PII: Exploring Peripheral Intervention User Interfaces for Internet of Things

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ABSTRACT
While still being researched, Internet of Things (IoT) is rapidly making its way to the consumer market. The new technology can create great benefits, but in its current state it can be more troublesome than helpful. IoT still needs to find a way to seamlessly integrate with consumers daily lives to truly create significant value. Current applications are far from seamless and are deliberately designed to either completely avoid user interference with full automation or to only operate on the user's explicit command. Both have significant drawbacks. To create insights on possible solutions for these drawbacks this research applied two interesting theoretical concepts to an IoT office setting: Intentional Interactive Programming and Intervention User Interfaces. This research explores different levels of user involvement in the system and creates the first insights on the application of the Intervention User Interface principle. Findings shed light on important aspects for the application of an Intervention User Interface in an IoT environment. The conducted user studies have shown that users prefer a highly informative interface. This helps them with feeling reassured and letting go control of the system. Different levels of information or attentional demand did not have a significant effect on the user's sense of control.

Author Keywords
Internet of Things; Intervention User Interface; Interactive Intentional Programming; Smart Office.

INTRODUCTION
Internet of Things (IoT) is growing at exponential rates [8] and is becoming increasingly more common in consumers' daily lives [14]. Currently most applications of consumer IoT systems either operate on the explicit command of the user or are fully automated, both have positive and negative sides. Explicit commanding makes sure that actuations only take place when the user intents them to happen. However, commanding an IoT system requires a user to spend a high level of attentional demand on the system. Automation could lower the attentional demand required by the user and could easily take care of redundant tasks.

However, highly automated IoT systems have a high level of complexity, lack sufficient reliability, do not fit current and changing lifestyles of users and might create a loss of control and apathy [3, 7] . These may seem like minor or unlikely limitations, but extensive lack of control and decisions making may diminish the overall health and well-being of people [16].

Interactive Intentional Programming (IIP) recognizes these problems and proposes a framework to capture the intents and preferences of the end-user in order to make suitable actuations in the IoT environment [9]. The researchers acknowledge two main areas of improvement: better methods for capturing scenarios, intentions, and preferences, and second, the creation of a feedback loop to facilitate adoption and learning over time. This research focuses on the latter.

Such a feedback loop should not only function as a learning mechanism for the system. It could facilitates a more seamless collaboration between user and system, similar to the vision of Weiser & Brown [18]. An IoT system for consumers should not be fully autonomous, neither should it require too much attentional demand from the user. The user needs confirmation and less complex ways to interact with IoT systems in order to truly accept the system [3].

The Intervention User Interface allows the user to intervene with the automated behavior of the system [17]. This allows the systems to operate at high levels of automation while only involving the user in the loop when necessary.

The implementation of intervention interfaces has not been researched previously. Papers that use the concept either summarize parts in a literature review or use it as comparison. There clearly is a gap in research and an good opportunity for applied research on the concept.

There are examples of research that explore theoretical concepts by applying them to designs. A good example is the application of the implicit interaction framework [12] to an interactive whiteboard called Range [11]. Range allows users to stop or revert automated behavior of the whiteboard. These interactions do not have the intent to inform the user or to teach the system. The research solely focuses on the attentional demand required by the user to interact and the level of initiative the system shows in its behavior. Research more focused towards informing the user is StaTube [10] unobtrusively informs the user about the states of coworkers on Skype. The product is placed on the desk to inform the user, but does not involve any automated behavior for the user to interact with. The work of Kymäläinen et al. [13] shows a good method for creating an environment that explores interfaces of automated systems for the future. The research does however not build on theoretical models, but only tries to discover new research avenues.

This paper applies the Intervention User Interface on a IoT system that uses the basic concepts of IIP. The system controls a hypothetical office environment that strives to have a high level of automation and autonomy while still giving the user the sense of control. Different levels of information are applied to three interfaces to examine the level of attentional demand and involvement preferred by the user (i.e. until what extend does the want to be in the loop). And how does it influence their sense of control.

The conducted user studies creates the first insights on the application of Intervention User Interfaces. Findings shed light on important aspects for the application of an Intervention User Interface in an IoT environment and are summarized as applicable design principles. Both quantitative and qualitative insights support and clarify factors that play an important role. Application of the Intervention User Interface principle has shown to be promising as a human in the loop method for automated IoT systems.

THEORETICAL BACKGROUND

This paper uses related work to construct a frame that helps to understand the concepts that are applied in this research. The Implicit Interaction Framework and Interaction-Attention Continuum help with creating a better understanding about the implementation of Interactive Intentional Programming and Intervention User Interfaces in a IoT environment. But firstly, the applied concepts are explained.

Interactive Intentional Programming (IIP) is a model that decides what actuation best suits the current activity of the user, taking into account the user's intentions and preferences [9]. To determine the current activity, IIP would use sensors in the environment. However, IIP still is experimental and capturing the activity of the user can be hard. There are also instances where the system might predict the activity correctly, but the user has other intentions or preferences for that activity than they normally do. The framework provides a good structure to create an easy-to-use overview of an IoT system with a high level of automation. IIP could also help the user with understanding the behaviour of the system in a more structured way.

Intervention User Interfaces have predictable proactive automation process [17]. The Intervention User Interface communicates options for the intervention of the automated processes. Allowing the user to immediately intervene or revert automated actions. The Intervention User Interface could function as a seamless feedback loop for learning automation system. It effects will be studied in this research.

Wendy Ju and Larry Leifer discuss different levels of attentional demand required by the user when interacting with an interface [12]. This attentional demand mostly refers to the amount of attention the user must pay to the interface to know what is going on and/or how much information is presented to the user. Similarly, this research will look at different attentional demands necessary to interact with an Intervention User Interface.

