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Contribution of smartpens to design studies in capturing design process

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Abstract

The paper focuses on technical and methodological aspects of using smartpens to capture sketching activities in the idea generation stage. Aiming to consider a more effective way to capture designers' decisions, moves, verbal and non-verbal cues; the paper attempts to provide a critical appraisal of how smartpen-based recording system are able to improve small-scale observational studies' rigorousness and increases richness of data. Comparison of conventional pen-and-video and smartpen devices are illustrated, by conducting two think-aloud design sessions using both mechanisms. Advantages and disadvantages will be analysed to provide balance views of the two tools. In general, both are able to capture sequences of thoughts, including moving through one page to another. Preliminary findings show that smartpens are somewhat superior in terms of: obtaining unobstructed views of the sketching process as result of participants' hand/shadow or glare, pencast (replayed video) aids exploration of design strategies investigation, auto-synchronised thinking aloud (verbal) and sketching (actions) foster the effectiveness of study, minimal use of a single recording device and also possibly promote exploration in shading, textual aids, contextual aids and other cues of sketches. However, pen-and-video tools are more efficient at capturing hand gestures. Some recommendations for future studies are also suggested.

research methods; smartpen; protocol studies; sketches; design research

The change of sketching tools to generate ideas, from pencil to proliferation of computer assisted tools to three dimensional printing pens, enriches the possibilities in design exploration. Studies related to sketching and technological development tend to focus on two areas: cognitive aspects- *how designers sketch* and computational aspects- *how effective digital sketching system is in terms of supporting the work of sketching* (Yang & Kara, 2012). In addition to the two categories, this study examines the use of smartpens as a

methodological aid to capture the design process. Limitations not using smartpens such as intrusive experiment setting and partially blocked views will be illustrated. The aim of the paper is to discuss to what extent smartpens improve small-scale observational studies' rigorousness and richness of data. The questions which the authors attempt to answer is "How can smartpens enrich design process observation in comparison with conventional pen-and-video-recording?" This preliminary study opts to explore possibilities to improve sketching recording systems for related future studies.

The paper is structured as follows: background literature, indicating how sketches attribute to design process exploration and what authors aim to seek through the design experiments; methodological considerations to capture the design process; subsequently focusing on technical ways to record sketching process; the recording setup; observed advantages and disadvantages of tools; discussion and concluding remarks.

Background literature

Process- oriented observation in design studies dates back to the early 1960s, starting with the method of introspection used by psychologists (Bilda & Demirkan, 2003). Although design processes are complex and vary, attempts to demystify the process lead to better understanding of how designers perform in a task; *"how designers design*. According to Cross (1994), ways to describe the process can be classified into two types: *descriptive models*- based on essential designers' activities and *prescriptive* models- to prescribe a better pattern and be adopted. Lawson (2005) summarises the design processes and infers that it is seen as an iterative negotiation between problem and solution, through three prominent activities: analysis, synthesis and evaluation, refer to Figure 1.

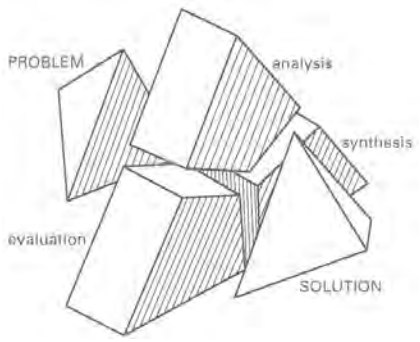

Figure 1: Design process as negotiation between problems and solutions (Lawson, 2005)

The essence of capturing the sketching process has a profound impact on revealing the nature of designing, from providing insights into the nature of idea development process (Kavakli, Scrivener, & Ball, 1998), underlying cognitive structures (Scrivener, Ball, & Tseng, 2000) and revealing the peaks and troughs of both lateral and vertical transformations in a period of time which might suggest modes of thinking at any particular time (Rodgers, Green, & McGown, 2000). Particularly, in this presented paper, sketches are chosen as a way to investigate the combination of the above-mentioned aspects; starting from how designers

first encounter the design problems, developing solutions, positioning themselves in design situations and the cognitive strategies in the idea generation stage.

What the authors intend to infer by capturing design processes are designers' decisions and underlying thoughts of these decisions. The decisions are attributed to the perception of designers in relation to the design situation (Dorst & Dijkhuis, 1995). Hence, understanding of design experience is indispensable (ibid). To be able to examine decisions, deconstructing the meanings of designers' actions is delineated. Goldschmidt described such a system in the framework of Linkography, dating back to her early works in the early 1990s, which discerned the importance of *links* among design *moves* and methods to notate and analyse such *links* (Goldschmidt, 2014). *Links* between moves and design arguments are fundamental, as it may indicate levels of productivity of the design process (Goldschmidt, 1997). *Links* and *moves* can be observed once they are documented and the next section will expand how they can be documented.

