEM (M = 4.77, SE = 0.23), with p < 0.001, or the SEM (M = 4.82, SE = 0.22), with p = 0.001. No statistical difference was found between the GEM and the SEM (p = 1.000).

Perceived competence. Figure 8(b) shows significant differences between the perceived competence of the physical activity under the different modes, $F(2)$ = 5.797, p < 0.01. The participants felt significantly more competent with HealthSit in IEM (M = 5.21, SE = 0.15) than in SEM (M = 4.69, SE = 0.20), with p < 0.05. The perceived competence in IEM was also stronger than in GEM (M = 4.95, SE = 0.16), but the

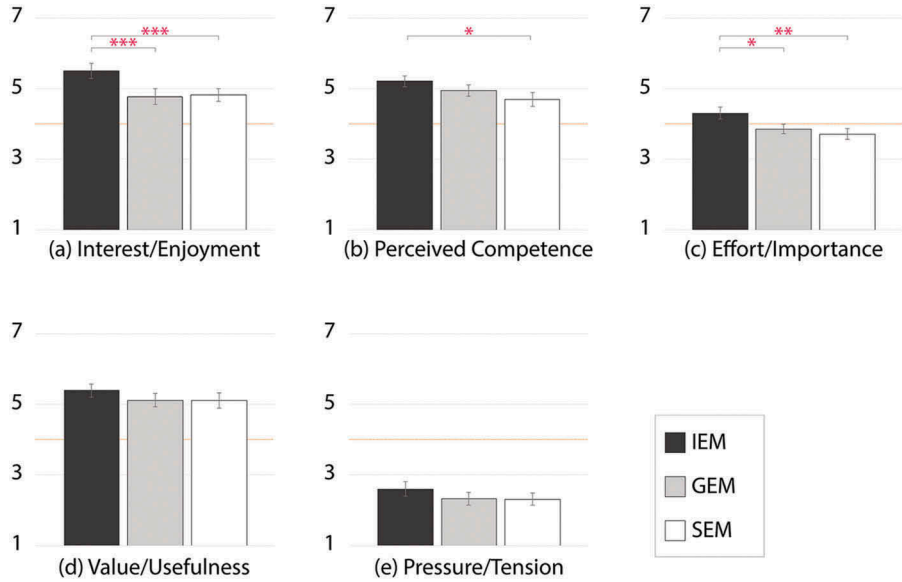

Figure 8. Mean and SE of IMI.

difference was not significant (p = 0.090). No statistical difference was found between the GEM and the SEM (p = 0.290).

Effort/importance. In the effort/importance subscale (see Figure 8(c)), the participant's ratings were also significantly different for three modes, $F(2)$ = 7.379, p < 0.01. The fitness activity was considered significantly more important in the IEM (M = 4.31, SE = 0.18) than in the GEM (M = 3.85, SE = 0.13), with p < 0.05, or the SEM (M = 3.71, SE = 0.16), with p < 0.01. No statistical difference was found between the GEM and the SEM (p = 0.787).

Value/usefulness and *pressure/tension*. On both of these two subscales, the IEM was rated higher than the other modes. However, regarding the perceived usefulness of the stretch exercise (see Figure 8(d)), there were no statistical differences among the IEM (M = 5.39, SE = 0.19), the GEM (M = 5.11, SE = 0.19), and the SEM (M = 5.11, SE = 0.22), $F(2)$ = 2.171, p = 0.123. Regarding the perceived tension of the exercise (see Figure 8(e)), there were also no significant differences among the IEM (M = 2.60, SE = 0.21), the GEM (M = 2.33, SE = 0.18), and the SEM (M = 2.31, SE = 0.17), $F(2)$ = 1.089, p = 0.343.

5.2.2. Workload

The workload was measured by NASA-TLX with three subscales: *cognitive demand, performance*, and *frustration*. As shown in Figure 9 (a), the perceived task load scored low overall on average, which resulted from relatively low levels of mental workload and frustration, and high satisfaction with exercise performance in all conditions. While participants scored the workload with IEM (M = 5.89, SE = 0.56) lower than with SEM (M = 6.08, SE = 0.48) and higher than with the GEM (M = 5.41, SE = 0.50), such differences were not significant according to a repeated measures ANOVA, $F(2)$ = 0.550, p = 0.580.

Regarding the mental load (see Figure 9(b)), the stretching exercise with HealthSit in the IEM (M = 6.93, SE = 0.86) was reported to require higher cognitive demand than the exercises in the GEM (M = 4.47, SE = 0.61) and the SEM (M = 5.53, SE = 0.77). A Friedman test indicated that there were no significant differences between the three modes. X^2 (2) = 2.418, p = 0.298. Regarding the self-evaluated performance (see Figure 9(c)), participants perceived their stretching exercise to be more successful in the IEM (M = 6.23, SE = 0.51) than in the GEM (M = 7.87, SE = 0.89) and the SEM (M = 8.13, SE = 0.86). According to the Friedman test, the differences were not significant, X^2 (2) = 2.155, p = 0.340. Regarding frustration (see Figure 9(d)), we observed no statistical differences for the IEM (M = 4.50, SE = 0.61), the GEM (M = 3.90, SE = 0.53), and the SEM (M = 4.57, SE = 0.68) in terms of participants' frustration with the exercise, X^2 (2) = 1.580, p = 0.452.

