Hybrid Design Thinking in a Consummate Marriage Of People and Technology

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Abstract: In this paper we take a hybrid design tool approach to integrate existing and new advances in HCI, problem-solving, decision-making, mind-mapping, universal access, in conjunction with multi-disciplinary and cross-domain areas based on holistic and interactive systems. Our hybrid approach constitutes on the exploratory and experimental tradition where we rely on an assortment of heuristics and operate mostly in highly unpredictable, probabilistic manners across boundaries and often un-structured approaches. The oscillation between real and virtual realities merges the autonomy of user and machine whilst progressively enrich the intuitive user experience, increase knowledge acquisition, and advance insight in understanding.

Key words: Hybrid Thinking, Design, Intuition, Creativity, Tools.

1. Introduction

New, immediate and emergent technologies have caused giant leaps in product use and transformed our daily lives and relations with things and elements massively. In dealings and connections with new pervasive technologies and systems the human persona experiences various stages of cyclic meta-cognitive change in the senses and behavioral aspects. The increase in electronic gadgetry, virtual environments and embedded electronic services continue to surpass the sensorial and usability landscape, leaving a trail of non-adapts and technophobes behind that in some way creates voids and in many cases are difficult or impossible to bridge.

The impact and implications of technology on society in e.g. education, business, socio-cultural realities, diversity and environments are enormous and a growing concern. Not only in terms of complexity within existing or renewable eco-systems but also in learning to deal with the lasting change in the human scale. The plethora of daily interactions between people and the hyper-world around them in close mediation and connection with these technologies, directs fundamental research to study how to include, actuate and holistically activate people in any of these scenarios. We propose the following hybrid design tool environment for intuitive user interaction and show experiments, findings and results from human interaction in support of consilience and innovation in design.

2. Design Interaction

In spite of all the good-intentions of designers and well-meant design efforts by the design industry in recent decades to invent, create and make better things in terms of products and services to increase function, usability or enhance pleasure in use, experience and user interaction, there seems to persist a lingering dissatisfaction, frustration and use-inability with people in relation to their realm of things. Understanding of the interface between things and mediation of technology calls for a calm, empathic, and, holistic approach to product creation. Lanier [15] argues that the deep meaning of personhood is being reduced by illusions of bits; people degrade themselves in order to make machines seem smart all the time. However, every instance of intelligence in a machine is ambiguous. Virtual reality, for instance, was built to make this world more creative, expressive, empathic and interesting. Current CAD developments make slow progression towards enactive modes of operation, but are still far off from what humans can accomplish in terms of cognitive transformation, commencing with sensorimotor representations (from simple reflexes to progressively controlled actions, for achieving effects in the world), through visual manipulations (drawing upon simple single representations to complex multiple representations), to fully matured formal operations (involving cognitive manipulation of complex symbolic systems) [21]. We concur with Dalcher [6] that design is neither orderly nor linear; it implies continuous and active search to resolve trade-offs and satisfy changing constraints. The 'jumping together' of knowledge by linking multi-disciplinary and cross-domain areas is beneficial for active sharing of knowledge. This will enrich variety, diversity, and serendipity in the discovery of overarching methods and solutions from other disciplines and synthesize mixed contexts.

2.1 Ideation, Creativity and Tools

One of the most essential activities and challenges during any design process for a designer is to be 'creative' and come up or externalize new ideas, concepts, and designs. The creative design activity can appear to be 'intuitive' because it appears suddenly [9], and this is what characterizes creative design as an exploration, rather than a search [3]. A designer may choose any kind of tool to assist and support the much needed inspiration, imagination, and creativity. Enactive modes of operation are at the core of designers' designing-and-making and pen-and-paper sketching activities [22]. Thus support for enaction [2] can be considered a natural, immediate and intuitive means of HCI for design. Next to this, a designer may choose other techniques, tools or methods to get inspiration or find creative opportunities in the mind's eye such as daydreaming, taking a walk, dig weeds in a garden, playing music etc. Of course brainstorming, mind mapping and formal structured creativity techniques could also be part of tool use in design processing.

