Experience over time: evaluating the experience of use of a squeezable interface in the medium term

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Experience over time: evaluating the experience of use of a squeezable interface in the medium term

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Abstract The paper presents the user experience evaluation of Squeeze Me, an interactive cover for tablet and smartphone that enables continuous and expressive interaction with electronic devices. The cover has been used to implement ”Squeeze to zoom”, a mobile application to zoom in and out while taking a photograph from a tablet. The experience of use was evaluated in the short and medium term, comparing the Squeeze Me interaction modality with classic modalities for zooming in and out commonly available on tablets and smartphones. The evaluation process was conducted using AttrakDiff [3] a questionnaire that measures hedonic stimulation and identity, as well as pragmatic qualities and attractiveness of software products. Participants were asked to try out different interaction modalities for comparison in the short-term (67 people) and over 4 weeks (8 people). Results obtained in the short-term evaluation reveal that “Squeeze to zoom” was awarded higher values than the classic “Slide to zoom” in the hedonic quality-stimulation and attractiveness dimensions, whilst it obtained lower values in the pragmatic quality and hedonic quality-identity. However, the experience of use changed over time. During the longitudinal study, the usability of “Squeeze to zoom” improved whilst the attractiveness of “Slide to zoom” decreases significantly. Furthermore results reveal that “Squeeze to zoom” is significantly more appreciated for its hedonic qualities and the effect is maintained over time. This study highlights the importance of evaluating the experience of use over time, a practice that is almost ignored in the literature on Experience Design.

Keywords Squeezable interface · Tangible interaction · User experience evaluation · Interaction design · Input/output devices · Longitudinal study · Short-term evaluation

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1 Introduction

A squeezable interface is a tangible interface that affords squeezing to control the behaviour of a system. Its main feature is to enhance expressivity in interaction, making it smooth, continuous and nuanced. Since interaction with this kind of interface is embodied, it requires only limited effort to be mastered. Squeezable interfaces are playful and engaging. They are designed in such a way to be comfortable to hold, pleasurable to manipulate, deformable and soft to minimize fatigue when an action is repeated several times.

At the CHI conference in 1998, Harrison et al. [2] presented one of the first examples of a squeezable interface. They implemented a simple application to navigate lists on a Palm Pilot. Pressure sensors were attached along both sides of the device in positions that aligned with the users' fingers and thumb. Differently from scrolling a list with a pen pointer, the squeezing gesture did not require the user to reposition either hand. This feature was appreciated during evaluation sessions.

From that pioneering implementation, an increasing interest toward these interfaces has been manifested by popular mobile phone brands like Nokia [13] and Samsung who developed concepts of smartphone designs (the latter patented) that allow physical manipulation of interface objects to enrich the user's experience. Nokia HumanForm is a smartphone concept that can be twisted to browse photos and bent inwards or outwards to zoom in or out. Samsung [6] patented a squeezable control for smartphones that can be squeezed to scroll a page or to lower/raise the volume according to the pressure applied. Neither of these patents is a commercial product.

Other attempts have been made in the music domain, healthcare [12] and game design.

Weinberg el al. [21] developed the Embroidered Musical Ball, a soft MIDI musical instrument that allows novice users to perform music with expressive hand gestures like squeezing and stretching. The system consists of soft balls that can be squeezed or pulled to change the sound. For example, the "Theremin ball" allows the player to change the pitch and the amplitude of sound by pulling or squeezing it. Mapping is direct: the higher the squeeze, the louder the sound.

ZonaPlus [8] is a handheld isometric therapy device used for lowering the blood pressure of hypertensive subjects. By squeezing the device, the person performs a series of hand contractions to reach the correct pressure. Bruns Alonso et al. [1] developed a pen that senses behaviours related to stress and restlessness, such as rocking, rolling and squeezing, with the aim of reducing stress for office workers.

Blobo is a soft, squeezable motion control device that allows players to compete against each other as avatars in a virtual 3D environment [7].

Our work contributes to research on squeezable interfaces by exploring an innovative coating paradigm. Instead of building a new squeezable device, we developed a soft rubber cover for tablet that communicates with different software applications. The coating material is interactive, since it embeds pressure sensors to detect input from the user and electronics and actuators to deliver an appropriate feedback.

The proposed approach is innovative since it relies on mapping the natural action of squeezing a soft material and its effects through a continuous action-perception loop exploiting the richness and continuity of our embodied skills. The coating paradigm allows the Squeeze Me to work as a standalone device, completely independent of the tablet. This opens up a wide range of possibilities for new applications of the device, such as the ones presented in this paper. More in general, it is suitable in contexts where expressivity in action can play a relevant role in what we are trying to achieve. Examples of potentially suitable contexts for application

include interactive games, therapeutic tools, and any other interaction design implying natural and continuous input/output mapping.

2 Squeeze me

Squeeze Me is an interactive cover mounted on a tablet with a two handed grip. The rubber material is soft and affords squeezing (shown in Fig. 1).

The hardware is composed of two parts that are 3D printed in different materials: a soft synthetic resin (the dark side) and a stiff acrylonitrile-butadine-styrene (ABS) plastic (white side). The synthetic resin hosts sensors and actuators, and the ABS plastic protects the electronic components. Overall the system [16] contains:

- An Arduino mini 328 3.3v 8Mhz that detects data through analog readings of the sensor's resistance variation.
- A Bluetooth modem BlueSMIRF Silver.
- 2 × 4.7 KOhm resistor.
- Printed circuit board.
- A LiPo battery 3.7 V 1400mAH to power the system that is programmed via FTDI.
- Pressure sensors that work as an analog press button with a resistive principle: high resistivity when not pressed, and low resistivity when pressed. They cover a wide area of the cover so that the squeezing gesture is not limited to a specific zone. In order to avoid unconscious or accidental pressure, the cover has to be squeezed with both hands to be effective. Data coming from sensors are digitally smoothed to minimize measurement errors; each sensor is read three times and the values are stored in an array, from which the modal value is extracted. Below this value, the system remains inactive. After the detection and smoothing phases, data are sent to the tablet via Bluetooth connection.
- Vibration motors that provide haptic feedback in response to the squeezing gesture. The greater the intensity of the pressure, the greater the perceived vibration. Motors were

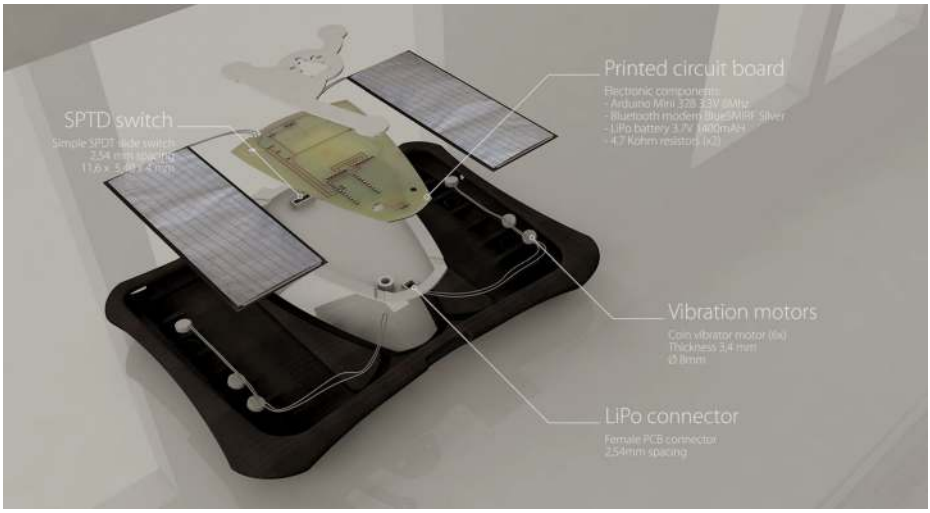

Fig. 1 Squeeze me: the inner part (sensors and electronics)

preferred to the built-in vibration of the tablet since the latter cannot support a continuous haptic feedback mapped to the intensity of the user input.