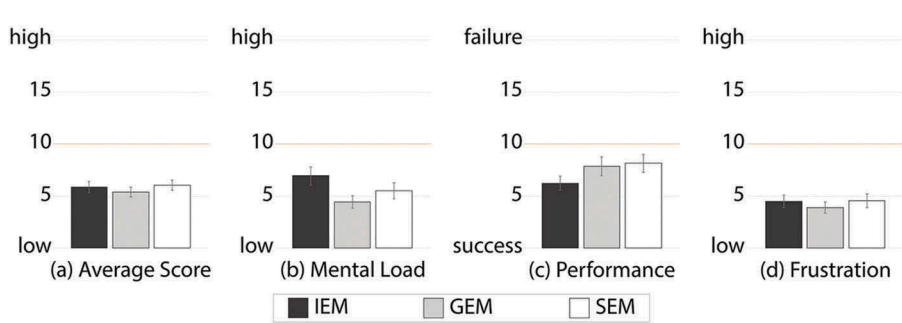

Figure 9. Mean and SE of NASA-TLX.

5.2.3. Summary

The results of IMI suggest that the interactivity of the HealthSit system enhances users' intrinsic motivation to carry out the lower-back stretching exercise in terms of enjoyment, competence, and effort. These elements can be important in encouraging adherence to fitness breaks in the workplace (Richard, Christina, Deborah, Rubio, & Kennon, 1997). On the other hand, stretching exercises with HealthSit scored relatively low in the workload survey. The real-time feedback from the HealthSit system in the IEM seemed to require more mental workload and effort from participants, but at the same time, they became more satisfied with it and rated their performance more positively. These results suggest that the interactivity of a fitness-promotion system may play a positive role in enhancing users' experience with physical exercises in the workplace, which might be used to sustain their engagement with and adherence to the activity in the long term.

5.3. System interactivity enhanced the arousal state during the exercise

5.3.1. Affective state

As can be seen from Table 3 (a)–(c), participants' pleasure, arousal, and dominance increased significantly after the stretching exercise under all three conditions, despite the greater arousal for the IEM. Friedman tests showed that there were no significant differences in the improvements related to pleasure and dominance. The improvement of arousal was significantly different among the three conditions. Pairwise comparison tests demonstrated that the improvement in participants' arousal state in the IEM was significantly higher than in the GEM ($Z = 2.748$, $p < 0.01$) and the SEM ($Z = 2.004$, $p < 0.05$). No significant difference between the GEM and the SEM was shown, $Z = 1.737$, $p = 0.082$.

5.3.2. Arithmetic tests

As shown in Table 3 (d), the scores on the arithmetic test improved after the stretching exercises in all three modes. However, the improvement was only significant in the SEM ($Z = 2.246$, $p < 0.05$). A Friedman test showed that there was no significant difference between the improvements in arithmetic scores under the three conditions (X^2 (2) = 3.35, $p = 0.187$).

5.3.3 Summary

The results suggest that a stretching exercise during a short work break can enhance participants' state of pleasure, arousal, and dominance. The human arousal level can play an important role in work performance (Thompson, Schellenberg, & Husain, 2001). A moderate arousal state leads to optimal performance. Based on our results, the stretch exercises in the IEM were more effective in mediating the participants' arousal level than the GEM, which reveals a psychological benefit as a result of the interactivity of fitness promotion in the IEM. On the other hand, the performance in arithmetic tests improved after all stretching exercises. There was no significant difference under the three conditions. However, the performance improvement was only significant in the SEM, where the participants performed stretch exercises in a self-directed way without any guidance, feedback, challenges, or rewards from the HealthSit system. We see that there is consistency between the results of the survey on the user experience (IMI) and the affective state (SAM). The IEM increased feelings of arousal, effort tension, and competence, which may promote stretching exercises, but might not lead to mental relaxation. The SEM needed less effort and arousal, which might lead to better mental relaxation and a more significant improvement when performing the mentally challenging task.

5.4. Interview results

5.4.1. The IEM

According to the follow-up interviews, 24 of the 30 participants preferred the IEM of HealthSit for lower-back stretching during work breaks. The reasons for their choice can be summarized follows. First, the responses indicated that more

Table 3. Mean and SE for pleasure, arousal, dominance and mental arithmetic challenge. Results of Wilcoxon tests between pre- and post-conditions. Friedman tests among the IEM, the GEM, and the SEM. 'Improvement' represents Mean and SE for the differences of SAM and arithmetic score between the pre- and post-conditions.

