Acceptance of Dynamic Feedback to Poor Sitting Habits by Anthropomorphic Objects

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ABSTRACT

The human body is designed for regular movement. Many humans, however, spend the bulk of their day sitting still instead. On average, for instance an adult spends approximately 10 hours each day sitting–in Asia, Europe as well as US. While a brief period of sitting here and there is natural, long periods of sitting day-in and day-out can seriously impact health and are associated with a significantly higher risk of heart disease, diabetes, obesity, cancer, and depression, as well as muscle and joint problems. Even working out vigorously may not compensate for long sitting sessions. The key is to build frequent movement variety into the day and to change the sitting position from time to time. About every 20-30 minutes the body needs a posture break by moving for a couple of minutes or, at least, by changing the sitting position.

Most humans, even knowing about bad behavior and willing to change it, are not able to do so for many different reasons. In order to support behavior changes we have developed a system which is able to track sitting behavior and reflect this by anthropomorphic objects. By doing so we can provide a constant feedback of the sitting posture and give a reminder to sit right, to change the sitting posture from time to time or to stand up.

A user study confirms that such a system is accepted and believed to lead to better posture awareness and sitting behavior by most users.

ACM Classification Keywords

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Author Keywords

ambient display, calm technology, persuasive technology, ubiquitous computing, change behavior, awareness, physical activity

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INTRODUCTION

The negative consequences of sitting are addressed repeatedly in the media. For instance, by the catchy slogan "Sitting Is the New Smoking." According to several studies prolonged sitting leads to an increased risk of all-cause mortality, including cardiovascular disease and certain types of cancer. To make things worse exercising, before or after long sitting sessions, seems to not be able to compensate for these negative consequences [1]. While there is still no definitive recommended maximum sitting time, it is suggested to get up at least every 30 minutes [8]. As a consequence of bad sitting behavior about 40% of all office workers are going to have back problems [9]. Constantly changing sitting position and preventing bad postures will help to reduce the mentioned risks.

It is difficult, at least for most people, to constantly check their sitting behavior and posture while working on a task. In addition, most people are usually not aware of the time spent sitting statically [5]. Therefore, systems have been developed using motion-sensor biofeedback and compared to guidelines-based care to reduce pain and activity limitation [17]. While such systems have been demonstrated to provide accurate motion-sensor biofeedback they require the full attention of the user to result in behavior changes. To give feedback without asking constantly for attention calm technologies have been proposed [26]. To prevent bad sitting habits it might be possible to present feedback without loosing focus on the main task by combining sensor biofeedback with calm technologies.

AMBIENT DEVICE

Weiser's vision of ubiquitous computing [25] still seems futuristic, but as new tools and technologies become available, new kinds of intelligent displays that present information in an effective and attractive manner can be developed. Indeed, in recent years, technologies that not only aim to inform but to lead to a behavior change have been proposed in different flavors and under different rubrics such as persuasive technology, calm computing, and gamification. They have in common that they provide feedback to the users or 'non-users'–in case of implicit interaction. The presentation of the feedback should "prevent unwanted distraction while delivering critical content in a timely and appropriate manner" [18]. Instead of overburdening the user's attention with mostly irrelevant information, only selected notifications are presented in the periphery when they are relevant. To fulfill this design goal *ambient devices* can be used which aim to naturally integrate into the environment, to use pre-attentive processing and to minimize the user's mental effort and distraction. Besides the pure transfer of information another important design goal should be to be entertaining and fun to use [21].

In the last decades, a lot of work with the goal of having a highly efficient interrupt with low intrusion has been published. For example Consolvo *et al.* [4] suggest to use virtual characters, like flowers or robots, to elicit vicarious emotions in users and support a change in their physical activities. Due to space limitations, in the following we constrain our brief overview to publications which have addressed to improve posture awareness through ambient devices. Already in 2005 *Breakaway* [16] was proposed: It is "an ambient display that encourages people, whose job requires them to sit for long periods of time, to take breaks more frequently." It used information from sensors on a chair to 'deform' a small sculpture placed on the desk. Its goal was to communicate how long the user was sitting in a non-obtrusive manner and a single-user study showed to lead to promising results.

