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# Multimodal Interaction in Collaborative Design of a Healthcare Space: A Social Semiotic Approach

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**Abstract.** In professional interactive practices, space, time, human bodies, and material objects as well as written and oral language are dynamically implicated in a multimodal co-construction of meaning. A healthcare space – an operating room – is a typical example of such a social-semiotic, multimodal arrangement of communication modes which impacts the practices that are played out therein. Therefore, in designing healthcare spaces, it is important to allow for proactive inclusion and engagement of the categories of professionals who carry out their daily work in these spaces. Today, such involvement can be facilitated through mediation tools and simulation in Collaborative Virtual Environments (CVE). However, how collaboration unfolds and manifests at the micro-level of collaborative design interaction remains under-researched. The aim of this discussion paper is to introduce a social-semiotic approach to the analysis of multimodal collaborative design. We show how combinations of modes can trigger transformational shifts in levels of interaction.

**Keywords.** Collaborative Virtual Design Environment; communication modes; healthcare spaces; multimodal meaning-making; social-semiotics

## 1. Introduction

Taking the well-being of prospective occupants into account in the design of hospital spaces is no simple feat, yet it is imperative. Furthermore, projecting ‘healthy’ workspaces that mitigate mental and physical stress for both the end-user professionals and the patients in the early phase of a project is critical. Yet, what a ‘healthy’ workspace means for different stakeholders depends on many different factors such as professional role, knowledge area, experience, institutional norms, local practices, and individual preferences. So, for example, a hospital operating theatre, the concern of the current paper, needs to be proactively designed to allow for the different professional staff to move about freely and smoothly as well as to access their respective equipment and tools without encumbrance. Moreover, for the patients, all possible risks of contamination must be avoided. Hence, including the embodied lived experiences of operating theatre staff to collaboratively design their future workspaces with professional designers and architects at an early stage is necessary.

With the rapid advances in digital technology, social interaction, for example collaborative design, are increasingly being shaped by enabling digital semiotic modes such as VR technology, broadly labelled CVE (Collaborative Virtual Environment). In

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such environments, professional designers' and practitioners' interactions are supported by both semiotic and technical resources to allow them to collectively visualize and probe their presuppositions in real time. However, the layering of face-to-face and virtual communication modes are complex and require shifts in mindset (from 2D drawings to virtual 3D representations) and in design practices (working at a drawing/sketching board to the mobile use of multiple and multifaceted mediating technologies). Design collaboration in CVEs has been argued to enhance spatial reasoning, generate collective and individual reflection on the actions and representations of designers as they occur, and facilitate creativity, thus resulting in improved design [1,2,3].

Most of the substantial body of research on collaborative design within AEC-related fields (Architecture, Engineering and Construction) has focused on improving collaborative design practices and tools to facilitate individual and collective cognition [4, 5]. What is notable, however, is that there seems to be little problematization of the meaning of the term 'collaboration', and hence, a lack of research on how 'collaboration' unfolds and manifests at the micro-level of collaborative-design interaction. It seems that gathering different stakeholders and tasking them to design 'together' will automatically result in 'collaboration'. Interestingly, the enabling VR systems and digital communication modes are also labelled 'collaborative'. Could it be that we are lulled by the metaphorical label into taking for granted that the metaphor entails the action?

There is no doubt that joint mediated activities planned to involve several people in a specific practice will eventually lead to interaction of some kind. However, to claim 'collaboration' – if by 'collaboration' we mean 'to work *together* to produce something' – would require that interaction be studied using a processual analytical lens with social interaction as its focus.

The overall aim of this discussion paper is to initiate interdisciplinary work toward the development of a social-semiotic approach to the analysis of multimodal interactive design. In this initial stage, we draw on multimodality constructs [6] to identify typical processual transitions during a collaborative design workshop carried out using CVE technologies. We explore how participants mobilize different communication modes, verbal, non-verbal and material/digital to get their meanings across. We show how combinations of modes can trigger transformational shifts in levels of interaction. For this paper, we have drawn on our joint extensive observations and studies of social and technical mediated interaction and have purposefully chosen one naturally occurring empirical example to illustrate our argument.

## 2. Research approach and data selection

We begin by stating criteria pertaining to the configuration of our research team. First and foremost, any ambition to develop a viable framework for analysis of social interaction in a multi-disciplinary sector such as AEC warrants a multi-disciplinary research team. For this study, social-science (applied linguistics, organization studies and architecture) and engineering (informatics and VR development and applications) researchers have joined forces to share theoretical as well as practical knowledge concerning multimodal mediated interaction and various forms of collaborative design. To facilitate our own action-driven learning, we have spent countless hours jointly scrutinizing the data in order to generate both individual and collective reflection loops [7, 8].