	(a) Pleasure				(b) Arousal			
Conditions	Pre	Post	*Z, p*	Improvement	Pre	Post	*Z, p*	Improvement
IEM	5.40	7.08	4.530	1.68	5.30	6.23	2.722	0.93
	(.27)	(.21)	.000***	(.32)	(.24)	(.32)	.006**	(.30)
GEM	5.25	6.63	3.970	1.38	5.40	5.67	0.756	0.27
	(.26)	(.21)	.000***	(.28)	(.20)	(.27)	.449	(.27)
SEM	5.35	6.73	3.942	1.38	5.22	5.73	2.408	0.52
	(.30)	(.23)	.000***	(.30)	(.21)	(.32)	.016*	(.29)
X^2 (2), *p*	1.477			1.839	0.077			9.851,
	.478			.299	.962			.007**

	(c) Dominance				(d) Mental arithmetic test			
Conditions	Pre	Post	*Z, p*	Improvement	Pre	Post	*Z, p*	Improvement
IEM	5.32	6.45	3.987	1.1	13.62 (1.09)	14.13 (1.55)	0.249	0.52
	(.23)	(.25)	.000***	(.25)			.803	(.83)
GEM	5.05	5.95	2.729	0.9	14.13 (1.42)	14.93 (1.29)	0.810	0.80
	(.21)	(.28)	.006**	(.29)			.418	(.66)
SEM	5.07	6.18	3.161	1.1	13.50 (1.21)	15.03 (1.07)	2.246	1.53
	(.25)	(.30)	.002**	(.32)			.025*	(.65)
X^2 (2), *p*	0.758			1.640,	0.362			3.350,
	.685			.440	.834			.187

participants expressed a positive attitude toward the health outcome improved by the HealthSit in IEM. They stated that they could see the potential benefits of HealthSit for physical (17/30) and psychological health (13/30) during long-term use. For instance, some participants mentioned that *"it relaxed your mind from work"* (P9), *"it energised me go back to work"* (P24), *"it helped me to learn the right way to do the exercise, which was good for back supporting muscles"* (P26), and *"the interaction makes me more aware of my body postures"* (P12). Second, the responses indicated that the interactivity of the system helped to improve the exercise quality and the engagement with the exercise. For instance, one participant (P10) explained: *"If I were to do it myself without feedback, perhaps I might do it wrong…I do feel more freedom and less pressure in self-directed exercises, but the feedback in the interaction-aided exercise mode helps train your posture."* Another participant (P27) stated: *"…. when the system told me that I am gonna get some rewards, I felt encouraged to do the exercise again and keep doing it as good as with the previous ones."* Third, the interactivity of HealthSit was seen as an emotion enhancer by the majority of participants. Totally, 25/30 participants described the interaction with HealthSit as "*enjoyable*" and 24/30 described it as "*exciting.*" Additionally, 21/30 mentioned, compared with the GEM, that the IEM increased the effort and the challenge of the exercise. For instance, some participants stated that: *"I appreciate it recognises my movements, which makes my experience alive"* (P30), *"I felt rewarding by achieving challenges continuously."* (P17) and *"It requires you to invest a big effort to get your awareness from work to the exercise."* (P2). In contrast, four stated that the challenges were too overwhelming for an exercise in fitness breaks. For example, one participant stated that *"There was a lot more happening in this task, it was more like a game. But it was a lot. I would prefer my mind to be free during physical exercise."* (P16).

5.4.2. The GEM and SEM

Only four participants selected the GEM, and two participants selected the SEM as their preferred mode. For those who preferred GEM, they stated that the exercise with the fixed instructions was easier to understand and follow and the repeated movement required fewer efforts, which helped them to relax from the busy work. For instance, one participant (P19) mentioned *"…it was more like a meditation exercise. So, the guided one was the easiest for me to follow without thinking too much and it was relaxing with music in the background."* In the SEM, the system did not provide any feedback or instructions. Two participants preferred it because "*I did stretching loosely*" (P6), and *"with more freedom*" (P14). On the other hand, 10 participants stated that they felt somewhat frustrated when exercising without the feedback about their performance. Eight participants reported some negative feelings of discomfort and awkward situation with SEM. Moreover, five participants also reported that it was easier to be distracted during exercises in the GEM and SEM modes.

6. Discussion

This article presents the design and evaluation of HealthSit, a workplace fitness technology which supports a lower-back stretching exercise during work breaks. A user study was conducted to evaluate the effectiveness of HealthSit in supporting the lower-back stretching exercise and to investigate the role of system interactivity in enhancing the user experience and providing psychological benefits. To achieve this, three working modes of HealthSit, IEM, GEM, and SEM, were developed and used in a within-subject experiment with 30 participants. The interactivity of the HealthSit system in the IEM is provided in three ways. First, HealthSit provides users with real-time feedback on their stretching performance through on-screen animation and musical output. Second, HealthSit randomizes the required duration of each stretch motion to increase the flexibility and challenge of the exercise. Third, HealthSit offers users a virtual reward (in the form of badges at various levels) to enhance motivation for doing the exercise. The latter two can be regarded as lightweight game mechanics in our interaction design for HealthSit.

