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Ambient Interfaces that Rely on Peripheral Information

An, P., Bakker, S., Ordanovski, S., Taconis, R., Paffen, C. L. E., & Eggen, B. (2019). Unobtrusively Enhancing Reflection-in-Action of Teachers through Spatially Distributed Ambient Information. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 1–14. https://doi.org/10.1145/3290605.3300321

This paper studies an ambient information system for secondary school teachers to use while teaching so they can know how they have spent their time and attention across students in their classroom. The goal of the paper was to study how to facilitate teacher's reflection in action, a significant skill for teachers to develop that helps optimize teaching behaviors in the moment, through using an ambient information system. The data in the study came from a field study of 11 teachers across 22 class periods. The ambient information system was called ClassBeacons and consisted of small lamps on the desk of each student group or pair. The lamps would change colors from yellow to green to show teachers information about who they have been spending their attention on. If the teacher has been around a student a lot then their lamp would turn green. To track the teacher's position a decimeter-level in-door tracking kit was used. They found Classbeacons helped transform teachers' proximity and helped promote learner-centered pedagogy. Teachers liked that they did not have to read anything while teaching but could instead glance at the lights and see where they needed to be. Further studies should not rely on teacher recall to study reflective behavior but should combine measures such as eye-tracking and cognitive load assessment. A limitation of the study was the size of the proximity tracker the teacher had to wear, which should be made smaller and less obstructive in future studies. Another suggestion teachers made for future studies is to be able to see attention distribution over students across multiple lessons, instead of just one class period. This is a high quality source, but I hope to utilize ambient systems in more creative ways than lights that illustrate time spent in the area.. This is of interest to my research because displays like this could be used to communicate other information, like maybe how much of a book or a reading still needs to be completed. If these beacons were located in busy areas of the home, they could act as motivators to complete tasks. Of interest to my work is possibly the projection of text, for instance important words related to my research so that they are always in my head increasing the likelihood a great idea might come to me while awake or asleep.

Cabral Guerra, M., Kommers, D., Bakker, S., An, P., Van Pul, C., & Andriessen, P. (2019). Beepless: Using Peripheral Interaction in an Intensive Care Setting. *Proceedings of the 2019 on Designing Interactive Systems Conference*, 607–620. https://doi.org/10.1145/3322276.3323696

The paper proposes a new form of interaction between nurses and clinical alarm systems that interact through the periphery of attention. In many intensive care units nurses are overexposed

to alarms. Alarms can also affect patients, especially if they are already in a fragile state. The paper uses a pictorial to present peripheral interaction being introduced in a neonatal intensive care unit to reduce the occurrence and duration of alarms. The study was conducted in the NICU of Maxima Medical Center. Peripheral interactions fit in this situation because they can enhance users' use of the interfaces to become secondary tasks while users are engaged in their primary tasks. They first conducted an ethnographic study using semi-structured interviews with nurses, biomedical engineers, doctors, and clinical psychiatrists at the site to identify where peripheral interactions could best be applied. Then they did a focus group with seven nurses to validate their concerns with the system currently in place. Then they deployed a prototype in an anonymous hospital for a week. It was found that some alarms in the NICU like "low battery" and "out of water" could be prevented if the nurse was informed remotely in a timely manner. A water supply indicator was developed that gradually changes color as the water level decreases. When the water supply is close to being out the light will begin blinking. If it becomes critical, the light will blink and an alarm will sound. Another design was the beepless pedal developed because the study found that 25% of critical alarms happened while the nurse was in the room because of a movement the nurse made that disconnected wires or a machine. The pedal could be used to silence the alarm process. They suggest more HCI research regarding nurses' routines. Also, further studies should be done to increase the sample size and the time-frame of the usability tests. This study is a good source to cover the medical side of ambient and peripheral displays, but I think these ideas could be built into bigger and better systems. This study is also of interest to my research because it pairs well with the ambient lights in the ClassBeacons article, showing lighting as a major player in this field. I think there a more applications than just lights to contribute to effective peripheral and ambient systems.

