Share and Share Alike? Social Information and Interaction Style in Coordination of Shared Use

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ABSTRACT

Interfaces are commonly designed from the perspective of individual users, even though most of the systems we use in everyday life are in fact *shared*. We argue that more attention is needed for system sharing, especially because interfaces are known to influence coordination of shared use. In this work, we aim to deepen the understanding of this relation. To do so, we design three interfaces for a shared lighting system that vary in the type of social information they allow people to share with others and in their overall interaction style. We systematically compare longitudinal and real-life use of the interfaces, evaluating (1) people's appraisal of three types of social information and (2) the influence of an interaction style on coordination of shared use. The results disclose relations between the interface and the amount of *verbal communication*, *consideration*, and *accountability*. With this work, we urge the need for interaction designers to consider shared use.

Author Keywords

Shared Use; Multi-user Interaction; Interaction Design; Awareness; Social Translucence; Connected lighting.

ACM Classification Keywords

H.5.2 User Interfaces, *Theory and methods* / *User-centered design*; H.1.2 User/Machine Systems, *Human factors*.

INTRODUCTION

With IoT developments catching on, our everyday systems are changing. Dynamic connections to different input and output devices, integration in the environment, and detailed personal control result in systems becoming more often *shared* since an interaction by one person can have an impact on other people. For example, if one person switches off the light, everyone else in the room will be sitting in the dark. It seems that interaction designers of contemporary IoT systems do not always recognize this shared use. Current interfaces mostly emphasize the individual, with personal pre-sets and profiles in mobile

phone applications. This is perhaps not surprising. Although much attention has been given to systems that are shared as part of their functionality – think of collaboration (e.g., [48,57]) and communication systems (e.g., [29,39]), playful interactions and games (e.g., [21,37]), or devices that aim to increase social connectedness (e.g., [27,43]) – the shared nature of IoT systems can be more difficult to recognize. Turning on the light or heating, or changing a music playlist, are examples where systems are shared as a consequence of their shared context, instead of as part of their functionality.

In consequential shared use, it can also be expected that the design of the interface influences coordination of sharing, as stressed in ethnographic research on home technology sharing (e.g., [4,19,20]): “*developers need to consider whether or not the technology they are developing should support sharing.*” [4:125]. In order to support designers in doing so, we require a better understanding of the social dynamics around coordination and the role of the interface in this process: how do people communicate in order to align use, to avoid conflict, and to act in compliance with the social context in everyday shared settings?

To investigate such questions, we compare shared use of three interfaces for a lighting system (figure 1). The interfaces vary on two aspects: their overall *interaction style* and the *type of social information* they allow people to share amongst each other. Firstly, since interface

Figure 1. Three interfaces for a shared lighting system used in this study: (A) the Floorplan application; (B) the Pointer remote control; and (C) the tangible Canvas interface.

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characteristics can affect shared use – even if perhaps not intentionally designed to do so – the interfaces vary on *distribution* and *modality* to represent three commonly-implemented interaction styles: a smartphone application, a remote control, and a tangible wall-mounted interface. Secondly, the interfaces allow people to share different types of social information to others: *intention*, *authorship*, and *preference*. Information is at the basis of any human interaction with an environment or system: people retrieve information from their environment, which modifies people’s awareness of that environment in order to direct further exploration or interaction [25,50]. Having awareness of other people thus lays at the basis of social behavior [6,25,59] and allows people to coordinate actions amongst each other. Research on collaborative work and social information sharing shows that interfaces can increase this social awareness by allowing people to share social information [17,25]. We are interested in whether social information in the interface can aid consequential shared use as well, and we specifically look at how the different types of social information are used and appraised.

In this paper, we systematically evaluate how the type of social information and the overall interaction style can affect the coordination of shared use. In a qualitative study, we observe the longitudinal use of three lighting interfaces in a real-life open-plan office. In previous work based on a subset of the data, we have evaluated people’s appraisal of personal control over lighting and the interfaces (reported in [66]). In this work, we specifically look at shared use, by focusing on two questions: (1) *How do people use and appraise the three types of social information (intention, authorship, and preference)?* And (2) *How do the different interaction styles influence people’s coordination of shared use?* Our insights show the potential of sharing social information in shared use and how important the implementation of this information is. Moreover, we present effects of interaction style on communication, consideration, and accountability. We discuss the implications of these findings to inform interaction design for systems that are shared in use.

RELATED WORK

While consequential shared use seems to have been underexposed in HCI research and interaction, there are exceptions. Ethnographic work has focused on technology sharing at home, especially focusing on the shared use of personal computers [4,19,20] and smartphones or tablets [34,36,45]. These studies demonstrate that interface characteristics (such as the location of the device and number of accounts) can encourage or inhibit sharing.

The focus on communicating *social information* in shared interfaces originates from research on Computer Supported Collaborative Work (CSCW). Fueled by observations of collaboration in non-digital situations [26,28], an interest arose in how people coordinate behavior amongst each other through *awareness*: ‘an understanding of what is

going on’ [15:36]. It was found that awareness plays an important role in making collaboration work (e.g., by simplification of verbal communication, support of anticipation, avoidance of conflicts, and assistance of others). The social information that feeds awareness can be obtained through direct or consequential communication, feedthrough, and environmental feedback [6,25,52].