2.1 Squeeze to zoom

"Squeeze to zoom" is one of the implemented applications of Squeeze Me [16, 19]. It is an Android mobile application that allows the user to zoom in and out while taking a photograph without removing the hands from the tablet. The pressure values coming from the Arduino are used to control the zooming of the tablet's built-in camera (shown in Fig. 2).

The cover must be squeezed with both hands to zoom in. The user can simultaneously squeeze the device and use the thumbs to take a picture. When the user reaches the desired zooming value, he can take the picture by simply touching the screen without releasing the handgrip. The zooming intervals of the camera are directly mapped to the pressure exerted on the sensors; the more the cover is squeezed, the more the camera zooms in. A haptic feedback in the form of a vibration is release each time the cover is squeezed. It is mapped to the pressure exerted on the sensors as well.

The zooming out effect is achieved with the same mechanism. When the grip is released, the application smoothly zooms out. Once again, the intensity of the pressure is mapped to the dynamic of the output.

3 User experience evaluation

The experience of use of "Squeeze to zoom" was extensively tested with potential users through three evaluation cycles of increasing complexity: a pilot study conducted in laboratory, a short-term evaluation conducted in the field [15], and a medium term evaluation also conducted in the field.

All cycles used the user experience method AttrakDiff, a questionnaire developed by [3] to assess the user's experience and feelings in relation to interactive products and therefore a product's overall attractiveness. The questionnaire uses the technique of the semantic differential on pairs of opposite adjectives to evaluate the user experience. Users are asked to assess their experience and their perception of the product, responding to pairs of opposite adjectives. The adjectives are assessed on a seven-point Likert scale, from −3 to 3, in which 0 indicates

Fig. 2 The zooming application

neutrality. The questionnaire was developed in German and then translated into many languages including English. It consisted of 28 items, broken down into four dimensions:

- *Pragmatic quality or PQ*: describes a product's usability. Indicates how the user can successfully achieve his or her goals using the product. A product need not be particularly beautiful or well-designed to satisfy this quality.
- *Hedonic quality – Identity or HQ-I*: indicates to what extent the product allows the user to identify with it in a certain social context. It relates to what we communicate socially when we use a product. Identification with a brand, for example a certain type of mobile phone, defines our inclinations and preferences of use of that product. Some products are preferred by certain categories of users because they are seen as cool, and not necessarily for the features they offer.
- *Hedonic quality – Stimulation or HQ-S*: indicates to what extent the product can support users' needs in terms of novelty, content, stimulating interaction, presentation of style. It is defined by attributes that encourage users to improve their skills of use of the product. Examples of hedonic stimulation are those features of software applications that are usually little used, and the shortcuts for some commands. Some products offer the user flexibility of use, and the person feels gratified to learn or to find alternative or more effective and efficient modes of use of the product.
- *Attractiveness or ATT:* describes the product's overall value on the basis of perceived quality.

Hedonic and pragmatic qualities are independent of one another, but together contribute to determining attractiveness.

The English version of the questionnaire was translated into Italian since there is no standardised Italian version yet. Our questionnaire contained 23 items. Five pairs of attributes have been eliminated from the original German version since they did not apply to our application.

The items contained in our questionnaire were broken down as follows:

- 6 items for assessment of pragmatic qualities (Complicated – Simple, Impractical – Practical, Cumbersome – Straightforward, Unpredictable – Predictable, Confusing-Clearly structured, Unruly – Manageable);
- 4 items for assessment of hedonic qualities – identity (Unprofessional – Professional, Tacky – Stylish, Cheap – Premium, Unpresentable - Presentable);
- 6 items for assessment of hedonic qualities – stimulation (Conventional – Inventive, Unimaginative – Creative, Conservative – Innovative, Dull – Captivating, Undemanding – Challenging, Ordinary – Novel);
- 7 items for assessing attractiveness (Unpleasant – Pleasant, Ugly – Attractive, Disagreeable – Likeable, Rejecting – Inviting, Bad – Good, Repellent – Appealing, Discouraging - Motivating).

The same questionnaire was submitted to users in both pilot and field evaluations.
The research objectives that guided both assessments were as follows:

- assessing whether the "Squeeze to zoom" system was capable of eliciting positive feelings, sensations and perceptions compared to classic zoom methods.
- assessing the usability and attractiveness of "Squeeze to zoom" compared to classic zoom methods.

3.1 Pilot test: short-term assessment in laboratory

In the pilot test, conducted in the laboratory, two modes of interaction were assessed: "Squeeze to zoom" (shown in Fig. 3) and "Pinch to zoom" (shown in Fig. 4). "Pinch to zoom" makes it possible to increase or decrease the camera's zoom with your forefinger and thumb.

Thirty people (Male = 23; Female = 7) with an average age of 30.3 years were involved in the study, primarily university students and technical and administrative staff members who voluntarily joined the study. Participants were asked to take a photograph of the same subject, an image of a face drawn on a board about three metres away, zooming in or out using the two modes: "Squeeze to zoom" and "Pinch to zoom".

Participants assessed both interaction modes, presented to them in random order. After using each mode they were asked to respond to the AttrakDiff questionnaire. A detailed analysis of the results is contained in [15].

To summarise the outcome of the pilot study, "Squeeze to zoom" scored higher than "Pinch to zoom" in all dimensions, in particular for Attractiveness and Hedonic Qualities-Stimulation. "Pinch to zoom" obtained only one value slightly below zero in the Hedonic Qualities-Stimulation dimension, but overall users found "Pinch to zoom" less stimulating in terms of novelty, content and interaction.

3.2 Short-term evaluation in the field

The short-term evaluation differed from the pilot test in many respects:

- number of people involved in the study: 67 people (M = 31; F = 36) with an average age of 28.02;
- setting: the test was conducted in the field and not in laboratory;
- interaction modalities: we compared three different interaction modalities – "Squeeze to zoom", "Pinch to zoom" and "Slide to zoom". "Slide to zoom" allows the user to zoom in and out with the thumb of the right hand, rotating it upwards (see Fig. 5). In this case the tablet's native camera software was used.

The test was conducted in the main square in the town of Siena, Piazza del Campo. The subjects were asked to take a photograph of the same subject, in this case the clock on the bell tower in the square, zooming in and out using the three modes: "Squeeze to zoom"; "Pinch to zoom" and "Slide to zoom".

Fig. 3 Squeeze to zoom

Fig. 4 Pinch to zoom

After an initial phase of familiarising themselves with the three different modes of interaction, participants were asked to assess them one by one. The three modes were presented in random order. As for the pilot test, we used the Italian AttrakDiff questionnaire composed of 23 items. Full details about the results of the short-term assessment are contained in [15].

