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In Search of Resonant Human Computer Interaction: Building and Testing Aesthetic Installations

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Abstract: Resonance (Gibson, 1986) of users while interacting with a product should be a key issue in the development of human computer interaction. Because resonance requires developing overall solutions, it unites research areas and capitalizes on their strengths. The fact that pleasant and attractive products actually work better (Norman, 2002) is an example that the whole exceeds the sum of its parts. Moreover, designing for resonance enables individuals to create their own experiences. In this paper we elaborate on the advantages of resonance and show on the basis of two interactive installations how to find salient aspects of resonance. *ISH* explores visual and musical group performances through tangible interaction. *Coppia Espressiva* studies in depth two forms of tangible interaction: phycons (i.e. physical icons) and expressive dynamic behaviour. Experimental tests with both installations show that diversity of interaction is a prerequisite to obtain resonance. Furthermore, a proper mapping between appearance, interaction, functionality and temptation increases resonance.

Keywords: Resonance, interaction design, aesthetic installations, emotion, experience, tangible user interfaces

1 Introduction

The history of HCI can, in many ways, be seen as an ongoing attempt to capitalize on the full range of human skills and abilities (Dourish, 2001).

In the beginning, computer science and HCI manifested themselves through encoded patterns (e.g. punch cards) and command lines, thus calling upon the cognitive skills of users. The shift to visual computing with a desktop and a mouse that was coupled to an on-screen cursor, expanded the interaction range towards perceptual-motor skills. If we look at the current developments within HCI, like tangible interaction, affective and social computing, we see a refinement towards the use of perceptual-motor skills and the urge to incorporate emotional skills. It seems that respect for the human as a whole has come into vogue, at least within a part of the HCI research community.

This emphasis on the human as a whole can also be seen in the shift of contextual focus. The computer is leaving the sphere of the workplace, thus widening the spectrum of efficiency, productivity and 'getting things done' with values like curiosity, playfulness, intimacy and creativity (Caenepeel, 2002; Overbeeke et al., 2003). The computer has entered our daily and social life. It is no longer just a means to perform our work; it helps us to pursue our lives (Gaver, 2002). In this way, the world of HCI has united with that of product design.

Although this is an interesting and challenging way to go, it isn't an easy one, especially in our contemporary culture that lost its unifying ideology (Branzi, 1989). We do not only have to develop the next generation of digital products with which we can pursue our lives, we also have to decide what kind of life and society we want these products to support.

Buchanan (1998), Marzano (1996), Borgmann (1987) and Saul (1997) all plead for respect and humanism; for 'real' individualism, in which the individual is part of society and takes responsibility for that society. This implies that we shouldn't design 'objective' products for a universal audience, or "the consumer". Products should be personal pathways that allow individuals to find and create their own experiences (Hummels, 2000).

'Capitalizing on the full range of human skills and abilities', as Dourish (2001) mentioned in the light of the history of HCI, is a condition to design such 'contexts for experiences'. However, we would like to expand the focus from human skills to the concept of *resonance*. In the remaining part of this text, we will explain this concept and our reasons for advancing it. Moreover, we discuss on the basis of prototyping and

testing two interactive installations, *ISH and Coppia Espressiva*, how to find salient aspects of resonance

2 Resonance

Resonance stems from the theory of ecological or direct perception, which also engendered the term affordance; a term that Norman introduced in the HCI community.

2.1 Radio Metaphor

Gibson (1986) used the term in combination with a radio metaphor to clarify the directness of our perceptual system. A radio station broadcasts information, i.e. waves with a particular radio frequency. The detection of radio waves is based on the principle of resonance. Given that many frequencies (stations) reach a receiver from the antenna, proper tuning of the receiver causes a current in it to resonate in response to one of the incoming signals, and not others.

In case of e.g. visual perception, the radio waves in this metaphor stand for light that is structured (broadcasted) by our environment (the radio station). Our eyes (the antenna) let the signals pass through, and we (the radio) must tune in to the information. For example, if we want to write a message, we are tuned in to information in our environment that affords us to write. Thus when a pencil comes into view, our perceptual system resonates to that information (Michaels and Carello, 1981).