2.2 Users, Intention, Usability and Experience

The suggested approach in hybrid thinking should facilitate creativity for both beginner (novice) and expert users alike, meaning that a user can have arbitrary experience in the realm of design, and that the degree of experience is independent of his experience with any particular tool. Krug [14] states that usability really just means making sure that something works well: that a person of average (or even below average) ability and experience can use the thing…for its intended purpose without getting hopelessly frustrated. Donald Norman [17] calls for natural mappings and argues to make sure that the user can determine the relationships between intentions and possible actions; between actions and their effect on the system; between actual system state and what is perceivable by sight, sound, or feel and between the perceived system state and the needs, intentions, and expectations of the user. Therefore the proposed tools (i.e. analogue, digital or hybrid) and solutions should be most widely applicable and it should be efficacious regardless of the user's experience in either dimension [23].

3. Heuristic Shape Ideation Approach

Our exploratory experiments [20] and fundamental research is based on the use of physical interaction in conjunction with virtual/synthetic processing systems. This hybrid environment combines the best of both realities and affords a continual challenging between tangible and visual representations. In turn this could enhance the heuristic ideation process and refine the process as long as the user feels that it serves intent, bring out capacities for action and accommodates multi-modalities. Exploratory experiment is the probing, the playful activity by which we get feel for things. It succeeds when it leads to the discovery of something there [16, 19, 20]. Heuristic ideation, illustrated in Figure 1, is action based on intended change, learning-by-doing, knowing-in-action, and thinking-on-your-feet as demonstrated in Schön [20]. The negotiations between abstract and material representations are instrument to thinking described by Brereton as distributed cognition in design engineering. Employing a physical prototype in a real context of use often reveals unanticipated information, which is one of the strength of physical prototypes. Material representations are external representations, the ability to reconfigure and reinterpret material representations is where their power lies in helping designers to think and learn [1, 16].

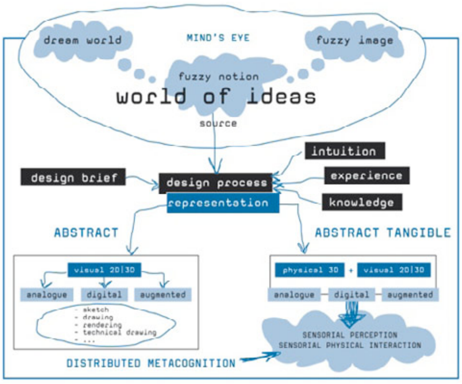

Figure 1. Exploratory experiment; heuristic ideation, exploration and representation.

Heuristics are not guaranteed to produce high quality or innovative design, nor do the systematically take the designer through all possible designs. Instead, heuristics serve as a way to "jump in" to a new subspace of possible solutions. Design heuristics move the designer into other ways of looking (eccentric positionality) at the same elements, and provide the opportunity for a novel design to occur [18, 29].

3.1 Tacit and Explicit Knowledge

What shapes our lives and natures is not simply the content of our conscious mind, but in much greater degree that of our unconscious. Between the two is a sieve (seam), and above is the consciousness, only the coarse (raw) material is kept back; the sand for the mortar of life falls into the depths of it; above remains only the chaff, the good flour for the bread of life collects, down there in the unconscious [12]. As Polanyi claimed, by reconsidering human knowledge, is the fact that we can know more than we can tell. When we touch something with our hands or with a tool our awareness of the impact is transformed into a sense of what thing or object we are exploring. An interpretative effort transposes meaningless feelings into meaningful ones. This is the semantic aspect of tacit knowing [4, 19]. The interface 'seam' in a hybrid design tool is very important, illustrated in Figure 2 on page 4, here lies the threshold or uncanny valley where the human user makes contact, mediates and interacts with a computer. The user interface should communicate to be intuitive at the same time be calm and comfortable to operate and interact with [24].

In order for our interface to appear intuitive for our target audience, we will need to both assume a relatively low prior knowledge of the user and aim to reduce the required knowledge to complete a given task as well. As such we need to take a look at the lowest common denominator in terms of prior knowledge and the required level of knowledge a user needs to have to complete a given task with our interface. The gap between the knowledge a user already has and the knowledge a user requires to complete a given task is our focus in intuitive design. In other words, we want to design an interface that will bridge this gap as easy as possible [26]. Conversely, an interface may appear intuitive if the gap is small or nonexistent between the knowledge a user already possesses and the required level of knowledge a user needs to have to complete a given task. According to Spool, see Figure 3, if there is indeed a gap in knowledge levels, an intuitive design will be a design that will help the user bridge this gap subconsciously [24]. In order to achieve this, we will rely heavily on metaphors a user is already familiar with in real life.