To summarise, "Squeeze to zoom" obtained lower mean values for the first two dimensions, the pragmatic and hedonic quality-identity dimensions, and higher values for the hedonic quality-stimulation and attractiveness dimensions, as for the pilot test. The other two modes received higher values for the pragmatic quality and hedonic quality– identity dimensions. "Pinch to zoom" maintained the same trend as for the pilot test, receiving lower values in the hedonic quality-stimulation and attractiveness dimensions as well. "Slide to zoom" received a higher value for attractiveness and a lower value for hedonic quality-stimulation.

Qualitative comments from participants confirmed the quantitative data. Some people underlined how fun and intriguing it was to use "Squeeze to zoom" as a new way of taking a photograph.

While in the pilot test "Squeeze to zoom" obtained higher values than "Pinch to zoom" in all assessment dimensions, in the short-term evaluation "Squeeze to zoom" obtained lower values in the first two dimensions, pragmatic quality and hedonic quality-identity. Specifically, "Squeeze to zoom" mode was assessed in the pragmatic dimension as: complicated, impractical, unpredictable and contorted in comparison with the other two modes.

In relation to the Hedonic Quality - Identity, it obtained lower values than "Pinch to zoom" and "Slide to zoom" for the following items: Unruly – Manageable, Unprofessional – Professional and Tacky – Stylish. On the other hand, for the item Cheap – Premium, "Squeeze to zoom" was

Fig. 5 Slide to zoom

given the same values as "Pinch to zoom", and higher values than "Pinch to zoom" for unpredictability-predictability.

In relation to the Hedonic Quality – Stimulation, "Squeeze to zoom" seems to stimulate users in terms of being pleasant and inviting to use. "Squeeze to zoom" is seen as creative, unconventional, innovative, attractive and new. "Squeeze to zoom" was considered more challenging than the other two modes. This can be explained by the fact that this is a brand new mode of interaction for taking photographs and therefore requires greater effort than the modes users habitually use every day and are familiar with.

A possible interpretation of the lower values obtained for "Squeeze to zoom" in the pragmatic qualities may be attributed to the current level of development of the prototype which still lacks fluidity of the zoom and this affects also the quality of the photograph. In this prototype version of the "Squeeze to zoom" there is in fact no step by step interpolation between zoom levels as there is in the camera's native "Slide to zoom" application; the result is an image which is not very well-defined or clear and a bit grainy.

A number of participants highlighted that at the moment the system is overly sensitive to the pressure applied, making it rather difficult to use; this might explain the low result obtained in the pragmatic dimension. On the other hand, participants greatly appreciated the double handgrip of "Squeeze to zoom". "Pinch to zoom" requires users to handle the table with one hand and zoom with the other hand; this may be uncomfortable due to the weight of the tablet.

4 Medium-term evaluation

In the field of Experience Design [10, 17] there are few studies assessing the changes in a person's experience in interaction with a product over time [20]. The *dynamic of the experience,* as defined by von Wilamowitz-Moellendorff et al. [20], is largely excluded from the assessment process. The relationship between product and user, and the way in which this relationship evolves over time, has practically been almost ignored. There are a number of reasons for this exclusion, starting with the complexity of a longitudinal assessment process requiring in-depth monitoring of people over time.

von Wilamowitz-Moellendorff et al. [20] defined three types of longitudinal study, *micro, meso* and *macro,* on the basis of the assessment time range. The authors state that during a longitudinal study, the dimensions of the pragmatic aspect of a product tend to remain stable or improve over time, while the dimensions linked with hedonic components tend to decrease. One aspect that has an effect on the stability or increase in pragmatic qualities is *familiarity.* Familiarity, in fact, increases in-depth knowledge of the product and the ways it is used, resulting in a decrease in hedonic qualities such as surprise, beauty and stimulation. This would seem to be consistent with the results obtained by Hassenzahl et al. [4], according to which an increase in the amount of time spent in mental effort results in a low assessment of perceived qualities in relation to usability (>Mental Effort = <Pragmatic Quality Value), while a decrease in mental effort results in higher values (<Mental Effort = > Pragmatic Quality Value). On the other hand, Kujala et al. [14] obtained different results through use of the UX Curve Method for retrospective assessment of the experience of using a social network and a mobile phone. Other authors have in fact found that the hedonic qualities of a product seem to increase with time, unlike pragmatic qualities, which seem to influence the initial moments of the experience [9].

Long term assessment of the experience of using a product is not simply the sum of single individual experiences [5], but is composed of a number of different aspects, such as the

memory of the experience itself, which becomes just as important as episodic memory in the long-term assessment process [11, 18]. Another important aspect influencing assessment is the learning factor, which has an impact on improvement of the user's experience over time [14].

The study presented here was conducted in natural settings, comparing the two modes - "Squeeze to zoom" and "Slide to zoom"- which had obtained higher values in the four dimensions of analysis than "Pinch to zoom" mode in the previous short-term evaluation .

Eight participants (Male = 4; Female = 4) with an average age of 36.75 participated in the assessment process. Each individual performed 6 sessions over 4 weeks, using a tablet to take photographs in both modes.

Participants were specifically asked to photograph a moving object or subject (such as a ball rolling over the floor, a moving car, a person walking, a plane in flight, a dog playing).

The research hypotheses informing the study were the same as in previous assessments, with the addition of a third hypothesis:

- assessing whether the object or action photographed might have an effect on the choice of zoom mode.

In fact, in the previous evaluation we assessed the zooming modes while taking a photograph of a still image. In the medium-term evaluation we tried to appreciate if the task (taking picture of a moving object or subject) may affect the user experience.

The assessment method used was AttrakDiff. The test was administered at three different times, T_0 (first session), T_1 (intermediate session) and T_2 (final session), in order to assess changes in the experience over time. AttrakDiff administered with repeated measurements permits evaluation of the experience over time on the basis of four dimensions: pragmatic, hedonic regarding identity, hedonic regarding stimulation, and attractiveness.

In the final session, participants were asked to answer a series of questions:

– assess, on a 5-Likert scale from 0 to 4 (*from not at all satisfying to fully satisfying*), their overall experience with "Squeeze to zoom" and "Slide to zoom";
– identify which of the two modes they preferred;
– identify which of the two modes they considered easiest and most efficient to use;
– identify which of the two modes they found most attractive.

After an initial stage of familiarisation, participants were asked to interact with the two modes randomly. Each mode was then individually assessed using AttrakDiff. There was time for reflection during individual sessions. Particularly, participants were asked to reflect and comment on their experience using the individual modes. The participants' comments were noted at the end of the sessions.

4.1 Results

4.1.1 AttrakDiff

The graphs below in Figs. 6, 7 and 8 show the average values for the four dimensions of analysis used in the test (PQ; HQ-I; HQ-S and ATT), calculated for the two modes during the three administration times T_0, T_1 and T_2.