However, resonance does not only relate to our perceptual-motor skills. It relates to our cognitive and emotional skills too. Moreover, it is not only a temporal response, e.g. we want to write, so we resonate with a pen. We also resonate with products because we are persons with certain needs, desires and intentions, a social and cultural history and position etc. Consequently, we do not all resonate to the same products. To elaborate on the writing example, one person might resonate with a cheap disposable pen, another person with the fountain pen he got from his grandpa and another person might resonate with the I-Mac that he bought from his savings.

2.2 A Mixture of Ingredients

Let us explore the concept of resonance a bit further. For example, the first author resonates with a Sunbeam toaster that she bought approximately ten years ago at a jumble sale (see figure 1). She resonates with it, because it functions even better than expected. It has a small catch which causes the slices to be automatically transported downwards at a calm pace and upwards again when they have a nice tan. This calm pace enhances the feeling of luxury and Sunday morning relaxation. The slow transportation of slices gives the impression that the toaster is saying: "Come, hand me your bread. I will take good care of it and produce the most delicious toast, specially for you." Due to this invitation, she places the slices of bread with a gentle and elegant gesture into the toaster.

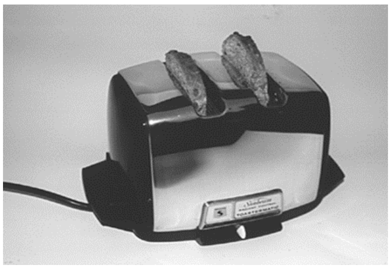

Figure 1: The first author's Sunbeam toaster

This example shows, that it is not just about tuning a product to one's skills, which makes a person resonate with a product. A resonant interaction is the result of a mixture of different ingredients like usability, human skills (cognitive, perceptual-motor and emotional), richness of the senses, individual and social needs, desires, values and interests, personal history, way of acquiring the product, context of use (situation, timing, environment, social setting), aesthetics of interaction, intimacy, engagement and openness to find and create one's own meaning, story and ritual.

Three things are important. Firstly, resonance can be a concept that provides respectful and humanistic human computer and product interaction, which allow individuals to find and create their own experiences.

Secondly, resonance can only be found in an ensemble of ingredients, thus requiring a holistic design approach. For example, Norman (2002) shows that pleasant and attractive products actually work better, providing that they are not used in emergency situations. Thus the whole exceeds the sum of its parts. This implies that people involved in the development of HCI and product design, e.g. designers, computer scientists, engineers, psychologists, marketers, should work together, combine their knowledge, capitalize on their strengths and develop integral solutions, in order to attain resonant products and interaction.

Thirdly, because of the personal character of resonant interaction, HCI and product developers should involve people for whom they are developing right from the start for inspiration, information, discussion, evaluation, testing and validation of resonant interaction.

2.3 Studying Resonance

Resonance is a rather unexplored area due to its complexity. Why do some people resonate with a certain product, while others do not? Can one formulate guidelines for designing a product that evoke resonance, while respecting its personal and context-dependent character? Within our research we are trying to answer four questions:

- What should be the salient aspects of human computer and product interaction in order to evoke resonance? For example, does one need unity of location, direction, modality and time, which are considered important aspects to obtain usability (Djajadiningrat et al, 2002)? And what is the role of temptation, intimacy and engagement?
- What are a person's desires, values, human needs, preferences, intentions etc.? What kind of products, (social, personal and product) interactions, rituals, and digitally mediated life does he prefer and how can he achieve it?
- What is the role of the context of use, e.g. situation, timing, environment, social setting, and to what extent can and should an interaction designer control these external factors?
- How can a designer link these three aspects: interaction, the user and the context? What are the implications of resonance for the design process?

Over the last few years we started several projects that try to answer these questions. A common feature of all these projects is their 'research through design' approach. Since resonance is personal, context-dependent and a result of interaction, true resonance can only be found through a loop of designing and building products with an experiential quality and testing them with real users (Hummels et al, 2000).

In this paper, we focus on the first question. We are trying to answer this question by designing and testing interactive installations and a variety of products. Let us show on the basis of two of our installations how we try to find salient aspects of resonance. The first installation called *ISH* explores visual and musical group performances through tangible interaction. The second one called *Coppia Espressiva* studies two forms of tangible interaction: phycons (physical icons) and expressive dynamic behaviour.

