Phlebotomists Do It Better: Exploring Soft Interaction In The Medical Domain

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Abstract
ForceForm is a dynamically deformable interactive surface in which lumps and indents can be created, and feels soft to the touch. In this paper, we present a study to explore users' ability to identify different levels of firmness generated in the soft surface of ForceForm. Our results show that those with medical training, in this case phlebotomists, perform the task with significantly better accuracy than those without a medical background and those without a medical background can achieve an accuracy similar to the medical group with five to six repeats of the experiment. We outline possible directions for future work given these results.

Author Keywords
Tangible User Interfaces; Medical; Health; Palpation

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces

Introduction
ForceForm is a dynamically deformable interactive surface in which lumps and indents can be created and it feels soft to the touch. We ran a focus group which indicated that interaction with ForceForm makes users think of that which is alive, such as skin [11]. We then

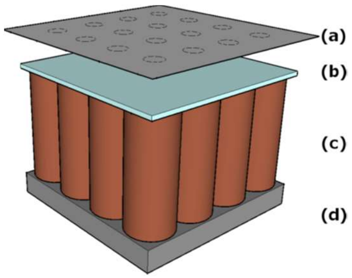

Figure 1: A scale diagram of ForceForm

ForceForm: As shown in Figure 1, ForceForm consists of a latex surface (a), suspended above the system, with embedded neodymium permanent magnets. A grid of computer controlled electromagnets (c) is used to attract and repel the permanent magnets. There is one permanent magnet per electromagnet in our prototype. The Perspex buffer (b) is present to prevent the surface magnets from attracting to the ferrous steel cores of the electromagnets. A steel base plate (d) is attached to improve the strength of the electromagnets.

conducted interviews with medical professionals where we discovered that ForceForm has possible applications within the medical domain for palpation training [10], which is explored further in this paper.

Palpation refers to a technique used by health practitioners whereby the practitioner uses their hands to feel an object in or on the body to ascertain properties such as size and firmness. We are able to change the firmness of ForceForm at localized positions to simulate different sized lumps underneath the skin for palpation training. We can also simulate the real world situation of lumps which move from side to side when pressure is applied, which was indicated as desirable during our interviews with medical professionals. ForceForm could be especially useful for simulating lumps and different skin behaviors which otherwise may be an embarrassing, painful or uncomfortable experience for a patient allowing themselves to be the subject of medical training, thus hindering the repeatability and accessibility of these conditions in the real world.

In addition to the change in surface firmness, ForceForm can also generate dome shaped items that protrude from the surface, and indents in the surface; however, a change in firmness is more suitable for palpation training as it simulates the existence of lumps beneath the skin. ForceForm's surface changes can also be useful as a notification method for users in general touch surface interaction scenarios. Further technical information about ForceForm can be found in Figure 1 and [9].

Background

Many dynamically deformable surfaces feel hard to the touch, and there is a shortage of research into understanding the different interactions that soft interactive surfaces provide. Furthermore, there are shortcomings in research into palpation training, especially with regards to the use of new interaction devices in this area.

Pin arrays have been used as actuated surfaces, such as Project Feelex [4] which uses an array of linear actuators to raise and lower metal rods which deform a white nylon cloth surface. The system has been used for palpation simulation but the user would be pushing on hard rods which may be less suitable than a soft surface, and it is unclear what the interaction would feel like if the rods are palpated from an angle, which can occur in real life palpation. Relief [6] is a similarly structured system, which consists of aluminum pins that are each actuated using a potentiometer.

Systems that provide soft interactive surfaces include soft overlays which consist of inflatable buttons [1], however, the buttons cannot be easily altered once the overlay has been made. Another device has been developed using air pressure to create lumps in a silicon sheet [3], which is implemented by a mechanical device moving the air nozzle in accordance to the user's fingertip location. MudPad [5] consists of a pouch of opaque magnetic fluid that can be stiffened using an underlying grid of electromagnets. The resulting change in viscosity is used to provide haptic feedback to a user touching the surface. TableHop [8] consists of a highly stretchable spandex fabric that is electrostatically actuated to create a deformable surface.

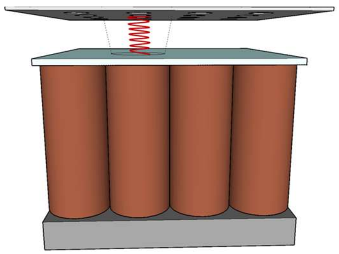

Figure 2: ForceForm has been modified to allow for firmness in the surface rather than visual modeling of the surface.