Colley, A., Raudanjoki, Ö., Mikkonen, K., & Häkkilä, J. (2019). Plant shadow morphing as a peripheral display. *Proceedings of the 18th International Conference on Mobile and Ubiquitous Multimedia*, 1–5. https://doi.org/10.1145/3365610.3368410

This paper is about manipulating the natural shadows produced by houseplants to display ambient information. They used back projection onto a screen that was made to look like a wall. A lamp was added to make it seem like the shadow was naturally cast. They conducted an exploratory study with 6 participants in a focus group. Participants were asked to think aloud during the study and then participated in a discussion and filled out individual questionnaires. There were 6 static images and 2 animated images of the plant shadow. The static shadows were manipulated to show a bee, to have the leaves droop, to be blown by the wind, to be spikier looking, and others. The bee on the plant shadow did not result in a common interpretation. The drooping plant shadow was connected to it or the user needing water. The animated images changed the size of the plant and the sharpness of the plant's shadow. The animated images were said to be more visible by participants and related to concepts like an appointment coming closer and progress in some area of their lives. The participants were interested in the shadows but felt the psychological effect could be negative for pets, children, or the elderly. Participants were concerned that an unnatural shadow would distort their reality over the long term. Other participants said it could be useful to act as reminders for things, but they would want to know what they were being reminded of and not want to think hard to figure out what it was trying to communicate to them after working all day. A limitation was that the participants were also not able to link abstract meanings to the shadow visualizations, always keeping the meaning linked

to the plant that was displaying the shadow. This study could have been organized better and used a bigger sample size. I think they should have had more easily interpretable shadows so the users could make better sense of them. Or, better instructions and explanations could have been given beforehand. This paper is of interest to my research because it uses domestic objects to display information. I am interested in how one might connect an abstract concept to a shadow, and if this might be a very subjective thing, like interpreting symbols in dreams. If an abstract connection could be made with the object, might the projection be much more helpful in communicating messages? There are so many shadows in every home and they change with the time of day. I think it is a fascinating area to try and place ambient information, especially when light seems to be a common aspect of ambient design.

Hausen, D., Tabard, A., Von Thermann, A., Holzner, K., & Butz, A. (2014). Evaluating peripheral interaction. *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction*, 21–28. https://doi.org/10.1145/2540930.2540941

This paper proposes an experimental method for the evaluation of peripheral interaction in early design phases. Digital devices require us to use an all or nothing approach instead of allowing interactions like singing while we cook, talking while we walk, and drinking while we read. They conducted a case study based on in-situ deployment. They presented an event-based task in parallel to an artificial peripheral task. Participants had to input a number on a keypad corresponding to the specific combination of shape and color. The participants were then invited to a group discussion. Participants were stressed or bored with the activity, so a continuous primary task was then developed and tested where participants had to click to remove shapes of a certain color displayed on a sidebar window. When all items were removed a new round would start immediately. Then they conducted a case study comparing the field and the lab. The case study involved participants controlling an audio player by carrying out simple commands while keeping focus on a primary task. The peripheral controls were graspable, touch, freehand, and media keys. They observed more errors in the primary task and the peripheral task with experienced users, but this was thought to be because they were involved with the in-situ testing they developed sloppier interaction methods. In the lab tests they found more usability issues. They had a technical limitation in the tracking of freehand gestures and misinterpretation of short gestures for the study. They feel their study enriched the number of evaluation methods available to designers of peripheral interaction. They concluded preliminary lab experiments will enable more successful field deployments of peripheral interaction interfaces. This paper was a little dense but seemed to provide a rigorous method of evaluation that could be applied to other ambient and peripheral interfaces. This is of interest to my research because I am interested in multitasking and peripheral interaction, specifically how we can engage with multiple interfaces at once. This article lays out a strong evaluation method and models the type of tasks I should be designing in my own research using primary and secondary tasks.

Kunze, A., Summerskill, S. J., Marshall, R., & Filtness, A. J. (2019). Conveying Uncertainties Using Peripheral Awareness Displays in the Context of Automated Driving. *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, 329–341. https://doi.org/10.1145/3342197.3344537