Haller *et al.* [14] developed, in 2011, a chair equipped with four sensors and investigated "three different ways of interrupting people to posture guidance." The alert modalities included a *graphical feedback* in the form of a pop-up window on the subject's desktop, a *physical feedback* in the form of a toy flower placed on the subject's desk mimicing the subject's posture by bending its leaves and stem and a *vibrotactile*[1] *feedback* in the form of vibrations originating from a game console controller. They concluded "While the vibrotactile feedback might have higher information awareness benefits at the beginning, it causes a huge intrusion side-effect. Thus, the physical feedback was rated less disruptive to the workflow as the other two feedback modalities." They also concluded that subjects were more likely to ignore or postpone graphical, compared to physical alerts.

Note, however, that due to hardware limitations, the different ways of interruptions investigated by Haller *et al.* were only able to render two states (correct vs incorrect posture). This eventually led to the work by Hong *et al.* [15] with the goal of smoothly shifting the focus of the user's attention from the background into the foreground. They used a physical avatar shaped as a flower similar to Haller *et al.* but with "much richer sensing system capable to discern among four different problematic sitting behaviors, and a much more expressive mechanical output display, capable of rendering uniquely and with multiple degrees of freedom each of the particular conditions affecting the user" [15]. Their prototype used two different sensor modules to track the back curvature and the user proximity to the computer monitor. While the way of providing continuous feedback about the posture of a user through an actuated flower shaped avatar that can change its colors, sounds, motion and animations of a bendable stem looks promising no user study has been conducted.

So far sensors, which have been mounted on the chair or the user have been investigated to determine the posture of a sitting person. Duffy and Smeaton [7] used an optical sensor, namely the Kinect, instead. But more about this in the next section. They developed a posture classifier with four possible states: unknown, good, z-bad and x-bad. Only the two states z-bad (forward leaning or slouching) and x-bad (leaning to either left or right) deliver interventions to the subject. The interventions were either a reduction in brightness (real-time response) of the monitor or a pop-up dialog window (once per hour). While the pup-up dialog window— not surprisingly—could *not* improve statistically the sitting posture of the four investigated subjects, the change in brightness showed an increase in better sitting posture of more than 30%.

[1] Vibrotactile relates to the perception of vibration through touch.

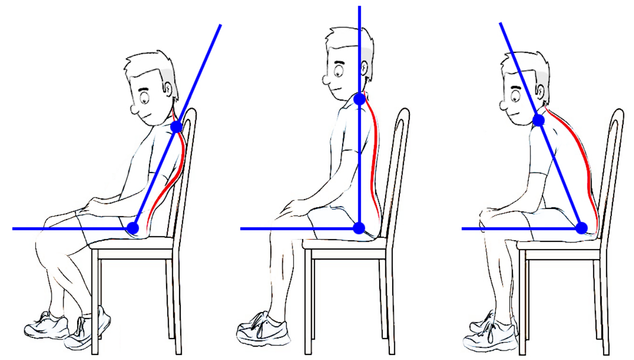

Figure 1. Angle and distance between neck and pelvis (blue) as well as spine curvature (red) for different sitting postures.

MONITORING BEHAVIOR

Different sitting postures, see Figure 1, can be monitored using either an optical sensor or a sensor array consisting of pressure sensors. The advantage of an optical sensor is that it is independent from the seat and that it can be reused to monitor other physical activities or exercises. We assume, at least for the purpose of our study, that both solutions can be realized with sufficient accuracy. Because of the given advantages, we favored an optical sensor solution.

It has been shown that the Kinect, running gesture recognition software [27], is a device capable of detecting postures and gestures with high accuracy if the people under observation are standing and not obscured [2]. Observing a subject seated next to a desk prevents some body parts to be seen by the sensor which might cause difficulties. Duffy and Smeaton [7] demonstrated, however, that the Kinect is capable of reliably tracking neck, torso, limb and head positions while elbow and shoulder provided a somewhat lower reliability while being seated.

