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INTRODUCING THE WAYFARING APPROACH FOR THE DEVELOPMENT OF HUMAN EXPERIMENTS IN INTERACTION DESIGN AND ENGINEERING DESIGN SCIENCE

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1. Human experiments in interaction design and engineering design science

With the special focus on interaction design [Moggridge and Atkinson 2007] science and related human-computer interaction (HCI), human factor engineering (HFE) and Ergonomics, and affective engineering [Balters and Steinert 2014, 2015], experiments are conducted in order to understand the underlying mechanisms of the interaction between human and object. To decode the black box of human behavior, measurement tools such as physiological sensors are implemented to quantify behavioral (re-)actions [Balters and Steinert 2015]. In order to firstly develop a human-centered experiment, to secondly analyze and interpret generated data and to lastly build a grounded hypothesis argumentation, the experimenter needs to possess the fundamental knowledge in multiple knowledge domains, such as engineering design, electro-physics, psychology, physiology, and even neuroscience. The development process of an experiment gains, thus, complexity. The main challenge is then to combine the complementary and yet potentially contrary aspects of each domain that influence decision making within the development process – resulting in high degree of complexity and uncertainty. This is especially the case in scenarios with no obvious experiment precedes, when the experiment is to be built from scratch. The development of experiments with such multi-disciplinary aspects and moreover a high degree of freedom, is complex and thus time consuming and expensive [Kirk 1982], [Antony 2014]. In that way, it resembles the journey of fuzzy-front end product development projects with high degree of intended innovation. Being trained to approach such complex challenges in the context of early product development with methods from design thinking, we recently presented our wayfaring approach for early phase product development [Gerstenberg et al. 2015]. The model grounds on abductive learning [Burks 1946], [Eris 2004], [Leifer and Steinert 2011] and Steinert and Leifer's [2012] hunter-gatherer model. As an exploration process, the model encourages to include all knowledge domains of the project from the beginning and to iteratively probe ideas in design, build, and test cycles. In this paper, we propose a modified version of the wayfaring model, aiming to support the early concept creation stage of designing experiments that include multi-disciplines and, thus, high degree of complexity. We illustrate our model by giving a concrete example: building and conducting an experiment aiming to monitor stress-levels of ship pilots in critical ship-maneuvering scenarios, in order to subsequently and accordingly (engineering) design stress-adaptive ship bridge interfaces. By applying the wayfaring approach in the early fuzzy phase of this challenge, we were able to run the experiment-pilot with participants within four weeks.

In the next section we lay the theoretical foundation for the wayfaring model. We further describe the setup and protocol of the experiment example case (Section 3). In Section 4, we highlight the main components of "wayfaring" and give concrete examples from our case experiment. Conclusively, we propose the wayfaring model for the early-phase development of experiments in interaction design (Section 5).

2. The wayfaring model

The wayfaring model, founded on Ingold [2007] and Steinert and Leifer [2012], is described as a exploration journey rather than a planning based approach to discover innovative ideas. Since, it has been further refined as a methodology for the early concept creation stage of product development projects with a high degree of intended innovation by Gerstenberg et al. [2015]. The main premise of the model is that an optimum new solution to a problem cannot be preconceived and targeted, as we do not have empirical evidence for the outcome of something that has not previously been done. Consequently, the model establishes the need for a pragmatic exploration of the problem and solution space - a bias towards action approach to uncover the unknown. The methodology, as depicted in Figure 1, includes four main aspects:

1. Probing ideas - exploring opportunities, sometimes simultaneously by means of low-resolution prototypes, in order to fail early and to enable abductive learning.
2. Merging multidisciplinarity - including all knowledge domains from the beginning, in order to uncover interdependencies and build interlaced knowledge.
3. Speed - planning based on short iteration timeframes, in order to maximize the number of iterations possible.
4. Agility - opportunistically choosing the next step and letting the development process shape the outcome, in order to make room for serendipity findings and innovative outcomes.