However, an IoT system does not only provide feedback to the user via the interface. The user is emerged in the IoT environment and thus is unconsciously or consciously aware of changes in their environment. The periphery of the user attention is used to create this awareness. This conscious and unconscious awareness could be seen as different levels of attentional demand. However, in the context of this research, the attentional demand refers to the amount of focused attention the user devotes to the interface itself during an interaction. Similar to the work of Bakker and Niemantsverdriet who present a continuum spanning from focused explicit interactions to unintentional implicit interactions [2]. In between lays a grey area of subconscious but intentional interactions, so-called peripheral interactions. For this research, the Intervention User Interface and the IoT environment create an interesting combination of supplying information to the user.

RELATED WORK

All published related work on IIP and Intervention User Interfaces only use the concepts as reference material for other theoretical models. This means that there is an important gap in research.

This research uses an exploratory method with a focus on the user experience (UX) when applying the Intervention User Interface concept. A good example of exploratory UX research is the work of Kymäläinen et al. [13]. The authors create a video-illustrated science fiction prototype that enables factory operators to experience control systems of 2050. The research tries to discover new possibilities for monitoring automation in factories. The setting this research tries to create is similar to a setting this research will create.

Research related to intervening automated behavior that also applies a theoretical concept to a prototype is an interactive whiteboard called Range [11]. Range allows users to stop or revert automated behavior of the whiteboard. These interactions do not have the intent to inform the user or to teach the system. The research solely focuses on the attentional demand required by the user to interact and the level of initiative the system shows in its behavior based on the implicit interaction framework [12]. Similarly, the StaTube [10] unobtrusively informs the user about the states of coworkers on Skype. The product is placed on the desk to inform the user, but does not involve any automated behavior for the user to interact with.

THE PERIPHERAL INTERVENTION INTERFACE

The aim of the research described in this paper is to study how an intervention interface can be implemented in a non-intrusive manner and what effects an intervention interface has on the user's sense of control. An Intervention User Interface has to be applied to a predictable form of automation; therefore, a basic version of IIP is implemented. The system has four preset workmodes that switch in the same order.

To evaluate the value of the Intervention User Interface a controlled office environment was designed to acquire the necessary insights. The office environment is controlled with the

Peripheral Intervention Interface (PII). PII is an interface that controls a three main parameters in the working environment:

- Light, which varies intensity to accommodate activities such as reading and discussing.
- Heating, that heats up the room during more relaxed activities in the office.
- Sound, which can be controlled in volume to provide music during breaks or casual working.

These parameters have predetermined presets for the workmodes that are programmed for the office. PII switches workmodes automatically to provided a work environment that is as comfortable and productive as possible. The four workmodes are defined as following:

- Focused working, cognitive intensive work, such as reading and writing. The system provides high light intensity without creating other distraction. Heating and music are turned off to create a calm environment for a sharp focus.
- Co-working, a relaxed working environment for activities that require less focus or have a co-operative nature. The system provides medium lighting, a medium temperature and soft background music.
- Break, a workmodes where users are encouraged to relax and to clear their minds. The system provides dim lighting, a warm temperature and music.
- Out of Office, which indicates closing times of the office. The system will slowly turn off all parameters to signal users that it is time to go home.

Users are free to change the parameter to their liking; however, in cases where the settings cause greater energy consumption than the regular settings the system resolves the custom settings after a period of time.

Real life implementation of IIP can be of far greater complexity and presumably takes into account many nuances based of sensor data captured by the system. For the scope of this research the simplified version operates on a fixed schedule, mornings are reserved for focused working, afterwards a break takes place, afternoons are used for for co-working and in the evening the system shuts off by moving to out of office.

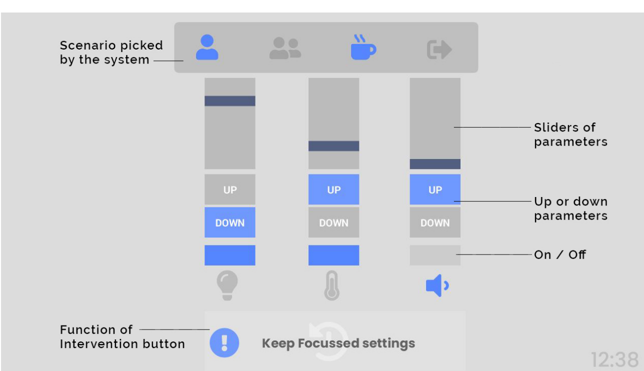

Figure 1. Explanation of PII's interface.

The user might not always be satisfied by this autonomous behavior. This is where the intervention button plays an important role. By pressing the intervention button the user can revert the system to its previous state. This can be done when the system is signaling that it will proceed to the next workmode or when the transition already has occurred (e.g. the user is reading an article while in focused work. The system start signalling that break mode will be enabled in a while. The user presses the intervention button to prevent the system from changing workmodes and continues reading.). The intervention button can also be used to remove custom input from the user (e.g. the user turns up the temperature to a level that causes the heater to turn on. After a while the user notices that it is getting too hot. The user presses the intervention button to remove the custom settings and reverts the system back to the standard workmode values.).

This way PII involves the user in the loop. The right extend until this should happen may be hard to determine, since the user wants sufficient information to feel in control, but a constant stream of feedback might frustrate the user [1]. This research explores three different variations of PII's interface that contain different levels of information (see figure 2) inspired by the attention-interaction continuum [2].