States

For the purpose of our application it makes sense to distinguish these four states:

1. **Idle**: a user is not present or standing
2. **Welcome**: a new user is detected to sit down
3. **Analyzing Posture**: The user's sitting position is constantly monitored.

4. **Long Inactivity**: The user has remained in the same sitting position for a long time.

The different states are changing according to the given sensor information and timing. For the purposes of this study, a Kinect V2 sensor is used. It allows the simultaneous detection and tracking of several body parts, the *joints*, available through the Kinect for Windows SDK 2.0.[2] To determine the four states it is important to detect if a user is sitting on a chair (States 2 to 4) or not (State 1). This can be achieved by evaluating the angle between the *Spine Mid* in the lower back, the *Spine Base* and the *Knee Left* or *Knee Right*—depending on whether the left or the right information is available. If this angle is getting below 145 degrees the state switches from one to two. If this angle is getting above 155 degrees it switches to state one. Note that the information about the knees is only available while sitting down or getting up (because the table is not obscuring the knees) and cannot be used as a source of information to determine the sitting posture. The total sitting time can now easily be calculated.

To measure the curvature of the spine, as well as leaning to the side or front, only information of the upper body can be used as all other body parts are obscured in this state. The spinal column consists of three joints, which are located in the height of the shoulders, at the level of the basin and in the middle of those two. Leaning front or sideways can be easily determined given this information. It turned out, in contrast to our expectations, that the determination of a curvature of the spine given the available information would not be possible. This is because the *Spine Mid* joint does not align well to the body posture. Our experiments have shown that the center joint of the spinal column is always placed centrally between the actual joints of the shoulder and the base of the spine. The points are connected by a straight line, so the angle between the upper back and lower back is always 180 degrees. The curvature of the spine can thus not be determined directly. Under the assumption that the user, while sitting down, has a straight back the distance between the *Spine Shoulder* joint and the *Spine Base* joint can be used as an indicator: If the current distance between those two is smaller than the saved distance, at the time sitting down, the spine is bended.

Long inactivity can be detected by calculating delta values of the *Spine Shoulder* joint. If the delta values keep below a range of 5 cm over 20 minutes we assume that the user has not been changing his position and thus the state changes from three to four. If the values are above 5 cm the time is reset and the state, if not already in state three, changes back to three.

ANTHROPOMORPHIC OBJECTS

The goal of calm technology is to leverage peripheral perception to deliver information, as opposed to constantly demanding direct attention. To reach this goal it is important that the visualization of the information seamlessly integrates into the environment, is appropriate and non-disturbing. According to Nakajima and Lehdonvirta [20] three types of information visualization approaches can be distinguished:

- *Visualization as transformation* refers to a traditional ambient display that represents information in an abstract form.
- *Visualization as augmentation* refers to ambient information that reflects and relates to the context, actions, and surroundings of the user.
- *Visualization as embodiment* refers to the notion of representing information as embodied objects.

The imitation of one's behavior in form of an embodied visualization provides users with a new perspective to perceive themselves. It might reveal or emphasize details that would otherwise be unnoticed. This becomes possible because particular neurons in the brain *mirror* the behavior of the other: Mirror neurons are cells that are activated both when we perform a certain motor act as well as when we *observe* another human performs that particular act [22]. This system is supposed to underlie the ability of empathizing primarily with other humans [11]. It has been, however, demonstrated by Tettamanti *et al.* [23], Gazzola *et al.* [12] and others that the mirror neuron system is also activated by observing actions by fictional characters. This attribution of human traits, emotions, and intentions to non-human entities is known as *anthropomorphism*. Fogg sees in such 'persuasive social actors' the opportunities to trigger natural, automatic processes in users and to cause certain reaction [10]. Our hope is to use anthropomorphic objects in the periphery of the user to change his/her sitting posture without distracting him/her from his/her main task.

Figure 2. Sketch of the setup.

Choice of Object

There are a couple of requirements to the object. It needs to...