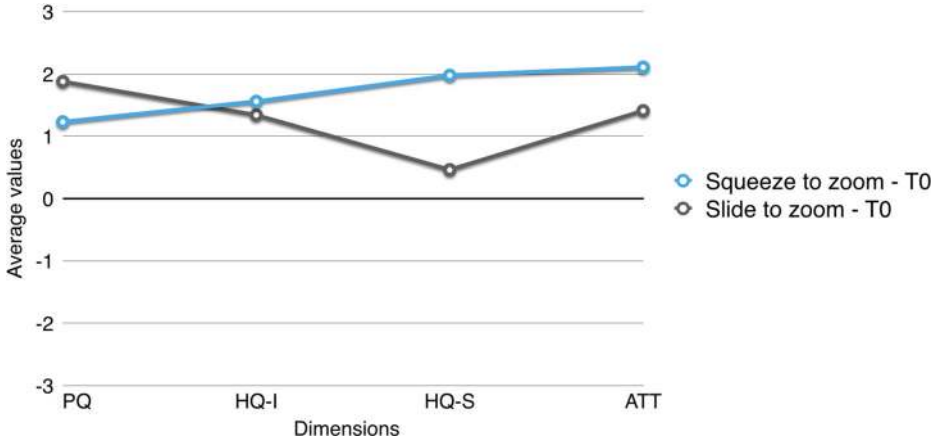

Fig. 6 Mean values for the four AttrakDiff dimensions for "Squeeze to zoom" and "Slide to zoom" - T_0

The graphs show an increase in the average values of pragmatic qualities and hedonic-identity qualities and a slight drop in the value of hedonic-stimulation and attractiveness qualities for "Squeeze to zoom" mode. The opposite was true of the values attributed to "Slide to zoom" mode. The values of the four dimensions in fact decreased over the course of the three assessments, with the exception of the dimension of hedonic-identity qualities, which obtained a slightly higher value during the intermediate assessment (T_1).

The table below shows details of the average values obtained for the four dimensions and the corresponding standard deviation during the three administration times for "Squeeze to zoom" mode (Tables 1 and 2).

The average values and standard deviations obtained for the four dimensions in "Slide to zoom" mode are shown below.

4.1.2 AttrakDiff: statistical analysis

We computed for each participant the scores on the four AttrakDiff dimensions, and analyzed the data using repeated measure ANOVAs. For each dimension, a two-way ANOVA was

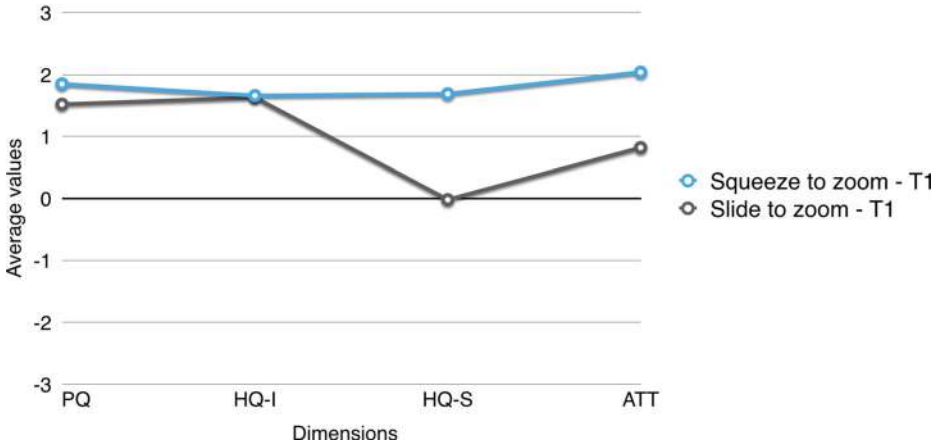

Fig. 7 Mean values for the four AttrakDiff dimensions for "Squeeze to zoom" and "Slide to zoom" - T_1

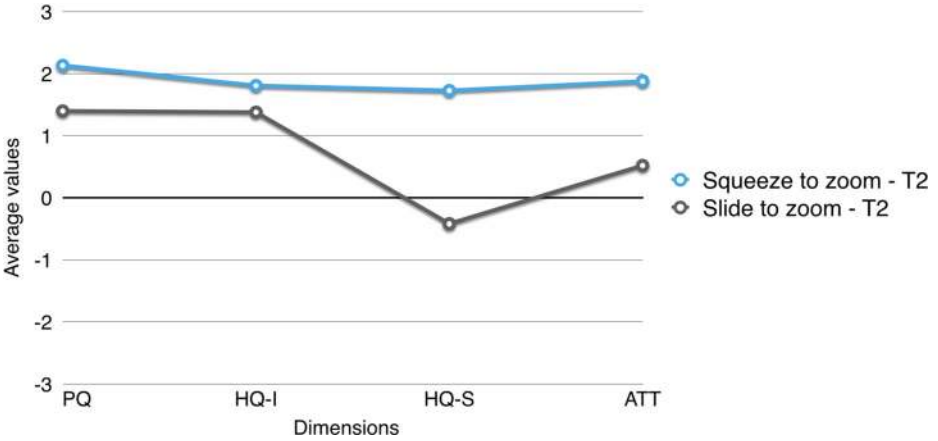

Fig. 8 Mean values for the four AttrakDiff dimensions for "Squeeze to zoom" and "Slide to zoom" - T_2

conducted including Time (3 levels: T0, T1 and T2) and Mode (2 levels: "Squeeze to zoom" and "Slide to zoom") as within-subjects factors.

For the PQ dimension, the results yielded a significant interaction between Time and Mode [$F(2,14) = 4.583$; $p = 0.029$], and no other significant effects. In Fig. 9, the marginal means of the PQ dimension are plotted as function of Time and Mode, revealing the source of the interaction effect: at T0, the PQ scores are lower for the "Squeeze to zoom" mode then for the "Slide to zoom", whilst at T2 the opposite pattern is present, and higher scores are observed for the "Squeeze to zoom" mode.

The average PQ scores at different modes were compared using paired t-tests for each time level, but the results were not statistically significant, possibly due to the low sample size. Tests of linear trends across time for the different modes were only marginally significant for the "Squeeze to zoom" mode [$F(1,7) = 4.216$; $p = .08$], providing partial evidence for an increase of the scores with experience of use, but not for the "Slide to zoom" mode.

No statistically significant differences were found in the HQ-I scores. The ANOVA for the HQ-S dimension revealed statistically significant differences for time and mode factors [time $F(2,14) = 5{,}668$; $p = 0.016$; mode $F(1,7) = 21{,}789$; $p = 0.002$], and no interaction. The Figs. 10 and 11 plot the average HQ-S scores for (a) Time and (b) Mode.

As it can be seen, the HQ- S scores tend to decrease with Time, and tests of polynomial contrasts found a significant linear component in the trend [$F(1,7) = 7.145$;

Table 1 Mean and Standard deviation for "Squeeze to zoom"

	Squeeze to zoom							
	PQ		HQ-I		HQ-S		ATT	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
T_0	1.23	1.57	1.56	1.19	1.98	1.39	2.11	1.19
T_1	1.85	0.95	1.66	1.23	1.69	1.45	2.04	1.04
T_2	2.13	1.04	1.81	1.23	1.73	1.66	1.88	1.21

Table 2 Mean and Standard deviation for "Slide to zoom"

	Slide to zoom							
	PQ		HQ-I		HQ-S		ATT	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
T_0	1.88	1.02	1.34	1.49	0.46	1.58	1.41	1.20
T_1	1.52	1.68	1.63	1.21	−0.02	1.67	0.82	1.34
T_2	1.40	1.33	1.38	1.10	−0.42	1.51	0.52	1.56

$p < .05$]. The scores for the "Squeeze to zoom" mode, moreover, are significantly higher than the scores for the other mode [diff = 1.79; 95 % CI for difference: .89–2.7]. Despite the interaction between Time and Mode was not significant, further tests (Tests of Within-Subjects Contrasts) showed a marginally significant interaction between Mode and a linear trend contrast on Time [$F(1,7) = 5.008$; $p = .06$]. The plot of the interaction in Fig. 12 shows that only for the "Slide to zoom" mode the average scores decrease with time.