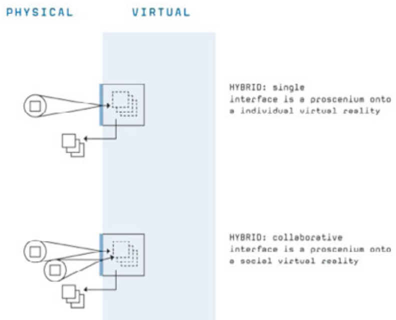

Figure 2. Diagram of interface design for the hybrid environment.

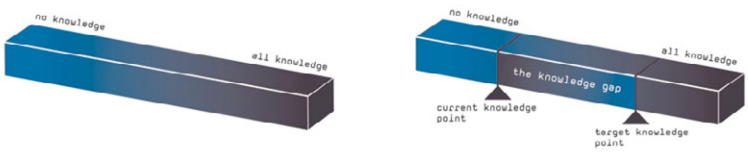

Figure 3. User and user interface knowledge gap.

3.3 Multi-modality in Hybrid Design Environment

The hybrid design tool environment (HDTE), as shown in Figure 4, consists of a physical workbench area (3, 4), a monitor (2), a standard PC with WinOS7 (6) and, a HD video camera (1). Real-time iterative captures (instances) are made by the user with a wireless capture button or footswitch (5, 8).

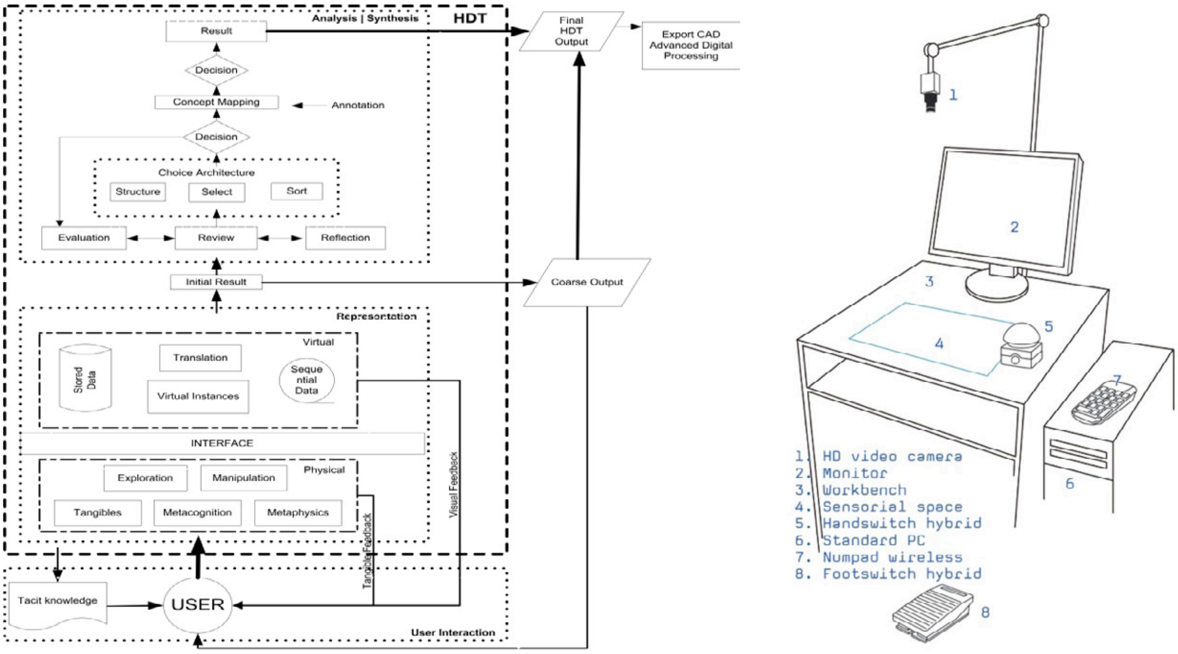

Figure 4. Hybrid design process flow diagram (left) and hybrid design tool (right).