The authors of the Intervention User Interface article supply the reader with a set of design principles to develop Intervention User Interfaces [17]. The most important and applicable design principles are arranged in three layers of attentional demand based on the categories of the attention-interaction continuum (these principles are be applied to the corresponding interface):

Essential features (implicit)

- The system has predictable automated behavior
- Easy reversal of automated and intervention actions

Secondary features (peripheral)

- Feedback about whether or not an intervention is occurring
- Communicate options for intervention

Optional features (explicit)

- Communicate the goals being pursued by the automated action
- Inform the user about the previous state of the interface
- Feedback about the impact of the intervention (temporal or permanent)

The explicit interface gives the user the most information. Sliders indicate the levels of the parameters, transitions indicate which parameters are about to change and the intervention button displays its current function in the bottom of the interface. The peripheral variation does not have have sliders, does have transitions that indicate which parameters will change, but does not display the current function of the intervention

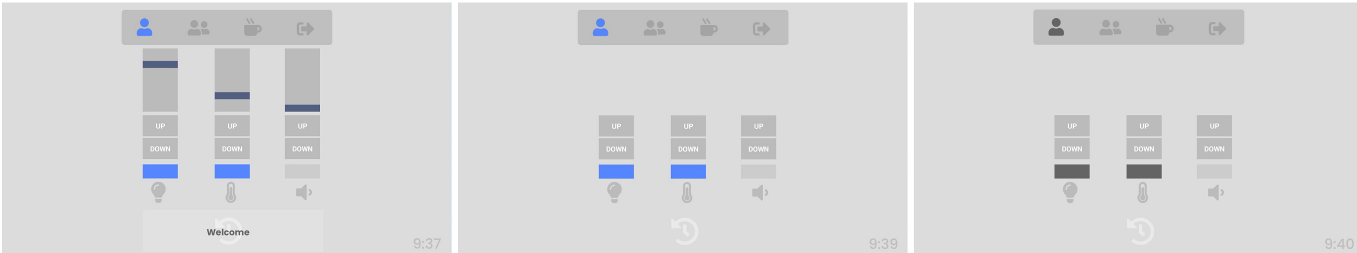

Figure 2. PII variations: Explicit interface variation, Peripheral interface variation, Implicit interface variation (from Left to Right).

button. Users are required to sense changes of the parameters in the environment around them. In this case the function of the intervention might also come down to common sense, a click on the intervention button will revert the system to its previous state. This is done whenever the system is about to or has changed to a workmode that is not preferred at the moment. The implicit interface gives the least information and challenges the user to get almost all information from the environment. The interface only shows the current workmode picked by the system and shows which parameters are active.

The most suitable variation might come down to a users personal preference, but there might be other factors that playing a significant role. Based on the background literature and related work it is hypothesized by the initial researcher that: users will prefer the explicit version in the first phase. This helps with getting a good understanding of the automated behaviour. When the system starts to become familiar to the user the high level of information on the explicit interface might become distracting in a work environment. The majority of users would prefer a peripheral interface with minimalistic information about the systems state. A slight few would understand or trust the system enough to operate it with the few essential controls of the implicit interface. This user acquires information about the system from the context.

USER STUDY SETUP

The authors of IIP acknowledge the need for a non-intrusive feedback loop in IoT systems that use IIP. This study aims to shed light on important aspects for the application of an Intervention User Interface in an IoT environment that uses a simplified version of IIP. Different levels of information are applied to three interface variations to examine the level of attentional demand and involvement preferred by the user (i.e. until what extend does the want to be involved in the loop?). Therefore, this research looks at what level of attentional demand (explicit, peripheral, implicit) is preferred by users when interacting with an Intervention User Interface in the Internet of Things smart office? And how does this influence their sense of control?

Participants and Setting

For this user study 16 participants were recruited (6 female) aged 17-53 (mean: 26,25, sd: 10,50). Testing was conducted in a lab setting where the participant would sit across the researcher. Each participant interacted with all three variations of PII in one continuous session. Every interface variation was experienced as a "sped up day at the office" where the user has to interact with the system. These "sped up days" were simulated with different tasks and scenarios that would be common during an office day. The user was able to adjust the environment with direct controls on the display. The autonomous behavior of the system was simulated by the researcher using the Wizard of Oz method [6].

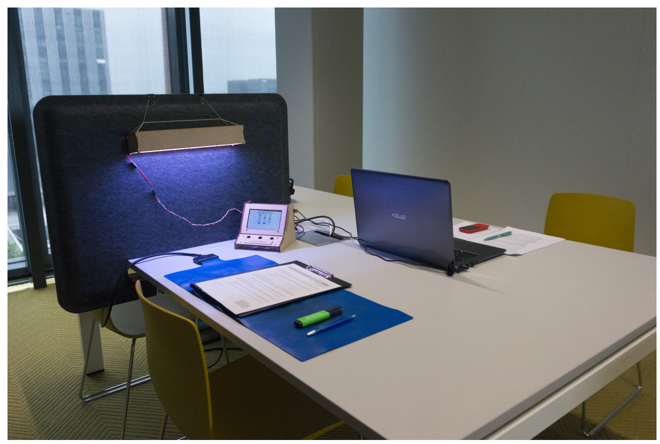

Figure 3. User study setup in lab setting. Blue area for the participant and the researcher on the other side of the table.

Materials

The variations for PII were realized in Processing programming environment. The laptop was used to run the Processing sketch and to control the autonomous behavior of the system (initiated by the researcher). The graphical user interface was casted on a smart phone that was docked in the PII prototype which was placed in the working environment of the participant. Allowing the participant to interact with the actuators in the environment. The dock enabled the user to interact with the interface that was running on the laptop. The dock contained a big space bar button that triggers an intervention, the intervention button. Making it easy and quick to use.

Adjusting parameters in the Processing sketch would send data to a Teensy that controlled different actuators in the environment. Light was emitted by multiple ledstrips that were positioned next to the participant. A heating mat was used to give the participants a more direct feedback about temperature changes. This was necessary due to the fairly short testing period, i.e., the user needs quick feedback to be able to detect change in such short periods of time. The heating mat was placed directly on the table surface, which also functioned as the working area for the participant. Music was played with the use of a Bluetooth speaker which was placed directly behind the small office divider, out of sight for the participant.