In multimodal collaborative-design studies in the built environment and architecture, it is assumed that collaboration builds on participants' individual and/or joint contributions using different communication modes, such as verbal, non-verbal, written, visual and material/technological [9, 3]. Multimodal research has tended to focus on verbal, visual and material modes although, of late, non-verbal modes, for example, gestures have been gaining attention [e.g., 10]. To date, gesture studies have mainly focused on hand gestures, mostly pointing [11]. Such gestures are most often seen as complementary to verbal, graphic and material communication modes rather than functioning as a meaning making semiotic resource of its own. In our collective reviews of multiple sequences of design-interaction data, we have observed that gestures, indeed the whole body, play an integrated and critical role in collaborative design communication.

In this exploratory paper, we mainly draw on the social-semiotic multimodal approach and constructs from [12, 6] to examine how participants deploy embodied knowledge in combination with technological and semiotic modes. Contrary to previous multimodal research in the built environment that views modes as separate and/or complementary, we view space, time, human bodies, material objects, written and oral language and images as dynamically implicated in a co-construction of meaning. The different communication modes or resources used (semiotic and technological forms, social norms, spatial organisation, body movements and discursive practices) are arranged to form dynamic sequences of meaning-making ensembles [6]. In these ensembles, the modes, with their inherent affordances and constraints, interact, each performing specific and interrelated semiotic work.

Since we want to showcase an illustrative example of a processual multimodal analysis of collaborative design interaction, we had several criteria for the selection of the data. First, it had to be naturally occurring data from a real hospital project. Second, the whole design session had to be video-recorded and as many technological and semiotic modes as possible had to be included so that we could observe when and how they were deployed throughout the session. We analyzed the affordances (possibilities) that the different modes provided to move the interaction forward, and whether and how they also blocked (constrained) interaction. Most importantly, we sought an illustrative example in which all the participants were observably active and engaged in contributing to the task at hand. Apart from the video recording, we were interested in data that included participants' formal or informal reactions to the technological mediation used (CVE). Finally, we wanted one of us to have attended and observed the selected design meeting in real time.

We found data that filled all our criteria in a study by [1], which aim had been to describe a newly developed CVE, ViCoDE, and to assess how well it facilitated design collaboration in a real-life context. Drawing on [13, 4 and 8], ViCoDE had to fulfill three criteria: 1. it had to support a creative and shared design process; 2. it had to result in better participation, communication and collaboration between designer and end users, and 3. it had to combine different technological digital and virtual technologies to facilitate individual as well as collaborative spatial reasoning. Based on an analysis of verbal and non-verbal modes in combination with uses of the technological modes, the authors found that the ViCoDE system did fulfil the three criteria. However, in this study as well, collaboration seems to have been taken for granted as prevailing throughout the workshop [1].

We revisited the original data (video recording, interview transcripts and the fieldnotes of one of the researchers) and re-analyzed the workshop participants'

interactions using a social-semiotic multimodal lens. Here, we want to stress that we do not contest the findings in [1]. On the contrary, and in line with recent multimodality studies in Architecture [3], there is no doubt that the semiotic resources afforded by CVEs, if used to their full potential, enhance understanding and interaction. Our intention is to contribute to a methodology for distinguishing between different levels and values of interaction.

### 3. Showcase example showing that collaboration requires hard work

The novelty of the ViCoDE system is that design participants can simultaneously and seamlessly interact face-to-face using several connected technological modes: collectively, using touch table and checking big screen projection; and individually, using HMD and checking 3D projection, see Fig. 1. This means that some participants can be virtually immersed in the design space while others use the touch table to move objects, test alternative placements, and obtain immediate feedback from the immersed participants. Contrasted with only face-to-face interaction, mediated by 2D drawings or by 3D projection, ViCoDE enables a holistic integration of design environment and performative practitioners' actions as they may be 'lived' in the prospective space through the mediation and resources afforded by the several immersive VR systems and a multitouch table.