Our results confirmed the effectiveness of HealthSit in supporting the lower-back stretching exercise as a new workplace technology, and also the decisive role of interactivity in enhancing exercise quality, motivation, and emotional state during the fitness break. First, our results showed that in the IEM, HealthSit could effectively facilitate the low-back stretching exercises, in particular leading to improved amplitude of stretch motion and time of stretch hold during the exercise. These results are likely to be related to the in-exercise interaction with real-time performance feedback, which focuses the user on the goal of the activity (Thin & Poole, 2010). Second, participants reported that exercising with HealthSit in its IEM significantly enhanced their user experience due to increased enjoyment, perceived competence, and the importance of making an effort. The improvements in user experience and motivation could be attributed to the game mechanics of "challenge" and "reward" in the interaction design. Various exergame studies have also proved the effectiveness of game elements and mechanics in improving the user experience and adherence to physical activities (King, Greaves, Exeter, & Darzi, 2013). This result was also partly supported by the user responses during the interview, in which 24/30 participants stated that the IEM was their favorite mode and also the most health-beneficial mode for carrying out stretching exercises during work breaks. Also, they described their experience in the IEM as "enjoyable," "exciting," and "challenging." Third, the stretching exercise with the IEM may enhance participants' emotional state during a fitness break. This finding is consistent with prior work, which revealed the emotional benefits of interactivity in a walking exercise (Tajadura-Jiménez et al., 2015). Together with the quantitative results discussed above, the qualitative results from the interview helped to yield more insights about the design of an interactive system for promoting fitness breaks in the workplace. We summarize them in a set of design implications as follows.

6.1. Design implications

6.1.1. Simple and clear interaction without overburdening during a work break

In daily routines, a work break usually takes just a few minutes. The fitness breaks are designed to help office workers to unwind mentally and relax physically, thus reducing muscle fatigue from inactive sitting (Healy et al., 2008). Therefore, the user interaction element of a fitness-promotion system should not be difficult but rather designed for simplicity, requiring low levels of effort and a short time to learn. As shown in Figure 1, the HealthSit system is a close-looped interactive system, whose feedback is implemented in both visual and audio modalities with an intuitively understandable form. Regarding the visual feedback, we used a visual character to provide explicit guidance for posture and exercise flow. The audio feedback was implemented by modulating the sound shift between the left and right channels to provide a cue to indicate the need for a weight shift between lateral postures. From the interview responses, it appeared that this direct mapping of the user's postures to the visual animations and sound shifts between the left and right channels were easy for the participants to learn and follow.

Besides the audio-visual cues, such simple interaction may also be provided by haptic feedback to support commitment to the exercise. As suggested by Stach and Graham (2011), the haptic feedback should be clearly mapped to the exercise performance to reduce the mental effort needed to understand the interaction. However, this suggestion is only used in the scenario of exergames but not facilitating the light-intensity desk exercise. In our study, for example, some participants have suggested supporting the exercise flow of such light-intensity desk exercise via haptic feedback from the sit pad directly, using the location and intensity of vibration to guide and inform users.

6.1.2. Gamification with rewards and challenges for motivation and engagement

Various studies have examined the impacts of a game challenge mechanism on sustaining exercise motivation. For example, Yim and Graham (2007) have suggested using achievable challenges in fitness technology continuously to foster the exercise habit. The interaction design of HealthSit also features an immediate virtual reward, and we embedded a simple challenge mechanism with a flexible stretch hold time and a reward mechanism by upgrading the level of a virtual badge based on performance. Our results suggested that game mechanics can have the positive effects in enhancing the user experience, especially the motivation and engagement related to the exercise.

On the other hand, we found that a short break with stretching exercise does not lead to improved cognitive task performance among office workers. The qualitative results revealed that this might due to a lack of transition time from the exercise to the cognitive task. Cambo et al. (2017) suggested that the balance between the desirability of the exercise during the break and the need to transition back to work should be deliberately considered for the fitness break game. To help users shift their attention back to work, we suggest that a "cooling down" session could be added after the exercise game.

6.1.3. Integrating fitness promotion into the work environment and work routine

HealthSit is implemented as an unobtrusive sensing technology for sitting postures and dynamics. The sensor pad used in the HealthSit system is relatively lightweight and affordable compared with other motion-tracking techniques. It can be fitted to office chairs in most workplaces and it communicates with a PC or smartphone wirelessly through a Bluetooth connection. The responses from the interview also revealed that the participants appreciated embedding a fitness-promoting system in office supplies or in the office environment. For instance, one participant (P8) stated: *"I like HealthSit because it looks good, comfy and it's integrated into the environment in such a way that I can use it without maybe even noticing it."* As mentioned, active workstations often occupy a large space or require a special construction of the workplace. We see the potential of lightweight interactive systems such as HealthSit to promote fitness practices in the workplace. Fitness-oriented interactivity could be embodied in various forms and embedded into a wide range of everyday objects to better fit the work environment. For instance, the data processing can be completed on a smartwatch (Kim et al., 2017) and feedback can be presented on a desktop display (Reilly et al., 2013).