When geographically distributed interactions came up, explicitly designing this social information in the interface became indispensable. Early examples of awareness systems use video streams of distributed coworkers to give awareness about presence of others (e.g., [2,12,22,33]), or present people’s actions in distributed collaboration software (e.g., [38]). The design explorations continued into more abstracted and varied visualizations of social information for a multitude web-based services. Examples include visualizations of people’s attentiveness and participation in chat rooms conversations [17], of bidding processes in online auctions [18], and of editing and authorship history in Wikipedia [53,60,65] and Github [9]. Designing for awareness can also be seen in *collocated* collaboration scenarios, such as when emphasizing actions of others in digital table-tops [47,63,67] and visualizing speaking time in face-to-face meetings [1,11,62].

Despite these large research efforts, designing for awareness is not common in interaction design for other systems than those aimed at (work-related) collaboration or that have awareness as their sole purpose (e.g., [27,40,43]). This is surprising because the importance of sharing information to coordinate actions in everyday life has been stressed by many (e.g., [7,14,51,58,61]). For example, Taylor et al. [61] claim that it is the *people* that make their environments (socially) intelligent by manipulating the physical world into arrangements that embed social information. Based on similar observations, Rodden et al. [58] conclude that interactive devices should be reconfigurable in terms of *placement* and *assembly* to support people in sharing information. Together, this literature highlights the importance of gaining a better understanding of the role of interface design in terms of providing awareness to support coordination of shared use.

METHOD

In this work, we investigate shared use of a lighting system in an open-plan office. In open-plan offices, a larger space is shared amongst a varied group of co-workers, having different needs and doing different activities. Lighting is an interesting example of a shared system because lighting adjustments made by one affect all other co-workers. Also, personal control over lighting is new (e.g., [55,56]) and people have limited experience with the detailed control parameters [42,54]. All these characteristics make it likely that shared use has not yet settled into established norms.

We equipped an open-plan workspace at our university with a connected lighting system [16] (see [66] for technical details). The workspace (figure 2) is one of many similar

Figure 2. Left: layout of the space showing the desks, the luminaires (grey) clustered into 4 areas (dashed lines), and position of the Floorplan tablet (Y) and Canvas (Z). Right: photo of the office taken from position X.

spaces in the building and is occupied daily by students and is used for a variety of individual and in team activities, and is not supervised by staff. The luminaires can be manipulated in intensity and color temperature. We restricted control to four areas (i.e., clusters of luminaires that are controlled as one), corresponding to the table groups to ensure that coordination is required amongst people working in one area. Such consensus control over lighting areas is common in office lighting systems [5].

Interface Designs

Three lighting interfaces¹ were designed, varying in type of social information and different interaction styles. *Intention*, *authorship*, and *preference* were chosen as information types. These three types are common in awareness information taxonomies (e.g., [25,46]). Furthermore, *intention* and *preference* correspond to known causes of lighting conflict (resulting from a difference in activity or preference [51]) and *authorship* is known to increase accountability [35]. The interfaces varied in *distribution over space* and *interaction modality* to come to three commonly-used interaction styles (an application, a remote control, and a tangible interface). The *distribution* of objects is known to influence communication [7,14], for example by allowing people to make meaningful spatial arrangements [8,58,61]. In addition, the *location* of

Figure 3. Interaction with the Floorplan. (A) Select areas on the map. (B) Adjust intensity and color temperature with the sliders and press the preview to apply. (C) Select an activity icon to show intention to other people (D).

¹ Video of the interfaces: vimeo.com/twerff/sharedlighting

technology and interfaces are known to influence perceived ownership and sharing behavior [4,19,24]. The interaction modality is also expected to influence coordination since physical objects are known to facilitate feedthrough of awareness information [25,30,64]. Furthermore, *tangible* and *tangible-gestural* interactions allow for expressive gestures [30,32,49]: “being able to see another’s physical actions can enhance awareness, which in turn can support fluid interaction and coordination.” [31:167]. The three interfaces implement these variations in the following way:

- The Floorplan application is a *GUI* that can be used on *personal* devices and that shows *intention*.
- The Pointer is a *tangible-gestural* interface *distributed* per area that communicates *authorship*.
- The Canvas is a *tangible* interface in a *central* location and allows for expression of *preference*.

Note that the interfaces only differ in their social information and interaction style; *not in lighting control*. They present the exact same control over the light. All interfaces are fully functional (see [66] for more details).

Floorplan Application

The Floorplan interface (figure 1A) is a graphical user interface that can be used on personal devices such as a laptop or smartphone. The application is also available on a wall-mounted tablet (position Y in figure 2). An interaction starts with a map of the space in which the user can select one or more areas where s/he wants to adjust the light (figure 3A). After selecting the area, a control menu pops up to adjust intensity and color temperature of the light relative to its current setting (figure 3B). By pressing the button in the center, the new light setting is applied to the luminaires. People can choose to add an activity icon to their light setting to communicate their intention with the new setting to other people, by pressing the corresponding icon (figure 3C). In this way, *intention* – i.e., the intended activity with a light setting – is made visible (e.g., in figure 3D the light has been set for a meeting). Activity icons can be changed or removed manually, without altering the light setting. We expect that the intention information in the activity icons can support people in estimating the importance of a light setting (*good lighting is more important for my focus group than for your coffee break*), or to evaluate whether the current light setting is still relevant (*the light was intended for a meeting but I only see people reading, so adjustments can be made*).