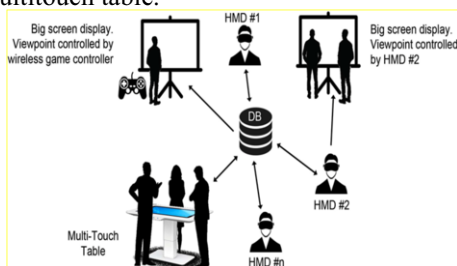


Figure 1. Schematic of the ViCoDE environment

By re-analyzing the data using a social semiotic lens, we contribute hitherto hidden processual insights and cues which could lead to deeper reflection around possibilities of further and finer-grained exploration of the complex multimodal layering involved in integrating face-to-face and virtual communication modes and resources. These insights could improve abilities to distinguish different nuances and levels of social interaction, which in turn would increase facilitators' and participants' awareness of cues they need to attend to effectively manage interaction levels toward collaboration

In the following, we introduce our re-analysis of the design workshop as a starting point for a multimodal semiotic approach to social interaction. Since social interaction in the AEC sector most often involves collective negotiations between multiple disciplines and professions – collaborative design being an increasingly popular case in point – we deem that applying such an approach would contribute to improving interactive engagement in the sector.

To help the reader, the nine active participants are identified and shown in Fig. 2.

- Main architect (Arch) and facilitator of the workshop
- Assistant architect (Arch-as), observes and takes notes for Arch
- Anesthetic nurses (AN1 and AN2)
- Operation Theatre nurses (TN1; TN2, TN3 and TN4)
- Researcher and technical facilitator (R1)

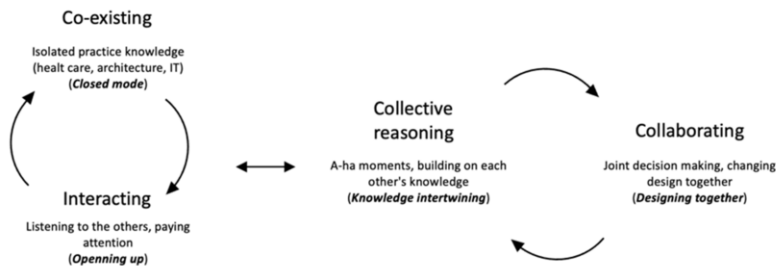
**Note:** Ideally there should have been at least one physician present, but no such data could be found.



**Figure 2.** Active participants in the design workshop.

The design context is a four-hour collaborative design workshop using ViCoDE as mediating technology. The architects and nurses were tasked to design the layout (equipment and furnishing) of two empty operation theaters: first, a standard sized room of 63m<sup>2</sup> (OP1) and then, a larger theatre measuring 82m<sup>2</sup> (OP2). In between the two theaters, there is a preparation room (PrepR) meant to service both theatres and accessed from the theatres. A researcher (R1) was on hand to observe the activities and to help the design participants with the technology. He is therefore considered as an active participant. The workshop starts with a 10-minute tutorial by R1 on how to use the touch table and its item library after which the participants start filling OP1 with equipment and furniture. This initial filling procedure is easily and rapidly accomplished, each category of participant placing different generic operation equipment in OP1. However, problems occur when they start to interact (see Fig. 4 and onward as well as commentaries).

The most important insight from our analysis was that ‘collaborative working together’ does not just happen, no matter how well designed the technological modal affordances may be thought to be or how motivated and goal-oriented the participants are. We can clearly show that achieving collaborative design is a processual joint endeavor requiring hard work. Different mindsets and work views need to be negotiated and preconceived representations need to be (re)conceptualized for the given situated prospective design object to satisfy all the involved participants. This means that participants need to imagine futures by tapping into their current and past knowledge and situated experiences and make visible what they are not aware that they know [14, 15]. They also need to understand ‘where other participants are ‘coming from’ to appreciate others’ representations. This means that for collaboration to happen, participants need to suspend their immediate reactions and actively listen to other participants deliberations.



**Figure 3.** Process framework for collaborative design practice

As shown in Fig. 3 and exemplified in the snapshots (Figs 4 to 19), we found four distinct levels of interaction: co-existing, interacting, collective reasoning and collaborating, each preceded by discernable cues. We also found that participants only really start sharing process and design together, i.e., collaborating, in the last hour of the four-hour workshop. Up until then, they take part in overlapping levels of interaction. In the following, we present the process framework by illustrating typical action snapshots that capture emblematic cues of each level. In the snapshot commentaries, we discuss contextual and situational specifics.