Additionally, we think that fitness breaks should be "woven" into a daily working routine. HealthSit enables a seated lower-back stretching exercise without taking users out of their environment or task. The short period of the break session allows office workers to divide exercise time into fragments and then blend them into workplace activities throughout the day. For instance, our participants suggested incorporating the HealthSit-assisted stretching exercises with other break activities such as fidgeting. Several HCI studies have explored interactive widgets that combine fidgeting with boosting creativity (Karlesky & Isbister, 2014) and respiration training (Liang, Yu, Xue, Hu, & Feijs, 2018). Similarly, we see an opportunity here to leverage interactive health-promoting systems such as HealthSit to develop new fidgeting patterns for workplace fitness initiatives.

6.2. Limitations and future work

The findings from our study may need to be cautiously interpreted due to the following limitations. One is that a lab-based experiment may not be adequate to reveal the impacts of the HealthSit system for fitness promotion in real office settings. The user study mainly focused on the effectiveness of HealthSit in supporting the lower-back stretching exercise and the role of system interactivity in enhancing the user experience and improving psychological effects, while the desirability of the system for everyday use was not evaluated. In the future, it will be necessary to conduct a field study in a real workplace to investigate how office workers interact with the HealthSit system in their daily routine. Another potential limitation might be the Hawthorne effect, which indicates that participants may enhance their performance due to the attention they are given during the study (Mayo, 2004). Although we have used qualitative results gathered from follow-up interviews

to support our interpretation of the quantitative data (Macefield, 2007), the results from this lab-based experiment might still be influenced by the Hawthorne effect. For our future work, we will conduct a long-term in-situ study where the system will be used as an everyday gadget in the workplace instead of as a research tool for experiment.

7. Conclusions

In this article, we present the design of HealthSit, a lightweight interactive fitness-promoting system supporting a lower-back stretching exercise during work breaks. In a within-subject study, we evaluated the effectiveness of HealthSit in facilitating the lower-back stretching exercise by comparing its three working modes (IEM, GEM, and SEM). As a research probe, HealthSit was also used to investigate the role of system interactivity in enhancing the user experience and creating psychological benefits. Comparisons among the three working modes of HealthSit showed the positive effects of system interactivity in improving exercise quality (the amplitude of stretch motion and the time of stretch hold), user experience (enjoyment, perceived competence, and importance of effort), and arousal state. Besides, based on our design explorations and the user responses in the interviews, we presented a set of design implications for interactive technologies to promote fitness breaks in the workplace.

Notes

1. Workout Trainer: itunes.apple.com/us/app/workout-trainer-fitness-coach/.
2. treadmill: www.lifespanfitness.com/uk/workplace/treadmill-desks/.
3. stationary bike: www.lifespanfitness.com/uk/workplace/bike-desks/.
4. balance chair: www.gaiam.com/products/classic-balance-ball-chair?variant=32936592129.
5. WorkPace: www.workpace.com/workpace/about/what-is-workpace/.

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References

Ahtinen, A., Andrejeff, E., Vuolle, M., & Väänänen, K. (2016). Walk as you work: User study and design implications for mobile walking meetings. *Proceedings of the 9th Nordic Conference on Human-Computer Interaction* (pp. 72: 1–72:10). New York: ACM. doi:10.1145/2971485.2971510

Au-Yeung, S. S. Y. (2003). Does weight-shifting exercise improve postural symmetry in sitting in people with hemiplegia? *Brain Injury*, *17* (9), 789–797. doi:10.1080/0269905031000088487

Beach, T. A. C., Parkinson, R. J., Stothart, J. P., & Callaghan, J. P. (2005). Effects of prolonged sitting on the passive flexion stiffness of the in vivo lumbar spine. *Spine Journal*, *5*(2), 145–154. doi:10.1016/j.spinee.2004.07.036

Bin, K. S., Lee, S. J., & Han, J. H. (2017). StretchArms: Promoting stretching exercise with a smartwatch. *International Journal of Human-Computer Interaction*, 1–8. doi:10.1080/10447318.2017.1342408

Borg, G. (1998). *Borg's perceived exertion and pain scales*. Stockholm: Human kinetics.

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry*, *25*(1), 49–59. doi:10.1016/0005-7916(94)90063-9

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(May 2015), 77–101. doi:10.1191/1478088706qp063oa

Burgess, D. A. (1992). Techniques for low cost spatial audio. *In Proceedings of the 5th annual ACM symposium on User interface software and technology* (pp. 53–59). New York: ACM.