We followed up this analysis running two 1-way ANOVAs on the effect of Time, and only for the "Slide to zoom" modality statistically significant differences: $F(2; 14) = 4{,}733$; $p = 0{,}027$ were found.

The analysis for the ATT dimension showed statistically significant differences only for the factor mode [$F(1,7) = 14{,}225$; $p = 0.006$], and the pattern of means (shown in Fig. 13) showed again higher scores in the "Squeeze to zoom" mode than in the "Slide to zoom" one.

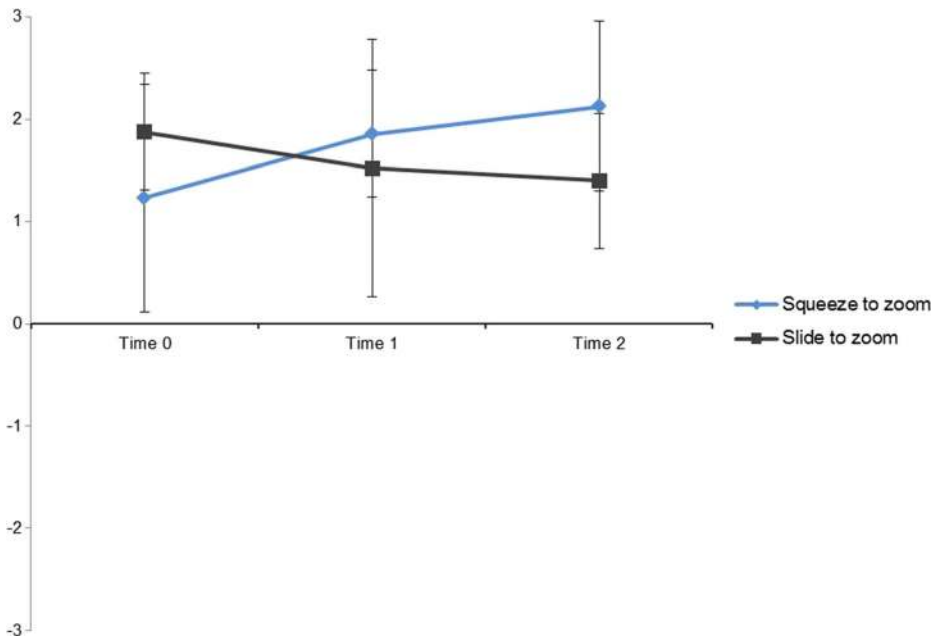

Fig. 9 Marginal means of the PQ dimension for "Squeeze to zoom" and "Slide to zoom" over the time

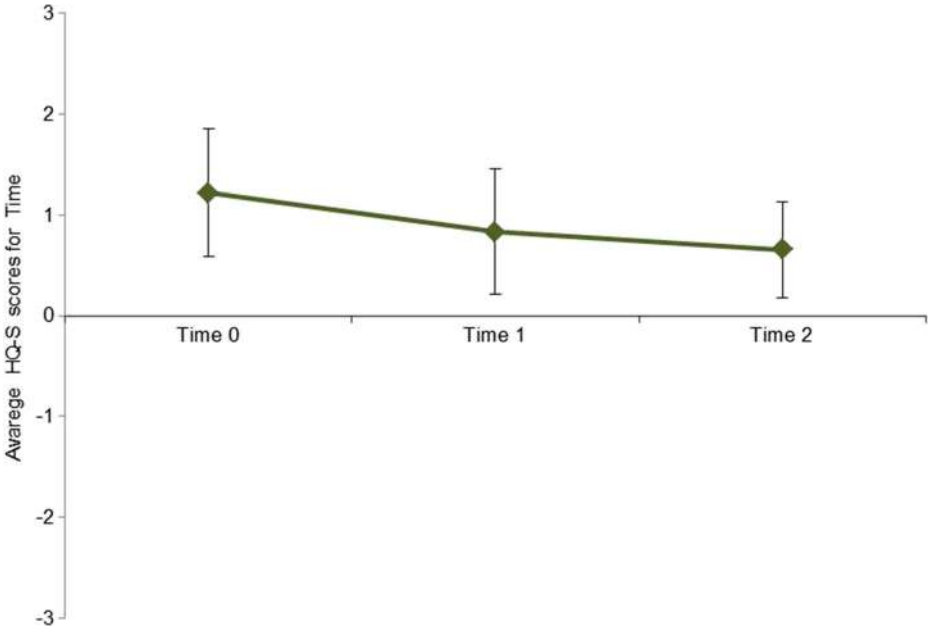

Fig. 10 Average of HQ-S dimension for "Squeeze to zoom" and "Slide to zoom" over the time

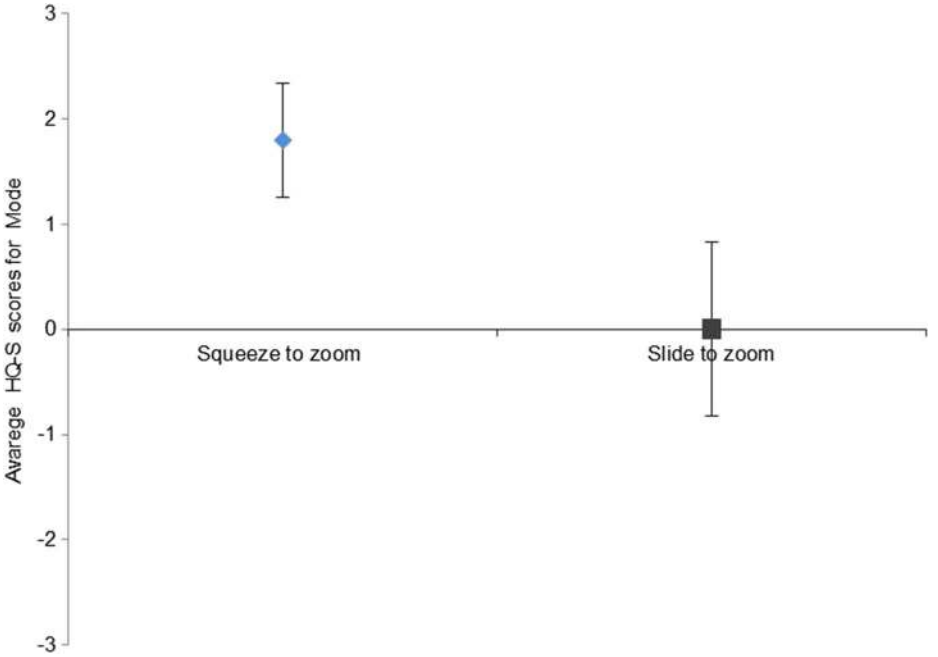

Fig. 11 Average of HQ-S dimension for "Squeeze to zoom" and "Slide to zoom" modes