Procedure

Testing sessions were held with one participant at the time in a isolated room. The session contains three parts: introduction, main test and a semi-structured interview. First, the lab setting was introduced to the participants as their new office environment that strives to keep them as comfortable and productive as possible. A short introduction about the different parameters and workmodes follows. The researcher explains the simplified version of IIP and how the system will transition from one workmode to the next. Finally, the user is informed about the functionality of the intervention button and is invited to play around with the parameters, followed by a press on the intervention button to revert the system to the standard mode.

When the participant has a basic understanding of the system the main test starts. The user is presented with the first interface variation of PII and is guided through a series of scenarios to simulate a sped up office day. These scenarios revolve around the different workmodes the system switches to(in fixed order: focused working, break, co-working, out of office). The workmodes were enacted in the following manner; during focused working the user was asked to fill a background questionnaire and to read the Intervention User Interface article [17], during break the participant was asked to relax for moment and to share their thoughts on the current interface, during co-working the researcher functioned as co-worker who asked some questions about their answers on the questions, and as last the system switches to out of office; the system shuts down. After fully experiencing one interface the participant is asked to fill in a Likert scale questionnaire on a scale from strongly agree to strongly disagree to evaluate the interface (see Table 1 or appendix I for the statements). The same procedure is used for the remaining interfaces. The interfaces were given in random order and the participant experiences a specific scenario at least twice, both on a different interface to make sure every interface gets the same amount of interactions.

After the participant experienced all three variations of PII, a semi-structured was held. During the interview participants were asked to compare the interfaces on three main aspects: the level of information provided, how this affected their focus and how it influenced their sense of control.

Data analysis

This research used a heuristic approach to gather a wide range of insights on the implementation of previously purely theoretical concepts. As a result a wide variety of qualitative data was collected. Not all of which were analyzed, as the background questions primarily functioned as a task for participants that requires focused attention. The use of these background questions doubled as trigger to put participants in the right mindset to evaluate PII and how it might be an improvement on their previous experiences with IoT.

Likert scale evaluation

Number	*Statement*
1.	I was aware of what the system was doing
2.	I knew what the intervention button would do at every point in time
3.	The information provided was useful
4.	I felt in control of the system
5.	I was distracted by the interface
6.	Both occasional and regular users would like this interface
7.	It helps me with creating a pleasant work environment
8.	I can use it successfully every time
9.	It is pleasant to use
10.	I noticed when an intervention was occurring
11.	I understood the goals of the system
12.	I felt like I could guide the system to act the way I want it to

Table 1. Statements showed to the participants after experiencing a new interface variation. Possible answers were: Strongly agree, agree, neutral, disagree, strongly disagree.

The quantitative data obtained with the Likert scale evaluations were analyzed with Excel. The data is used to find a preferences in information levels used in PII's variations and to back-up statement derived from the interviews. Participants might not all be able to explain certain concerns, but the data from the Likert scales might help with spotting or conforming a common trend.

The interview recordings were transcribed in the original language (Dutch or English). A thematic analysis [4] was carried out to synthesize insights from participants, which are afterwards presented as a series of design rules. In some cases participants only answered without any substantial argumentation. Good responses with argumentation were used as quotes, in total 75 quotes were identified which were used to create themes. The themes are highly correlated, because most aspects have effects on other themes as well or might even be placed in both categories. The themes extracted from the interviews are as follows:

- *Distractions* (26 quotes): types of distractions that are or could possibly be created by PII or the environment. Subthemes consist of *disruptions, inviting for interaction, & unexpected behavior.*
- *Information* (30 quotes): types of information and the way information is presented. Subthemes consist of *direct feedback, intervention information, & layered information.*
- *Control* (13 quotes): specific functions available to the user and how control is distributed between user and system. Subthemes consist of *sense of control, distribution of control, & autonomy.*
- *Learning* (6 quotes): how learning impacts the user experience with PII.

Quotes presented in this paper are freely translated to English by the principal researcher (a native Dutch speaker).

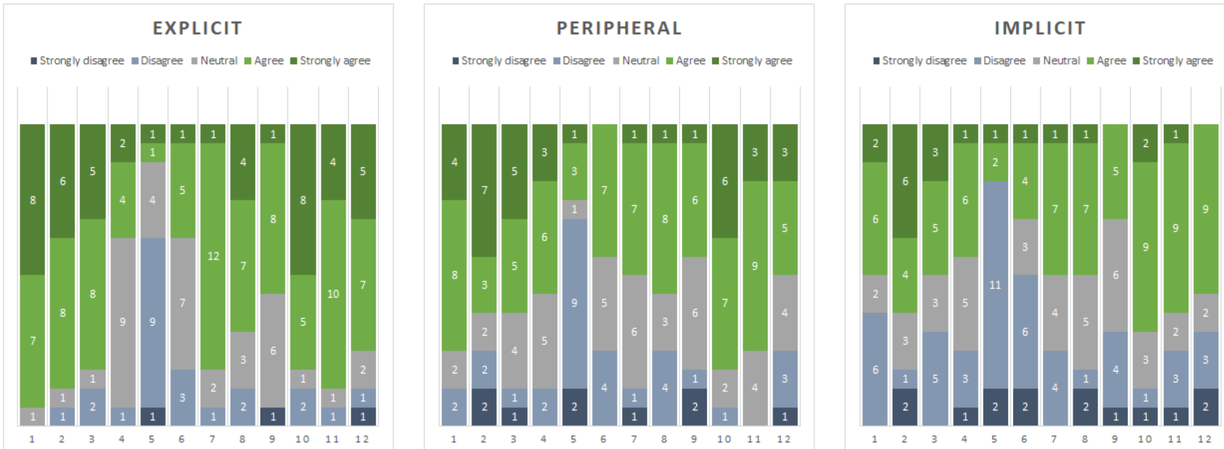

Figure 4. Results Likert scale evaluation: Explicit interface, Peripheral interface, Implicit interface (from Left to Right). Question number below, number of participant that answered one of the option of the answer inside the bar.