1. *not* be perceived as a technical obstacle.
2. be accepted as a living being, with whom a user enters into an empathic relationship and connects emotionally.
3. fit naturally into a desktop environment.
4. have enough 'expressional' freedom to reflect the state of the user well.
5. be interpreted easily by the user (e.g. communicate meaning through metaphors).
6. be able to provide immediate feedback.

[2]https://www.microsoft.com/en-us/download/details.aspx?id=44561

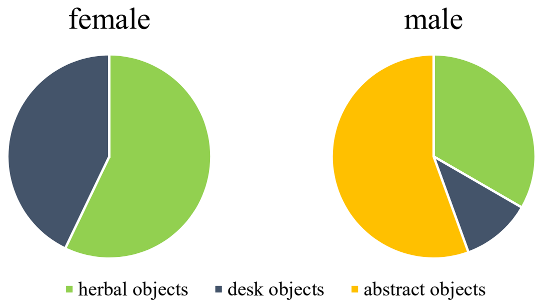

Table 1. Preferred object type.

Figure 3. Anthropomorphic flowers in Disney's Alice in Wonderland. Image left TC 00.26.49, image right TC 00.31.07

Even though a flower has been used by the reviewed papers frequently, no evidence has been given that this type of object would provide the best possible fit. Therefore, we conducted a small survey among 28 participants, mainly university students, to see what objects would fit well. We provided animations of herbal objects (e.g. orchid, sun flower), desk objects (e.g. lamp) and abstract objects (e.g. diamond) to choose from. A sketch of the setup is provided in Figure 2: A projector displayed the animations onto a wall next to a computer screen so that they appeared perspectively correct (adjusting accordingly to the viewer's head position) and at a position where a physical representation of the object would be placed.

From Table 1 we see that there is a stark difference in gender: While abstract objects have been favored by males, they have not been chosen by females which favored herbal objects followed by desk objects. It turned out that there is not a 'one fits all' solution, but different users prefer different objects. This insight has also been mentioned by participants: "you should give the user the freedom to choose his/her own object." Herbal objects were, however, the best consensus. Besides the given objects, the participants proposed to use human like objects such as action figures and robots or stuffed animals such as giraffes.

Half (50%) of the participants would prefer a physical object over a virtual object. 32% would prefer a virtual object while 18% were undecided. This is surprising because all participants favored the higher degree of freedom and fidelity of the provided virtual objects in contrast to physical representations. No particular differences could be observed between females and males.

The Orchid

The inspiration for design and animation of the orchid is Disney's Alice in Wonderland [13]. In one scene (TC 00:26:23 to 00:31:43) Alice meets a group of flowers that come to life and are animated in anthropomorphic way, see Figure 3. Some of the plants have explicitly been drawn with human facial features including eyes and mouth, while others create the impression of human postures by skillful placement and animation of petals or other parts of the flower. The orchid, from the broad possibility of herbal objects, was chosen by us because of its close resemblance to the human body and its visuality: Our visualization as shown in Figure 4 was, however, in comparison to the orchids in Alice in Wonderland a little bit more abstract.

To change behavior *emotional engagement* is a very powerful tool [20]. Balancing positive and negative feedback [19] is important to design successful persuasive visual expressions: If negative emotions are evoked too often, the user feels helpless. If too many positive emotions are evoked, on the other hand, the user feels bored. In both cases the user might not use the system over a long time span. The challenge is to develop an object that keeps users attracted and does not wear off after a short usage time.

As described before we used four states which have to be reflected by 'our' anthropomorphic orchid and therefore respond with different behavior:

1. **Idle**: The orchid is behaving like a real flower. In order to keep the distraction as low as possible the flower is not animated in this state.

2. **Welcome**: In the first contact the user and the object are connected through a social stimulus. The orchid is greeting the user kindly by lingering briefly. This incentive is also telling the user that he/she is registered and that the system is now 'actively' observing him/her.

3. **Analyzing Posture**: The posture of the user is transferred to the visualization of the orchid. While the first four distinguishable postures are used for direct feedback of the sitting position, the fifth posture makes the object more vivid and playful:

   - If curvaturing the back, the stem is bended.
   - If leaning to the side, the flower is leaning to the side.
   - If leaning to the front, the flower is leaning to the front.
   - If being in a bad pose, the 'face' of the flower is getting sad over time.
   - If the arms are moving, the leaves are moving respectively.