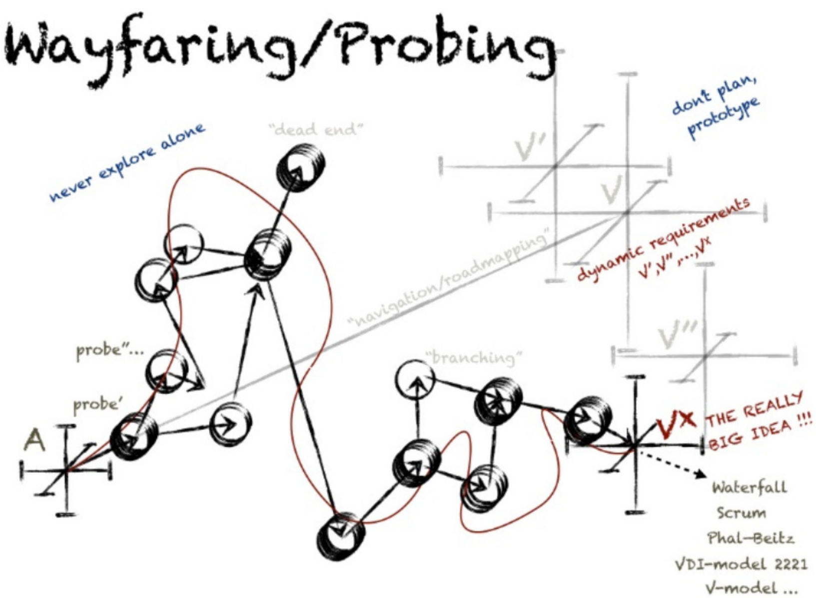

Figure 1. Wayfaring as proposed by Steinert and Leifer [2012]

(1) By employing iterative probing cycles (Figure 2), the aim is to test critical functionalities of the envisioned system from the beginning, in order to generate proof-of-concept feedback. In the divergent thinking phase, a probing cycle is initiated with the target to come up with as many solutions as possible based on the current understanding of the problem. These ideas are rapidly prototyped - designed, built, and tested - with focus on the most critical functions. This creates an opportunity to reflect and converge towards the most promising option, enabling the use of abductive reasoning [Burks 1946]. Importantly, the methodology promotes the concept of safe failure: test and fail as early in the development process

as possible in order to learn and minimize the resources spent developing into a disadvantageous direction. (2) When working on projects involving technical components from multiple disciplines, these components should be prototyped simultaneously and merged, to test the system at large as soon as the components are available in their most rudiment form. The aim is to discover interdependencies early, and to build interlaced knowledge between the different disciplines. (3) Instead of planning the development process based on a predefined outcome, the process is scheduled in short iteration timeframes. This ensures a rapid progression, increasing the number of iterations possible, minimizing the time and resources spent developing into a disadvantageous direction and maximizing the efficiency towards innovative solutions. (4) Rather than having a predefined outcome from which the development process can be pre-planned, the wayfaring model lets the development journey shape the outcome. The development journey consists of many iterative probing cycles, each of which is able to increase the understanding of the problem and solution space. In other words - learning by doing. This fast-learning process enables the engineering designer to opportunistically choose the next step from the continuously updated practical knowledge base, entering a successive probing cycle. Accordingly, the perceived target shifts as one wayfare, making room for discovering highly innovative solutions that could not have been preconceived.
With focus on their practical application in the experiment example case, the four key features are further elaborated in section 4. Before, section 3 provides the description of the experimental setup and protocol.

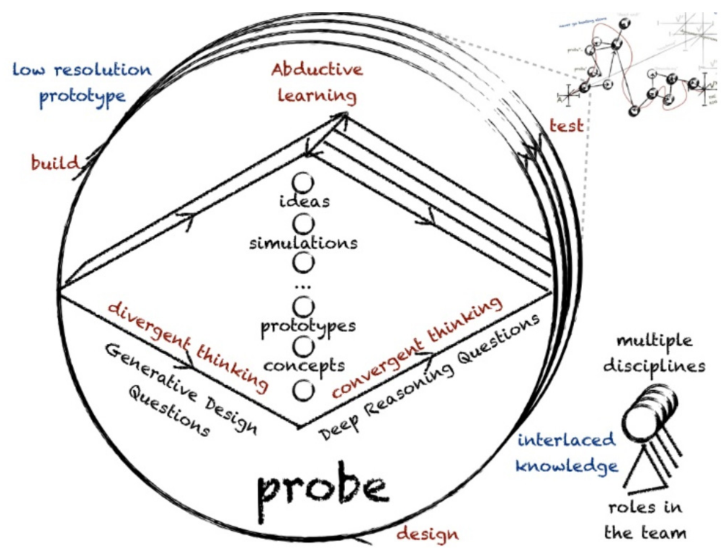

Figure 2. Probing as proposed by Gerstenberg et al. [2015]