### 3.1. Co-existing: Level 1

What we see at this level is a locking of entrenched positions and representations of two very different professional knowledges and expertise with very different ways of practicing their professions. Architects deal with formal, rule-based knowledge of spatial dimensions and relations as represented and codified in the brief whereas the nurses' spatial perceptions are based on their internalized and tacitly embodied daily uses of the space. At this level of interaction, they co-exist rather than interact. They use their bodies to stake out territory and alliance around the multitouch table technology and occasionally refer to the 3D projection to help them navigate aspects of their situated practice. In this way, they trigger what [14, 15] call 'arresting moments'. Such moments could create opportunities for collective reasoning but does not do so here.



**Figure 4.** Co-existing



**Figure 5.** Co-existing

Sequence	Description
Figure 4	Full attention is on the touch table. The nurses and Arch place relevant apparatus in what they see as appropriate locations, respectively. AN1 does not actively use the touch table but takes on the role of overseer of others' work at the table, directing and correcting the moves made. Here, her attention is concentrated on the Arch's actions. AN1 uses alternating body movements to show disagreement: arms akimbo, slight turning away from Arch, scratching head (in snapshot), shaking head, constrained smile and tense jaw movements and lips. She interjects with short, terse utterances of assent or veiled dissent, which are immediately counterargued by the Arch, who justifies her actions referring to brief codes.
Figure 5	The nurses are markedly dissatisfied with the Arch's design of OPI, which they show by demonstrative hand waving and pointing at touch table or, more rarely, at 3D screen. For them OPI is too small to work in. The Arch insists it is of standard size and in line with directives. Secure in her professional knowledge, she continues to import and place objects, ignoring protests. AN1 mobilizes both TNs and ANs to unanimously reject Arch's representation.



Figure 6. Co-existing



Figure 7. Co-existing

Sequence	Description
Figure 6	The Arch and AN1 are the main protagonists as demonstrated in their body language and reinforced by their verbal articulations and their occupation of strategic space at the touch table. Arch and AN1 perform an interesting dance along the length of the table vying for space and proximity. When the Arch fails to get the attention of the nurses, she symbolically uses the table pen to hand over her facilitation responsibility. Her movements are tense, her smile tight and somewhat contrived. Her symbolic offer of the pen, however, is not taken up by the nurses. The implication of this refusal would warrant further probing.
Figure 7	AN2 and TN1 take turns to demonstrate their points by navigating the touch table, which is orchestrated by AN1. The Arch has stopped engaging with them. This is a typical example of how the two categories of nurses share ideas. Although they have different expertise domains, they are grounded in the same professional knowledge area and, more importantly, have experiential knowledge of each other's everyday work functions and practices. After each discussion between the parties, TN2 directs their attention to the 3D representation on the screen as a check.

There is no participative verbal or non-verbal action between the architects and the nurses at this co-existing level, nor is there discernable signs of active listening across the professional boundaries. Furthermore, the two parties use the technological mediating tool of the touch table to strengthen their separate positions rather than to interact. In other words, there is no communication; rather, most of the verbal exchanges consist of information and opinions. Interestingly, the touch table risks becoming a constraining rather than enabling tool; it draws the participants in and forces their attention on it, which is positive, but since they are not familiar with all its functions, they are yet unable to use the semiotic meaning-making potential resources it can offer. Instead, they become fixed on their contradictory views concerning OPI and use the



table to mark their individual positions. For the workshop to progress, they are dependent on a timely intervention of R1.

3.2. Interacting: Level 2

A shift in interaction level takes place when R1 invites the participants to test the VR-HDM mode. Three nurses accept. The dynamics at the table change. Since AN1 has moved away, the Arch uses the opportunity to take over the table. She changes her discourse from instruction and correction and starts asking for explanations. This raises the energy level and generates some dialogic exchanges. The participants start to collectively refer to the 3D screen representation to locate themselves in the ‘real’ OP1 space and to compare that with what they see on the touch table.



Figure 8. Interacting



Figure 9. Interacting

Sequence	Description
Figure 8	Arch’s attention is on TN1’s spatial arrangement. After contemplating the touch table, she says: “I’m surprised that one can place the [item] here, considering there is the mobile C-arm”, she emphasizes her doubt by turning her hand outward, palms up. TN1, using assertive hand gestures, explains the placements and movements of operation staff in the room and around the mobile C-arm. Arch, still with her palm turned up, responds: “Ah...you mean if one uses equipment a and b simultaneously ....?” TN1 continues to explain: “No, not simultaneously, but ....”
Figure 9	Arch: “Ok! so, then we have the anesthetic equipment here and ....” Arch is now more relaxed and engaged, repossessing her role as facilitator and posing open questions. Arch: “And what about this item?” Here both Arch and nurses use the 3D screen representation and compare what they see to the 2D representation on the touch table.