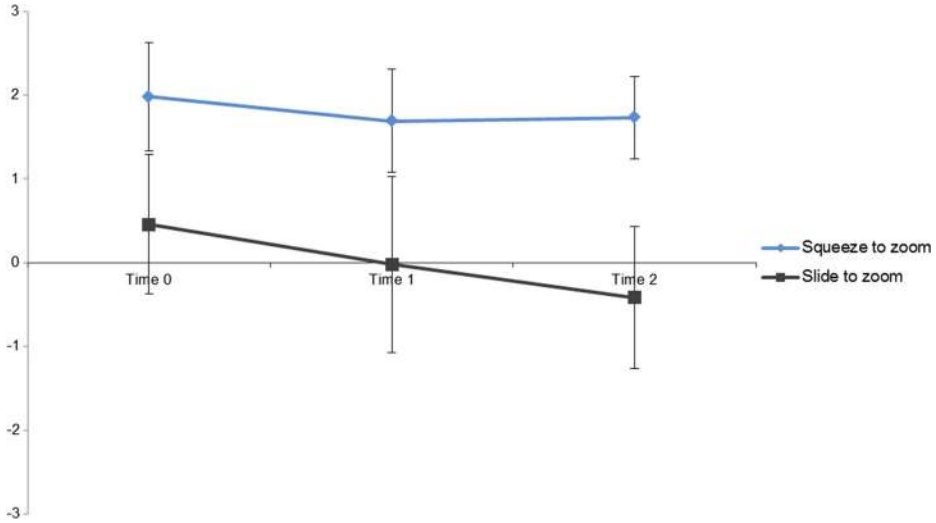

Fig. 12 Average of HQ-S dimension for "Squeeze to zoom" and "Slide to zoom"

4.1.3 Data final questionnaire

In the end of the medium-term evaluation, participants were asked to respond to a questionnaire. The final questionnaire contained six questions on the experience of use, appreciation, efficiency and efficacy of the two systems used. The responses to the questions are reported below.

In response to the questions, "*How would you rate your overall experience with* "*Squeeze to zoom*"*?* and "*How would you rate your overall experience with* "*Slide to zoom?*", on a 5-point Likert (from not at all satisfactory to completely satisfactory), participants responded as follows (shown in Fig. 14):

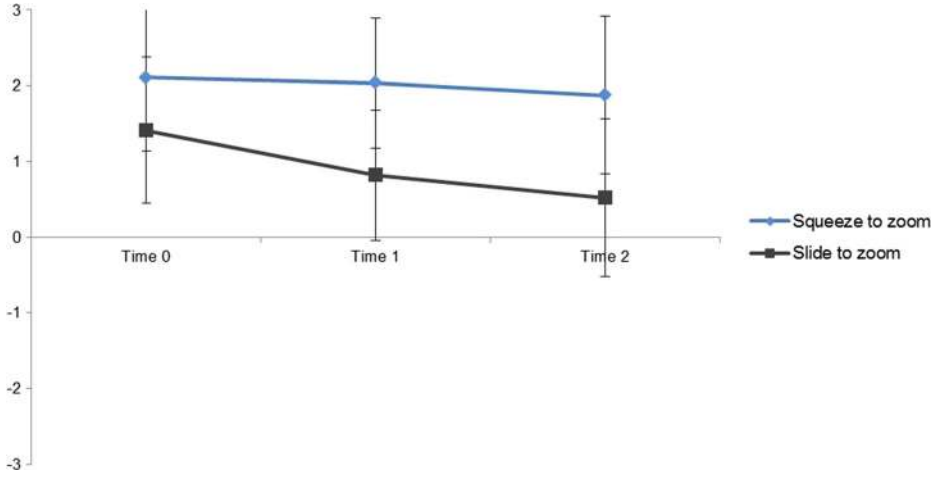

Fig. 13 Average of ATT dimension for "Squeeze to zoom" and "Slide to zoom"

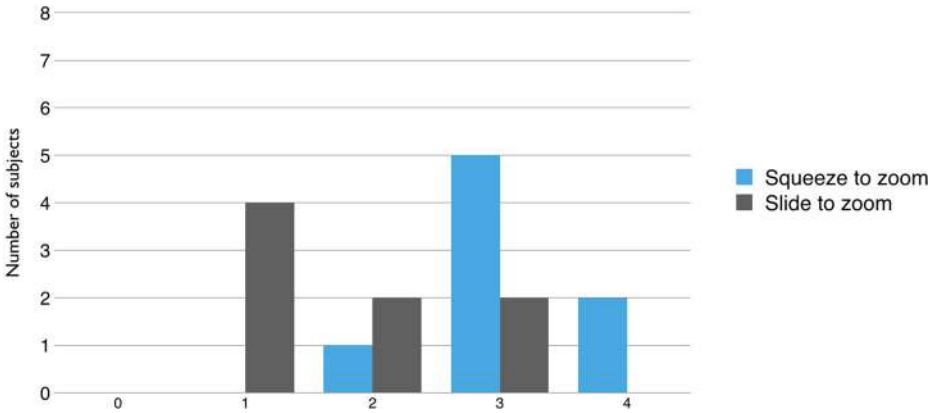

Fig. 14 Frequency of answers to the question "*How would you rate your overall experience with "Squeeze to zoom"?* and "*How would you rate your overall experience with "Slide to zoom?*" (From *0* = Not at all satisfactory; 1 = Not very satisfactory; 2 = Somewhat satisfactory; 3 = Quite satisfactory; to 4 = Completely satisfactory)

As the graph shows, the subjects prevalently attributed a positive assessment (quite satisfied) to "Squeeze to zoom" mode but were not very satisfied with their experience with "Slide to zoom".

In response to the question "Which of the two modes did you finds easiest to use?", participants replied "Squeeze to zoom". Participants found "Squeeze to zoom" mode more efficacious and efficient than the other mode ("Which mode did you find most efficacious and efficient?") (shown in Fig. 15).

Participants responses to the questions "Which mode do you find most attractive?" and "Which mode do you prefer?" are shown below (shown in Fig. 16).

As the graphs reveal, there is a clear preference for "Squeeze to zoom" over "Slide to zoom" mode. Only one person consistently expressed greater appreciation for "Slide to zoom" rather than "Squeeze to zoom" mode throughout the study.

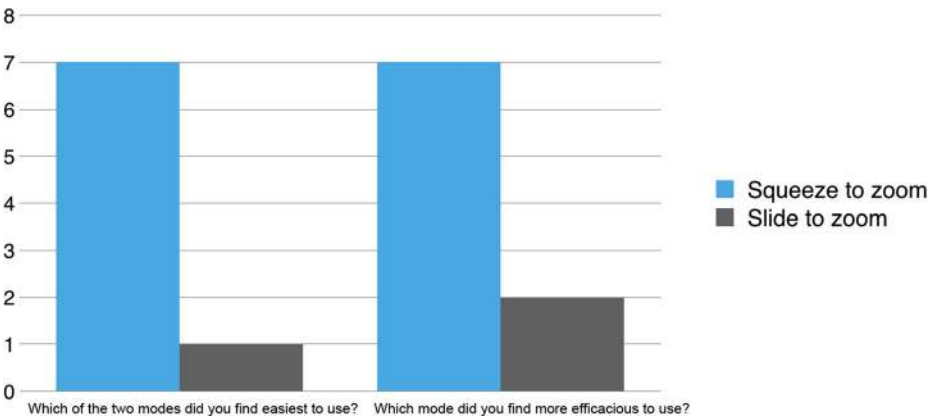

Fig. 15 Frequency of answers to the questions "Which of the two modes did you find easiest to use?" and "Which mode did you find more efficacious to use?"