This paper develops a new system to alert drivers of automated cars that they need to take back control of the vehicle. Previous systems relied on instrument clusters in the dashboard to deliver this information which increased the workload of the driver and their possibility to miss signals. A peripheral awareness display can be a means of presenting information to car operators without requiring them to switch their gaze between several areas in the car. Peripheral display is a term used for interfaces that are not within the user's primary focus of attention and that function as a tool for communicating information about a secondary activity of a user. An initial prototype was designed with four levels of increasing uncertainty. The levels of uncertainty are communicated through vibration motors in the bolster, seat pan, and back rest. Changes in color were used in addition to the vibration feedback. The study was conducted in a driving simulator. 24 participants took part with an average age of 27. Fog was used as an indicator of uncertainty in the automated car. The independent variable was display type. After each scenario the participants were asked to fill out a questionnaire. Then semi-structured interviews were conducted following the completion of both scenarios. They found that when using the peripheral awareness display safe driving performance improved. One of the limitations was that the study only dealt with the uncertainty of fog density. Another of the limitations was the sample size. This is a strong source to represent the automotive area of ambient interfaces. This study is of interest to my research because one of the interfaces I am developing is an interactive music player that fits on the steering wheel and forces the user to keep their hands on the steering wheel and tap the beat to make music play through the car radio. I had imagined something like this to be useful in autonomous cars to keep users' attention on the car and on the road, hoping to have another place to provide haptic feedback and peripheral alerts as well.

Matthies, D. J. C., Urban, B., Wolf, K., & Schmidt, A. (2019). Reflexive Interaction: Extending the concept of Peripheral Interaction. *Proceedings of the 31st Australian Conference on Human-Computer-Interaction*, 266–278. https://doi.org/10.1145/3369457.3369478

This paper introduces the idea of Reflexive Interaction, an extension of the idea of Peripheral Interaction. Reflexive Interaction is when a short secondary task is executed using interactions shorter than microinteractions without straining the user's attention. They classify HCI into three general classes: focused interaction, peripheral interaction, and implicit interaction. Reflexive interaction is a subcategory of peripheral interaction. A reflexive interaction is enabled because humans can complete tasks with divided attention. Reflexive interactions may occur subconsciously and do not allow interruptions to the user's primary task. They give the example of a person riding a bike and getting a call. The system would analyze the context and choose the body part that is not yet occupied with another task to alert to the phone call. The notification would be just noticeable and would not interrupt the current sequence of actions. The limitations of reflexive interaction are that it may only be enabled with feedback and input no greater than 2 bits. Another limitation is extensive training is needed until the task is conditioned enough to enable performance of more complex tasks, like turning on a car's blinker while driving. The paper describes natural reflexes, primitive reflexes, and myotic reflexes. The paper also describes two types of multitasking, sequential and concurrent. The paper then presents an elementary taxonomy of the historical development in HCI based on user's attention. Then there is the helpful classification of interaction concepts into a 12-attribute taxonomy and how they relate to focused interaction, peripheral interaction, reflexive interaction, and implicit interaction. The 12-attribute categories are: task complexity, attention and cognitive load, interaction time,

multitasking, task order, training required, awareness and consciousness, interaction modalities, feedback, trigger, context dependency, and technical requirements. They recommend greater research on the optimal number of assigned input gestures that can be internalized while still enabling reflexive interaction. This is an important source because of the discussion of subconscious peripheral interactions, what my original topic was aimed at for this research paper. The aspects about amount of data reflexive interactions can handle will be helpful for me deciding which projects to focus on in the paper. I am also very interested in automatic actions we perform daily and want to harness that space for interaction with information of some kind.

Raudanjoki, Ö., Häkkilä, J., Hurtig, K., & Colley, A. (2020). Perceptions of human shadow manipulation as an ambient display. *Proceedings of the 9TH ACM International Symposium on Pervasive Displays*, 71–77. https://doi.org/10.1145/3393712.3395180

This article uses human shadows as ambient information displays. They created artificial human shadows and conducted a study on users. Ambient information displays deliver information through the periphery of human attention. The human shadow display is created using projection rather than using AR. The researchers chose to use shadows because humans are naturally aware of shadows. Shadows have been used as themes in art for centuries. They performed an exploratory study on user perception and design requirements of using shadows. They used a back projection with a short-throw projector in a cafeteria setting. The study used two participants at a time seated at a small table. The shadow of an actor was projected in 6 static and 2 animated shadows. The shadow would pick up a book, become surrounded by spikes, change into bubbles, take a coffee cup and drink from it, and sit still. Participants sat at a table near the shadow and were asked about what they saw and how they perceived it. The participants were encouraged to think out loud during the study and were given a questionnaire at the end. 12 participants in total took part. Many participants did not take notice of the shadow when they first entered the setting. The movements of the shadow were reported to be unnatural and asynchronous. The shadow was also seen to be an instructor as participants would mimic what the shadow was doing. Generally positive feelings were reported by the participants. Unnaturally modified shadows provoked the strongest reactions, including laughter and surprise. The researchers felt they were limited by the location and the quality of the animations of the shadows. This paper is of interest to my research because participants felt the need to follow the shadow, especially if the shadow projected was of themselves as part of the mirroring effect. I wonder if shadows could somehow be applied to my domestic installations to encourage better habits or allow yourself to study harder because your shadow self is studying too. There are also interesting splits here where your shadow could be projected studying in your peripheral vision when you are watching TV. Would this make you feel like you were still learning? Could this make you feel more prepared for a test? These are the type of peripheral applications I am interested in.