4. **Long Inactivity**: The orchid falls asleep by bloom, petals and leaves hang limply. Meanwhile, the plant is not animated to keep the salience low because the user might not have the ability to move in the current situation.

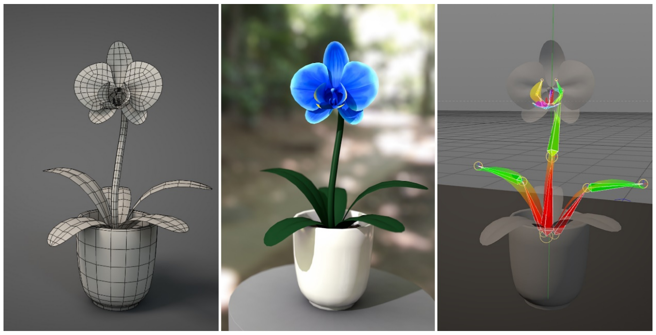

Figure 4. The orchid: polygone structure, texture and material, bones and weights of the visualized character.

USER STUDY

The success of the proposed application is whether it is used or not and if its use can change behavior to positive effect. Only the continuous voluntarily use of the application can support a better sitting posture and activation. The use of an application does not preliminary lie in technical achievements, but according to the *technology acceptance model* it lies primarily in its perceived usefulness, perceived ease of use, attitudes towards using and behavioral intention to use [6]. Not to forget about personal data security, e.g. that the data is not used by the employer or other companies such as health insurance. The goal of our research, therefore, is to verify that it "works for the user". This goal cannot be represented in recognition accuracy or other technical measures, but on personal judgments of the users. It is needless to say that, to satisfy our goals, a system is required which provides feedback which is or at least feels precise and accurate.

Experimental Setup and Implementation

To carry out the user study a situation is established, which corresponds to a possible real use of the application. The user is sitting at a desk and working on a computer or laptop. The orchid is projected on a wall next to the computer or laptop screen so that it can be perceived by the peripheral vision of the user. To provide a strong impression of three dimensionality the perspective view of the orchid is coupled to the actual viewpoint of the observer by constantly adjusting the virtual camera according to the head position of the observer. The reader particular interested in this effect may refer to Ware *et al.* [24]. To provide a perspectively correct mapping of the orchid the virtual setup (orchid and camera) is set to resemble the physical setup (wall and head).

The user is invited to sit in front of the computer or laptop and to research any topic in the online encyclopedia Wikipedia. This should be an everyday situation modeling, both private as well as workplace scenarios. The user has been informed that the virtual plant reacts to his/her actions, but no details have been given.

A total of 16 people, 56% males and 44% females between 19 and 53 years, participated in our user study. None of them had ever been exposed to such kind of system before. After testing the system for three hours straight the subjects were asked to fill out a questionnaire.

The results are shown as median scores, average scores and variances to provide a convenient overview.[3] To test for statistical significant differences between females and males we used Cohen's d [3]. In addition we provide diagrams for more detailed information. For all closed-ended questions we used a 1-to-5 Likert scale, ranging from (1) strongly disagree, (2) somewhat disagree, (3) undecided, (4) somewhat agree to (5) strongly agree. Results for the closed-ended questions are shown in Table 2, 3 and 4 and are briefly discussed next. In addition we provided some open-ended questions to let the user share his/her own thought and to give suggestions.

Perceived Usefulness

Table 2 gives information about the perceived usefulness of the application. According to Fred Davis perceived usefulness is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" [6]. In our case this has to be rephrased into "the degree to which a person believes that using a particular system would enhance his or her sitting posture".

Asked about their opinion of their sitting posture 1/3 of the participants were not satisfied and aware that there might be room for improvement (median: 3; average: 2.7; standard deviation: 0.7; female: 2.9; male: 2.6; Cohen's d≈0.4 between females and males). Nobody was completely satisfied with his/her sitting posture. The difference between males and females can, according to Cohen's d, be determined small. The results of this question provide no information about how problematic the attitude of the subjects actually is. They show, however, that an application to improve the posture could have attracted great interest.