Pointer Remote

The Pointer (figure 1B) is a tangible-gestural remote control. Each area in the space has one Pointer with a distinct color. One receiver per area is mounted on the ceiling above the tables. The Pointers have two sliders to adjust the intensity and color temperature. A preview of the new light setting is shown in the button on top of the remote (figure 4A). People can apply the new setting to the lights in the space by pointing at the receiver in the area they want to adjust and pressing the button (figure 4B). The light in

Figure 4. Interaction with the Pointer interface. (A) Adjust the sliders for intensity and color temperature. (B&C) Point to an area and press the button to apply the setting. The indicator light in the receiver takes on the sender's color.

the receiver takes on the color of the remote that was used to set the light in that area (e.g. figure 4C shows the receiver in the *blue* area that has been adjusted by the *green* Pointer). In this way, *authorship* – i.e., which table group is responsible for the current light setting – becomes visible as a consequence of interaction (in contrast to the Floorplan and Canvas, where providing social information forms an explicit additional step). Knowing authorship might stimulate people to consult the author of a light setting before making an adjustment, which could help to avoid conflict. And seeing that the light in one's own area has been set by people in another area might assure people that they are allowed to make an adjustment.

Canvas Interface

The Canvas (figure 1C) is a tangible interface placed at a central location in the space (figure 2, position Z). The four table groups are represented by four colored tokens (they use the same color coding as the Pointer). The tokens can be moved around the canvas to change the light at the corresponding table group – vertical movement to adjust the intensity, and horizontal movement to adjust color temperature. The gradient on the canvas shows a graphical indication of the new light setting (figure 5A). People can draw a boundary around tokens using a laser stylus (figure 5B). In this way, *preference* – i.e. acceptance of new adjustments – is communicated to possible future users (e.g., the red boundary in figure 5B might indicate that the intensity can be adjusted but that the color temperature should not be changed). Boundaries can be removed with the stylus or by moving the tokens out of that boundary. Expressing *preference* to others might help people to take the wishes of previous actors into consideration in their interactions. The absence of specific preference information might reassure people that an adjustment is allowed.

Study Setup

Participants (n=31, f=11) were recruited during the introduction of an educational project about lighting interaction design. This involvement in the project made that the participants became sensitized, which is known to be helpful when studying lighting use because people can find it difficult to talk about lighting [41,51,54]. Participation in the study was voluntary and in no way part

Figure 5. Interaction with the Canvas. (A) Area tokens can be moved freely over the canvas: vertical to adjust intensity and horizontal to adjust color temperature. (B) Using the stylus, boundaries can be drawn to indicate preference.

of the educational project, and the primary researchers had no role in the assessment of students. The participants were allocated to work in the workspace of the study for a semester, together with non-participating students. Also, the space is open to other students in the department. Therefore, also other people interacted with the lighting system and all interactions with the system are included in the quantitative data. It is impossible to distinguish between interactions by participants and others in the quantitative log data. In qualitative data only participants were included.

Protocol and Planning

The study was conducted twice (session A and session B). The sessions have a different order of interfaces and a different group of participants (see table 1). This allowed us to balance the order in which the interfaces were introduced and to study a larger and more diverse participant group. Studying shared systems requires a longitudinal and in-context setup since people need to make the system their own and establish norms and routines [23,44]. Session A was 14 weeks. The Floorplan was introduced first, followed by the Pointer in week 6. The Canvas interface was implemented last in week 11. During the study, log data was collected for every interaction (*time and date, interface ID, adjusted light parameters and social information*). Every week, participants received a survey in which they described a specific interaction. After each interface (week 5, 10, and 14), a semi-structured interview was conducted with every participant. The results of the weekly surveys were used to fuel discussion in these interviews. Participants were asked to reflect on the general use of lighting and space, to describe specific interactions with the interface, and to evaluate the interface using five-point Likert-scales about specific features (e.g., ‘How enjoyable was the interface?’, and ‘How much effort did interaction take?’). At the end of the final interview, participants were asked to compare their experiences with the three interfaces on 5-point scales (e.g. on ‘precision of control’ and ‘social threshold’). All interviews were audio-recorded.

Session B was six weeks – two weeks per interface. Since reminders were not needed in the two-week spans, the weekly surveys were not used. Instead, one survey was sent out at the end of each interface use period (at the end of

	Date	Order	Participants	Data collection	Data		
Session A	Sep - Dec '16 14 weeks	1. Floorplan	17	Log data	1059 interactions	15h of	962
		2. Pointer	age 20-30	3 interface interviews (A1-3)	Floorplan (27%)	audio	quotes
		3. Canvas	F=5	11 reminder surveys	Pointer (40%)		
				1 comparative interview (A3)	Canvas (33%)		
Session B	Feb - Mar '17 6 weeks	1. Canvas	14	Log data	498 interactions	10h of	573
		2. Pointer	age 20-30	3 interface surveys	Canvas (37%)	audio	quotes
		3. Floorplan	F=6	1 comparative interview (B)	Pointer (46%)		
					Floorplan (17%)		

Table 1. The details of the two study sessions A and B.

week 2, 4, and 6) with the same Likert-scales that were used in the three interviews of session A. Only one concluding interview was held per participant. Participants were asked to reflect upon their experiences with the system and each of the interfaces, describe specific interactions and compare the interfaces using the same scales that were used in the final interview of session A.