Interaction: ForceForm is able to create observable hills and valleys. However, for this experiment the surface layer of ForceForm is positioned so that energizing an electromagnet results in a change of firmness of the surface which has little visual protrusion above the surface. An increased voltage results in a firmer lump, and vice versa. In our experiment, the small lump can be felt in a 20mm diameter, and the big lump can be felt in a 30-40mm diameter. This behavior is aligned with palpation, where lumps beneath the skin are felt. Participants interacted in an eyes free manner.

The Phantom [7] offers high fidelity feedback but usually involves a tethered stylus, rather than whole hand interaction. It has been adjusted for palpation by having the user press a pad with their fingers rather than use a stylus [12]. However, a maximum of two fingers can be used on the pad, and the display cannot be aligned with where the user is interacting.

Example Application

Our interviews [10] indicated that ForceForm could be used in medical training for palpation scenarios. In the experiment presented here, participants were asked to differentiate between differently sized simulated lumps in the surface of ForceForm. We developed this experiment in order to work towards developing the example application specified below.

Palpation Simulation. A medical student interacts with the soft surface of ForceForm. She identifies the size and firmness of lumps using her fingers, and gains feedback from ForceForm to know whether she is correct. ForceForm will suggest improvements to the novice user’s technique for detecting lumps, according data gathered from an expert user’s palpation interaction with the system. When the user is interacting, the system dynamically provides suggestions to the user, that she should press harder, lighter, or at an angle, etc, in alignment with expert users’ palpation behavior.

Experiment Design

The study answers the following research question: can users identify lumps in the surface? If so, how many lumps can be differentiated? The experiment has parallels to previous work on Texture Displays [2], in which the researchers sought to establish users’ textural discrimination of different materials to communicate information.

Participants

We recruited 26 participants from two groups: 13 (7 males, 6 females, mean age: 29) from a non-medical background and 13 (1 male, 12 females, mean age: 33) from a medical background. Those with a medical background were employees of the Canberra Fertility Centre in Canberra, Australia. The female bias was representative of this workplace. Of the medical participants, one was an Embryologist, two were registered nurses, and the remaining ten participants were Phlebotomists. All of the medical participants had been trained in taking blood from patients, and therefore had experience with touching the skin of patients in order to identify underlying veins.

Procedure

Each participant was given a short questionnaire at the beginning of the experiment to gather demographic information including age, profession and experience using similar devices. Another questionnaire was presented to participants at the end of the experiment to gather qualitative feedback about the task. The medical participants completed an additional questionnaire upon completion of the experiment to understand further details of their medical background.

There were three states of surface firmness that the user was required to identify. State 1 resulted in no change of firmness of the surface, state 2 was a small change of firmness to simulate a small lump under the skin, and state 3 used twice the amount of power as state 2.

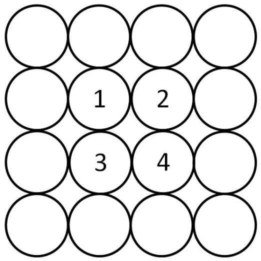

Figure 3: Possible positions of lumps during the study.

Lump Generation:
ForceForm consists of 16 electromagnets, represented by the circles in Figure 4. Lumps were formed at positions 1 to 4. This required the participant to search for a lump rather than feeling the same position, more adequately simulating a real world scenario. Table 1 shows the power levels of each of the three states presented to the user.

State	Amps	Volts
1	0.67A	10v
2	1.00A	10v
3	1.32A	10v

Table 1: Total power used for each state presented to the user, including idle current drawn.

These different levels of firmness were achieved by a predetermined repulsive strength of the corresponding electromagnet beneath the surface, which in turn alters the firmness of the surface. After a training set, each participant was presented a different permutation consisting of each state eight times and had to verbally identify the state in the following manner: "no lump" (state 1), "small lump" (state 2), or "big lump" (state 3). Figure 2 explains the interaction further and Figure shows a study participant feeling for a lump in the surface of ForceForm. Each participant experienced each state twice in each of the four possible locations outlined in Figure 3. The power usage for each of the states is defined in Table 1.

Figure 4: A study participant identifying a lump in the surface of ForceForm.

We also trialed two additional participants in a four state version of the experiment which indicated that four states do not yield high levels of accuracy, so we opted to focus on the more accurate and therefore practical three state experiment.