Asked about their opinion if the recognition of their sitting posture was accurate they answered that they believe that the application can improve their sitting posture and motivate them to move more: median: 4; average: 4.3; standard deviation: 0.6. female: 4.6; male: 4.1. According to Cohen's d≈0.8 the difference between males and females were significant in this case and females seemed to better trust the recognition. This has been inverted (female: 3.9; male: 4.3; Cohen's d≈1.0) for the question if they think that they can improve their sitting posture using this application: median: 4; average: 4.1 standard deviation: 0.4.

Females also believed more strongly than males that they were activated to move more using this application: median: 4; average: 3.9; standard deviation: 1.2. However, the difference between females 4.1 and males 3.6 according to Cohen's d≈0.4 is small.

Comparing the self-evaluation of the sitting posture to the questions of improved sitting posture as well as activate to move there was no significant evidence that the sitting posture is correlated. This is also true by comparing the self-evaluation of the sitting time to the latter questions.

[3]We are aware that Likert scales are classified as ordinal variables. In our case it is, however, closer to interval scale Likert data because we provided the numbers and a description of the different values.

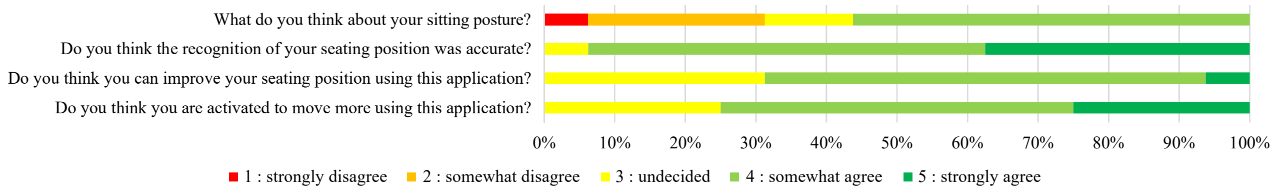

Table 2. Answers concerning the perceived usefulness.

Perceived Ease of Use

Table 3 gives answers of the perceived ease of use. According to Fred Davis perceived ease of use is defined as "the degree to which a person believes that using a particular system would be free from effort" [6]. In our case this has to be rephrased into "the degree to which a person believes that using a particular system would be free from distraction and easy to comprehend".

Most people answered that they could focus on their task without getting distracted by the application: median: 4; average: 4.0; standard deviation 1.0. There was only a small difference, Cohen's d≈0.4, between females 4.1 and males 3.9.

The provided information by the orchid could easily be comprehended by most subjects: median: 4; average: 4.3 standard deviation 0.8. There were no differences, Cohen's d≈0.0, between females 4.3 and males 4.3. By having only a briefly look the updated information could not be so well interpreted: median: 4; average: 3.8; standard deviation: 0.6. Just like before there was no difference, Cohen's d≈0.2, for females 3.7 and males 3.8.

The visualization of the orchid was liked equally well, Cohen's d≈0.1, even though males would have preferred a different type of object: median: 4.5; average: 4.4; standard deviation 0.7 by females 4.4 and males 4.3.

When asked what the users like about the orchid, the entertainment was a common response. Some subjects mentioned that they didn't like the animations, but no hints have been given what exactly could be changed/improved to make the animation more appealing. The orchid seamed to be well suited for some of the participants which had explicitly noted that the selected object was well-suited for the visualization of this kind of information.

Intention to Use

Table 4 gives answers of the intention to use the application. The general question how well the users like the application, has been almost exclusively answered positively: median: 4; average: 4.1; deviation: 0.6. It seems that females 4.4 liked the application significantly (Cohen's d≈0.6) better than males 3.9. This might be caused by the visualization as an herbal object which as stated earlier, see Table 1, is preferred by female users while male users prefer abstract objects.