3. Example case: Piloting a ship bride interaction design experiment

The following example case stems from the front-end (FFE) [Kim and Wilemon 2002], [Koen et al. 2002] of a comprehensive research project currently undertaken by TrollLabs at NTNU addressing user interaction design [Moggridge and Atkinson 2007] in a ship bridge scenario. The ultimate aim of the project is to generate adaptive interface solutions, such as alarm systems, suitable to the ship bridge operators under the various conditions of workload they are facing [Stanton 1994]. Importantly, the solutions aim to monitor operator stress to control their performance during critical events. This challenge fits within the realm of affective engineering [Balters and Steinert 2015], where we seek to understand the relationship between engineering designs and the behavioral response of the user. In order to be able to (1) decode and quantify human behavior and subsequently (2) design stress-adaptive interface solutions, the need to build competence on capturing affective response in the specific context of the user interaction scenario emerges. Instead of starting by seeking for expert consultants, we decided to employ a fast-learning development process inspired by the wayfaring model. We decided to apply this approach due to its successful application in innovative early phase product development projects with a high degree of uncertainty [Gerstenberg et al. 2015]. Rather than emphasizing the research question, hypothesis, and data outcome, the focus of this paper lays specifically on how we projected and applied the wayfaring approach from the early-stage product development context onto the concept development of an interaction design experiment.

3.1 Experimental tasks

All simulated boat-conducting tasks were run on a 2x3.60 GHz CPU 16 GB RAM computer by using the Ship Simulator 2008 software, a commercial ship simulation game developed by VSTEP [2007].
Three experimental tasks were custom-made with the "Mission Editor" application in the Ship Simulator 2008 software package:

- With one minute of trial run in the environment "Marseilles", the participant was given time to familiarize with the game interface. No traffic or obstacles were added to the environment, nor was any mission-objective declared. Weather conditions were set to the software's default "Good weather", time was set to "noon" and the vessel "VSTP7" was selected as the player object. Overall, the task was designed to be a simple introduction to the dynamics of the game, with a minimum of taxing elements.
- The mission "cruise" was created with the intent to be a "non-stressful", undemanding task to perform. Weather conditions were set to the software's default "Good weather", time was set to "noon" and the vessel "VSTP7" was chosen in the "Phi Phi Islands" environment. No mission-objective was given, as the participant was instructed to just enjoy cruising around for the duration of the task, which lasted for 5 minutes.
- The mission "race" was designed with the purpose to create a "high stress", step-wise increasingly demanding task for the test subject. The task was set in the "Atlantic Ocean" environment, where rows of stationary "Supertanker" vessels were used to confine the straight-lined course area. A successively increase in difficulty was accomplished by manipulating the density of various obstacles such as ships, ramps and icebergs, and by successively manipulating weather condition variables: "Rain", "Thunder", "Fog" and "Waves & wind". These factors were step-wise manipulated at "waypoints" which occurred at fixed length intervals. Furthermore, the participant was set to play the course with the "Hydrojet", which combines high speed and aggressive steering dynamics, resulting in what testing revealed to be the game's most difficult vessel to maneuver. The course was designed to be impossible to finish within the fixed duration of 5 minutes, after which the performance of the participant was recorded manually by the experimenter as the number of "waypoints" attained. In order to promote a competitive mindset, the participants were informed in the pre-game instructions that the best performer receives a gift card of 500 NOK for the university cafeteria. In addition, it was (pretendingly) informed that performance outcome would be publicized on the class' website, with the intent to induce "social strain". Simultaneously to performing the racing task, the participants were instructed to conduct simple calculations as they appeared on the instruction screen. The calculations were implemented to investigate problem solving ability at various time points during the "stressful" task. The first calculation appeared after 24 seconds of racing. In total, nine calculations appeared on the screen, for 6 seconds each, with 24 second blank screen intervals in between. The participants were informed in the pre-game instructions that the secondary task was equally important to their racing performance score.