FINDINGS

Likert scale evaluation

To discover guidelines to help successful implementation of the intervention interface principle, this research presented three variations of PII. The Likert scale evaluations were used to sense the main preference of the participants. For every interface the Cronbach's alpha [5] has been calculated to estimate internal reliability of the Likert scale evaluation; values of alpha higher than 0.70 are considered acceptable. The result for the Cronbach's alpha for the explicit variation $\alpha = 0.73$, for the peripheral variation $\alpha = 0.88$ and for the implicit variation $\alpha = 0.81$. All results deemed acceptable, where the explicit variation shows the least internal consistency. This slight dissemination among participants is also recognized in the semi-structured interviews.

Overall, the data indicates that participants are most positive about the explicit variation (please note that disagreement with statement 5 is regarded as positive). Specifically looking at statement 1 & 5, it becomes apparent that with the explicit interface variation participants were more aware of what the system was doing without significantly affecting their focus. The explicit variation also shows a great improvement in understanding of the intervention button compared to the other two variations, which do not indicate any significant difference for statement 2. Results of statement 4 shows that any of the different variations do not have significant impact on the participants sense of control. However, increased levels of information do seem to improve the participants ability to use the interface successfully to create a pleasant work environment while having a good understanding of the systems goals and its behavior (statement 7 till 12).

Thematic analysis interviews

A semi-structured interview was used to gather participants opinions and thoughts on PII. In the interviews participants were asked to voice a preference for one specific interface variation with an explanation. Twelve participants (75% of the sample size) stated that the explicit variation is their favorite, mostly due to the informative nature of the interface. Two participants had a preference for the peripheral variation, one preferred the implicit variation and the single remaining participant disapproved the idea of an interface in their periphery while working: *"The idea of an interface in my working environment is awful for my concentration."* (p16).

Distractions

The implementation of an intervention interface should be calm and should easily move between the users center of attention to the periphery to be able to integrate seamlessly [18]. I.e., the interface should not be distracting. Participants identified a few instances where an Intervention User Interface might be distracting.

Disruptions

Disruptions created the most distractions for participants. The number one cause was the transition phase where the explicit and peripheral interface shows a blinking animation to indicate upcoming changes in the system: *"If I am working and I see the sliders go up and down, then yea I am distracted."*(p15) & *"I would generally prefer more information, but without a countdown or things that start blinking"* (p5). Complete removal of the transition information does however limit the users understanding of the system *"I did find the blinking distracting. [...] The second one [implicit variation] was the least distraction, but also was unclear."*(p8). The transitions can give information to the users to help their understanding, but still not all transitions are noticed: *"The blinking and stuff. I did not really notice it when I was reading the paper with focus."*(p1). One might argue that information that either distracts or goes unnoticed is useless: *"I do not think that you need the warning [transition animation]. You do not look at the screen when you are focused at work."* (p12). In some cases it helped the participant with preventing sudden changes in the system, but this already forces the user to partially lose their focus. Preferences seem to vary quite a bit between participants, especially with the explicit variation.

Inviting for interaction

Distractions might not always be caused by actions of the system. For some people the fact that there is something engage within their periphery already creates a distraction: *"The idea of an interface in my working environment is already bad for my concentration."* (p16). This temptation to interact might be an internal driver, but small alerts also give users a incentive to interact, even when this might not be necessary: *"The second one [explicit variation] with the alert. I had a small moment like: oh what is going on?"*(p15). Participants also feel an obligation to check the interface on a regular basis to spot transitions so that they could stop unwanted behavior from the system: *"The fact that I have to pay attention when it gives a new suggestion. [...] Then I have to check every 30 seconds or something."* (p2). This obligation might become tiring when having the interface nearby for long periods of time. Participants advocate for methods that shift the interaction initiative more to their side: *"Rather like WhatsApp or something, that I decide myself when to check it."*(p3).

Unexpected behavior

Distractions also occur when the users expectations and the behavior of the system do not match. Sudden decisions of the system result in users completely losing their focus: *"I have a hard time concentrating, so if I hear some music or something then I could press the intervention button but then I already lost my focus."*(p16). An intervention interface should not surprise the user with sudden changes: *"I found that the information about transitions demanded a lot of attention"*(p16). The transitions can be distracting, but prevent instances where the user is completely surprised.

Information

Information helps the user with understanding the system in order to co-operate with it. In an IoT environment information can be presented in numerous ways. For the scope of this research two main information sources are taken into consideration: information from the interface, and information from the environment (e.g., a user hears that the music starts playing which means the break workmode is initiated.). For automated systems a few points about informing seemed important during user studies.

Direct feedback

Users require direct feedback from the interface for their own input. Even though the environment directly implements the users input, users felt left in the dark with the two variations that did not show the impact of their input on the interface: *"I liked the first one [explicit variation] because I was able to see how high the levels were. The second one [implicit variation] when I had to turn up the temperature, I did not really know what I was doing."*(p13). Participants did not always know if their input had impact or if parameters already might be at their maximum: *"For sure the one with the sliders where I could see what the maximum was. [...] With other interfaces when I had to turn them on, I just pressed a lot and did not really know what I was doing."*(p14). The direct feedback participants get with the sliders helps them to feel reassured, which prevents major distraction: *"Interface number two [explicit variation] had the least negative effect on my focus. I was quickly reassured. [...] That is why it distracts the least."*(p9).