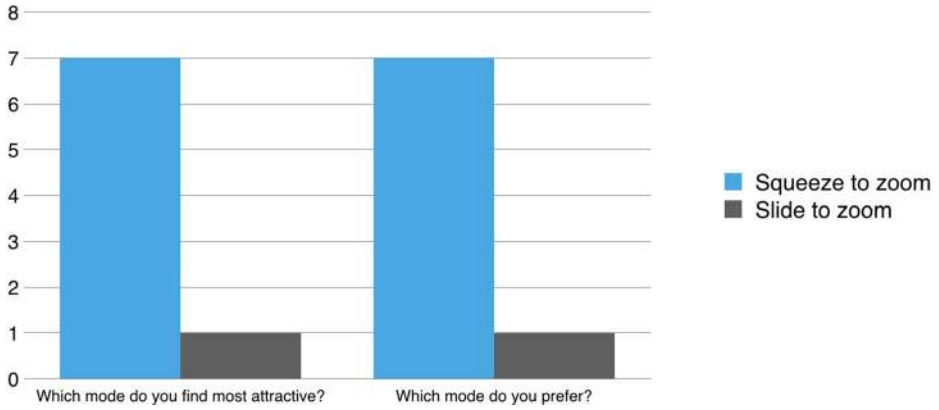

Fig. 16 Frequency of responses to the questions "Which mode do you find most attractive?" and "Which mode do you prefer?"

No significant differences in the trends of the data in the three assessment sessions were registered between men and women. On average, women awarded higher values in all 4 dimensions than men, especially for "Squeeze to zoom" mode in the final assessment session (shown in Fig. 17).

4.2 Discussion of results of the medium-term evaluation

The longitudinal study data revealed a clear prevalence of preference for "Squeeze to zoom" over "Slide to zoom", even though "Slide to zoom" mode was considered simpler, more linear and easier to handle in the short-term evaluation, as shown in the graph below (shown in Fig. 18), which shows the mean values obtained by "Squeeze to zoom" as compared to "Slide to zoom" for the pragmatic dimension in the short-term assessment session.

During the longitudinal study, participants reported positive comments and expressed greater interest in "Squeeze to zoom" mode, also in relation to usability.

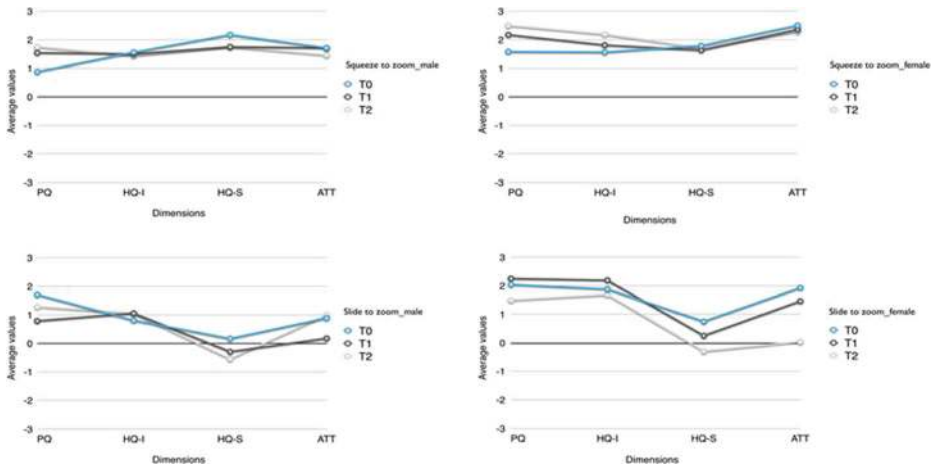

Fig. 17 Mean values for the four AttrakDiff dimensions for "Squeeze to zoom" and "Slide to zoom" for male and female

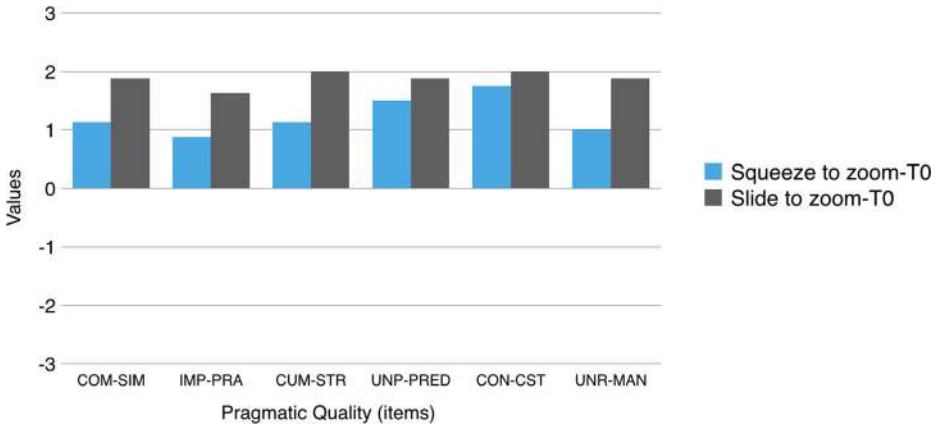

Fig. 18 Mean values for Pragmatic Quality items for "Squeeze to zoom" and "Slide to zoom" – T_0

This is an interesting outcome since it reveals that familiarity and learning compensate usability problems emerged in the short-term evaluation.

One 26-year-old man said, "*Squeeze to zoom mode definitely makes it easier to take photos because you don't have to take your hands off the tablet, and you can take a photo by touching any point on the screen*"*;* similarly, a 40-year-old man noted that "Squeeze to zoom" was easier for him to use than the other mode because he could use both hands instead of a single digit (the thumb, as in the other mode) to perform two separate actions: selecting the zoom level first, and then taking the photograph at the point subsequently established. Two 50-year-old women emphasised that interaction with "Squeeze to zoom" came much more naturally to them over time.

The figure below shows two pictures shot during the test. The picture on the left was taken using "Squeeze to zoom", the one on the right was taken using "Slide to zoom" (shown in Fig. 19). The person who made the photographs declared that she could not take a better picture with "Slide to zoom" since the subject was to fast with respect to her ability to use the "Slide to zoom".

The presence of feedback, in the form of vibration, in "Squeeze to zoom" mode was considered practical and gladly accepted by participants as it permitted direct perception of the action they were performing.

As the figure below shows (Fig. 20), the values attributed to "Squeeze to zoom" mode in relation to the Attractiveness dimension decreased slightly over the three assessments.