3.2 Sensors and data capturing

Five biometric sensors, all provided by Libelium [2015], were used to collect physiological response data from the test subject, shown in Figure 3. A galvanic skin response (GSR) sensor was placed on participant's non-dominant hand to gather skin conductivity measurements, with the electrodes on the middle and ring finger. An accelerometer was placed on the top of the dominant hand, to measure hand movement during execution of experimental tasks. An airflow sensor collected the respiratory rate from the nostril openings. A temperature sensor placed on the left side of the neck measured body temperature. An electrocardiography (ECG) sensor was used to measure the electric activity of the heart.

Due to electrical interference between the ECG and GSR sensor, no neutral electrode was used for the ECG. The negative electrode was placed on the left side of the chest, while the positive electrode was placed on the right side. Resulting signal noise was removed in pre-processing. The biometric sensors where initiated through an Arduino UNO with an e-Health sensor shield. An Ethernet shield was used to transmit the data to the synchronization software provided by iMotions [2015], run on a 2x1.80 GHz CPU 8 GB RAM computer.

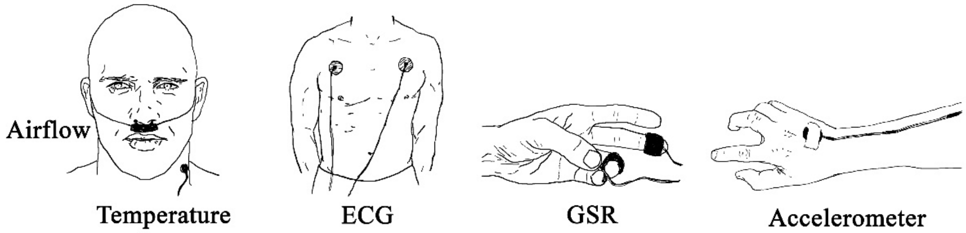

Figure 3. Sensor placement (for right-handed participant)

Affect grids [Russell et al. 1989] were used to gather emotional response data by means of self-report. A scene camera was used to record the participant, the gaming screen and the performance of the secondary task, all within the same frame.
A pre-experimental questionnaire was used for mapping demographics, specific health issues, diets and current emotional state. A post-experimental questionnaire was used to uncover prior experience level in boat conducting and computer gaming, current emotional state, as well as general feedback on the experiment.

3.3 Mockpit

The experiment was conducted within a simple ship cockpit environment, as illustrated in Figure 4, from now on referred to as "the mockpit". A 24" LED gaming monitor was integrated into the rear wall of the mockpit, to mimic the feeling of looking out of a cabin window when performing the experimental tasks, along with a 17" LCD monitor to give instructions during the experiment. The four arrow-keys on a regular computer keyboard were used for maneuvering during execution of the experimental tasks, with all other keys disabled by a physical barrier cover. A notepad was fixed in the center of the mockpit for performing the secondary task. An armrest to restrict non-dominant hand movement and the affect grids changed places according to hand-dominance. A box was placed in the rear to collect the affect grids.

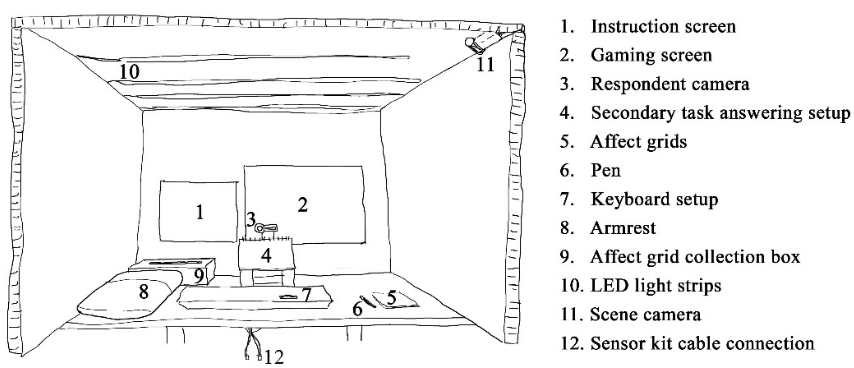

Figure 4. Mockpit layout (for right-handed participant)

3.4 Protocol

34 mechanical engineering students and 6 engineering department employees performed the pilot-experiment, distributed over the course of five days. Three experimenters were needed to conduct the experiment.