Intervention information

Some participants were hesitant with using the intervention button in certain cases. Additional information that explicitly states the function of the button helps with making users feeling reassured when using it: *"I liked the intervention button here because it said what clearly what it would do."*(p12). Participant were not always fully certain what the function would do. Only after using it several times the participant would use it without much hesitation, casually clicking the button when something changed that they did not like. The additional information lowers the bar for using the button with unfamiliar users: *"I liked it when the intervention button said what it would do. I did not always know what the previous settings were."*(p3). When using the intervention button the direct feedback also showed to be of importance. Seeing the parameters change on the interface reassures the user that the intervention has been registered: *"[...], when I did an intervention then I could see it having effect because the bars in the sliders change."*(p9).

Layered information

There seems to be a strong preference for highly informative interface, but participants also voiced concerns for information overload, where information might become redundant or distracting in general. The lower levels of information used by the peripheral and implicit variation were appreciated: *"On the other side, it is also nice when the screen does not contain much information."*(p2). Some participants did not mind the limited amount of information and described how they easily knew that the system was changing through the environment: *"Well, you feel the change anyway."*(p1). This was not the case for the majority of participants. A few had suggestions for other methods of communicating information. By keeping the screen dimmed when the information is not important: *"The same information is possible, but you could decide to let the screen dim during the focused work."*(p11); this suggestion also lowers the probability that user feels the need to interact with the interface. Or by communicating information through the environment, which makes the user aware in a less intrusive way: *"When you are then you do not really look at the screen. Then maybe something with a sound or something with the lights [talking about transitions]. There is no warning from the environment."*(p12).

Control

Creating a pleasant balance between user input and automation can be a difficult challenge. Results show different opinions about the types of control they want over a system such a PII.

Sense of control

The high level of information on the explicit interface has a big impact on the participants sense of control: *"The more information the more I felt in control"*(p4). The quick overview does not only help with reassuring the user, but it also contributes to their sense of control over the system. Changes are easy to spot and the user is less likely to hesitate about the actions taken by the system: *"I think that three [explicit interface] had the most effect on my sense of control, because you could see how high or low something was."*(p8). The distribution of control also affects the sense of control. Giving options to the system that are not available to the user might seem unfair: *" Yea the feedback did not really give me a feeling of control, because I could not decide where I was [current workmode]."*(p16).

Distribution of control

Participants were not always satisfied with the system calling the shots for the workmodes, sometimes users want to change workmodes themselves to quickly create a comfortable working environment: *"I would like shortcuts to the workingmodes"*(p11). In some cases going back to the previous working mode would not make sense in their situation: *"A button for every workmode is necessary. I do not always want to go back to the previous state. When I am working over hours then I want to focus instead of coworking."*(p9).

Autonomy

A significant amount of participants actually prefers the system to be autonomous, relieving them from tedious repetitive tasks: *" You also do not have to think when you are working. Like, I have to check if it is blinking. Purely the fact that it is autonomous and calm, that is what I like"*(p5). The majority trusts the system to do what it is designed to, as long as the system is as transparent as possible about the actions it is taking: *"I would have something like: the system does what it has to do, I trust it. The overview gives you a sense of control."*(p6). On this topic several participants stressed the importance of having functions similar to the intervention button, which allow the user to directly overrule system decisions: *"Yes, a system is allowed to be autonomous, but I do want an overview and the controls to overrule."*(p7). Users are not hesitant to stop the automated of the system as long as it is easy to do: *"If the system wants to do something then I would not have any empathic feelings. If the system wants something different then I do, then it is in bad luck. If necessary I will pull the plug."*(p1).

Learning

Learning and understanding the behavior of the system plays an important role in the implementation of Intervention User Interfaces. Participants had trouble when interacting with the system for the first time: *"The first time you have to get used to the system and you try to understand it."*(p6). Participants operate the system easier with less information when they start to get to know the system: *"I think it depends on the learning curve, that I knew what it would do."*(p3). The explicit information does however play an important with better understanding and getting to know the system: *"The third one did not say what the intervention button would do, but I had expectations because of the two previous interfaces. If I would have seen it for the first time, then I would not have a clue."*(p9). Participants did voice concerns about the redundancies possibly involved when the system still is very informative: *"It might be annoying to receive a lot of information on a long term basis."*(p1). Most information might not be necessary when you know the system well.

DESIGN PRINCIPLES

The findings of this research are shaped in a way that they become useful and applicable for researcher and practitioners, similar to the design principles presented in the Intervention User Interface article [17] this paper presents its own addition of design principles for designing Intervention User Interface for IoT.

The Design Principles

- *Only inform users with the essential automated decisions.* Users want to limit distractions as much as possible. Only the most important information has to be communicated to the user. This has to be done in a non-intrusive manner. Otherwise informing the user is just as distracting as executing the automation without first consulting the user.
- *Use the IoT environment to inform the user about the systems state in non-intrusive ways.* Users acknowledge there ability to sense changes in the environment and advocate for ways to let the environment inform them. Using the environment in creative ways to signal can help the user with being subconsciously aware of what the system is doing.
- *Allow the user to access additional information if necessary.* There are instances where users want more information than the interface currently supplies. Keep the screen clean for general use and prevent creating distractions, but allow users to access additional information when initiating an interaction with the system themselves. This provides transparency and helps new users with understanding the system.
- *Give direct explicit feedback for interactions initiated by the user.* Information must be kept to a minimal, except for interactions initiated by the user. The user needs quick feedback to know if their interaction had any effect on the system.
- *Do not invite for interaction. However, keep the barrier to do so low.* Users see interfaces in their periphery as easy distractions. Playing around with settings can be tempting when it is within arms reach. Prevent any unnecessary interactions by making the interface less tempting to use, but keep the barrier to interact low when users want to intervene unwanted automated behavior.
- *Give users the same controls the system has.* Users demand equal rights and functionality for man and machine. Systems are possibly better at making complex decisions, but allow users to do the same. Knowing that the system has certain functionality that is not accessible for users can create frustrations.