Data and Analysis

Most of the findings presented in this work are based on the qualitative data from the interviews. The quantitative data² (log data and Likert scales) were mainly used to get an understanding of general use during the study. In total, the system was used 1557 times. It was used at least once every day of the study, and people generally interacted at least once when they were present. In 23.7% of interactions, people adjusted all four areas, mostly when being the first to enter or the last to leave. In more than half of the interactions (58.5%), people only adjusted their own area.

To prepare the qualitative data for analysis, all interview recordings were transcribed. Since all researchers are native Dutch speakers, the interview transcripts were analyzed in the original language (English or Dutch) and translated into English when finalizing this paper. In a thematic analysis [3], the two first authors first used 10% of the transcripts to select quotes and to get a common understanding of the labels. Based on this common understanding quotes were selected in all transcripts, resulting in a total of 1535 quotes. The quotes were clustered into three main themes:

- *Information* (780 quotes): types of information that are taken into account during an interaction. Subthemes include *intention*, *authorship*, and *preference*.
- *Views on Shared Use* (444 quotes): people's reflections about *acceptance of change*, *sharedness*, *affecting others*, and *rules of use*.
- *Coordination* (311 quotes): specific scenarios of shared use, including subthemes on *verbal communication*, *consideration*, and *accountability*.

Furthermore, all quotes were double-labeled with the corresponding interfaces, (resulting in 157 quotes about the *Floorplan*, 211 about the *Pointer*, and 227 about the *Canvas* interface). To address the first research question (*how do people use and appraise the three types of social*

information?), we used the *Information* theme. The second research question (*how do the different interaction styles influence people's coordination of shared use?*) was addressed by looking at the overlap between the *Views* theme and the *Interface* labels. We identified differences in three aspects of coordination: (1) the amount of *verbal communication*, (2) people's *consideration* of others, and (3) perceived *accountability*. The quotes in the *Coordination* theme were used to confirm these differences with actual use scenarios. The findings are presented in two separate sections that match with the two research questions and are illustrated with quotes (p1-A2 is a quote from participant 1 in the second interview of session A).

EVALUATION OF SOCIAL INFORMATION

The three interfaces each present a different type of social information: *intention* in the *Floorplan*, *authorship* in the *Pointer*, and *preference* in the *Canvas*. In this section, we describe how the information was used.

Intention

With the *Floorplan*, people provided information about their *intention* by adding an activity icon. This was done with 26.3% of all interactions. We expected that knowing the original intention for the light setting would help people to estimate the importance of that light setting for other people. Indeed, some people mentioned that they perceived some activities as more relevant than others: "If they are working concentrated, they of course have priority over someone who's just drinking coffee" (p9-A1). However, the activity icons were often too general to communicate importance, especially because activities did not vary much amongst each other: "I assume that [...] 90% of the people just filled in 'work'. [...] that is what the space is for." (p21-B). Instead, the icons were often interpreted as discrete indicators of importance: if someone had put in the effort to add an activity to the current setting, it should not be adjusted at all. "... at that moment one person was sitting in the space who had added a 'laptop' icon [...] so that really showed: I do not want the light to change" (p3-A1).

We also expected that people would use the intention information to evaluate whether the current setting was still relevant – i.e., to see if people were still performing the activity that the setting was intended for. However, people mentioned that the link between activity and light setting is often not that rigid: "I never really added an [activity icon], because I was doing so many different activities." (p3-A1). Moreover, people found the information about the current

² The quantitative dataset is available at DOI: [10.4121/uuid:7e4c84ad-921a-44c1-bcf9-2b4c8bcfb6a6](https://doi.org/10.4121/uuid:7e4c84ad-921a-44c1-bcf9-2b4c8bcfb6a6)

situation that can be seen by looking around more relevant than the intention communicated in the interface – *“Why would you set [an activity]? If you look around in the space you can clearly see what everybody is doing.”* (p20-B) – especially because the information was often not up-to-date: *“I don’t think anyone would say: ‘I am not writing, I am brainstorming. Let’s change [the icon].’”* (p18-B). Furthermore, the information was only visible after opening the application, which was too late: *“At first you might ask ‘Can I adjust the light?’ and then he might say ‘No, I am working on something for which I need this light’ or Yes, go ahead’. Then you open up the app and adjust the light. So, at that moment the icons do not matter anymore.”* (p8-A1).

Authorship

With the Pointer, *authorship* information becomes visible in the color of the indicator lights. As expected, some people took the author of the current setting into account when making an adjustment: *“when you see that the light has been set by the blue table, then you would first look and think: ‘oh, who’s sitting there? Would they really need [this light setting]?’”* (p23-B). So for the person interacting, knowing authorship a means get awareness of e.g., the *relevance* of a current setting, the *importance* of the setting to the author, or their *intention* and *preference*. For that purpose, the indicator light provided perhaps too little detail: *“Actually, you can only see which controller was used. Then you still don’t know who it was”* (p2-A2). As expected, people felt like they were allowed to make an adjustment in their own area if the current setting was made by people sitting in another area: *“if someone in the space had adjusted all three areas, you would know that he doesn’t really need that. And then you can just change it.”* (p5-A3). But because people hardly adjusted other areas apart from their own, this situation did not occur often.