Methodological considerations

In design studies, several methods are used to identify design behaviour. Cross (1999) details methods which are widely used such as: interviews with designers, observations and case studies, protocol studies, reflection and theorising and also simulation trials. The growing interest in the last decade in protocol studies has been identified by Chai and Xiao (2012) who conducted bibliometrics and network analysis to investigate core themes in design research. The argument concerning whether verbal data is an effective tool to represent internal thoughts dominates the debate in this area; considering that more than one mechanism (thinking and talking out loud) happens concurrently. This issue was explored in the pre-pilot study of two designers, vocal feedback through open-ended interviews suggests for the first participant that it aided focusing her attention, whilst the second participant mentioned that it was effortless. In addition, the degree of fluency varied between them, related with personal strategies (the second participant found the method natural for her as she uses similar methods while designing).

With regards to protocol studies, different methods can be deployed to capture the design process, such as: the observation of problem-solving behaviour, structured techniques and the think-aloud method (Solomon, 1995). The aim is to explain almost every single step taken by the problem solver (ibid). Unlike body movement which is open to direct observation, contents of the mind are private and only available indirectly. A view by Bayne (2013) mentions that as a linguistic creature, the most important clues about somebody's state of mind is provided by the speaker him/herself. The think-aloud method *("what they say")* is chosen as the primary tool due to the fact that there is no delay in verbalisation, it does not involve self-reflection which might alter existing design conditions, and most importantly it is the most effective way to represent thoughts. This paper focuses only on the think-aloud method. To minimise its disadvantages, in the future study, it will be supported with triangulation between: 1) *"what they report"* afterwards through retrospective reports

2) *"what they do"* from post design sessions observation and 3) direct observation from field notes taken during design sessions; which will be expanded in another paper. Drawbacks such as failure to capture inaccessible thoughts, particularly non-verbal thoughts, and disrupting the natural flow of thoughts are hoped to be minimised by combining verbal data with observational and self-report measures.

Apart from exact reproduction of verbal cues (spoken words) into text, the degree to which transcription for protocol studies needs to be detailed is arguable. Referring to non-verbal cues such as gestures; they serve to contribute to the content and help to manage the conversation (Warren, 2013).

With respect to the above-mentioned background literature and methodological considerations; to summarise, to aid the exploration of process-oriented observation in the early design phase related to sketches; designers' decisions and rationale between their moves, links, design operations and other design activities need to be captured. One of the ways of doing so is to conduct protocol studies using think-aloud method to have access to designers' internal thoughts. Verbal and non-verbal cues contribute to this exploration and a capturing tool is needed.

The conventional way of capturing the sketching activities in a controlled experiment is by using an audio-video recording device. A comparison of ways to record the activities will be demonstrated in the next section.

Ways to record the sketching process

The need to record the act of sketching and ways to conduct the exploration have been illustrated. In this section, the apparatus setup to capture the process will be explained. Attempting to draw a comparison between the conventional way to capture the sketching process: video-audio recording and smartpens, the authors will evaluate each of the methods.

Conventional pen-and-video recording

In most protocol studies in sketches, the need to record how participants first encounter design problems and subsequent moves towards final design solution is apparent. Generally experiments utilise audio-video recording devices from different angles to capture the process, angled in such a way that drawing pads and hands can be framed. With the nature of the close distance between the subject and the work, there is a tendency to partially block the sketch paper; either by the participant's own hand/shadow or glare from lights. This leads to the necessity of using more than one device to capture different unblocked views concurrently, which might adversely affect the experiment setting, or by having a more distant camcorder position which means that audio quality might be compromised unless audio is recorded separately- again, necessitating additional equipment which further clutters the workspace. Difficulties of the conventional ways of capturing the process are rather sparsely mentioned in methodological insights of design experiments; however, this paper

tries to illustrate that by using other methods such as smartpens, the process of acquiring data might be improved with more clarity and the convenience of a single file.

Smartpens

With the recent spread of digital technology, the use of electronic aids in the form of sketching tools and recording pens has become a prominent feature in design activities. In terms of digital tools, this paper focuses on the methodological support to aid the data collection process for further use.

The breakthrough movement of the pen dates back to 1996 in Sweden, Christer Fåhraeus founded Anoto; focused on developing *"a high-tech pen that could get the paperwork done more efficiently*" and created an ink pen with a built-in camera which can record what the pen writes which was launched for the first consumer use in 2001 (Schreiner, 2008). After some development including pentop computers in 2006 developed by LeapFrog, the recent smartpen generation was introduced with a built-in voice recorder, launched by Livescribe™. The first Livescribe™ Pulse was available from the year 2008, the range became a valuable addition to writing research, and is increasing useful for other disciplines also. This most recent paper-based platform is now used widely and changing the way users capture and share information; for instance Schreiner (2008) points out the possible use in combination with other technologies to assist users with disabilities and to aid animal health data sharing in rural area in Africa.