Results and Discussion

We used a Generalized Linear Model (GLM) to assess the results of the experiment, from which we can determine that the participants with a medical background performed significantly better than those without a medical background ($p=0.008$, $p<0.01$).

Those with a general background completed the task with 80% accuracy overall. State 1 was reported with 92% accuracy, State 2 with 81% accuracy and State 3 with 69%. Those with a medical background completed the task with 87% accuracy overall. State 1 was reported with 100% accuracy, state 2 with 89% accuracy, and state 3 with 73% accuracy. The accuracy levels for each state are illustrated in Figure 5.

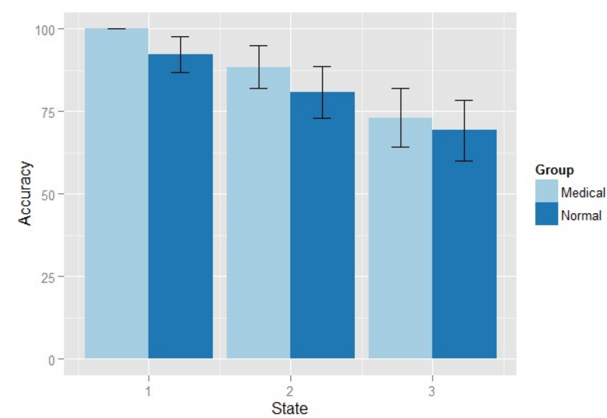

Figure 5: The accuracy levels for each state, separated according to participants' background.

Since those with a medical background perform the task better than those without a medical background, it may be interesting to determine how their interaction behavior differs from those without a medical background. The findings of this study support the previously stated example application of using the interactions of an expert user to suggest improvements to the interactions of a novice user.

Longitudinal Study

We recalled five of the participants with a non-medical background (3 female, 2 male) to repeat the experiment bi-weekly to investigate learning effects. These participants were chosen because of their availability. The participants did not receive feedback on their performance throughout the study. It took five to six repeats of the experiment for the participants to reach a similar accuracy level to that of the medical participants, as shown in Figure 6.

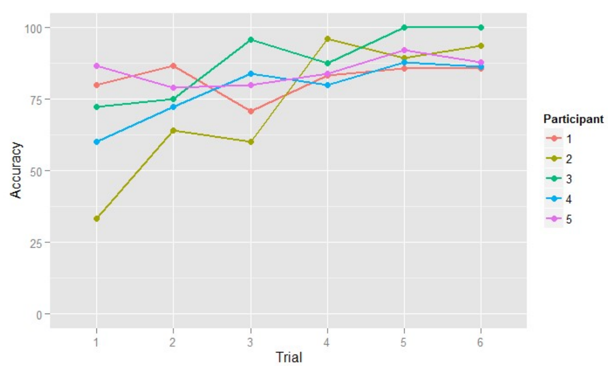

Figure 6: Improved accuracy of non-medical participants after six repeats of the experiment

It also appears to be the case that the participants' accuracy largely plateaus at around the fifth to sixth trial. Their accuracy overall at trial 6 is 91%. These results indicate that the participants' knowledge of the task is improved by repeated exposure to interaction with soft surfaces.

Conclusion

We have determined that users with a medical background can identify different levels of firmness in the surface of ForceForm significantly better and without additional training when compared to a non-medical group. We have shown that relatively few training sessions are needed to improve non-medical subjects' use of the system. The findings of this study support our future goal stated in our example application of using the interactions of an expert user to suggest improvements to the interactions of a novice user. Furthermore, there is a possibility of ForceForm being used as a test to ascertain a users' level of kinesthetic skill, which may correspond with how well they can perform medical tasks such as feeling for veins in skin.

This study highlights the importance of taking into account users' backgrounds when interacting with new tangible interfaces, as participants from certain backgrounds may have predispositions to particular methods of interaction and that may be advantageous for the user interface designer to know.

Future Work

These results have provided numerous possibilities for further research. The results support the example application outlined in this paper, so further steps should be taken towards developing an application which uses the interactions of an expert user to suggest improvements to the interactions of a novice user.

Further research can be undertaken to ascertain whether the gender of the participants had an effect on the results, as the medical participants were predominantly female. It would also be useful to determine whether the repeat training of the nonmedical participants can be achieved in a shorter timeframe; for example, repeat interaction over one or two days. It may also be interesting to repeat the experiment with those from the longitudinal study at a later date to ascertain whether their improved performance is lasting.

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