Limitations

This research looked at possible ways new concepts like IIP and the Intervention User Interface principle could be implemented. This study used a heuristic approach to create new insights on these topics. This approach does have its limitations in terms of generalizability.

First being the environment in which the concepts are applied: the smart office. The researcher picked this settings, because it is a fairly structured environment that allows potential users to have an interface in their periphery. The fact that only three parameters are implemented in a environment with a clear structure makes it easy to test and to recreate the setting. However, everyday implementation of IoT might be chaotic and unstructured. Opinions on the topics might change when the complexity of the environment and the system increases.

In this study the PII only controls a small system that only directly involves the user of the interface. Implementation of Intervention User Interfaces in larger shared systems might also influence opinions about systems like PII due to the social aspects of shared systems. In this research the user only interacts with the system. Involving social interactions increases the complexity significantly, as is seen in the work of Niemantsverdriet [15].

Testing sessions were no longer than 45 minutes. Therefore, insights can only be considered as insights for new users. Some participants already voiced concerns about the problems frequent users might experience with the system. However, this is only speculation since one can only really tell after long-term deployment of the system.

Future research

This study looks into the first implementation of the Intervention User Interface and at the important aspects to take in consideration when designing such a system. Now that there is more known about good ways of implementing such an interface it becomes obvious to look into the real impact the concept has when compared to regular interfaces.

Future research could create a comparative set-up where systems with and without Intervention User Interface principles are compared. This could create clearer insights on aspects such as the amount of positive effect an Intervention User Interface has on the users sense of control.

Some participants already voiced some concern about long-term usage of such a system. Future research can look into the long-term effects of intervention interfaces. With learning system there might be an possibility that the intervention button might become nearly obsolete when the system starts to learn and operates without making significant mistakes. It could be that the interface would only functions as something that gives the user a sense of control or peace of mind.

CONCLUSION

This research shows first implementations of the Intervention User Interface principle. The research focused on the preferred attentional demand by users and how this affects their sense of control. The user study has shown that users prefer highly informative interfaces. This helps them with feeling reassured and letting go control of the system. Different levels of information or attentional demand did not have a significant effect on the user sense of control. In addition, this research gathered a set of design principles that can be used by researchers and practitioners for further research on or implementation of Intervention User Interfaces.

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REFERENCES

[1] Saleema Amershi, Maya Cakmak, William Bradley Knox, and Todd Kulesza. 2014. Power to the people: The role of humans in interactive machine learning. *AI Magazine* 35, 4 (2014), 105–120.

[2] Saskia Bakker and Karin Niemantsverdriet. 2016. The interaction-attention continuum: considering various levels of human attention in interaction design. *International Journal of Design* 10, 2 (2016), 1–14.

[3] Nazmiye Balta-Ozkan, Rosemary Davidson, Martha Bicket, and Lorraine Whitmarsh. 2013. Social barriers to the adoption of smart homes. *Energy Policy* 63 (2013), 363–374.

[4] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative research in psychology* 3, 2 (2006), 77–101.

[5] Lee J. Cronbach. 1951. Coefficient alpha and the internal structure of tests. *Psychometrika* 16, 3 (01 Sep 1951), 297–334. DOI:http://dx.doi.org/10.1007/BF02310555

[6] Nils Dahlbäck, Arne Jönsson, and Lars Ahrenberg. 1993. Wizard of Oz studiesâĂŤwhy and how. *Knowledge-based systems* 6, 4 (1993), 258–266.

[7] W. Keith Edwards and Rebecca E. Grinter. 2001. At Home with Ubiquitous Computing: Seven Challenges. In *Ubicomp 2001: Ubiquitous Computing*, Gregory D. Abowd, Barry Brumitt, and Steven Shafer (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 256–272.

[8] D Evans. 2011. The Internet of Things: How the Next Evolution of the Internet is Changing Everything. *Cisco Internet Business Solutions Group (IBSG)* 1 (01 2011), 1–11.

[9] Mathias Funk, Lin-Lin Chen, Shao-Wen Yang, and Yen-Kuang Chen. 2018. Addressing the need to capture scenarios, intentions and preferences: Interactive intentional programming in the smart home. *International Journal of Design* 12, 1 (2018), 53–66.

[10] Doris Hausen, Sebastian Boring, Clara Lueling, Simone Rodestock, and Andreas Butz. 2012. StaTube: Facilitating State Management in Instant Messaging Systems. In *Proceedings of the Sixth International Conference on Tangible, Embedded and Embodied Interaction (TEI '12)*. ACM, New York, NY, USA, 283–290. DOI: http://dx.doi.org/10.1145/2148131.2148191

[11] Wendy Ju, Brian A. Lee, and Scott R. Klemmer. 2008. Range: Exploring Implicit Interaction Through Electronic Whiteboard Design. In *Proceedings of the*

2008 ACM Conference on Computer Supported Cooperative Work (CSCW '08). ACM, New York, NY, USA, 17–26. DOI: http://dx.doi.org/10.1145/1460563.1460569

[12] Wendy Ju and Larry Leifer. 2008. The design of implicit interactions: Making interactive systems less obnoxious. *Design Issues* 24, 3 (2008), 72–84.