All the captured data is stored in a repository, the data is accessible for review, decision-making, concept-mapping and annotation with a frugally designed wireless numpad interface (7) [27, 28]. All the iterative content and merged stacks (MS) from an ideation or creative process can be retrieved, reviewed and reused. The combination between physical (tangible) and virtual representation, as shown in Figure 5, allow the user to explore the problem-solutions space in every aspect and detail necessary to fulfill or execute a design task. Through exploration of the design space the hybrid environment promotes learning in the flexibility of experiences and generates tacit and applicable knowledge. The hybrid design environment enables real-world layering of design processing, real-time visualization and representation. Consequently it affords taking greater steps in the design thinking process to enhance insight and understanding. However, we concur with Duffy that we are only starting to learn, and how to complement that learning process within a computer based system in order to enhance a designer's "creative" activity [7]. We keep oscillating between the physical and virtual abstractions (sketches, drawings, models, prototype etc.) whereby the trade-offs between the tangible and virtual realities are tested, explored and questioned.

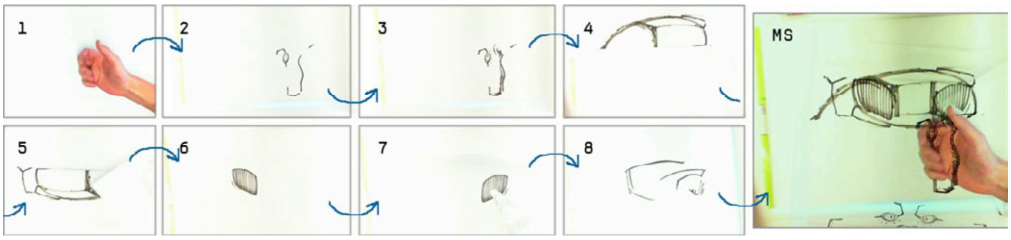

Figure 5. Hybrid design iteration flow (example), visualization and representation (MS = merged stack).

4. Experiments and Testing

The two experiments described here address presentation and representation in a hybrid design tool environment (HDTE) that includes traditional and computational design tools as shown in Figure 6. The experiments attempted to test creative problem-solving, sequencing of iteration process, performance success and solution time. We included master design engineering students in our design experiments. Participants in Experiment I and II solved design problems using prescribed constraints in the form of analogy and metaphors.

Figure 6. Visual impression of hybrid design tool environment.

In design by analogical reasoning and concept blending, the designer uses his own intuition, experience and knowledge and applies them to the new problem. The design metaphors are real-world artifacts (i.e. raw functional elements) to be included and become part of the solution space. All the interaction was video recorded with consent of the participants. The video footage was analyzed using Video Interaction Analysis (VIA) [13] to make qualitative investigations and evaluations on human activities, such as talk, nonverbal interaction, and the use of artifacts and technologies, identifying routine practices and problems and the resources for their solutions.

Research questions:

- How do design-engineering students explore the design space during the initial ideation phase of design?
- How do they use product features and constraints to generate potential design solutions?
- How will the use of a HDTE support the design process to generate and transform ideas?
- How will the use of a hybrid design environment support flow in design processing?

4.1 Exploratory experiment I

This design task was executed by individual participants, they were asked to create and design new product concepts using the HDTE as illustrated in Figure 7.

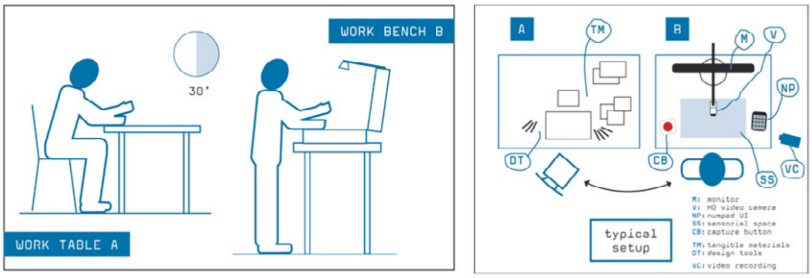

Figure 7. Diagram of setup individual HDTE.