For the impacted people, knowing authorship made it possible to hold people accountable at the moment of interaction: *“I once saw that the light at the big table was adjusted by another table. It suddenly changed from really bright to really dark. And we were like ‘what is happening?’ [...] And then you can directly look in their direction: ‘Hey, you did this!’”* (p22-B). However, the indicator lights were often superfluous: *“you can also see someone pointing upwards.”* (p24-B). The playful ‘shooting’ interaction of the Pointer invited playful use, which led to somewhat chaotic situations. At those moments, the indicator lights were helpful: *“If multiple tables are pointing, you do look at the color of the remote and the color of the [indicator] lights at the ceiling. That did help to locate the person.”* (p24-B). Interestingly, this playful interaction could be a conversation starter: *“With the [Pointer] you change it and they can start laughing and they can start talking to you.”* (p28-B).

Preference

With the Canvas, people could draw a boundary around a token to indicate their *preference* to others. In total 223

boundaries were drawn, of which 39 boundaries remained for at least 60 seconds on the canvas. The short-lasting boundaries were likely to be part of exploration: *“I mainly used [the boundaries] because it was fun to play with.”* (p4-A3). However, not everyone removed their boundaries, which made it difficult for people to estimate the relevance: *“You don’t know who set [the boundary] and you don’t know whether that person already left. So, you don’t know if it still important to keep [the tokens] within [the boundary]. That is confusing.”* (p31-B).

We expected that the boundaries would help people to express their preferences to others in a low-threshold manner. For some people this was indeed the case: *“Yes, it was useful to draw a line around the [light setting] you liked, or your table liked. Because in the morning, one of the tables always wanted very bright light. I am not a morning person, I’d rather have a little less light. [...] in the end, our [token] wasn’t touched at all. Maybe the [boundary] contributed to that.”* (p22-B). However, many people mentioned that their preferences were often not very explicit. And since most people took each other into account during an interaction, settings were often acceptable: *“Let’s say that people go to the extremes a lot, then the boundaries would have been better. [...] Now I don’t feel like I need them because [the light] is going to be somewhere in my general tolerance area.”* (p12-A3). Besides, people felt that their boundary could limit other people in their interactions: *“especially if you add a [boundary] it could be a bit touch-and-go. Is everyone going to be OK with this?”* (p19-B).

We also expected that the boundaries would not only be used to restrict others but also to express that adjustments are acceptable (by drawing bigger boundaries for example). This indeed occurred: *“I didn’t want it to become whiter or bluer. But I didn’t mind it a bit brighter or less bright. So, I drew some sort of ellipse around it, from the top down.”* (p19-B). Most people, however, perceived any type of boundary as an indication that the token should not be moved at all: *“When a [boundary] was added I did not feel like I was permitted to move the token within that [boundary]. It felt more like somebody drew a [boundary], so I wouldn’t touch it.”* (p22-B). Still, most people appreciated the preference information, even though they did not use it often: *“The boundaries as a feature was a useful thing because it made people think about changing the light within other’s boundaries. It wasn’t used that much but the presence of it had an effect.”* (p12-A3).

When asked directly, people were hesitant about the usefulness of the three types of social information. Still, people’s reflections show that they do take different types of social information into account when interacting with the shared system: *“I definitely take into account how many people are there and what the setting currently is. [...] for some people I know the light settings better than for others, because they complain about it. If it is [colleague X] and I,*

I pick a slightly warmer setting. So, I do some mediation between the stakeholders” (p12-A2). This quote highlights the relevance of knowing the *identity* of others, the *content* of the setting and *system state*, and others’ *preferences*. Other potentially relevant types that were mentioned by participants include the *importance* and the *relevance* of the current setting to the people present. If such information is not available in the interface or context, people try to obtain it through conversation: *“So, the lack of visibility of who has controlled it and how comfortable they are with change makes it [that] you have to talk to people. [...] I don’t want to go around interviewing everyone every time I want to change the light.” (p12-A2).* But this need for conversation could discourage people from interacting with the system, as we shall see in the next section.

INTERACTION STYLE AND COORDINATION

In this section, we analyze how the interaction style of an interface can influence coordination of shared use. We identify differences on three aspects of coordination: (1) the amount of verbal communication, (2) the extent to which people take others into consideration while interacting, and (3) people’s perceived accountability.

Verbal communication

The first aspect in which the interfaces differ is the extent to which people talked about while interacting with the system: people communicated more when using the Pointer and Canvas, than when using the Floorplan: *“I don’t remember any conversation I had with the digital interface...” (p6-A2).* In general, people found verbal communication important. They often did not want to make an adjustment to a shared light setting without consulting others and expected other people to consult them in return: *“And maybe you like it, but others might like it less at that moment. So, I don’t know, it’s just more sociable to ask.” (p22-B).* However, starting up this conversation was not always easy and could discourage interaction with the system: *“If someone is working really focused on his computer – and especially if it is a third-year student that I don’t know personally – then I wouldn’t touch [the system]. Neither would I ask ‘Would you mind if I change the light?’” (p20-B).* We found two roles of the interface in verbal communication: it can show *who to address* and can *externalize and visualize* discussion.