Even though the previous questions have been answered very positively the intention to use the application on a regular basis is not so high: median: 3; average: 3.3, standard deviation: 0.8, without any difference between females and males. This is quite surprising because the average usefulness 4 (without sitting posture) and average ease of use 3.9 are judged very well. This, however, is not converted into an intention to use the application.

Comparing the self-evaluation of the sitting posture as well as sitting time to the question if the application would be used regularly, no significant evidence of correlation could be found.

Being asked where the application would possibly be used, 75% answered that they would use it at home and 38% at work (both possibilities could be selected not only one or the other). This is also an important finding because all previous applications focused on the work environment only.

CONCLUSION & OUTLOOK

We have investigated an anthropomorphic object, namely an orchid, which is imitating the sitting posture to foster behavior changes for improved sitting posture. While this idea is not unique and has been proposed before we were able to provide some novel insights not addressed previously including: herbal objects are not mutually the best choice for everybody; an actual object is not preferred by everybody over a non-physical object; people reflect their sitting postures and think they get more activated by such kind of applications. Even though the people are aware about their bad sitting behavior some would not use the application. We also found no correlation between the self-evaluation of the sitting posture and intended use of the application.

While the Kinect seems to be a perfect choice to track postures and gestures for standing persons, it might not be the optimal choice for sitting persons: Some body parts are not seen in a sitting posture and the—for our application—very important *Spine Mid* joint is not estimated from information provided by the depth sensor, but it is a simple interpolation between the *Spine Base* and the *Spine Shoulder* joints and thus cannot be used for our purpose.

Based on our findings there are a couple of further improvements necessary to make such an application successful and widely used over a long period. The two most important questions to be answered are a technical one and one to improve interest in particular for long term use.

To answer the former questions different solutions can be investigated:

- To improve skeleton tracking with the goal to provide a real estimate of the *Spine Mid* joint.
- To use an optical sensor in combination with chair mounted pressure sensors and fuse that information into one model

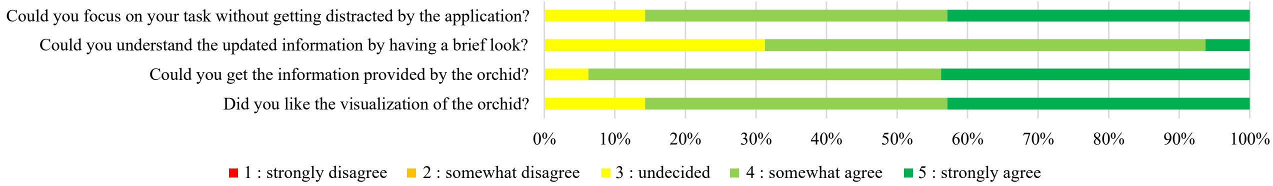

Table 3. Answers concerning the perceived ease of use.

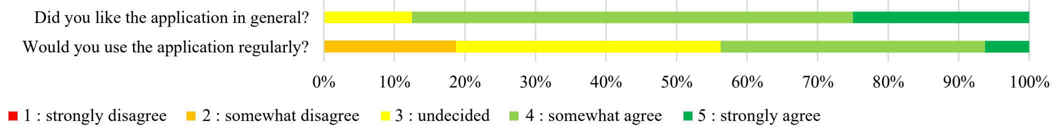

Table 4. Answers concerning the intention to use (acceptance).

to be able to compensate for the weakness of one or the other.

- A data fusion with fitness tracker would also be possible and might provide positive effects.

To improve interest in long term use it might be interesting to reward the use over longer time periods. This might be possible by growing the plant over time or by comparing the quality of sitting to other users. It might be also interesting to include mini games: for example the orchid demonstrates some exercises by moving the leaves and the user has to follow these movements. The 'face' of the orchid is getting happier if the user is more precise in following the gesture and vice versa.

With our study we have proven that such systems are accepted by the users and that they find such applications useful and easy to use. The issues of personal data security have not been addressed in our study. This, however, might be an important point in accepting such applications and should be investigated in the future. The value of the provided feedback is believed by the user to be helpful, however, it is not medically proven. That means a user study of long term use has to be performed which investigates if that kind of technology is able to reduce commonly known risks of long and wrong sitting.

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