The design experiment was conducted with seven participants. A total of seven concept design tasks were executed and seven individual feedback forms were handed in. They all had no former training or experience with the HDTE. The allowed time constraint was thirty minutes per participant. In some cases we allowed more time for unexpected downtime, questions or rupture in the system. Virtual iterations (instances) made by the participant were captured by the user and stored in the data repository of the computational hybrid design tool. Tangible iterations and representations were saved and documented after each session.

The participant was shown an analogical image of a whisk and handed two predetermined metaphorical artifacts as design constraints to facilitate and enhance the design task as shown in Figure 8 [8, 10]. The task to perform was to design an electrical mixer from scratch.

Figure 8. Analogical image (left), metaphorical artifacts; DC motor and power cord (right).

Overall, intention and motivation was very high during interaction and processing. Creativity was evaluated on the basis of the generated design concepts, number of iterations, interaction time, total tangible and virtual models, task success, and level of completion. In Figures 9, 10 and 11 on page 7 we show snapshots of the design processing sequences, the back and forth between design table and design tool during the iteration and ideation process is clearly visible. Metrics of the seven individual product creation processing's (PCP) are shown in Table 1[25], at the end of each task we collected the data and at the end of the entire session.

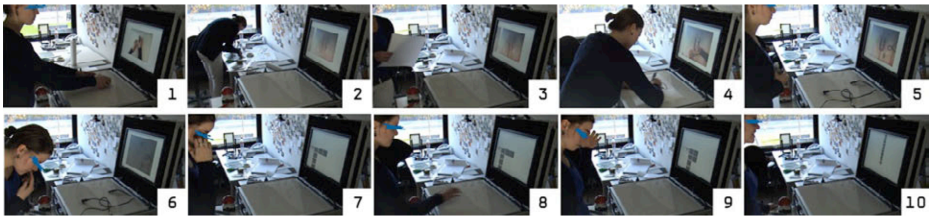

Figure 9. Individual user interaction, case-study P1.

Figure 10. Individual user interaction, case-study P4.

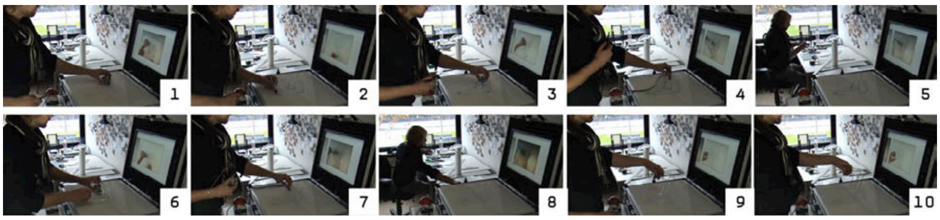

Figure 11. Individual user interaction, case-study P7.

Some of the tangible and virtual results will be shown in Figures 12 and 13 on page 8 to visualize the variations and serendipity in solutions and presentations. Preliminary findings and conclusions from this on-going research will be discussed in Chapter 5. The results are evaluated based on the amount of satisfaction and ease of use that the participants communicated in their feedback after the sessions.

Table 1. Features of the design process and interaction from the individual design task.

Experiment I : PCP Individual							
participant number:	P1	P2	P3	P4	P5	P6	P7
number of iterations	46	31	36	41	31	73	32
interaction time in min.	38	35	46	55	35	44	23
average iter./min.	1,2	0,9	0,8	0,7	0,9	1,6	1,4
number of vr models	5	4	9	6	5	10	2
number of phys. models	6	12	5	8	14	8	6
task succes	50%	60%	70%	95%	60%	90%	50%
completion	40%	50%	75%	90%	50%	80%	30%

Experiment I : PCP Individual							
participant number:	P1	P2	P3	P4	P5	P6	P7
satisfaction UI	4	2	2	1	2	1	2
ease of use	3	3	1	2	1	2	2
satisfaction PCP	L	L	L	N	N	L	U

Satisfaction UI / Ease of use
1 = no problem
2 = minor problem
3 = major problem
4 = failure / gave up

Satisfaction PCP
L = like
N = neutral
U = unlike

Totals Ind. Exp. I	
7	particip.
290	iterations
4,6	hrs. HIA

Physical abstractions (i.e. sketches, drawings, low-fidelity models etc.) and virtual representations are an essential part of the externalization to support the creative process. They quickly convey a possible direction and are used to explore a product's shape, assembly and configuration. The physical aspects of tangible interaction in conjunction with virtual simulation and visualization, enhances the user experience and foster insight and understanding during iteration and processing.