Shelton, B., & Nesbitt, K. (2016). The aesthetic awareness display: A new design pattern for ambient information systems. *Proceedings of the Australasian Computer Science Week Multiconference*, 1–10. https://doi.org/10.1145/2843043.2843371

This paper provides a narrative review of developments of Ambient Information Systems since 1996. They discuss key design features and categorize 36 Ambient Information Systems in an existing design taxonomy of design patterns. They list four common definitions for Ambient Information Systems in a table. Some of the Ambient Information Systems they discuss are Informative Art displays, Digital Family Portraits, Ambient Mirrors, Tangible Bits, Invisible Displays, and Virtual Paintings. They next discuss Tangible Ambient Information Systems, displays that use physical media in order to deliver peripheral information to the user. Then they go over the development and terms used for different levels of ambience from 2002 to 2010. They discuss the Ames and Dey design taxonomy for Ambient Information Systems which provides great definitions and ways of looking at designing for these systems. The paper then discusses the four design dimensions of information capacity, notification level, representational fidelity, and aesthetic emphasis. Multiple tables are then presented with past ambient systems and which of the four design dimensions they fit in. This paper provides a great overview of the history of Ambient Information System design. They also discuss some work which falls outside of the taxonomies they for instance Sculptural Symbolic displays and Multiple Information consolidators. A limitation of their research was that they used implemented systems from the domain of IT and would like to expand to a more systematic review of areas like psychology and peripheral displays. This paper provides an excellent foundation for the area I am researching. I can at the very least use it to direct me to some designs that interest me to include in the final paper. I can attempt to apply some of the newer work to the taxonomies they suggest as well. (I can't remember if you said we could use other literature reviews. That is why I included 9 papers instead of 8.)

Thompson, E., Potts, D., Hardy, J., Porter, B., & Houben, S. (2021). AmbiDots: An Ambient Interface to Mediate Casual Social Settings through Peripheral Interaction. *33rd Australian Conference on Human-Computer Interaction*, 99–110. https://doi.org/10.1145/3520495.3520504

This paper focuses on the design and implementation of AmbiDots for use in casual social interactions. AmbiDots is meant to be a playful interactive system that helps mediate conversation and social interactions in settings like bars, cafes, and restaurants. Most early ambient systems focused on output with little to no interactivity. Of interest in the AmbiDots design was to elicit emotions from users rather than productive ends. AmbiDots uses a visual language of ambiguously behaving colored dots in a dynamic interface that responds to motion and objects by being projected on a flat surface. To gain feedback they had a formative workshop with a non-interactive prototype in a controlled laboratory environment where participants took part individually. From the workshop they found that participants expected to interact with the system by using their hands, they expected dots to be attracted to objects and repelled by motion, and that the dots seemed to be pre-programmed rather than agent driven. They used Computer Vision to recognize objects and motions within the interaction space. The reactions would be altered behaviors of the dots. Each dot had character defining variables: purple was excited and fast moving, yellow was curious and moderate moving, cyan was shy and slow moving, and green was normal and moderate moving. They conducted an exploratory user study to reveal insights about the effect that ambiguous ambient systems have on users in casual social settings. 22 participants were involved in the pseudo-social study environment of a semi-public shared office building. The trials lasted 10-12 minutes. The data was collected through

questionnaire and unstructured interview. Overall, the response was positive to the trial experience. Another key finding was that the participants found it relaxing. Participants also felt that AmbiDots were a conversational aid. Another common theme across the data was a sense of intrigue and interest. Some participants thought the dots were not engaging. Overall, they found that AmbiDots did not hinder conversation and many participants claimed it improved their social experience. The limitations were that this was a pseudo-social environment and should be attempted in a field study. The study aids my research in that it focuses on affective components of the experience, an area not mentioned in any of the other papers. I lately have been considering if many of my ideas about learning and reading through peripheral interactions have any merit. If not, an affective approach to these interfaces would be the next route to pursuing similar work.