Within the scope of the paper, the authors use a 2GB Livescribe™ Echo among other Livescribe™ pens, due to the flexible system support and platforms (Windows or Mac). It is also declared that the study is an objective exercise and the authors do not have any affiliation with any smartpen companies. There are three main parts of the smartpen system: the pen, Livescribe™ paper and Echo Desktop (software to manage notes). As can be seen from Figure 2, the pen has a normal ink tip and comes with a built-in microphone. The overall look and the feel of sketching with the smartpen are similar to using an ink pen, apart from slightly increased weight (36 grams without pen cap, vs. approximately 10 grams for a disposable pen). To capture what the participant writes, the pen uses a built-in infrared camera to capture digital snapshots of the dot pattern (limited to dotted Livescribe™ paper only) at a rate of between 50-100 frames per second (Livescribe, 2008). The whole process can be recorded, played back through the software or shared as a pencast. Also, the audio, pencasts and images can be saved separately.

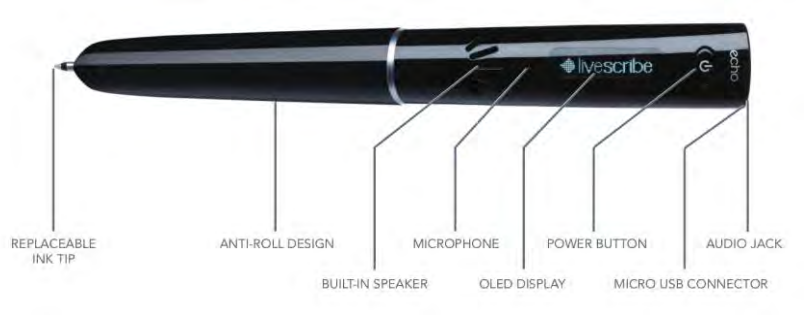

Figure 2: Livescribe™ Echo smartpen (Livescribe, 2015)

From another perspective of design research pertaining to the use of smartpens in design exploration, Hernandez, Schmidt, Kremer, and Lin (2014) made comparison of the use of three cognitive design aids: TRIZ (an ideation method), sketching, and smartpens. The effectiveness of concept generation was observed; and the results indicate the great contribution of smartpens in terms of increased quantity of generated ideas. This may indicate that there is a growing interest in terms of how smartpens can be used to aid designing activities.

Recording setup

Data was collected from two design sessions from two different stages of study (pre-pilot and pilot study) with two different tools: the pen-and-video recording and the smartpen. English is the medium of instruction in the university, and was used in both sessions, although neither participant was a native speaker. The study has been reviewed according to the University's Code of Research Conduct and Research Ethics; and consent was obtained from both participants. Although overall experimental procedure varied between the two stages; the experimental setup of the design sessions was identical. Differences are illustrated as follows: aiming to obtain feedback from participants about how intrusive the think-aloud method is, after design session 1, the pre-pilot experiment was concluded with a set of cognitive checklists and open-ended questions. Conversely, the pilot study (design session 2) did not use the checklist. Further methodological aspects will be expanded in another paper.

Two participants (henceforth P1 and P2) are final year architecture female students. The two design sessions were chosen because they both provide different kinds of reflections on how to conduct a design session. They are part of a bigger study pertaining to the use of sketches and mental imagery in design ideation stage; however the two sessions are derived from SK (sketching) sessions only. Other similarities and differences are summarised in Table 1. Both studies were conducted using the think-aloud method so that verbal data might be transcribed and analysed to unveil their cognitive strategies.

Table 1: Design sessions setup

Design Session	Stage of study	Participant (P)	Brief	Sketching recording device	Duration (mins)
Session 1	Pre-pilot	P1	Two-storey detached house	Pen-and-video	30
Session 2	Pilot	P2	Movable library pavilion	Livescribe™ Echo smartpen	30

Design session 1

P1 was asked to design a two-storey detached house, a drawn site plan was provided and requirements were as follows:

"To design a two-storey house for a family with a teenaged son. The wife is passionate about gardening and the husband likes to have a shed in the house for his hobby. Would also accommodate fundamental needs such as bedrooms, bathrooms, social space, kitchen, dining, storage and car parking"

In terms of equipment (Table 2), the main video recorder to record the sketching process is on the table, mounted on a tripod (refer to Figure 3). It was mentioned that the brief was open to interpretation for unspecified matters.

Table 2: Breakdown of experimental equipment of design session 1

Equipment	Description
Primary video recorder to capture sketching process	Video camera 1 (highlighted in orange colour) on the table, refer to Figure 3
Other video recorder	Video camera 2, Echo 360- *a learning and lecture capture software* Video camera 3- *to capture participant from a front view* (both refer to Figure 3)
Audio recorder	Echo 360- *a microphone on the table*
A DSLR camera	For still images
Sketching medium	A ruler, a pen, brief on an A3 paper and additional A3 papers.