3 Prototype 1: *ISH*

ISH (Image and Sound Handling) is an interactive multi-media installation that allows a group of people to create together an atmosphere through visuals and music (see figure 2). *ISH* is a dynamic research environment which allows us to evaluate resonant interaction through loops of (re)designing, building and testing. At the moment, *ISH* consists of eight tangible products and a projection screen. Every product has its own character with respect to feedforward, feedback, time-delay, temptation, clarity etc., which allows us to evaluate different aspects of resonance.

Figure 2: The interactive installation *ISH* uses tangible objects to create visuals and music.

For example, *ISH* studies whether unity of location, direction, modality and time with respect to the user's actions and the product's feedback, are prerequisites to obtain resonance. These aspects are considered important in strengthening inherency of feedback, and thus usability (Djajadiningrat et al 2002). Moreover, is it necessary that a product shows what the user can expect after he carries out an action or should a product seduce a person to explore it? Should one pursue subtle interaction and what makes it engaging and beautiful?

3.1 Describing *ISH*: 8 Tangible Products

To 'run' *ISH* we use data flow tools from the field of musical performance and new media art, namely Max/MSP. This program allows us to interface sensors easily through MIDI. Moreover, most of the sensors that are used by *ISH*, like capacity and infrared sensors, are developed within our lab (see figure 3).

Gatherish.

A person selects audio samples and images by moving his hands through the sand of Gatherish. The position of the hands and the character of the movements determine the expression of the sounds and images.

Compositish.

Four sequentially placed images containing holes create the projected environment. A person determines with four tangible transparent cards the order of the four layers. Moreover, one of the layers can be made active by placing a banner next to it. One can manipulate the image in the active layer using *Gatherish*, *Smallish*, *Stirish* and *Jitterish*.

Smallish.

Smallish alters the volume of the audio part and the size of the image in the active layer (which is selected through *Compositish*). The volume and the size increase by pushing the square plane.

Stirish.

The difference in force exerted to the pillows of *Stirish* alters the position and orientation of the selected image.

Jitterish.

ISH has its own character, which means that the images have their own movements, depending on the mood of *ISH*. These movements are influenced by the kind and number of actions the users make on the eight products.

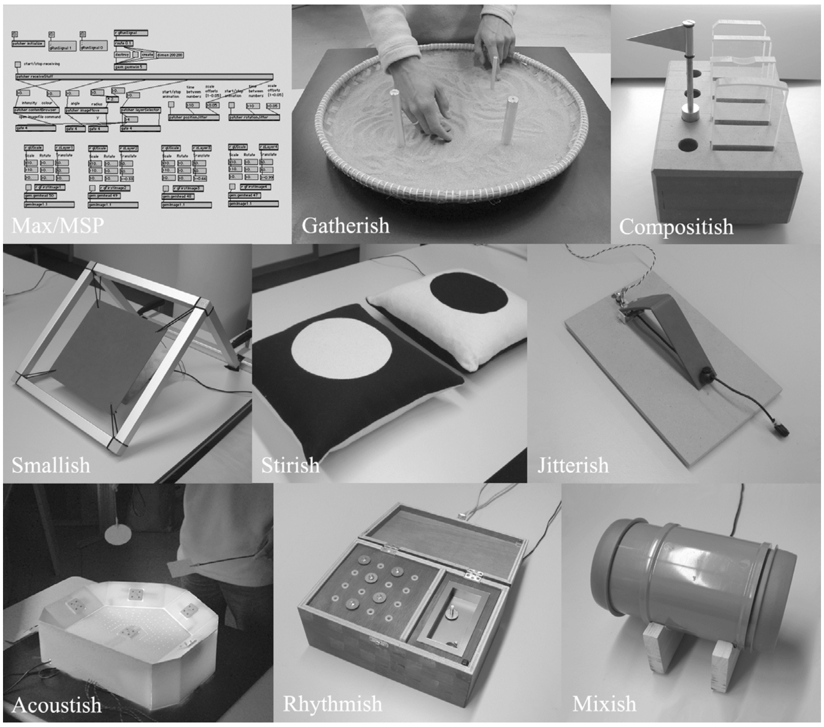

Figure 3.: *ISH* consists of eight tangible products to generate music and projected visuals

Moreover, one can set the mood (tensed – relaxed) by increasing or decreasing the tension (curve) of *Jitterish*.