Figure 12. Tangible iterative models from different use-cases.

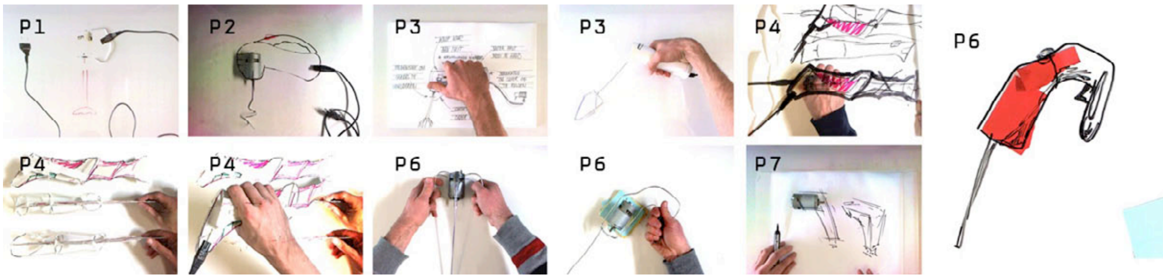

Figure 13. Virtual iterative models from different use-cases.

4.2 User feedback experiment I

We gathered feedback from all seven users after each session terminated the users expressed and evaluated their experience, interaction, ideation process, and performance. They all liked the speed and fast iteration combined with the virtual visualization and representation on the display. The use of the physical constraints were considered very helpful and informative by five users. They liked the direct tangible information on weight, proportion, and scale to use in relation to the design task. The visual analogy was neither effective nor stated helpful, this could indicate that the product design task (mixer) already has associative meaning and context known to the participants. Some indicated that the hybrid tool constitute a rupture in user behavior and the user had to first disconnect themselves from earlier learned methods and techniques. Most users liked the real-time capturing of iterative content and some indicated that the merge of physical (i.e. hands) and virtual (i.e. prototype) were very useful. Positioning and placing parts in different angles gave clues and information about location, assembly, aesthetics, and user functions. Also the use of less material for physical prototyping in conjunction with the constraints was indicated as a gain. Three users indicated that the buildup of the design by layers offered creative freedom makes you think about progression of the next iterative step (-s) and, the possibility to build a product-architecture. Some drawbacks of the hybrid system mentioned were the user-interface (UI) (numpad) to some this should be a multi-touch and interactive on the screen. Some indicated the UI initially hard to understand in functionality. One user, as shown in Figure 9 (sequence 6 to 10), indicated that although she really enjoyed working with the tool she could not complete the design task because of frustration and loss on how to use the functions of the user- interface (numpad). P1 indicated: *"I lost my way! Did I do something wrong?"* Experimenter: *"No, there is nothing you can do wrong."* P1: *"I tried everything."* Experimenter: *"What did you try to do?"* P1: *"Copy the cord into it…but it doesn't work."*

4.2 Exploratory experiment II

In this experiment the participants were asked to perform a collaborative design task using the hybrid design tool environment illustrated in Figure 14. The design experiment was conducted with four participants, randomly paired in two groups. A total of two concept design tasks were executed and four individual feedback forms were handed in. They all had no former training or experience with the HDTE. The allowed time constraint was forty-five minutes per group. In some cases we allowed more time for unexpected downtime, questions or rupture in the system. The sessions were video recorded with consent of the participants. Iterations made by the participants were captured by the user and stored in the computational hybrid design tool.

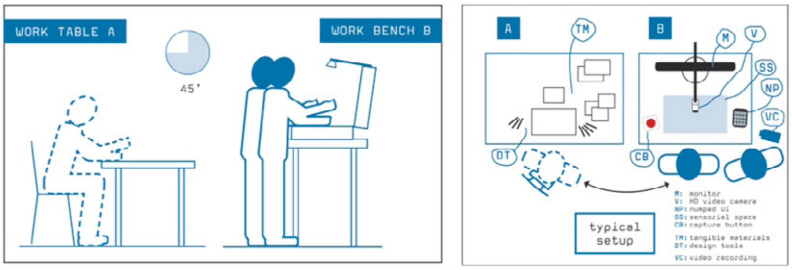

Figure 14. Collocated experiment setup in HDTE.