Burkland, D. S. (2013). *The effects of taking a short break: task difficulty, need for recovery and task performance*. Menomonie, Wisconsin: University of Wisconsin–Stout.

Cambo, S. A., Avrahami, D., & Lee, M. L. (2017). BreakSense: Combining physiological and location sensing to promote mobility during work-breaks. Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17, 3595–3607. doi:10.1145/3025453.3026021

Chen, Y., & Pu, P. (2014). HealthyTogether. *Proceedings of the second international symposium of Chinese CHI on - Chinese CHI '14* (pp. 25–34). New York: ACM. doi:10.1145/2592235.2592240

Cheng, P.-T., Wu, S.-H., Liaw, M.-Y., Wong, A. M. K., & Tang, F.-T. (2001). Symmetrical body-weight distribution training in stroke patients and its effect on fall prevention. *Archives of Physical Medicine and Rehabilitation*, *82*(12), 1650–1654. doi:10.1053/apmr.2001.26256

Choi, W., Song, A., Edge, D., Fukumoto, M., & Lee, U. (2016). Exploring user experiences of active workstations. *Proceedings of the 2016 ACM international joint conference on pervasive and ubiquitous computing - UbiComp '16* (pp. 805–816). New York: ACM. doi:10.1145/2971648.2971756

Chung, C.-F., Jensen, N., Shklovski, I. A., & Munson, S. (2017). Finding the right fit: Understanding health tracking in workplace wellness programs. In *Proceedings of the 2017 CHI conference on human factors in computing systems* (pp. 4875–4886). New York: ACM.

Church, T. S., Thomas, D. M., Tudor-Locke, C., Katzmarzyk, P. T., Earnest, C. P., Rodarte, R. Q., … Bouchard, C. (2011). Trends over 5 decades in US occupation-related physical activity and their associations with obesity. *PloS One*, *6*(5), e19657. doi:10.1371/journal.pone.0019657

Commissaris, D., & Reijneveld, K. (2005). Posture and movements during seated office work: results of a field study. *In* B. Veiersted, K. I. Fostervold, KI Gould & K. S. Gould (Eds.), *37th annual conference ergonomics as a tool in future development and value creation, nordic ergonomics society (NES), Oslo* (pp. 58–61).

Consolvo, S., Everitt, K., Smith, I., & Landay, J. A. (2006). Design requirements for technologies that encourage physical activity. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '06, 457–466. doi:10.1145/1124772.1124840

Da Costa, B. R., & Vieira, E. R. (2008). Stretching to reduce work-related musculoskeletal disorders: A systematic review. *Journal of Rehabilitation Medicine*, *40*(5), 321–328. doi:10.2340/16501977-0204

Falkenberg, L. E. (1987). Employee fitness programs: Their impact on the employee and the organization. *Academy of Management Review*, *12* (3), 511–522. doi:10.5465/amr.1987.4306566

Foster, D., Linehan, C., Kirman, B., Lawson, S., & James, G. (2010). Motivating physical activity at work. Proceedings of the 14th International Academic MindTrek Conference on Envisioning Future Media Environments - MindTrek '10, 111. doi:10.1145/1930488.1930510

Gao, Y., & Mandryk, R. (2012). The acute cognitive benefits of casual exergame play. *Proceedings of the 2012 ACM annual conference on human factors in computing systems - CHI '12* (pp. 1863). New York: ACM. doi:10.1145/2207676.2208323

Gao, Y., & Mandryk, R. L. (2011). GrabApple: the design of a casual exergame. *In International Conference on Entertainment Computing* (pp. 35–46). Berlin, Heidelberg: Springer.

Gerling, K. M., Livingston, I. J., Nacke, L. E., & Mandryk, R. L. (2012). Full-body motion-based game interaction for older adults. *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1873–1882). New York: ACM.

Gorm, N., & Shklovski, I. (2016). Steps, choices and moral accounting: Observations from a step-counting campaign in the workplace. Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing, 148–159. doi:10.1145/2818048.2819944

Grooten, W. J. A., Conradsson, D., Äng, B. O., & Franzén, E. (2013). Is active sitting as active as we think? *Ergonomics*, *56*(8), 1304–1314. doi:10.1080/00140139.2013.812748

Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. *In Advances in psychology* (Vol. 52, pp. 139–183). North-Holland: Elsevier.

Healy, G. N., Dunstan, D. W., Salmon, J., Cerin, E., Shaw, J. E., Zimmet, P. Z., & Owen, N. (2008). Breaks in sedentary time. *Diabetes Care*, *31*(4), 661–666. doi:10.2337/dc07-2046

Henning, R. A., Jacques, P., Kissel, G. V., Sullivan, A. B., & Alteras-Webb, S. M. (1997). Frequent short rest breaks from computer work: Effects on productivity and well-being at two field sites. *Ergonomics*, *40*(1), 78–91. doi:10.1080/001401397188396

Hodgson, J. (2010). *Understanding records: A field guide to recording practice*. London: Bloomsbury Publishing.