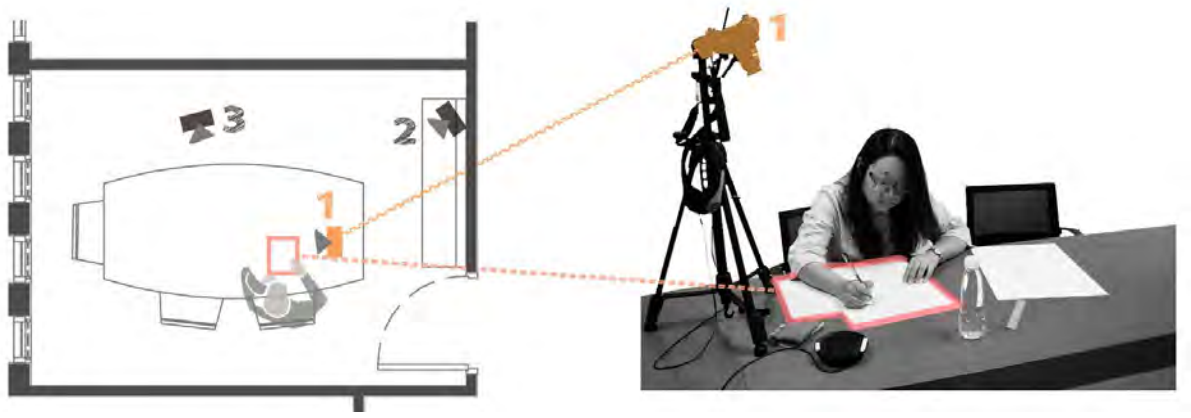

Figure 3: Design session 1- apparatus plan

Design session 2

P2 was asked to design a library pavilion, requirements as follows (none of the resulting site plan is given):

"To design a library pavilion, with no more than 15x15m footprint. The pavilion is to have an open space for book shelves, serves as informal meeting plaza and relax-work-mingle or community events. It is movable from one site to another, as it needs to be easily dismantled and assembled. Potentially it could become a moving public art object too"

It was stated that the minimum expected outcomes are plans, elevation and three dimensional views. Similarly with session 1, it was mentioned that the brief was open to interpretation for unspecified matters. As far as the main recording device for the sketching process, the session used an Echo smartpen. Similar to session 1, redundant devices were used as back-ups. Equipment setting can be seen on Table 3 for the breakdown and Figure 4.

Table 3: Breakdown of experimental equipment of design session 2

Equipment	**Description**
Primary video recorder to capture sketching process	Livescribe™ Echo smartpen, refer to Figure 5
Other video recorder	Video camera 1- *to capture participant from a front view* Video camera 2- *to capture participant from a front view* Video camera 3- *to capture participant (top view)* (Refer to Figure 4)
Audio recorder	Livescribe™ Echo smartpen Wireless lavalier microphone and USB 5.1 channel audio interface Voice recorder
A DSLR camera	For still images
Sketching medium	Livescribe™ dotted paper, A4 size

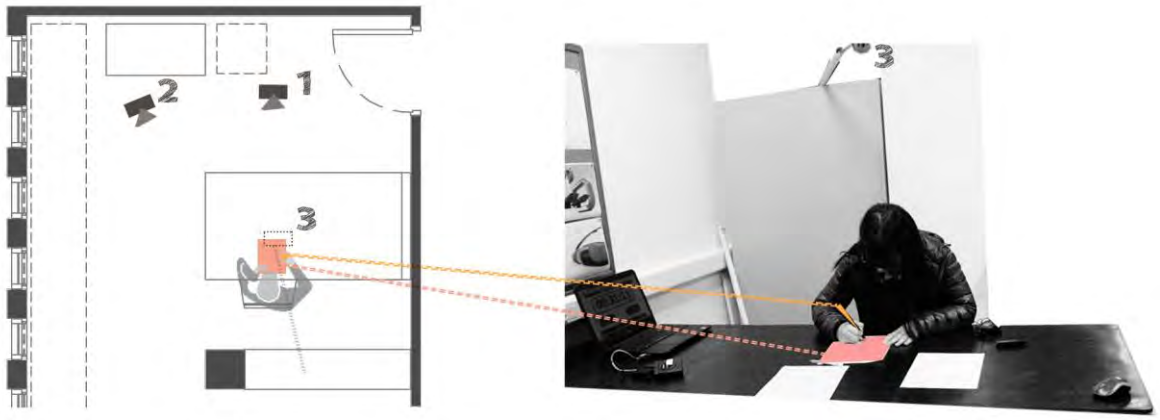

Figure 4: Design session 2- apparatus plan

Observations

The comparison between the two tools (video-and-paper and smartpen) will be expanded merely based on the primary recording devices, highlighted in orange and pink colour in Figure 3 and 4, for the sketching process and its relation with the sketching medium. Additionally there are a number of other devices for other purposes (for instance, the front view of participants) and some redundant apparatus. Table 4 provides the summary and more explanations will be expanded in the next section (discussion).