In the invitation for the experiment, the participants were informed not to eat, drink any caffeinated drinks or use any nicotine substances within the hour before their assigned experimental time slot. Upon arrival, the participant was greeted by the 1st experimenter who guided them to a preparation room. The participant was assigned to fill out the pre-experimental questionnaire along with a compulsory consent form, before being outfitted with the sensors and hearing protectors to cancel any external noise.
The participant was then guided to the experiment room by the 2nd experimenter, where the participant was seated in the mockpit. After the 2nd experimenter had connected the sensor kit, she left the room in an obvious manner.
All instructions following this were presented on the instruction screen. The instructions, as well as the secondary task, were initiated automatically by the iMotions software. The experimental tasks were initiated by the 3rd experimenter manually, and presented on the gaming screen. The participant was given no clue of the presence of the 3rd experimenter. The secondary task was presented on the instruction screen during the racing task. In order to avoid order-effects, half of the participants were randomly assigned to conduct the experimental tasks "cruise" and "race" in reversed order. A sequence of: affect grid - 1 minute baseline signal - affect grid, was implemented after each experimental task. The same sequence followed the final task, succeeded by an instruction informing of the completion of the experiment.
The participant was then guided back to the preparation room by the 2nd experimenter.
The 1st experimenter detached the sensors, before asking the participant to fill out the post-experimental questionnaire.

4. Wayfaring in the example case

By the end of the four week development journey, we had gone from scratch to being able to run a comprehensive experimental pilot setup, implementing multidisciplinary experimental components previously far beyond our proficiency. The rapidness of which we accomplished this, we attribute to our bias towards action approach, facilitating fast-learning, inspired by the wayfaring model [Steinert and Leifer 2012], [Gerstenberg et al. 2015]. This section highlights and illustrates the four main aspects of the wayfaring model - probing ideas, merging multidisciplinarity, speed and agility - by giving concrete application examples from our development journey.

4.1 Week 1 - example of probing ideas

At the start of the development process, the three-person team was already familiarized with the extensive research project conducted by TrollLabs at NTNU that addresses the design of user interactions in critical ship maneuvering scenarios. Through the research in this project prior, we could quickly reach common ground that understanding the impact of stress was going to be an important factor for the experiment. Our "challenge" of "making an experimental setup in order to understand the influence of stress in a ship bridge interaction scenario", immediately gave us a vague vision of some experimental components we would probably need - a physical space "ship simulator", a bunch of biometric sensors, and crucially, a ship-navigation-task that induces "stress" in comparison to a baseline task. By the end of the first day we had built a low-resolution ship simulator space out of cardboard, including monitor and controls, as well as a trial version of a ship simulation game (see Figure 5).

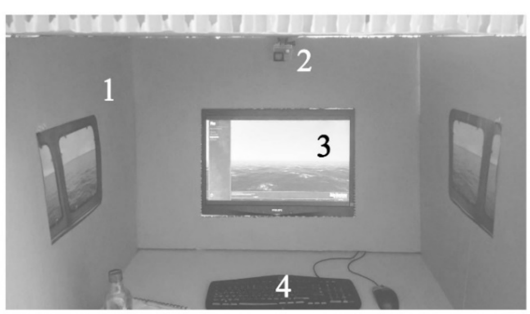

Figure 5. First day low-resolution simulator environment

Within a week we had done multiple physiological measurements in the simulator, using a low-cost, open-source biometric sensor kit [Libelium 2015] consisting of ECG, GSR, airflow, accelerometer and airflow sensors. The approach was to explore our opportunities as fast and cheap as possible, to avoid wasting resources by developing into a disadvantageous direction. Through this "bias towards action" approach, we started building practical experience from day one. This was especially crucial regarding the biometrical sensors, of which we had limited experience. The experiences gained in this process of probing ideas, importantly including experiences of failing, enabled the use of abductive reasoning, increasing our understanding of the problem and solution space. Simply put - learning by doing.