Knowing who to Address

The difference in distribution and modality between the Floorplan, Pointer, and Canvas resulted in a difference in visibility of an interaction. Seeing that someone is interacting aided verbal communication, both for the impacted person and for the person interacting. For the person being impacted, knowing who is interacting made it possible to respond and start a negotiation. This was easier with the Pointer and Canvas – where pointing to an area or walking up to the interface is visible to others – than with the Floorplan – where actions are hidden in people’s smartphone or laptop. *“[With the Floorplan] you don’t*

really know who changed the light. So, you cannot really talk to him and say: ‘maybe we can do like this, maybe we can choose a brightness and color together’. My experience [with the Floorplan] was that people change light, I change it back, they change it back, I change it again.” (p28-B). For the person interacting, being visible to other people made it easier to consult them during interaction: *“I was at the central interface and [person X] was sitting by the window and I changed it and he looked up. And the fact that he looked up and noticed me, made me enter into a negotiation with him and we talked about how it should be.” (p12-A1).* With the Pointer and especially with the Canvas, the intention to start an interaction was visible even before the lighting was affected. This made it possible to intervene, and was especially appreciated by the person interacting as it prepared others for a potential conversation: *“If you pick up the Pointer, other people at the table notice that right away, which makes it easier to start a conversation. With the Floorplan app, other people do not see that you are interacting with the light, which makes it awkward to start a conversation about the light.” (p11-A3).*

Externalizing & Visualizing Discussion

The three interfaces differ in their expressiveness – i.e., their ability to communicate the effect of an interaction [25]. The Floorplan displays the color of the area on the map and the small sliders disappear after selection, and Canvas clearly expresses information about the parameters in the setting. This made it easier to ask for consent: *“[with the Floorplan] you didn’t show your phone and asked: ‘Is this good or not?’ It didn’t really send a message about how the light would be. You couldn’t really show it. And [with the Pointer] you can, not only with the preview light but also by showing the sliders.” (p16-A2).* Moreover, the tangible tokens of the Canvas served as an *externalization* of the discussion [30]: they facilitated conversation and provided a record of the outcome of the negotiation: *“[With the Canvas] it is nice that you’re able to see how everything is set. To me that seems to make it easier to talk about it with someone: ‘you have [your token] over here, I want it here, let’s put it in the middle’. Without the interface, it becomes way more difficult to have that conversation.” (p27-B).* When the interface is used as a tool during a discussion, its size and position determine who can be included: *“you can discuss from a distance with the people sitting there. [...] with a small tablet on the wall that you stand in front of talking about ‘put it a little bit more up or down’ is much more difficult.” (p25-B).*

Consideration

In general, people took others into account in most actions: *“Of course if I was with my group we would decide together and it would be more blue and white light. [...] if I would be by myself I would choose a more relaxed [light setting].” (p28-B).* But the extent to which this was facilitated differed per interface.

Individual and Shared Interactions

Although the lighting system is shared, the ownership over the interfaces differs: The Floorplan runs on a personally owned device, the Pointers are shared with people at the same table, and the Canvas is shared with everybody in the space. This influenced the extent to which an interaction was perceived as personal or shared: "... the fact that you need to share [the Pointer] makes it that you don't just go with your own vote, but that you need to negotiate: 'Is it OK like this?' But if it would be yours, you would want your preferred light." (p3-A2). Shared interfaces resulted in more cooperative interactions – "With the canvas, you can go there together and discuss 'How are we going to solve this?'. And with [the Pointer] it is more like 'I want it like this', 'No, I want it like that'." (p27-B) – while individual interfaces provoked individual interactions: "[with the Floorplan] in the end, you do it alone. And with [the Pointer and Canvas] you do it together." (p17-A3). With the Pointer interface, people consciously played with this by keeping the interface close to inhibit other people from making adjustments: "... [with the] Pointer, placing it close to me would make me feel like the owner of the area. So, someone reaching out and taking it to control the light would feel like an intrusion in my area." (p12-A3).

Considering Size and Location of an Adjustment

In general, people preferred to make small adjustments to the current setting to minimize the impact on others: "[I took into account] how the other areas were set to make sure I wouldn't disturb others too much." (p3-A3). Seeing the position of the tokens on the Canvas allowed people to make adjustments *relative* to the current setting. This was more difficult with the Pointer since the sliders could have changed after the setting was applied: "[With the Canvas] it is very easy to think: 'OK, it is on that intensity, let's change it from there'. And with the Pointer, you would start all over with setting the light. You don't really have a reference." (p20-B). The Canvas is the only interface that shows the current light parameters for all areas at once, which made it easier to take people in adjacent areas into account: "Suppose the table next to you has a completely different setting, you will notice that anyway. [...] So then it is nice to see how [all areas] are set." (p27-B).

With the Pointer, people were most inclined to adjust only one area (69.7% of the interactions), compared to the Floorplan and Canvas (46.8% and 53.5% respectively). People were most inclined to adjust all four areas at once with the Floorplan (35.4% against 9.3% with the Pointer). These differences can be explained by the sequence of interaction and the focus of attention: The Floorplan allows people to select multiple areas at once, which invited for making bigger adjustments: "With the [Floorplan] I was more inclined to adjust the whole space, [...] it is tempting to just select everything since it's the same action anyway." (p24-B). In contrast, people were more considerate when adjusting other areas with the Pointer, because the interaction made them focus on the location that they were

about to adjust: "[With the Pointer] it is almost as if you are shooting at people, you're pointing at them. Yeah, you're not going to do that." (p26-B). Compared to the Canvas and Floorplan, the Pointer made people more aware of the presence of others, which reduced the chance of affecting other people by mistake: "With [the Pointer] you were clearly aiming at somebody else's table. You are very consciously changing the light of someone else instead of your own. Whereas [with the Canvas] you are not looking at the table you're adjusting. So, it is easy to move everything around without paying attention to which table you are actually affecting." (p29-B).