Fig. 19 Pictures shot using "Squeeze to zoom" (left) and Slide to zoom (right)

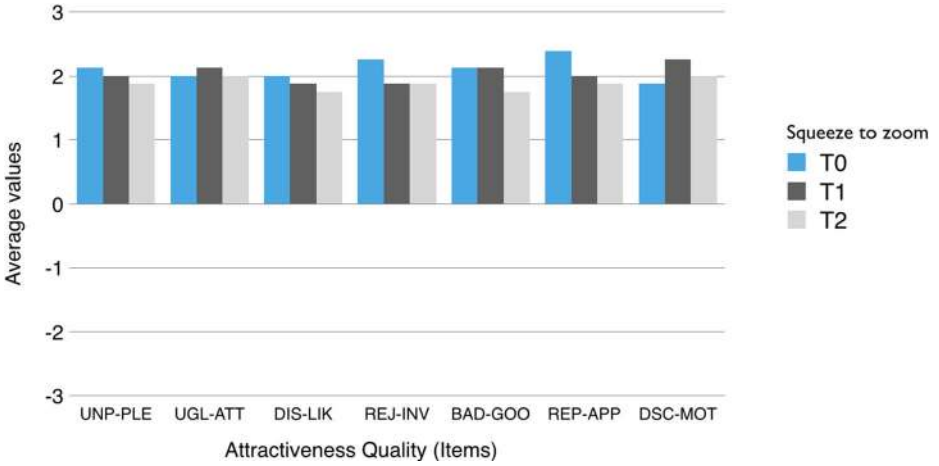

Fig. 20 Mean values for Attractiveness items for "Squeeze to zoom"

The same trend, with an even more significant decrease, was registered for "Slide to zoom" mode (shown in Fig. 21).

The graphs in Figs. 20 and 21 show that in the final assessment, participants awarded a lower value to the 7 dimensions of analysis of attractiveness which was significantly decreased for the "Slide to zoom" mode.

All subjects also expressed a clear preference for "Squeeze to zoom" mode for taking photographs of rapidly moving objects, such as a car travelling along a road. This mode was chosen because it permitted the photographer to follow the object's motion in a more natural, practical way and made it easier to take a photograph. "Slide to zoom" mode was considered more appropriate for photographing objects moving more slowly, where the interest was in focusing on a detail, such as photographing people going through a sliding door. Some participants also pointed out that "Slide to zoom" mode was not appropriate for photographing quickly moving

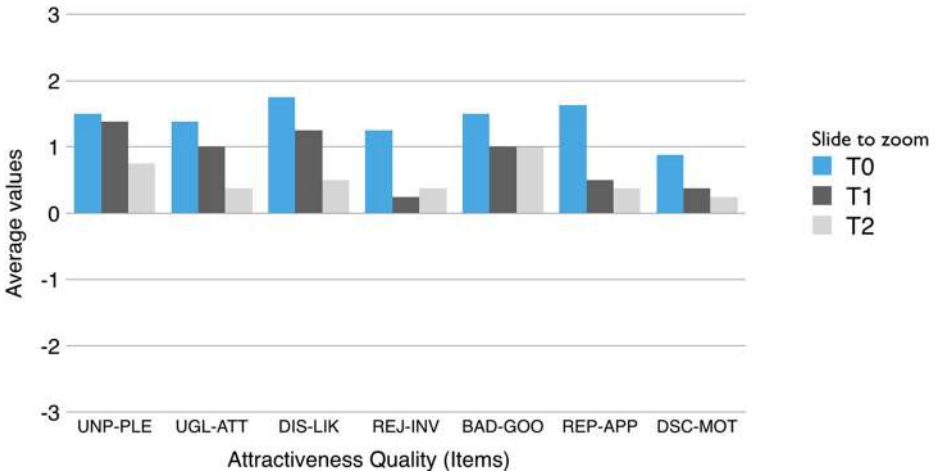

Fig. 21 Mean values for Attractiveness items for "Slide to zoom"

subjects because the frame they chose to photograph could not be fixed in the resulting image, as it went on to the next frame.

As in previous assessments, participants emphasised the difficulty of using "Squeeze to zoom" to define the desired zoom level in the first few sessions, noting that the prototype's current sensitivity affects its usability.

Even if the longitudinal study was conducted on a limited number of subjects, the results are not due to chance as confirmed by the ANOVA test and their significance is remarkable. A positive usability test conducted at the first encounter with an interactive system does not guarantee a positive user experience over time.

5 Conclusion

With the design of the Squeeze Me, we explored different opportunities for bodily interaction with a squeezable device. In particular we explored new forms of coupling between input and output that make interaction rich, expressive and continuous. The proposed solution is innovative since it relies on mapping the natural action of squeezing a soft material and its effects through a continuous action-perception loop exploiting the richness and continuity of our embodied skills.

The experience of use of "Squeeze Me" was evaluated in the short and medium term. Results obtained in the short-term evaluation reveal that "Squeeze to zoom" mode was awarded higher values than "Slide to zoom" in the hedonic quality-stimulation and attractiveness dimensions, whilst it obtained lower values in the pragmatic quality and hedonic quality-identity. "Squeeze to zoom" seemed to mainly stimulate users in terms of being pleasant and inviting to use, and it is seen as creative, unconventional, innovative, attractive and new.

However, the experience of use changed over time. Interestingly, during the longitudinal study, participants reported positive comments and expressed greater interest in "Squeeze to zoom" mode, also in relation to usability. This is a noteworthy outcome since it reveals that familiarity and learning compensate the usability problems emerged in the short-term evaluation. This result confirms the findings of von Wilamowitz-Moellendorff et al. [20] and Hassenzahl et al. [4] according to which pragmatic qualities tend to increase or remain stable over time, while hedonic and attractive qualities tend to decrease. In our study, as in the study conducted by Hassenzahl et al. [4], familiarity and learning had a major effect on the assessment. Furthermore the values attributed to "Squeeze to zoom" mode in relation to the Attractiveness dimension decreased slightly over time whilst the values attributed to "Slide to zoom" decreased more significantly. These results seem to indicate that when a product is considered very attractive at the first use, its attractiveness is somehow maintained over time or decreases slightly. On the contrary, when a product is not considered very attractive at the first use, its attractiveness drops over time more rapidly.

Another interesting result of our study is that the typology of task impacts on the experience of use. In fact all subjects expressed a clear preference for "Squeeze to zoom" mode for taking photographs of rapidly moving objects in comparison with still objects, stating that this mode permitted the photographer to follow the object's motion in a more natural, practical way and made it easier and engaging to take a photograph. This means that when evaluating the

experience of use, a particular attention has to be devoted to the nature of the task and not only to the context of use (e.g. laboratory vs in the field experiments).

In sum, the study described in this article can be regarded as a contribution to the practice of evaluating the User Experience in particular with respect to the way in which the relationship between user and product evolves over time, an aspect that has been largely ignored in the research on User Experience evaluation.

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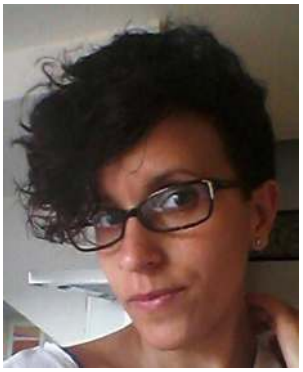

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