Acoustish

The audio part consists of sounds and rhythms, which can be interactively manipulated. The expression of the sounds and the rhythm can be altered with *Acoustish* by making bridges between an infrared four senders and receiver, using several reflectors.

Rhythmish

The expression of the visual pattern of tokens that is created with *Rhythmish* fits the expression of the rhythm section. For example, a low number of tokens placed in an orderly way, creates a simple and relaxed rhythm.

Mixish

Mixish determines the balance between *Acoustish* and *Rhythmish*. Shifting the cylinder towards *Acoustish* puts an emphasis on *Acoustish*, and shifting it towards *Rhythmish* fades *Acoustish* away.

3.2 Evaluating ISH

ISH is evaluated by observing people interacting with *ISH* and each other. We observed the behaviour and remarks of the audience that was unacquainted with our research during open days and demonstrations.

Their behaviour and remarks show that the overall installation, enabling people to generate visuals and music, resonate with most spectators during interaction. However, the social aspect of it, i.e. creating this atmosphere together, is still underexposed. This is partly the result of the set-up. All products were faced towards a vertical screen, thus complicating natural interaction between people. The successor of the present set-up will arrange all products circular around a horizontal projection of the visuals.

The individual products show different reactions with respect to resonance. They can be divided in three groups.

A vast majority

Smallish and *Rhythmish* seem dead on target with respect to resonance. People considered them to be extremely clear and pleasurable. The mapping was considered natural in both cases: for *Smallish* between distance / force and size / volume and for *Rhythmish* between the visual pattern and the resulting rhythm. Moreover, the subtle flexibility when pushing the square of *Smallish*, caused by the elastic suspension was experienced very pleasurable and resonant. The intimate and expectant moment of closing the box and hearing the created rhythm, seem to enhance the resonance with *Rhythmish.*

Exploration seekers

The feeling of sand through one's fingers, made *Gatherish* very attractive, similar to *Stirish* and *Acoustish*. However, only a minority of the users experienced these three products being resonant over a longer period of time, because they demand exploration. Cause and effect are not immediately clear. It appeared that less goal-oriented and more imaginative people find themselves attracted to this kind of interaction.

Functional but somewhat dull

Most people experienced *Compositish*, *Jitterish* and *Mixish* clear and simple to operate, with appropriate tactile and kinaesthetic feedback. They were considered pleasurable with respect to interaction, functionality and appearance. Nevertheless, they sparsely challenged extensive interaction, due to their simple and functional character. This made them less resonant for the exploration seekers in contrast with the goal seekers.

These results show that unity of location, direction, modality and time with respect to the user's action and the product's feedback, are not per definition prerequisites to obtain resonance. However, *Smallish* and *Rhythmish* do show that a mapping between appearance, interaction, functionality and temptation, which is experienced as natural, increases resonance.

Moreover, one cannot draw general conclusions with respect to feed forward and temptation. Some people prefer products that show what the user can expect after he carries out an action, whereas others prefer products that seduce them to explore. Obviously, these preferences are dependent of the task and context too. All in all *ISH* shows the importance of pursuing diversity within product interaction; not all people resonate to the same things. We will expand *ISH* with respect to diversity, by incorporating others forms of modality, like speech (intonation, volume) and gestures, and add / alter products.

ISH also revealed some drawbacks: it is predominantly suited for short-term interaction. The Sunbeam toaster showed that time has an important impact on resonance. Moreover, *ISH* is developed for observing people's behaviour and feelings through different products. Because the products have different functionalities, they are unsuitable to compare in experimental tests, so the results remain rather general.

4 Prototype 2: Coppia Espressiva

Tangible interaction can be approached in various ways. *Coppia Espressiva* is an installation that is designed to compare two forms of tangible interaction through experimental testing: phycons and expressive dynamic behaviour. Before discussing *Coppia Espressiva*, let us explain why we've chosen these two types of interaction.