[13] T. Kymäläinen, E. Kaasinen, M. Aikala, J. Hakulinen, T. Heimonen, H. Paunonen, J. Ruotsalainen, L. Lehtikunnas, and P. Mannonen. 2016. Evaluating Future Automation Work in Process Plants with an Experience-Driven Science Fiction Prototype. In *2016 12th International Conference on Intelligent Environments (IE)*. IEEE, London, UK, 54–61. DOI: http://dx.doi.org/10.1109/IE.2016.17

[14] Sarah Mennicken and Elaine M. Huang. 2012. Hacking the Natural Habitat: An In-the-Wild Study of Smart Homes, Their Development, and the People Who Live in Them. In *Pervasive Computing*, Judy Kay, Paul Lukowicz, Hideyuki Tokuda, Patrick Olivier, and Antonio Krüger (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 143–160.

[15] K. Niemantsverdriet. 2018. *Designing interactions with shared systems*. Ph.D. Dissertation. Department of Industrial Design. Proefschrift.

[16] Judith Rodin and Ellen J Langer. 1977. Long-term effects of a control-relevant intervention with the institutionalized aged. *Journal of personality and social psychology* 35, 12 (1977), 897.

[17] Albrecht Schmidt and Thomas Herrmann. 2017. Intervention user interfaces: a new interaction paradigm for automated systems. *interactions* 24, 5 (2017), 40–45.

[18] Mark Weiser and John Seely Brown. 1996. Designing calm technology. *PowerGrid Journal* 1, 1 (1996), 75–85.

APPENDIX I - QUESTIONNAIRES USER STUDY

Background Questionnaire

Gender: M/F

Age:

1. What methods do you use to keep your working environment as product?
2. What kind of distractions cause you to lose focus during work? Do you think that automation could help with eliminating these distractions?
3. Do you have any prior experiences with Internet of Things systems? If yes, what aspects do you like about the system and what aspects do you dislike?
4. Do you trust technology to operate autonomously or should an Internet of Things systems only operate on the user's explicit command?

Likert scale evaluation

1. I was aware of what the system was doing
2. I knew what the intervention button would do at every point in time
3. The information provided was useful
4. I felt in control of the system
5. I was distracted by the interface
6. Both occasional and regular users would like this interface
7. It helps me with creating a pleasant work environment
8. I can use it successfully every time
9. It is pleasant to use
10. I noticed when an intervention was occurring
11. I understood the goals of the system
12. I felt like I could guide the system to act the way I want it to

Semi-structured interview

- Did the different interfaces inform you sufficiently?
- How did the different interfaces influence your focus?
- How did the different interfaces influence your sense of control?
- Do you have a preference for one of the interfaces?
- How did you experience the different working modes?
- Would you prefer different interfaces for every working mode?

APPENDIX II - REFLECTION

This was the first full research I ever did, so there was a lot of exploration happening during the course of this semester. While feeling lost at certain times, I do think I made great improvements on my ability to do research. There would be a lot that I would do differently when I do my next research. The process would have a lot more structure which would enable me to do more in less time.

One of the first things that involved a lot of struggling was the academic exploration of a certain field at the start of my research. Not fully knowing what to look for and how to gather information in a structured manner. My approach was something like this: I went to read a paper that seemed interesting and went after sources it referenced. If found any of the sources are referenced topics interesting then I would start reading those papers. When looking back at it in hindsight it is obvious that this process is way to slow. It might possibly cause you to miss a lot of interesting information. While progressing through the research the importance of creating a good reference frame became apparent. In future research I would create this reference frame in a lean way: only reading abstracts and conclusions of papers and categorizing these in an excel. This way it will quickly help me with having a good overview and knowing which areas are interesting and which are not. Additionally, the overview of papers will help me with quickly finding related work in the area that I am looking for. It would have saved me a lot of time if I would have been more selective in deciding what papers to read and which not.

That brings me to the next point: creating a good scope for the research. The scope shifted a lot during the research and only became more structured when there was a prototype which made it hard to shift to something else and forced me to stick with what I have. First of all, I think having the better reference frame will help a lot with creating a good scope, so solving the previous probably would already go a long way. Secondly, dedicating to one really specific area will help with constructing the right scope around it. I learned that it is almost impossible to really only test one thing, but it is good to focus on just one specific aspect of the testing. I tried to do to much with too little time. A narrow scope would have saved me from doing unnecessary work that I did while using a more heuristic approach. Furthermore, I became a lot better at finding the right academic material which will help with finding the right information for the scope in future research projects.

One major aspect that I missed in this project was the collaboration with others. Personally, I get a lot of ideas and creativity by debating topics and discussing ideas. Doing this research individually held back a lot of progress and inspiration that I generally would get from having other people involved in the project. However, during my research I started to develop a method that made up for a big portion of this lack. I started to use a journal that I used to "debate" with my own thoughts. Writing down interesting findings, question, and sources of academic information to support claims or answer questions. The method was far from perfect, but did speed up my thinking and creative process. It helped a lot with structuring thoughts and staying on track. With some improvements it might have great opportunity for future projects and research.

In the research there was the opportunity to work on my personal development goals. I wanted to improve on my coding skills, which actually went pretty well. There are however some improvements that I could implement when prototyping with code for future research and projects. Some limitations of the code that I wrote only became known at the end. These problems with the code forced me to spend a lot of time on workarounds to finally make it work. In future projects a more structured approach could prevent these problems. For the next time a plan with clear milestones and intermediate testing moments will be useful to prevent sudden surprises. The milestones will help with creating a good focus on certain aspects of the code and the intermediate testing moments makes sure that the code still operates the way it was intended to. This testing was done in this project, but without clear goals and small shortcuts were used to test it quickly. If the first test was done with a full setup then it would become apparent that the used library might not have been the best option. However, these might also just be aspects that come with experience, knowing what to look for when you are writing code.

In conclusions, I think that I experienced a very steep learning curve during this research. I spotted a lot of little flaws in my approach that would otherwise have spared me a lot of time. The start was somewhat chaotic but I created methods to create more structure in my approach. I feel confident that my next research will be a lot more effective. I look forward to the apply what I learned in my next research.