Figure 10. Interacting



Figure 11. Interacting

Sequence	Description
Figure 10	Now, over an hour into the session, the Arch tests the HMD. Seemingly, her first try ever. The nurses continue developing OP1 on their own from their practice perspective. They check with the spatial relations on 3D screen. On this snapshot the nurses have taken out their smart phones to photograph (fix) their representation.
Figure 11	However, positions have not changed. AN2 again takes command of the touch table and of the TNs' attention. The Arch still insists that there is sufficient space for movement in OP1. Ignoring AN1, she addresses AN 2, steps away from table, making broad and vague circular movements with her hands, showing that there is space for moving between objects. AN1 interrupts to correct Arch's misunderstanding of how the space is used, stating: "the person fetching the items from <u>here</u> [showing with hand on table] is not <u>this</u> person <u>here</u> but is <u>that</u> person <u>over there</u> [moves hand]". The Arch signals through her body language that she does not agree.

Although the level of interaction is heightened as manifested in the increased use of mediating technology, movements between screen and touch table, and linguistic shifts toward a more dialogic rhetoric, the participants remain locked in their separate representations of a future OP1 room. They hear what the other is saying, but they are not really listening. An interesting and unanticipated addition to the technological panoply of mediating tools is that of the smartphone, which first appeared at this level (Fig. 10). Here it is the nurses that 'fix' [6] the representation they have achieved by instantiating it as retrievable image. This use of the smartphone recurs throughout the rest of the design workshop at moments when there is some kind of agreement either within one party as in Fig. 10, or between both parties as seen in the following two levels.

### 3.3. Collective reasoning: Level 3

The move from interaction to collective reasoning is fascinating. Looking at the figures, we can almost feel the participants thinking!



Figure 12. Collective reasoning



Figure 13. Collective reasoning

Sequence	Description
Figure 12	Arch is thinking out loud: “So, what happens? Yes, it’s cramped! She cups hands around cramped area in center of OP2 and then moves finger to forehead [typical thinking gesture] ... and then it is empty on the sides. That is a dilemma!” TN2 explains that they need the space. TN1 “we have the preparation space [PrepR] between the rooms”. Arch agrees: “you have that, but others don’t ... they do not reason the same way as you do ...” TN4 protests: “But we are not allowed to walk [between OP rooms]”. Arch “...if you cover the equipment trolley ... then you are allowed to [in another hospital]”. Nurses accept the explanation with comment “yes ... it is an organization practice issue.” The nurses’ facial and body postures signal concern at this information, they are all intent on the table and seem at odds with how to respond.
Figure 13	TN1 says “here we have much more space to move around, and I can promise that in 10 years’ time this will not be the only [alternative] ... there is already talk about other design and equipment being developed.” Arch agrees. TN3 then offers a suggestion in support the Arch’s argument based on recent developments of large post-op rooms: “it may be good with a large room...but we also need to think about the extra steps.” Arch turns to TN3 and both agree verbally and with head nods.



Figure 14. Collective reasoning



Figure 15. Collective reasoning

Sequence	Description
Figure 14	Arch again reflects aloud using the table image: “OK, let’s see... where are we now [moving hand slowly to demonstrate] ... if we think that we are here [points to OP1, then shows narrow space, then moves hand to OP2 and makes circular movements around empty space]... here we have space to move and bring items [moves arms horizontally from center outwards then turns to TN1] ...yes, that’s how it is ...” She nods with both her head and body. This is the first real agreement between Arch and nurses.
Figure 15	Arch says “we can say like this, we have the situation that is we [with emphatic use of hands and eyes and gaze on nurses] ...augment one room and diminish the other then we have two rooms that fall out of the standard... possibly we could ...” Note: it is at this point that collaboration starts!

An important cue for the shift from level 2 to 3 occurs when R1 helps the participants extend the image on the touch table. Moreover, AN1 has left the workshop and the dynamics have been reconfigured; TN1 and AN2 jointly become the main voice for the nurses. R1’s facilitation triggers an important processual shift in that it changes the spatial representation of the design object for both parties. This forces them to think beyond the constraints of the one OP and to view the design space holistically. The discourse and body language change dramatically, see commentaries below. Notable cues here are tentative shifts to an inclusive ‘we’ perspective and a reflective thinking-out-loud on the part of the Arch: she is not only thinking on-the-hoof but more importantly, she is sharing her thoughts with the nurses, resulting in their following up with their own thinking-out-loud reflective responses. Comparative referencing between representation and the lived spaces are used to support each other’s arguments rather than

to oppose them. We suggest that the collective reasoning phase is probably the most important phase in a collaborative design process and needs to be taken into special account in the improvement of technical and/or communicative facilitation.