4.1 Semantic Approach versus Direct Approach

Designers have the task to shape meaning in the appearance of and interaction with physical products. In general a designer has two ways to create meaning: using a semantic or a direct approach. The semantic approach starts from cognition. The basic idea is that we use our knowledge and experience to interpret the symbols and signs of products. These products use metaphors in which the functionality and expression of the new product is compared to an existing concept or product that the user is familiar with (Djajadiningrat et al, 2002). The desktop metaphor with its files, folders and trashcan, which is used by the majority of desktop computers, is a 2D example of the semantic approach.

The second, approach is called the direct approach. This approach takes behavior and action as its starting point (Djajadiningrat et al, 2002). Meaning is created in the interaction between person and object. The term affordance is a key element of this approach. Although there are many definitions of affordance, in general one could say that an affordance invites a person to a particular action, based on the person's effectivities (i.e. what he can perceive and what he can do with his body) and intentions. For example, a chair affords sitting to an adult person when he is tired, and it affords stability to a small child who wants to stand up (Hummels, 2000).

The alarm clock of Wensveen (Wensveen et al, 2002) is an example of this direct approach. It is able to read the mood from the way it is set, because the alarm clock invites rich expressive behaviour. Although not yet implemented in the prototype, the alarm clock will choose an appropriate wake up sound, based on the detected mood.

Coppia Espressiva explores and tests the value of both approaches with respect to resonance. The installation consists of two products, which allows individuals to express their feelings by creating music. The first product makes use of the semantic approach and is called *Poco* (short for the music term *'poco a poco'* which means 'bit by bit'). The second is designed using the direct approach and is called *Moto* (after the music term '*con moto*' which means 'with motion'). We will explain them successively, before describing the experimental test with its results.

4.2 Poco

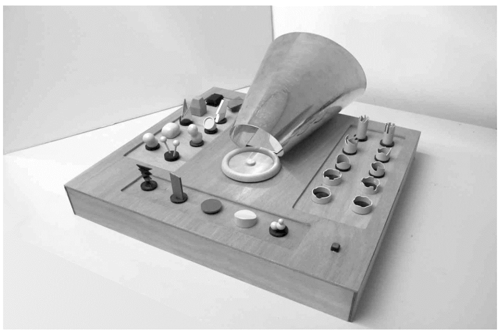

Figure 4: Poco uses the semantic approach

Poco consists of three sets of phycons; one set of 10 phycons which represent various kinds of rhythm, one set of 10 phycons which represent various kinds of two-chord progressions and one set of 5 phycons which represent various kinds of sampled sounds of nature (rain, birds etc.).

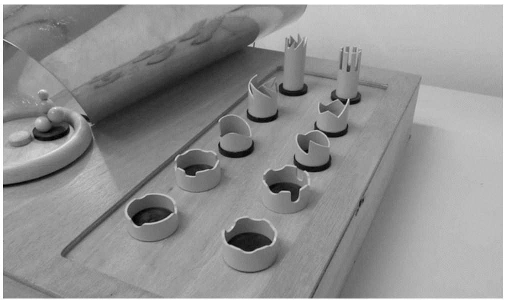

Figure 5: Rhythm phycons

The appearance of a phycon reflects its musical expression. For example, a short cylinder with only a few notches represents a slow and easy rhythm, whereas a high cylinder with several irregular notches represents an upbeat and hectic rhythm.

A person can create a musical expression by placing maximally one phycon of every set on a rotating platform. All phycons contain an RF tag, so as soon as a phycon is placed on the platform it is recognized and the accompanying rhythm, chords or sample starts playing. To emphasize the musical character of *Poco*, the music is amplified by a brass horn. Once a person is satisfied with the music expression, he can push a button on the product and record this piece of music.

Both *Poco* and *Moto* are developed using Max/MSP, similar to *ISH*. For *Poco*, one patch is written to recognize the RF tags, whereas several others control the selection, mixture and recording of the chords, rhythm and sample.