The participants were briefed on the design task by the experimenter. They were shown an analogical image of a pad / tablet and five metaphorical artifacts were handed as predetermined parametric and physical constraints during the PCP shown in Figure 15 [8, 10].

Figure 15. Analogical image (left) and metaphorical artifacts; battery, PCB, led, connector, and SIM card (right).

The group interaction and dynamic were very lively and the overall intention and motivation was very high during the sessions. Figures 16 and 17 show an impression of the group interaction during processing and ideation.

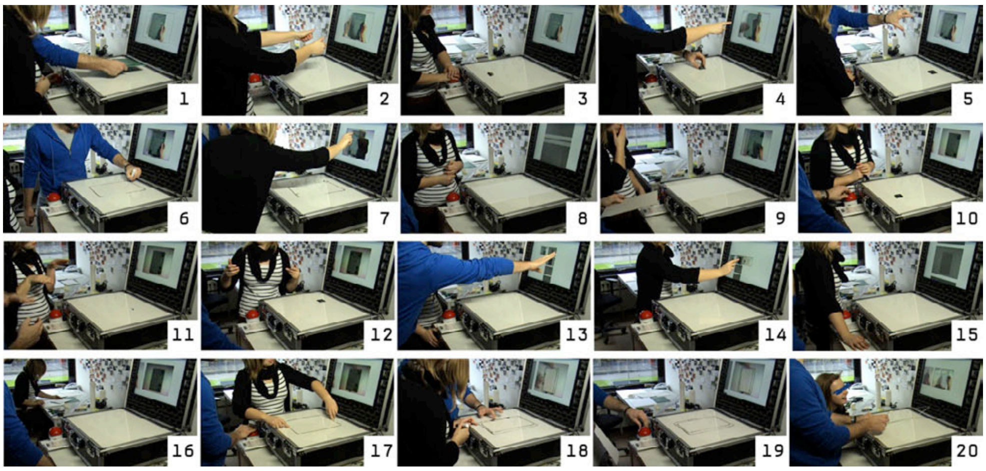

Figure 16. Collocated user interaction, case-study G1.

Figure 17. Collocated user interaction, case-study G2.

Metrics of the two collaborative PCP's are shown in Table 2 [25], at the end of each task we collected the data and at the end of the entire session. Preliminary findings and conclusions from this on-going research will be discussed in Chapter 5. The results are evaluated based on the amount of satisfaction, comfort and ease of use that the participants communicated in their feedback after the sessions.

Table 2. Features of the design process and interaction from collocated design task.

Experiment II : PCP Collaborative		
group number:	G1	G2
number of iterations	46	93
interaction time in min.	59	58
average iter./min.	0,8	1,6
number of vr models	5	9
number of phys. models	7	16
task succes	60%	80%
completion	70%	90%

Experiment II : PCP Collaborative		
group number:	G1	G2
satisfaction UI	1	2
ease of use	1	2
satisfaction PCP	L	N
satisfaction coll. effort	L	N

Totals Coll. Exp. II	
4	particip.
139	iterations
2,0	hrs. HIA

Satisf. UI / Ease of use
1 = no problem
2 = minor problem
3 = major problem
4 = failure / gave up

Satisfaction PCP
L = like
N = neutral
U = unlike

In Figures 18 and 19 we present some results of the collaborative iterative PCP and show the variety in tangible materials, representations and virtual iterations made during the sessions. The low-fidelity models are very frugal and simple but convey the intention and make the ideas of the designers clear in their approach to the problem-definition. The negotiation and reflection-in-action [20] during the collocated experiments showed the effectiveness and efficiency of tangible representation, gestures, and speech to communicate thoughts and express ideas. Conscious deliberation is a goal driven process.