Table 4: Advantages and disadvantages of pen-and-video and smartpen recording system

Method	Advantages	Disadvantages
Pen-and video	Hand gestures are included	Partially blocked views by hands/ shadow or glare
		The need for more than one recording devices (audio video and audio only) and the need to sync more than one video
		Intrusive camera setting placed too close to participants
Smartpen	Sketches are not partially blocked by hands or shadow	Faint Livescribe™ dotted paper with grids might fixate two dimensional thinking
	Replay function (pencast)	Hand gestures are not included
	Better synchronisation between thinking aloud (verbal) and sketching (actions)	Audible scratches sound when participant makes rapid sketches
	Single device is adequate	
	Aid exploration of shading, textual aid and context (trees, environmental strategy) of drawings	

Discussion

Before attempting to answer the question "How can smartpens enrich the design process observation in comparison with the conventional pen-and-video-recording?" other avenues about how the pen-and-video recording system supports a protocol study and limitations of smartpens to support a protocol study will be explored. In general, both methods are able to capture the sequence of thoughts, including moving back and forth through different pages. The latter feature is however better facilitated by the smartpen, although it is not impossible for the conventional system. An example of how the smartpen facilitates this from another exercise is illustrated, refer to Figure 5. Screenshots were captured when a participant was about to start with the fifth page during a design session. Before he decided to jot down ideas on page 5, he went through some options in the previous pages; leaving crossed marks (circled in purple) on page 3 and 4 for alternatives he dismissed. Subsequently, he chose an option on page 4 and put a checked marked (circle in purple) before developing that particular option on page 5. The sub-two minute moves were recorded by the smartpen in live mode. This particular function is a great help to see how a designer first encounters design problems, develops solutions and takes a position in the design world in the idea generation stage.

To put the short episode in design operation terms according to Lawson (2005), the process can be seen as "generation" and subsequently going through an "evaluation" stage when the participant makes conscious decisions about which scheme he will develop further.

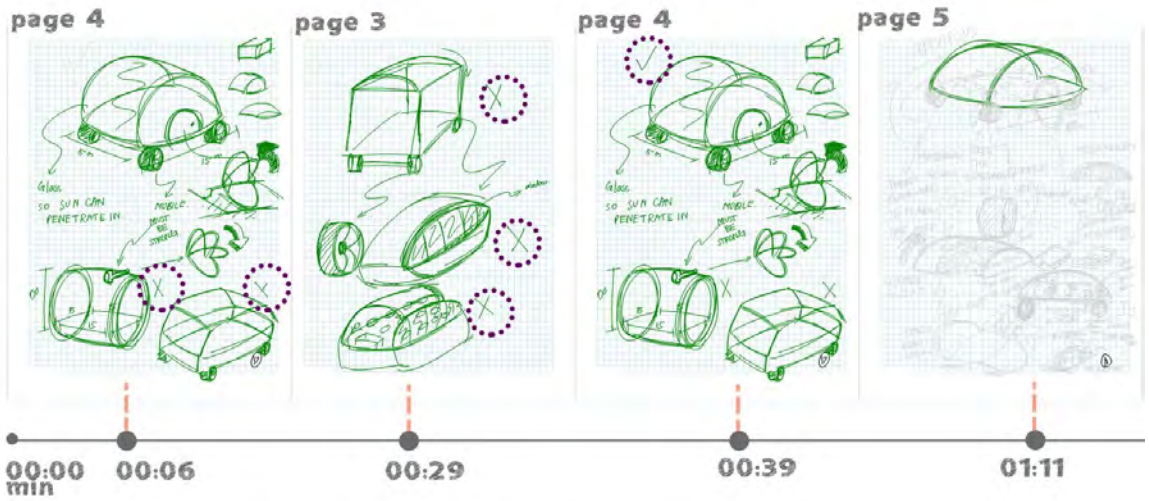

Figure 5: How the smart pen captures moving back and forth between pages

Pen-and-video recording

Firstly, in terms of an advantage; with an angled camera view, hand gestures are captured. This relates to previously mentioned literature in that non-verbal cues such as hand gestures convey meaning of the design strategies. An example is illustrated in Figure 6, P1 is thinking through the possible plan solutions. In three seconds time, she decides that to achieve an open feeling of space, she does not want to have a distinguished spatial arrangement hierarchy. The overlapped hand gestures of 'hierarchy' through the long side of the site plan are presented to illustrate the direction of hierarchy she is thinking about, without any sketching *moves*. This is an analytical *move* which cannot be captured unless hand gestures are recorded also. According to the two functions of gestures as previously mentioned by Warren (2013), this type of hand gesture is used to contribute to the content of speech.