Accountability & Conflict Resolution

Even when people considered each other in their interactions, this did not always lead to a satisfying result for everyone, which in some cases led to conflict. "[Somebody] took all the tokens and moved them to orange, just like that. [...] And we completely flipped at her: 'WHAT ARE YOU DOING?!'" (p3-A3). The extent to which people held each other accountable for undesired actions and the extent to which they felt accountable for their own actions, differed between the interfaces. People felt least accountable with the Floorplan, and most accountable with the Canvas: "What I'm going to say now is a bit exaggerated, but it is almost a walk of shame when you have to walk back [from the Canvas] to your table while nobody likes your setting." (p19-B). These differences can be explained by the level of *exposure and vigilance* due to the visibility of an interaction and shared ownership; and by the ease of *retrieving* a previous setting in case of conflict.

Exposure and Vigilance

Visibility of the interaction seems to be a prerequisite for accountability. People felt less accountable for their action when their identity was unknown to others: "I know that I adjusted it, but other people don't. So, then I don't feel responsible for it." (p8-A3), "I could screw up the lights and no one will know." (p3-A3). In visible interactions, the increased accountability resulted in more cautious consideration and raised a threshold to interact: "Everybody is looking: 'Is he taking off a token? What is he doing with my light?'. It's like being in front of a classroom. [...] You're not going to do anything stupid." (p24-B). The indicator lights of the Pointer showed which controller was used for an adjustment. The lack of visibility of *who* exactly made the setting, resulted in a feeling of shared accountability for all people at the table: "For the Pointer interface, I felt like every time we made changes we did it is as a group. So, I felt like the group is accountable for it." (p16-A3). Others recognized this and held a group as a whole accountable for undesired actions: "And with the Pointer, you could easily say: 'Hey, you guys at that table, cut it out!'. You just address the whole table." (p22-B).

The ability to hold others accountable made that people paid more attention to actions of others, which sometimes

felt like a burden: *“With the Canvas I was constantly thinking [...] oh no, someone is standing at the Canvas again. – sigh –”* (p22-B). On the other hand, not knowing who to hold accountable made people refrain from responding to an action, since it made conflict resolution impossible: *“One time somebody changed my light because he wanted to try it out [...], but I didn’t know who. Of course, I could’ve changed it back but for all I know it gets adjusted again in one minute.”* (p19-B). Generally, people appreciated some feeling of accountability, despite the fact that the exposure sometimes raised a threshold to interact, and vigilance could feel like a burden: *“a social threshold to changing someone else’s light seems like a good thing to me. [...] It’s some sort of lighting etiquette.”* (p29-B).

Readjusting or Retrieving Settings

In the case of an undesired adjustment or conflict, a common resolution strategy was to restore the original setting. Retrieving the original setting was easiest with the Canvas: *“[placing back a token] was easier since you remember its visual location without having to think about it. This was more difficult with the [Pointer], like ‘umm, what was it like again?’”* (p27-B). Knowing that a setting can be retrieved easily felt reassuring and resulted in more explorative behavior: *“Just assume that I [adjust the light] and someone disagrees. Then it is easy to undo my change [with the Canvas] which makes me feel less guilty than if someone else’s perfect light setting is irretrievably lost.”* (p27-B). The person interacting often restored the previous setting directly after noticing a conflict. When the person interacting failed to notice the conflict, the impacted people had to respond themselves. In some cases, the actor was asked to undo the changes. However, most people avoided confrontation and re-adjusted the setting themselves instead. The ease with which this could be done depended on the accessibility of the interface: *“You have to open the application, select an area, adjust [the settings], and choose an activity... And with the [Pointer] you just do like that, and the [previous setting] is back.”* (p31-B). Knowing that a setting can be restored without much effort eased the previously-mentioned burden of vigilance: *“with [the Pointer] I wasn’t afraid that people would touch it. I could just change it back if I wanted to.”* (p24-B).

DISCUSSION

In this research, we focused on two main questions: (1) *How do people use and appraise the three types of social information (intention, authorship, and preference)?* And (2) *How do the different interaction styles influence people’s coordination of shared use?* In this section, we discuss what implications our findings on these two questions have for interaction designers that want to design interfaces for shared use.

Designing Social Information in the Interface

Our findings indicate that intention, authorship, and preference are all potentially relevant types of information for coordination of shared use. People consider it important to know the relevance of a setting for other people’s

intended activities. Moreover, they want to consult the author of a previous setting and want to take other people’s preferences into account. However, the way that the information was implemented in our interface limited its usefulness. More specifically, we found the following:

- Information has to be visible at the right moment.
- People should be able to assess the relevance of the information for the current moment.
- A lack of information needs to be interpreted as a lack of information, not as an acceptance of change.