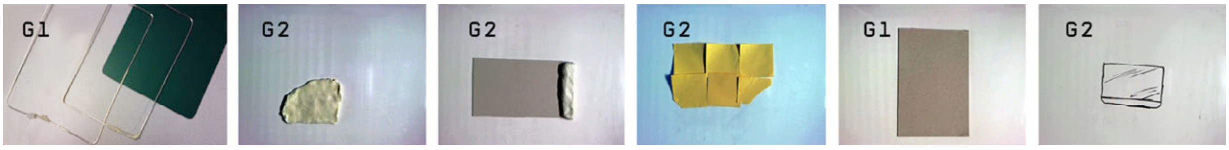

Figure 18. Tangible iterative models from the two use-cases.

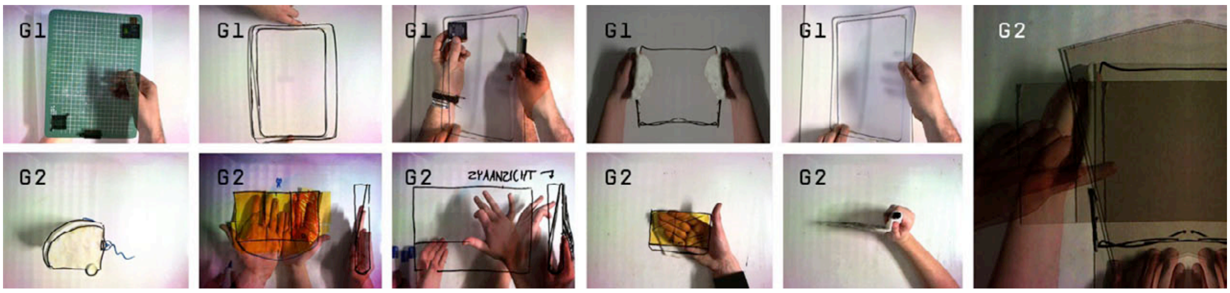

Figure 19. Virtual iterative models from the two use-cases.

4.2 User feedback experiment II

In the feedback we gathered from the four participants we noticed some differences in experience. One group indicated that the collocated process was very pleasant and that they gained from mixing ideas. The other group were divided one participant wrote that the collaboration went great, the other had doubts about his own performance and thought that the collaborative aspect had a direct influence on his own ideas and thinking. It deviated too much from the target of their individual path (ibid.) Working in the hybrid design environment was considered by both groups as a positive experience and enjoyable. They indicated that the manipulation of objects and artifacts was easy with two persons collaborating on the same design task. One participant wrote,'…through the combination of physical and computational 'tinkering' there seems to be more space for creative ideation. You do not feel limited by the computer, but it allows total freedom of creation, which in turn leads to interestingly fascinating results. It is really easy to get real-life models in the computer.' Another participant noted,'… Every material has constraints and needs a certain kind of processing and thinking. (Advantages and disadvantages were automatically weighed) This is exactly what is so great about this apparatus, keep it that way! (It seems logical and on target).' Notably is the amount of discussion, reflection and deliberation in collaborative interaction, whereby ideas are externalized, manifested and pondered frequently. In such cases the external process stopped to allow internal contemplation and imagination. Disadvantages mentioned by two users were navigation and interaction with the numpad, this should be supported with a multi-touch screen instead.

5. Conclusion

In the user feedback we noticed an overall appreciation of the hybrid design tool environment. The users all indicated to find the hybrid tool not invasive or obtrusive during interaction, some mentioned the interface being intuitive and comfortable. The supported multi-modality and physical aspects of the HDTE were considered very helpful and stimulating, according to some the complete design process becomes much more interesting once you understand the interface fully. Findings from Experiment I support some of our research questions in exploration and the front-end of a design ideation process. The use of constraints,'… so that the user feels as if there is only one possible thing to do - the right thing, of course' [17], added favorable to exploit and explore potential design solutions. The generation and transformation of ideas and abstract notions were clearly visible during the sessions and documented in the database of the system. We can conclude that the HDTE supports this hypothesis. Most participants expressed that they would have liked to spend more time on the design task and wanted to work in the HDTE again. Furthermore, this suggests that time was consumed much quicker than anticipated and points in the direction of flow. Flow as described by Csikzentmihalyi as the merging of actions and awareness-avoiding distractions-forgetting self, time, and surroundings [5]. Experiment II is too small in sampling rate to justify any conclusions at this point in time. However, both experiments foster further investigation and experimentation, the challenge for the future is to map and extend the details of this multidimensional space.

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