Figure 6: Hand gestures of P1

Figure 7: Blocked view to the sketch pad

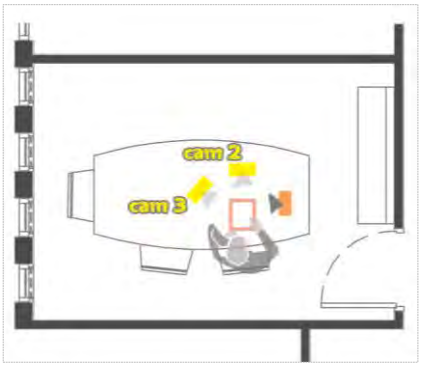

Figure 8: Provision of more cameras

Secondly, some drawbacks of pen-and-video to capture sketching process will be discussed. It is understood that some kind of recording device needs to be placed close to the participant to be able to record what they are sketching; otherwise the relation between the sketcher and their output is absent. With the nature of a recording device on one side, there is always potential for blocked views (Figure 7). Additionally, based on the observation, shadows and glare often occur. Glare is easier to tackle (and can be tested beforehand) in comparison with hand movements and shadows of hands. The sporadic blocked views can be addressed by having more than one camera to achieve alternative unblocked angles, illustrated in Figure 8. However, this will lead to the need to sync more than one primary video, which will considerably affect the effectiveness of the study and also the highly intrusive equipment setting for the participant. This is also related to the next point about equipment setting.

Placing one or possibly more video recording devices close to the participant might affect his/her psychological state; and possibly serves as a threat to the internal validity of the study. The intrusive equipment setting might give rise to this and creates a non-conducive environment for the participant. The dilemma authors often face is that the recording device needs to be as close as possible to be able to obtain the data, but also distant enough to give the participant more space and a less stressful setting. This also relates to the next point where audio quality might be compromised. With the camera built-in audio recording, it should not be placed too far from the participant. The intrusive camera setting placed on the table can be seen in Figure 9.

Figure 9: Design session 1- experiment setting

Thirdly, on a related point, the combination of think-aloud and pen-and-video recording system provides a useful insight into the ability to capture design behaviour. A particular design *move* is captured, including the act of *repositioning* in problem state and reshaping the *need* from verbal data; which indicates how effective protocol studies are in order to understand designers' internal thoughts. The example also favours the argument that important clues about somebody's state of mind are provided by the speaker herself (Bayne, 2013). In the protocol below (Figure 10) P1 repositioned by creating a context (China) and started to re-clarify the task by shaping a new *need*. In subsequent utterances, P1 thought about ideal family spaces within the re-shaped context. This is also achieved with the use of smartpens.

Figure 10: Partial utterances- P1

How the conventional pen-and-video recording system support sketching process is recorded has been expanded. Turning to the use of the particular smartpen used in design session 2, the authors would like to clarify again that this observation is based on the Livescribe™ Echo smartpen only, and generalisation for other products may be appropriate but has not been tested by the authors.

Smartpen

Firstly, the observed disadvantages of the use of smartpens to capture the sketching process are posited. The smartpen uses a special dotted paper which allows the pen to record the exact location of what the participants draw or write. Livescribe™ released dotted paper with lines and grids. Lined papers are avoided due to their distractive horizontal lines and faint grid lines are used, refer to Figure 11. Although the grids are less distracting, based on observation, the available paper pushes participants towards two dimensional drawings instead of three dimensional drawings. This might also lead to design fixation, which is a state where the designer is reluctant to view design from different views and premature commitment to a particular problem. Although fixation is usually a result of exposure if inspiration sources (Cai, Do, & Zimring, 2010) or level of expertise; in this study, a similar view is that the provided paper might affect the way participants carry out their investigation.

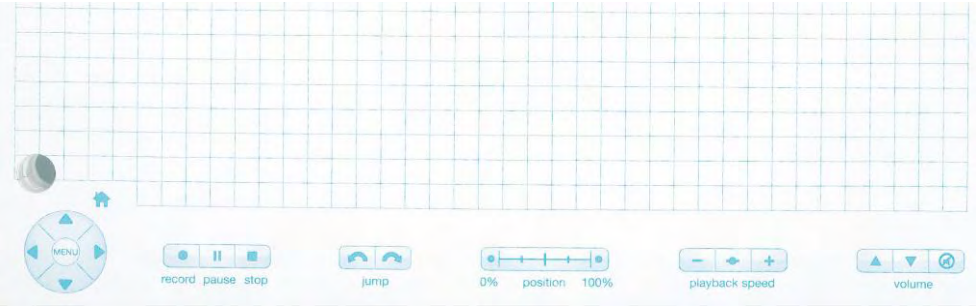

Figure 11: Livescribe™ paper used during design session 1 and 2

As can be seen in screenshots (Figure 5), non-verbal cues such as the hand gestures are not captured. The pencast (replayed video) captured the sketching process in a disembodied manner, as pen and hand were not visible. Hand gestures then cannot be inspected, leading to cues being disregarded. Another drawback is the audible scratching sound when a participant makes rapid sketches, which makes the participant's utterances slightly inaudible. Conversely, when a participant does rapid sketches in the form of shadings or hatches, s/he tends to remain silent.