### 3.4. Collaborating: Level 4

Collaboration may follow upon collective reasoning if the participants are sensitive to the possibilities, the arresting moments that their reasoning affords. We do not have space here to elaborate; rather, we will let the snapshots and commentaries speak for themselves.

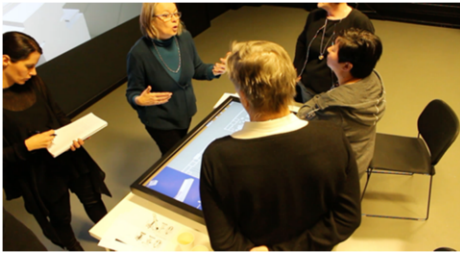


Figure 16. Collaborating



Figure 17. Collaborating

Sequence	Description
Figure 16	Arch elaborates possibility of diminishing OP2 since, according to her, this is more justifiable, but there will be a cost. She suggests there “may” be a way of circumventing the brief. Here, she uses body and face to emphatically express: “but I do not know”. She states: “ <u>w</u> e have now made changes to the design counter to specifications ... and not only one, but <u>thre</u> !” Arch looks at table: “But it feels like, this room, the really large room, it may work”, then she steps back, cocks her head looking at table. Then steps a bit forward, cocks her head, gazes intensively at nurses as she addresses them: “or what do you think?” Nurses start talking at the same time agreeing and iterating the reasons comparing again to OP1. Everyone talking at once and waving hand in all directions. The smartphones come out and the image is fixed [not in snapshot].
Figure 17	The Arch demonstrates by moving an object around OP1 that now they can move around without difficulty. But then she highlights the arm of the robot machine and says that it is very annoying. TN1 compares it with OP2 and moves it so that it no longer obstruct movement [another agreement point]



Figure 18. Collaborating



Figure 19. Collaborating

Sequence	Description
Figure 18	AN2 starts furnishing PrepR on her own. Arch turns to TN1 and AN2 to respond to their joint queries regarding the size of the rooms. She then moves from the touch table to ‘walk-the-talk’ i.e., bodily measure the imagined space through role-play. In the meantime, three nurses are in the VR-HMD environment, embodying the changes made on the touch table.
Figure 19	Arch is step-walking to test their decision and AN2 asks the Arch-as whether the idea AN2 is toying with of reducing the size of PrepR would be feasible. R1 suggests “You can move the wall”. AN2 and TN3 together move the wall. TN3 calls to TN1 “Come and look at <u>your</u> smaller prep room.” Arch rejoins with an “Oh!, <u>you</u> have done that” [surprised and positive ‘oh!’]

Figures 16 to 19 demonstrate how collaboration happens when all the available semiotic and technological resources are orchestrated to act in concert (simultaneous concerted use of multitouch table, HMD, embodied role play, speech, body language etc...) enabling actions to feed back into collective reflections and further feeding back into orchestrated actions. For this to happen, we argue that level 3, collective reflecting, is the most important and sensitive phase of a collaborative workshop process and the one that requires skillful and participative facilitation.

#### 4. Concluding reflections

In this paper we have problematized the meaning of ‘collaborative’ and ‘collaboration’ by analyzing the unfolding of a real-life design practice, a four-hour workshop, using a multimodal social semiotic approach. We focused on how participants mobilize different communication modes, verbal, non-verbal and material/digital and argue for their ideas. We identified combinations of modes that can trigger shifts in levels of interaction. We found that the design workshop process consisted of four distinct yet overlapping phases: co-existing, interacting, collective reasoning and collaborating.

Our main aim has been to introduce an illustrative example of a multimodal analysis in the hope of stimulating colleagues to join us in further developing a multimodal social semiotic methodology suitable for studies of/within the built environment. Fine-grained studies to further test and develop the approach and framework and further query the quality of ‘collaboration’ are warranted. These studies should strive to include all the medical staff implicated in the day-to-day work in the space being designed. We hope that this initial articulation of a possible methodology will spark interest and further reflection what the implications may be for enhancing collaborative design.

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