4.3 Moto

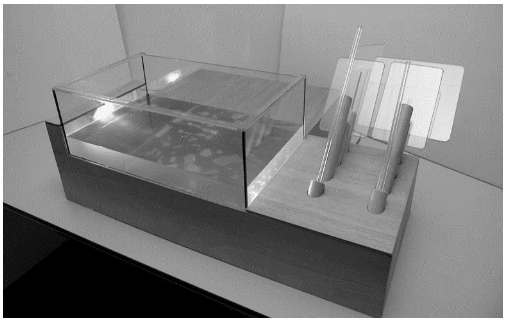

Figure 6: Moto uses the direct approach

Moto consists of a water reservoir and eight tools. A person can create a musical expression by moving one or two tools through the reservoir. The kind of tools and the way they are moved determine the musical expression: an array of light sensors detects the selected tools and a camera detects the movements of the tools and the water. In contrast to *Poco*, where a person can control the different aspects of the musical expression, *Moto* enables a person to create an overall expression 'in one go', which means that rhythm, chords and a sample are selected simultaneously.

The set consists of eight tools. The tools have similar handles, but differ in feel when moved through the water. To achieve this, the shape and area of the blade and the materials used are varied. For example, when a person moves one of the big blades through the water, he automatically feels the resistance of the water, which partly steers his actions. The person can change the orientation of the blade and in- or decrease the pace of movement, but the movement will maintain some sort of cumbersome character. The generated musical expression, being a mixture of rhythm, chords and a sample, is analogously cumbersome. Every tool has its own characteristic behaviour, which helps the user creating the desired musical expression. Once a person is satisfied with the music expression, he can activate a switch with his foot and record this piece of music.

Moto uses the basic Max/MSP patches of *Poco*, supplemented with patches to recognize the different tools, detect and interpret the camera images of the reservoir, and allocate rhythm, chords and samples.

4.4 Experimental Test

We have conducted an experimental test to validate the two approaches with respect to resonance. The study consisted of two parts. In the first part, the creative part, we invited eight undergraduates of the School of Industrial Design Engineering (four male, four female) to create four musical expressions, after training both systems for forty-five minutes. Two of these musical expressions had to be created using *Poco* and two using *Moto*. In the second part, we conducted a matching experiment in which 22 subjects evaluated these musical expressions.

In order to be able to compare the two systems, we used the Mood Induction Procedure that was used by Wensveen to validate his alarm clock (Wensveen et al, 2002). Wensveen used four film clips to target the dimensional quadrants of the circumplex model. This model organizes emotions in a two dimensional arousal / valence space. The students were asked to create a musical expression, after seeing a film clip while empathizing with the situation shown. Based on literature one can expect that the created musical expressions match the emotional expression of the film clips. We used the clips that Wensveen generated (ranging in time between 2 and 3 minutes):

- High arousal / positive valence: *Blues Brothers*
- High arousal / negative valence: *Koyaanisqatsi*
- Low arousal / negative valence: *Stalker*
- Low arousal / positive valence: *Easy Rider*

4.5 Procedure Creative Part

On a 4 m wide screen in a darkened room, the four movie clips were shown, proceeded by a trial clip. The subjects were instructed to empathize with the situations depicted. After every clip, the subjects first had to describe their mood in terms of arousal and valence using the 'Self Assessment Model' (SAM) (Lang, 1985). The subjects were then asked to use either *Poco* or *Moto* to translate this mood into music. (All conditions were counterbalanced within and between subjects). The subjects were told they had two minutes to make a satisfactory expression. However, this time limit was never actually imposed. When the subject was satisfied with the music, he was asked to rate this satisfaction on a scale from 1 (very dissatisfied) to 5 (very satisfied) and the effort it took, also on a scale of 1 (very hard) to 5 (very easy). The time was measured and logged. After a short relaxation clip (cloudy skies for 30 seconds), the subject was exposed to the next film clip and the procedure repeated. After the four clips, the subject was asked a few general questions.