Secondly, the extent to which the smartpen is more effective in comparison with conventional tools will be expanded. According to a comparison study (pen-and-paper, smartpen and TRIZ ideation method) conducted by Hernandez et al. (2014), within one week, the use of smartpen technology tremendously improved the quantity of design ideas. The observations of how the participants used smartpens were not presented; however, it is possible that due to the replay function, it aids the solution generation. In addition, the unblocked views of the drawings are beneficial for thorough inspection and analysis of the design activities. Providing insights into the nature of idea development (Kavakli et al., 1998) is more manageable due to unrestricted views. Giving substantial support to unveiling the underlying cognitive structures, the essence of capturing the sketching process mentioned by Scrivener et al. (2000) was made possible by the use of replayed videos (pencasts). Auto-synchronisation between the thinking aloud (verbal) and sketching (actions) aid the effectiveness of exploration with an absolute synchronisation and the minimal use of one single device to pursue the investigation. Figure 12 shows progressively how a single page evolves over approximately nine minutes, drawn by P2. For the purpose of the investigation, by using the pencast, direct observations can be made due to the fact that it is composite file. Conversely, although it is derived from a single file, different types of file (final outcome of sketches without grids as images and audio files) can also be obtained separately and used according to preferences.

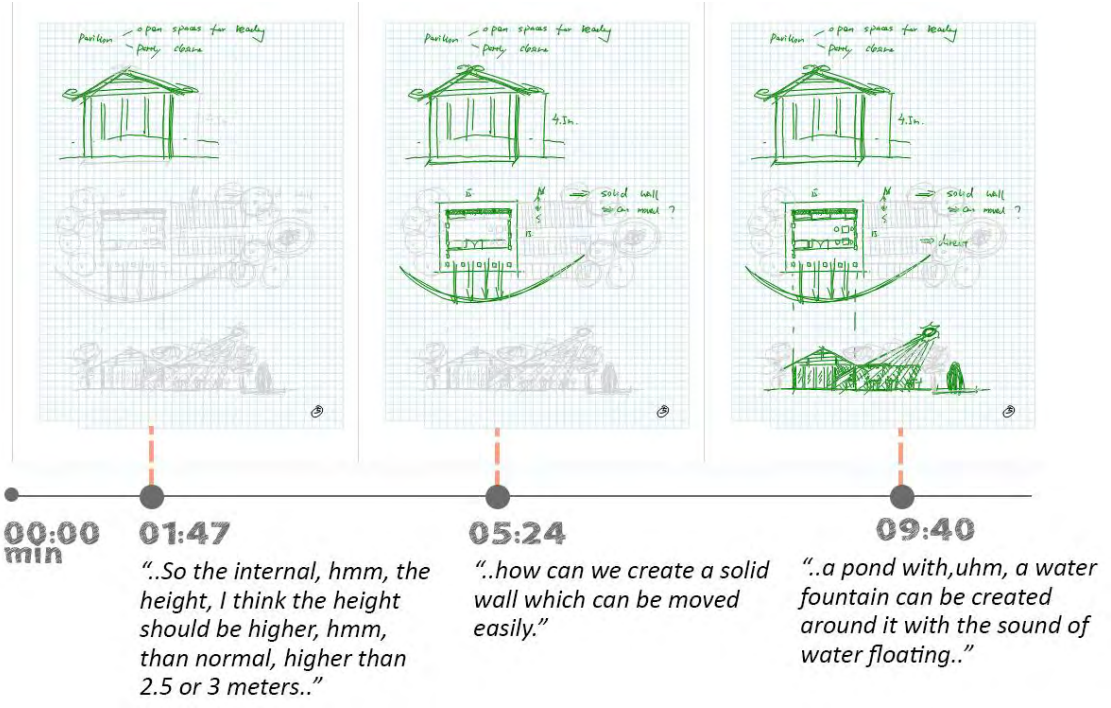

Figure 12: Screenshots of a timely progressive page using a smartpen

In addition, the use of smartpens might foster design research on the exploration of the roles of shading, textual aids, context (trees or environmental strategy) of drawings. For instance, if authors want to know what P2 says while she draws trees in Figure 13 (shaded in green by authors), double clicks on trees in Echo™ software will reveal from the audio and sketching process that trees serve as an environmental strategy, for shading purposes. Likewise, if authors want to observe the significance of textual aids (for instance, "solid wall" in Figure 13, highlighted in blue colour box by authors), the pencast made it possible with a quick gesture to gain the information.