4.2 Week 2 - example of merging multidisciplinary components

Entering the second week, the team split into different problem areas. Two team members were resolving an uncovered electrical interference issue between the ECG and GSR signals, along with implementing all the aforementioned biometric sensor signals into a synchronization software [iMotions 2015]. The other team member was working on creating a "high stress" and a "low stress" simulator task and refining the mockpit. An alternate solution of using an open source algorithm for extracting pulse rate from a facial video recording [Wu et al. 2012] was tested to replace the GSR signal, but deemed unsuitable for our purpose due to its low tolerance on subject movement within the video frame and the light condition changes from the computer screen induced by playing the simulator game. While the GSR/ECG interference issue remained unsolved, we were able to confirm or reject potential solutions efficiently by directly integrating them with a meaningful experimental task. Consequently, the sensors gave us indications on factors within the game that were able to induce stress related responses in the sensor signals. The complexity of developing a plausible experimental setup was in large parts due to the interdependencies arising between the multidisciplinary experimental components. When probing on isolated components, e.g. biometric sensors, one is restricted to uncovering issues in that particular problem domain only, such as the electrical interference issue between the ECG and GSR signals. However, not until connecting two or more experimental components, one can discover arising confounding variables, such as the impact of task-induced limb movement and task-dependent sensor placement on signal data. These unknown interdependencies are revealed when merging different experimental components. For instance, our experimental setup needed to enable comfortable execution of the experimental tasks for both right handed and left handed participants. Beside a suitable experimental space layout, enabling a common ergonomically comfortable task execution, this meant for example to keep a flexible wire connection to the biometric sensors, to be able to reversely switch the item positions inside the simulator space, and to provide time buffer in the protocol for the possible resulting reconfiguration. These factors were discovered and thereafter solved, by probing the experimental components in context. As the wayfaring model proposes, including as many multidisciplinary components as possible, as soon as possible, is all-important in order to test and fail early. By probing the "global" problem instead of its constituent subproblems separately, we were able to uncover the essential interdependencies of our envisioned system, which can render spending a lot of time optimizing a subproblem futile. To save time, we would temporarily divide the team, solving different problem domains, e.g. sensors, simulator and programming. By working side-by-side, each within their continuously expanding field of expertise, we could merge and test our multidisciplinary components for integration issues quickly.

4.3 Week 3 - example of speed

At the beginning of week three, we were presented an opportunity to invite an engineering class to be participants in our pilot experiment. While we still had a long way to go, we decided to grab this opportunity even though this meant a limited time of two weeks to finalize the experimental setup. To ensure a rapid progression of our development, while keeping the entire experimental protocol under control, we imposed short iteration timeframes of one day. In other words, we had to conduct at least one test run of a comprehensive experimental protocol at the end of each day leading up to the experiment, relying on team members and colleagues as test subjects. Working more closely on creating a complete experimental protocol, the approach was to focus on the critical functionalities and leave the "nice to have" add-ons for later. We moved our setup from the lab into a separate room to isolate the experimental area from disturbance. Within this room, we built a cardboard wall to separate the experimental area from the observation area that was reserved for the experimenter. We further implemented an instruction screen in addition to our gaming screen into the mockpit, in order to give task instructions during the experiment. Focusing on making the critical functions work, we decided on a solution for the discovered ECG/GSR interference issue: disabling the grounding electrode of the ECG sensor. This brute solution allowed us to finally get reasonable skin conductance readings, however, at the cost of increased noise in the ECG signals; yet still good enough to extract reliable data to calculate heart rate. Following the iteration timeframes, the development process was not planned according to a fixed outcome, but on a day-to-day basis. Each iterative experiment providing clear feedback in terms of the most critical issues we had to resolve to increase the robustness of the subsequent iteration of the setup.

4.4 Week 4 - example of agility

In the final week, we were finalizing our protocol by testing it within the team and with colleagues. Some changes had to be made accordingly. Notably, after experiencing several malfunctions in the synchronization software [iMotions 2015] from switching between two alternating sensor kits, we decided to only use one sensor kit. This put extra time strain on our protocol, because the second participant could not be equipped while the first participant was conducting the experiment; however, this change of protocol was possible since we had implemented a time buffer between subjects in our schedule. Gaining confidence on the robustness of our setup, we decided to test the possibility of implementing a secondary problem-solving task for the high stress condition. This had been one of the "nice to have" add-ons that had been in the back of our minds while focusing on the more critical functionalities. We focused on making this solution as simple as possible in order to avoid conflicts with the proven protocol, by adding a separate answering sheet setup (see Figure 4) and camera to record and analyze the time the participant used to answer simple calculations presented on the instruction screen (see Figure 6).