It seems that the way the information is designed in the interface becomes more important when applying this strategy to interaction with systems that are shared as a consequence of use, compared to systems that are shared as part of their functionality. For example, the timing of the information becomes more important. Compared to collaboration systems, where people generally pay more attention to the interface, interaction with systems that are consequently shared is less focused, less frequent, and based on turn-taking. For example, *intention* information in the Floorplan is only available *after* people take out their phone and open the application, while it is most useful when people are deciding whether to interact. Firstly, our findings suggest that information is more useful if the state of the interface is visible at a glance (e.g., the size of the Canvas), or if it is located in a separate information display in the context (e.g., indicator lights in the Pointer). Secondly, we found that people need to be able to assess the relevance of the information. This relevance was ensured when information was the automatic result of an interaction (e.g., authorship in Pointer). Yet, when people needed to intentionally add information (Canvas and Floorplan) they did not keep this information up to date (e.g., by removing their boundary or changing their activity icon). Therefore, if information needs to be added manually, extra design effort is needed to help the user to assess the relevance of that information (e.g., by showing how long it has been there, or by automatically removing it). Thirdly, we found that intentionally provided information was often perceived as ‘a change is not accepted’: people generally did not change settings with a boundary or an activity icon, for example. Because of this discrete interpretation, providing information could feel as limiting to future users. Therefore, people often did not add explicit information, which meant that a lack of information (not having a boundary) could not be interpreted as ‘change is accepted’. Thus, it could be interesting to add an intentional action that explicitly indicates that changes are allowed, so that people also clearly see when no information has been added.

Implications of Interaction Style on Coordination

Our second aim was to investigate the effect of interaction style on the coordination of shared use. Our findings demonstrate the interfaces influenced the way people coordinated shared use. We especially found differences in the amount of verbal communication, the level of

consideration, and the level of accountability. Because the three interfaces in the study combine variations of several different characteristics, it is difficult to directly link one characteristic of the interface to an effect. Nevertheless, we can speculate about possible implications that design decisions can have on coordination, and that designers should consider when choosing a certain interaction style:

- *Visibility of the interaction*: Exposing the actor during an interaction informs the author of the setting, lowers the threshold for starting a conversation, and is a requirement for holding others accountable for undesired actions.
- *Ownership*: With a personally owned interface, people tend to make individual adjustments. With a shared interface, people tend to involve others in the interaction.
- *Attention to Context*: If people look at the location of the planned adjustment, they tend to consider the impact on others more.
- *Verification*: A two-step sequence allows for exploration before making an adjustment, so people can consider the size of their adjustment and potential impact on others.
- *Retrievability*: If previous settings are easily retrievable, people tend to be more explorative.
- *Expressiveness*: Showing the current parameter values of the system in an interface aids negotiation as it allows people to make changes relative to a setting, which is useful for making compromises.

The design decisions explained above lead to the availability of different types of implicit information, for example, about authorship and identity (visibility of actor), other people (attention to context) and their preferences (expression of parameters), or the expected impact (verification). If an interface does not implicitly provide this information, designers should consider designing relevant information more explicitly in the system.

It is important to note that supporting coordination of shared use does not mean that we want to remove all conflicts in shared use. Conflict can be beneficial in establishing social norms and gaining an understanding of each other's needs and wishes [10], and we also found that playful teasing (e.g. with the Pointer) can be an icebreaker to discuss preferences and lighting use. Still, it is impossible to state in general which coordination style would be most desired: even our participants did not agree on whether more or less verbal communication, more or less consideration, or more or less accountability would be better. Instead, we recommend designers to consider coordination strategies that could be desirable in the context they are designing for, and to make decisions accordingly.

Generalizability of the Results

There are different ways in which the study context (a student workspace), the participant group (students involved in a lighting interaction project), and the type of shared system (lighting) affected our findings and the generalizability of the design implications. The student workspace is comparable to a general open-plan office in

terms of diversity of tasks, flex-desk usage, and in how familiar participants are with one another. The atmosphere could possibly be more informal than a general open-plan office, which probably led to more playful behavior, possibly more verbal communication and a higher acceptance of changes made by other people. The fact that participants were involved in an educational project helped to sensitize them and resulted in rich conversations during the interviews. However, their increased interest in the system and interaction in general might have resulted in an increased number of interactions. In conclusion, the participants reported that there was a rather high threshold to impact others with a change, and to start a conversation. It is likely that this threshold can be even higher in other contexts. Besides, there are some characteristics that make a lighting system different from other contemporary IoT-like systems. Lighting needs are known to be latent [54] and lighting preferences are less explicit than, for example, preference for music or movies. If preferences are strong, conflicts are likely to manifest [10,13] but if preferences are latent, the interface can keep conflicts hidden (as with the Floorplan) or can bring conflicts out (as with the Canvas). This makes it likely that the interaction style plays a greater role in coordination of use with lighting systems compared to other shared systems. To conclude, the role of interface design in shared use is influenced by the context, people within, and system type.

CONCLUDING REMARKS

In this work, we have investigated how the design of an interface (in terms of social information and interaction style) can influence coordination of shared use, and we have provided in-depth insights into the social dynamics that evolved around that coordination. We found that design decisions in the interface can impact coordination by stimulating verbal communication and negotiation, by helping people to take each other into consideration and adjust their interactions accordingly, and by increasing feelings of accountability. We also found that although intention, authorship, and preference are potentially useful information types, people need the information at the right moment, should be able to estimate the relevance of the information, and interpret what a lack of information means to make the information useful in coordination of shared use. To conclude, if interfaces are designed from an individual perspective, there is a risk that they do not support people in shared settings and shared use. Therefore, we emphasize the importance of considering shared use when designing interfaces for everyday systems.

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