Jafarinaimi, N., Forlizzi, J., Hurst, A., & Zimmerman, J. (2005). Breakaway : An ambient display designed to change human behavior. *CHI'05 Extended Abstracts on Human Factors in Computing Systems*, 1945–1948. doi:10.1145/1056808.1057063

Janneck, M., Jent, S., Weber, P., & Nissen, H. (2017). Ergonomics to go: Designing the mobile workspace. *International Journal of Human–Computer Interaction*, 1–11.

Karlesky, M., & Isbister, K. (2014). Designing for the physical margins of digital workspaces: Fidget widgets in support of productivity and creativity. In *Proceedings of the 8th international conference on tangible, embedded and embodied interaction* (pp. 13–20). New York: ACM.

Kim, S., Park, Y. A., & Niu, Q. (2017). Micro-break activities at work to recover from daily work demands. *Journal of Organizational Behavior*, *38*(1), 28–44. doi:10.1002/job.2109

King, D., Greaves, F., Exeter, C., & Darzi, A. (2013). *"Gamification": Influencing health behaviours with games*. London, England: SAGE Publications Sage UK.

Liang, R.-H., Yu, B., Xue, M., Hu, J., & Feijs, L. M. G. (2018). BioFidget: Biofeedback for respiration training using an augmented fidget spinner. *In Proceedings of the 2018 CHI conference on human factors in computing systems* (pp. 613). New York: ACM.

Lin, J. J., Mamykina, L., Lindtner, S., Delajoux, G., & Strub, H. B. (2006). Fish'n'Steps: Encouraging physical activity with an interactive computer game. *UbiComp 2006: Ubiquitous computing* (pp. 261–278). Berlin, Heidelberg: Springer. doi:10.1007/11853565_16

Macefield, R. (2007). Usability studies and the hawthorne effect. *Journal of Usability Studies*, *2*(3), 145–154.

Mandryk, R. L., Gerling, K. M., & Stanley, K. G. (2014). Designing games to discourage sedentary behaviour In *Playful User Interfaces* (pp. 253–274). Singapore: Springer.

Mayo, E. (2004). *The human problems of an industrial civilization*. London: Routledge.

McAuley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric properties of the intrinsic motivation inventory in a competitive sport setting: A confirmatory factor analysis. *Research Quarterly for Exercise and Sport*, *60*(1), 48–58. doi:10.1080/02701367.1989.10607413

Miller, K. A., Deci, E. L., & Ryan, R. M. (1988). Intrinsic motivation and self-determination in human behavior. *Contemporary Sociology*, *17*, 253. doi:10.2307/2070638

Morris, D., Brush, A. J. B., & Meyers, B. R. (2008). SuperBreak: Using interactivity to enhance ergonomic typing breaks. *Proceeding of the twenty-sixth annual CHI conference on Human factors in computing systems - CHI '08* (pp. 1817). New York: ACM. doi:10.1145/1357054.1357337

Mueller, F. F., Edge, D., Vetere, F., Gibbs, M. R., Agamanolis, S., Bongers, B., & Sheridan, J. G. (2011). Designing sports: a framework for exertion games. *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2651–2660). New York: ACM.

Neuhaus, M., Eakin, E. G., Straker, L., Owen, N., Dunstan, D. W., Reid, N., & Healy, G. N. (2014). Reducing occupational sedentary time: A systematic review and meta-analysis of evidence on activity-permissive workstations. *Obesity Reviews*, *15*(10), 822–838. doi:10.1111/obr.12201

Owen, N., Healy, G. N., Matthews, C. E., & Dunstan, D. W. (2010). Too much sitting: The population health science of sedentary behavior. *Exercise and Sport Sciences Reviews*, *38*(3), 105–113. doi:10.1097/JES.0b013e3181e373a2

Probst, K., Lindlbauer, D., Haller, M., Schwartz, B., & Schrempf, A. (2014). A chair as ubiquitous input device. Proceedings of the 32nd Annual ACM Conference on Human Factors in Computing Systems - CHI '14, 4097–4106. doi:10.1145/2556288.2557051

Reilly, D., Westecott, E., Parker, D., Perreault, S., Neil, D., Lapierre, N., … Bal, H. (2013). Design-driven research for workplace exergames: The limber case study. *In Proceedings of the first international conference on gameful design, research, and applications* (pp. 123–126). New York: ACM.

Ren, X., Lu, Y., Oinas-Kukkonen, H., & Brombacher, A. (2017). Perswedo: Introducing persuasive principles into the creative design process through a design card-set. *In IFIP conference on human-computer interaction* (pp. 453–462). Cham: Springer.

Ren, X., Lu, Y., Visser, V., Le, P. D. H., & van den Burg, R. (2017). Interaction matters? exploring interactive music as a reminder to break sedentary office time. *In ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction* (pp. 1–8). International Association for Automation and Robotics in Construction, Taipei.