Figure 6. Experimental setup including secondary task

As a serendipity finding, this additional camera recording was able to eliminate the need of two separate video recordings; a scene camera recording and a simulation game recording, by including all the necessary information within the frame of the new camera angle. Conducting final trial runs of the entire protocol with this addition did not reveal any integration issues. Hence, we decided to implement it in our pilot experiments. This "irresponsible" last minute addition, promoted by the agility principle of the wayfaring model, ended up increasing the overall robustness of our setup. Throughout the entire development process, our approach was to be agile, exploring opportunities that were not pre-planned and letting the wayfaring journey shape the outcome of our process.

5. Principles of the wayfaring model applied in an interaction design experiment

While the wayfaring approach has previously been promoted towards tangible product development [Gerstenberg et al. 2015], [Reime et al. 2015], we aim to emphasize its application to developing interaction design experiments on the basis of our experiences described in the previous sections. This section aims to provide the general concept of the wayfaring model for the early-phase development of experiments in interaction design. The main argument for applying the wayfaring approach is its ability to drastically reduce concept creation time for development scenarios involving a high degree of uncertainty, while enabling innovative solutions. This is descriptive of the kind of scenario we encounter when developing a new experimental setup for interaction design experiments. The complexity, thus uncertainty, of this development process is in large parts due to the multidisciplinary knowledge domains one has to handle and bring together, such as psychology, physiology, programming and engineering.

5.1 Probing ideas

The wayfarer starts the journey with a vague vision of the setup we want to achieve, as depicted in the wayfaring model as starting point A and initial vision V of our experimental setup, making initial, more or less naïve guesses on the design of the relevant components required to get there. The user-interaction scenario for the project is known, thus probing a low-resolution representation of the context becomes a natural first step, along with sensors to see how we can capture human behavior in this environment. If possible, we temporarily divide the team into the different problem domains, designing, building and testing various ideas in the different disciplines simultaneously; continuously trying to get fast proof-of-concept feedback, to fail early and to converge on the most promising solutions. The wayfarer focus on representing the component's critical function(s), utilizing readily available resources to remove uncertainties in essential operations quickly. This can be depicted as the first probing cycles in the wayfaring model (Figure 7). Each probe is initiated by asking open-ended questions in a divergent thinking phase - designing, building and testing the ideas quickly - creating empirical evidence for reflecting and implementing the most promising option in a convergent thinking phase.

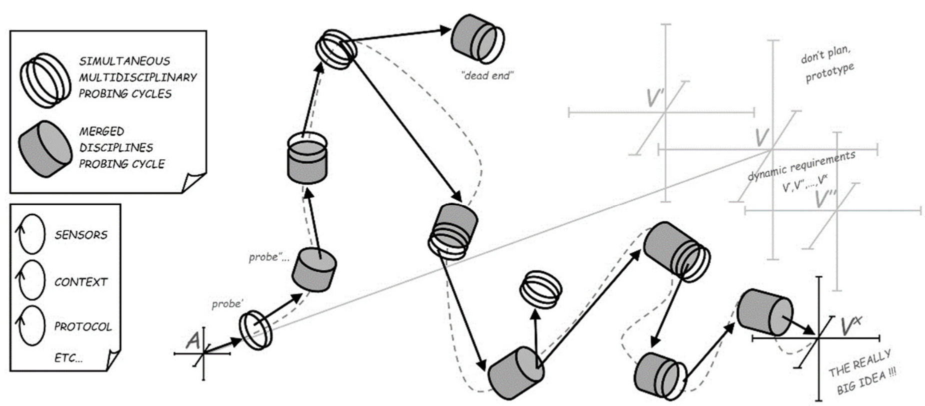

Figure 7. Wayfaring in the development of an experimental setup

5.2 Merging multidisciplinarity

Whenever a probing cycle proves an experimental component fulfilling its critical function, it ought to be merged with the other components in the subsequent iteration round to check for integration compatibility and to discover unexpected interdependencies. In the wayfaring model for the early-phase development of experiments, we propose depicting this as cylinder rather than a circle, to illustrate the handling of two or more experimental components as one coherent part of your design. The aim is always to test the global solution before fixating on the local solutions. An important point is that having an expert within each isolated knowledge domain does not guarantee a holistic expert knowledge on the entire experimental setup. The wayfarer can only start accumulating expert knowledge on a new experimental setup when he/she starts bringing the multidisciplinary experimental components together. This interlaced knowledge is crucial know-how in order to build a successful/robust experimental setup. In that way, having expert knowledge in each of the relevant domains is not a prerequisite for starting the wayfaring journey, as we gradually overcome this inexperience through the fast learning process it enables.