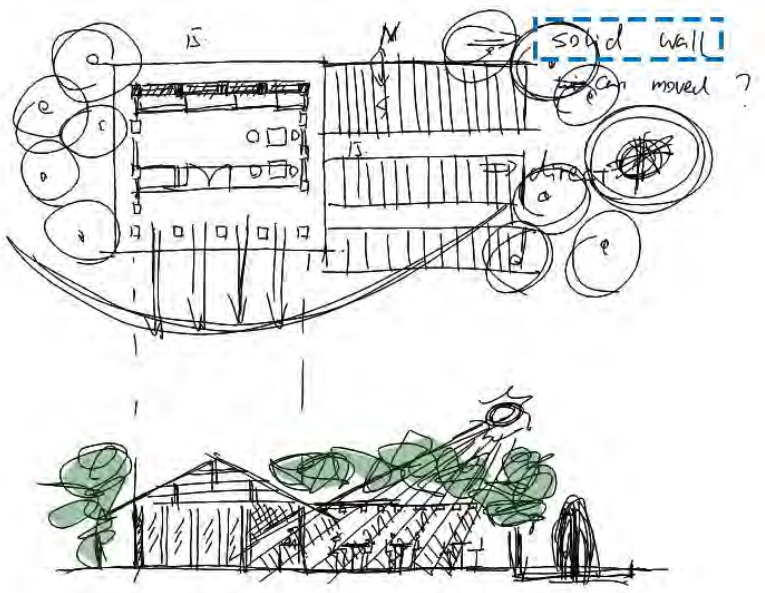

Figure 13: Textual and environmental cues

Conclusion

Reiterating the question which under consideration, “How can smartpens enrich design process observation in comparison with conventional pen-and-video-recording?”; the authors have presented background literature about what authors seek to demystify the design processes, the focus of sketching studies in relation with design process studies, methods, and what and how to capture design activities. It has also been demonstrated that the two mentioned sketching recording methods (pen-and-video recording and smartpens) have their own strengths and drawbacks. To conclude, the use of smartpens benefits design process observation in terms of: 1) unobtrusive sketching activities by participants’ hands, shadow or glare; 2) the replay function has been a tremendous aid to understand designers cognitive strategies; 3) an auto-synchronisation between thinking aloud and the act of sketching and; also 4) possibly aiding exploration of shading, textual aid, contextual aid of drawings and other cues in sketches.

Consequences for not having such information are: less effective experiments due to dealing with more than one primary apparatus, missing information due to the blocked/ partially blocked views (for instance in Figure 14, P1 constantly blocked the view for more than two minutes) and other cues thus might not be obtained. Conversely, the conventional pen-and-video tools are more effective in terms of capturing hand gestures. The consequence is illustrated in P2 in minutes 14:38 when the notion of ‘referring to brief by looking at the given brief’ is not able to be captured by the smartpen.

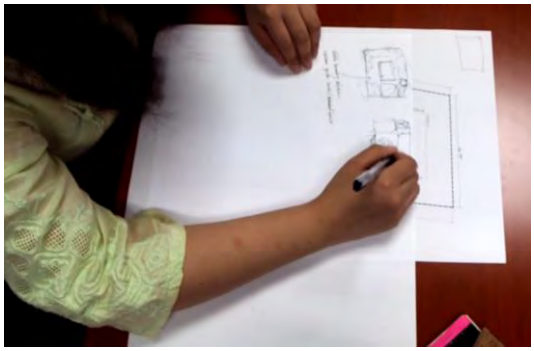

Figure 14: Design session 1, minute 07:15

The question still remains, however, to what extent hand gestures contribute to the exploration and how smartpen- based studies are able to incorporate them. A trial has been conducted through the pilot study by using another camera to obtain top view videos as back-ups, but it can also be used in combination with the smartpen interactive pencast by overlaying two videos. In the light of future development, studies related to the use of smartpens in designing activities can be explored: 1) whether a smartpen can used as a design tool, particularly related to the ability to be replayed for personal reviews and progress 2) it is also possible to support the notion of ‘tracing over’ to develop options by obtaining screenshots of the process at any chosen moment 3) the pen might be able to promote collaboration between designers by sharing pencasts 4) investigation of sketching

speed analysis is made possible, and most importantly in relation to the study is: 5) to be used as visual cues during retrospective sessions in protocol studies.

With regards to limitations, it is conceded that the observation is based on one type of smartpen produced by one manufacturer. Additionally the limited number of sessions might restrict authors in terms of thorough exploration of the use of the pen; however, it is hoped that this preliminary study provides some useful insights for further exploration in design studies.

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