4.6 Procedure Matching Experiment

A total of twenty-two undergraduates (fourteen men, eight women) of the School of Industrial Design Engineering participated in the matching experiment. In each session three to five participants sat in a slightly darkened room facing towards the projection screen. They were exposed to the same Mood Induction Procedure-clips as the eight subjects from the creative part. They were first asked to look at the film clip and try to empathize with the situation depicted. Subsequently, they heard ten 14 second musical expressions and were asked to judge each stimulus based on similarity and certainty:

- Certainly not matching the induced mood
- Probably not the induced mood
- Probably the induced mood
- Certainly the induced mood

This procedure was repeated for the four film clips. The four film clips were preceded by one trial movie clip, to familiarize the participants with the procedure.

4.7 Results & Discussion

As expected, the participants of the creative session experienced the two products differently. In the questionnaire, all participants praised *Poco* for its clearness and controllability. The participants saw the connection between the expressive shape of the phycons and the music they contained and were able to deploy these phycons intuitively. Having the possibility to create every element of the music (rhythm, chords and sample) separately, they experienced total control over the product. Besides this, the participants all indicated they enjoyed using *Poco* very much.

As for *Moto*, the subjects' opinions differed. All participants indicated, they found using *Moto* more complex than using *Poco*. Two participants observed that, especially when using a tool in each hand, the machine was difficult to control. It turned out, the feedback *Moto* gave often differed from what was expected. This diminished their feeling of control over the machine. Most participants at first made expressive movements with the tools, but when *Moto*'s musical feedback differed too much from the tactile feedback the tools in the water gave, they changed their way of interacting from expressive to compliant. To achieve their goal, the participants searched for movements that yielded the intended effect. However, five of the participants indicated that they were more emotionally involved when using *Moto* then when using *Poco*.

When asked which product the participants preferred using, seven out of eight participants replied '*Poco*', because it offered total control over the music. However, the five participants that indicated to partly understand *Moto* all reported they could put more feeling into the interaction with *Moto*. Statistically, we can not conclude there is a difference between satisfaction with the music clips generated on *Poco* and *Moto* (Mann-Whitney $U=115$, $p=0.843$). The same goes for the rated ease of use (Mann-Whitney $U=98$, $p=0.384$). Even the time needed did not differ significantly (Mann-Whitney $U=116$, $p=0.874$).

The matching session, where the appropriateness of the music clips from the creative session was rated, revealed that there was a significant difference in how the clips from each product were rated ($\chi^2=14.121$, $p=0.03$). The appropriateness was computed by rewarding two points to a certain correct match, one point to an uncertain correct match, zero points to an uncertain incorrect match and minus one point to a certain incorrect match. A match being correct when the music clip was actually intended to match the expression of the movie clip it was played by in the matching session.

Comparing the mean rank of the appropriateness of the music clips, we find that the clips made with *Poco* have a significantly higher mean rank than *Moto*'s (Mann-Whitney $U=87429.00$, $p=0.031$). However, when we focus on the group of five participants, who indicated to be able to put more feeling into interacting with *Moto*, a different relation surfaces. The music clips made on *Moto* by this group of people actually turned out to score better in the matching session than the clips made by these participants on *Poco* (Mann-Whitney $U=38983.00$, $p=0.004$). When participants resonated, the limited control over the product did not stand in the way of their ability to express their mood.

5 Overall Conclusions

Resonance is an individual experience. Nevertheless, some general conclusions can be made. Firstly, control and experiencing the relation between cause and effect increases resonance. The installations do not indicate that unity of location, direction, modality and time are prerequisites. A natural mapping between product appearance, interaction and resulting feedback is more important, as *Poco*, *Smallish* and *Rhythmish* show.

Secondly, temptation, intimacy and engagement during interaction are generally considered essential to increase resonance, provided that a user feels in control. Nevertheless, the preferred amount of temptation is dependent on the person, the situation, the task etc. *ISH* proves that some people prefer products that show what the user can expect after he carries out an action, whereas others prefer products that seduce them to explore. This shows the importance of our other three research questions. Therefore, the next step in our search for resonance will be creating a theoretical model that connects the individual (e.g. personality types, skills, effectivities, preferences, intention) with the product (e.g. function, feedback) through interaction profiles.

As stated before, resonance is not an easy goal to achieve, but certainly worthwhile pursuing. The HCI and design community can help each other designing, building and testing experiential prototypes. After all, the proof of the pudding is in the eating.

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