5.3 Speed

Instead of focusing on reaching a fixed target, that is a predefined experimental setup and the actions necessary get there, the wayfarer sets short time frames, e.g. 1 day or 1 week, in order to complete the current probing cycle while remaining open and opportunistic towards the outcome. Setting these deadlines creates a speedy cadence between the divergent and convergent thinking phases, which maximizes the efficiency of the development process. While divergent thinking is largely accomplished by asking open-ended questions and overcoming the fear of failure [Lee et al. 2004], a fixed time frame creates a need to converge on the most promising solution. Setting short iteration timeframes increases the number of iterations possible to ensure a rapid progression and minimizes the time spent developing into a disadvantageous direction, while allowing the exploration of multiple solutions. Through the iterative process, each probing cycle provides not only new knowledge on the deductive and inductive level, but also generates abductive learning. This enables us to master each of the experimental components, and importantly mastering the components in context, as we wayfare - learning by "making it work". Importantly, while it is possible to achieve a good understanding of the experimental setup while probing within the development team, a setup cannot be proven until tested on unbiased test subjects. Including the human factor is crucial in order to uncover unknown unknowns, which are undiscovered parts of your solution affecting the outcome in a confounding way. Essentially, when aiming to induce certain affective responses, verification can only be attained after running pilot experiments, including all experimental components in a comprehensive probing cycle. Following the same wayfaring mindset as previously described; doing this as soon as possible is all important, to fail early with the intent to increase the understanding before entering the next iteration.

5.4 Agility

The low-risk probing method enables the wayfarer to discover dead-ends quickly, avoiding developing into a disadvantageous direction. In addition, by restraining from fixed variables early on, the wayfaring model encourages an agile approach, opportunistically choosing the next step from the continuously updated understanding of the envisioned experimental setup. This creates room for serendipity findings as it enables us to develop into directions that were not initially perceived as beneficial. Ultimately, the probing method is bound to uncover unknown unknowns and unexpected interdependencies, causing requirement changes to our designs. These are essential parts of the envisioned experimental setup we were unaware of prior to probing. This is the point; the wayfarer aims to facilitate the process of failing rather than try to avoid it, because he/she realizes it is an inevitable part of the development journey towards something that has not previously been proven. Failing early is essential to minimize the cost and time utilized to make these discoveries, as well as providing us with an empirically sound platform to build on our initial ideas through abductive logic. The initial "naïve" guesses gradually changes into more "educated" guesses, deflecting our journey towards the dynamically evolving experimental setup. Accordingly, the perceived outcome of the development process shifts as we wayfare, depicted as iterative targets V, V', V"… in the model. Rather than having a predefined outcome from which the development process can be planned, the wayfaring approach lets the development journey shape the outcome.

6. Outlook

In this paper, we applied the iterative wayfaring product development process for early stage concept development to the early fuzzy conceptualization and design of a human-machine interaction experiment. Like in product development, the journey became one of intense learning, based on fast and early failures. And, like in product development, the speed and agility of the process has overpassed our own expectations, allowing for achieving extra milestones. Once an experiment design enters its later design stages or if an experiment is of confirmatory or incremental nature, traditional engineering design tools such as the Plan Do Check Act Cycle [Deming 1950], [Moen and Norman 2006] or similar approaches are appropriate. However, based on our experiences, we propose that as long as high degrees of freedom and unknown unknowns are still within the current scope of the experimental campaign, a wayfaring and probing approach is superior due to its sheer learning speed and ability to manage the shifting requirements. In the next step, we aim to generate quantitative data in order to numerically compare traditional approaches with the wayfaring approach in phase 0. In addition, we would invite fellow researchers to share their experiment design approaches in the early phase, and, if nothing else, we invite you to wayfare and probe rather than navigate – this way truly unknown shores might just be reached faster.

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