Ren, X., Ma, Y., Lu, Y., & Brombacher, A. (2017). ShuttleKicker+: Designing gamified sonification to augment the physical leisure activity. *In Extended abstracts publication of the annual symposium on computer-human interaction in play* (pp. 471–478). New York: ACM.

Ren, X., Visser, V., Lu, Y., Brankaert, R., Offermans, S., & Nagtzaam, H. (2016). Flow pillow: exploring sitting experience towards active ageing. *In Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct - MobileHCI '16* (pp. 706–713). ACM, New York

Richard, M., Christina, M. F., Deborah, L. S., Rubio, N., & Kennon, M. S. (1997). Intrinsic motivation and exercise adherence. *Int J Sport Psychol*, *28*(4), 335–354.

Riedel, J. E., Lynch, W., Baase, C., Hymel, P., & Peterson, K. W. (2001). The effect of disease prevention and health promotion on workplace productivity: A literature review. *American Journal of Health Promotion*, *15*(3), 167–191. doi:10.4278/0890-1171-15.3.167

Saunders, W., & Vogel, D. (2016). Tap-kick-click: Foot interaction for a standing desk. *Proceedings of the 2016 ACM conference on designing interactive systems* (pp. 323–333). New York: ACM. doi:10.1145/2901790.2901815

Singh, A., Klapper, A., Jia, J., Fidalgo, A., Tajadura-Jiménez, A., Kanakam, N., … Williams, A. (2014). Motivating people with chronic pain to do physical activity: Opportunities for technology design. *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2803–2812). New York: ACM.

Stach, T., & Graham, T. C. N. (2011). Exploring haptic feedback in exergames. In *IFIP conference on human-computer interaction* (pp. 18–35). Berlin, Heidelberg: Springer.

Tajadura-Jiménez, A., Basia, M., Deroy, O., Fairhurst, M., Marquardt, N., & Bianchi-Berthouze, N. (2015). As light as your footsteps. *Proceedings of the 33rd Annual ACM conference on human factors in computing systems - CHI '15, (April)* (pp. 2943–2952). New York: ACM. doi:10.1145/2702123.2702374

Taylor, W. C. (2005). Transforming work breaks to promote health. *American Journal of Preventive Medicine*, *29*(5), 461–465. doi:10.1016/j.amepre.2005.05.009

Thin, A. G., & Poole, N. (2010). Dance-based exergaming: User experience design implications for maximizing health benefits based on exercise intensity and perceived enjoyment. *In Transactions on edutainment IV* (pp. 189–199). Berlin, Heidelberg: Springer.

Thomas, D. R. (2006). A general inductive approach for analyzing qualitative evaluation data. *American Journal of Evaluation*, *27*(2), 237–246. doi:10.1177/1098214005283748

Thompson, W. F., Schellenberg, E. G., & Husain, G. (2001). Arousal, mood, and the Mozart effect. *Psychological Science*, *12*(3), 248–251. doi:10.1111/1467-9280.00345

Tudor-Locke, C., Schuna, J. M., Frensham, L. J., & Proenca, M. (2014). Changing the way we work: Elevating energy expenditure with workstation alternatives. *International Journal of Obesity*. doi:10.1038/ijo.2013.223

Van Dantzig, S., Geleijnse, G., & Van Halteren, A. T. (2013). Toward a persuasive mobile application to reduce sedentary behavior. *Personal and Ubiquitous Computing*, *17*(6), 1237–1246. doi:10.1007/s00779-012-0588-0

Van den Heuvel, S. G., De Looze, M. P., Hildebrandt, V. H., & Thé, K. H. (2003). Effects of software programs stimulating regular breaks and exercises on work-related neck and upper-limb disorders. *Scandinavian Journal of Work, Environment & Health*, 106–116. doi:10.5271/sjweh.712

Wang, S.-C., Jiang, C., & Chern, J.-Y. (2014). Promoting healthy computer use: Timing-informed computer health animations for prolonged sitting computer users. *Behaviour & Information Technology*, *33*(3), 295–301. doi:10.1080/0144929X.2012.695394

Wynne-Jones, G., Cowen, J., Jordan, J. L., Uthman, O., Main, C. J., Glozier, N., & Van der Windt, D. (2014). Absence from work and return to work in people with back pain: A systematic review and meta-analysis. *Occup Environ Med*, *71*(6), 448–456. doi:10.1136/oemed-2013-101759

Yancey, A. K., McCarthy, W. J., Taylor, W. C., Merlo, A., Gewa, C., Weber, M. D., & Fielding, J. E. (2004). The Los Angeles Lift Off: A sociocultural environmental change intervention to integrate physical activity into the workplace. *Preventive Medicine*, *38*(6), 848–856. doi:10.1016/j.ypmed.2003.12.019

Yim, J., & Graham, T. C. (2007). Using games to increase exercise motivation. *In Proceedings of the 2007 conference on Future Play* (pp. 166–173). New York: ACM.

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