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Material Mediation in Collaborative Activity

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The material qualities of technological mediators are vital to collaborative activity, but current paradigms for collaboration support leave the potential of material mediation largely untapped. The HCI literature addresses both material mediation for individuals and coordination between collaborators — but rarely does it discuss the more direct role of the material as standing between people: its communicative role. This paper unfolds a material/linguistic analysis of four empirical examples from previous work on collaborative writing to showcase how material qualities of both tools and the text-in-progress, used in both planned and improvised manners, *help co-authors shift between levels of collaboration, from independent co-ordinated activity to highly collaborative co-constructive activity*. On one hand, we see co-authors successfully collaborating through material means; on the other, we see frustrations resulting from limited material expressivity in current tools. This duality between the significance of material mediation and obstacles to drawing on its potential makes clear that our conception of materiality needs elaboration. We point to multimodality as one opportunity for this.

CCS Concepts: • **Human-centered computing** → **HCI theory, concepts and models**; **Empirical studies in collaborative and social computing**.

Additional Key Words and Phrases: material, collaboration, mediation, activity theory

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1 INTRODUCTION

Material qualities and materials have been a concern in Human-Computer Interaction (HCI) for the past 20 years. Robles and Wiberg [47] identified what they called a ‘material turn’ in Human-Computer Interaction. Following this, Wiberg et al. [57] envisioned a radical shift of perspective in HCI, from the computers as tools for human users to to users acting on the computational as material. The notion of computational material draws attention to the way (inter-) actions in/with the digital rely on the computational manifesting through dimensions such as positioning and appearance [23]. Such computational, or digital, material may be without physical properties [38] or be entangled with physical properties [45]. The problem with the material turn of HCI is that it is often described and analyzed from an individual user standpoint and does not touch on what materials and materiality means *among* people. With this paper, we address the roles of materials and materiality in human-computer interaction as *material mediation*, and we argue that it is important to analyze materiality from a collaborative viewpoint.

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From the beginning of CSCW as a field, the role of shared material objects and shared materials has been discussed with respect to how they help or hinder collaboration. Sørgaard [53] talks about material as “the *‘thing’ people work on, manipulate, move, etc.*” and discusses two examples of things that help or even ‘dictate’ coordination: two people carrying a large piece of furniture through an open door where this could not have been done by one person alone, and a paper-based file that gets handed over. Sørgaard points out that many of these material (and in essence, multimodal) qualities, which very directly shape coordination, disappear with, e.g., computerized filing systems.

Similar thoughts are developed by Schmidt and Randall [50]: When working with physically tangible tools and objects, people make use of “*the various accidental features of the material setting*” [50], but when moving to digital tools, people tend to be relegated to an ‘impoverished’ space in which this ability to adjust and exploit material features is gone [50]. When we work together in a physical space, not only can we use different pen colors and cross things out (as we may in a digital document); we can also annotate in all manner of ways: from the front to the back of a sheet, from one sheet to another, by crumpling up a sheet to discard it without completely getting rid of it – all leaving signals for us and our collaborators as to the state of the work and decisions made [1]. In the current digital space, we are left with font coloring and highlighting, and comment fields to position in 2D. O’Hara et al. [42] suggest that these kinds of shortcomings are rooted in attempts to emulate the affordances of physical material (in this case, paper) rather than focusing on the unique affordances of the digital. Might it be time to open up to a broader conception of materiality?

This paper unfolds a material/linguistic analysis of four empirical examples from previous work on collaborative writing. We showcase how material qualities of both tools and the text-in-progress, used in both planned and improvised manners, help co-authors shift between levels of collaboration, from independent co-ordinated activity to highly collaborative co-constructive activity. The paper is structured as follows: In the next section, we take a deeper look at more recent related work before presenting the empirical and theoretical basis for our argument. Following that, we analyze the four empirical examples, before moving to a discussion of materiality and multimodality.

2 RELATED WORK

2.1 Materiality and Cultural Practices

While the literature lacks a focus on material properties for communication, there has recently been related attention to materiality in connection with social and cultural practices [23]. To Giacardi and Karane, *materials* is used “*not just to indicate what objects are made of but also the properties, embodiments, and arrangements through which they can be experienced and performed.*” Giacardi and Karane offer a vocabulary for articulating and configuring the situational, experiential whole where materials and practices are involved. However, like most others, they stay very much within an experiential framing of individual practices, and none of their discussions of material seem to discuss the roles of materials among people or in collaboration. Focusing on creativity, Hsueh et al. [28] take a starting point in material and collaborative conditions of creativity and how technology remediates traditional practices, with a focus on shared practices more than collaboration.

There have also been studies of collaboration and awareness on a larger scale, particularly in software platforms where people — together on a large scale — produce jointly developed software. Dabbish et al. [21] studied visual cues for social collaboration in GitHub and point out that actions convey meaning and history in ways that other users can choose to follow to learn from. Howison and Crowston [20] studied a community of open software developers, identifying mediating, socio-technical contingencies that are likely to support collaboration through the open repository, including characteristics of artifacts made when the objects are being worked on. Both of these contributions consider

a somewhat larger scale than we are interested in here, and hence while these works share fundamental conceptions of collaboration and awareness with ours, the current paper distinguishes itself by looking deeper at what is essential in moment-to-moment collaboration and how that is supported materially.

2.2 Material Mediation in Collaboration

The relationship between material mediation and collaboration has been discussed by Heath and Luff [25] in greater detail. They point out how people organize and collaborate around material objects over time. Schmidt and Wagner [51] focus on material artifacts as publicly accessible and inspectable by other collaborators, specifically with a focus on materiality of artifacts that are physical and not interactive. Conversely, in Rosner’s view [48], materiality can be interactive and not necessarily connected to physicality; hence, material mediation does not only pertain to physical objects and mediators. Jensen et al. [31, 32] embrace both the physical and the digital and illustrate differences and similarities between the two by comparing physical and digital sticky notes as two forms of material mediation in collaboration and turn-taking.

Orlikowski [44] and others [7, 37, 52] have focused on practices that are *socio-material*, addressing the cultural nature of technology and material objects and how they are used and developed within a practice and in everyday organization of activity. This framing offers a way of analyzing how human activity is both *collaboratively* and *materially* mediated; yet, little of this work addresses directly how people communicate through the material artifacts and objects, i.e., how these artifacts and objects are also signs [10].

We address this as *communicative mediation* (detailed in subsection 3.1). The CSCW community’s understanding of this side of human activity needs to be developed further; a development we initiate with this paper. We propose that the material qualities of technological mediators are vital to collaborative activity, not only because materiality is culturally situated, but also because it plays a role in communication between people. That is to say, we propose a further and more detailed focus on material and communicative mediation. The current paper picks up on this collaborative aspect with a focus on how communication and division of work is mediated by (digital) material(s) and tools. Collaboration and sharing are, certainly, a matter of doing, but they also entail communication, and we look into better understanding how joint, developing, and overlapping uses may happen.

2.3 The Role of Mediation in Shifting Collaborative Activities

Bardram [2] differentiated between three different levels of collaboration in human joint activity: *Co-ordinated*, *co-operative*, and *co-constructive* collaborative activity (elaborated in section 3). These three levels point to how communication and joint action go hand-in-hand, between the shared understanding of artifacts, objects, and purposes and the understandings of individuals. While Bardram’s work focuses mainly on the relationships between different activities, our effort here is to address shifts of ‘mode’ *within* collaborative activities and, in particular, how such shifts are mediated — for instance, when, in collaborative writing, a suggested change in a document pulls the co-authors out of their co-operative work and into a co-constructive discussion, which prompts one co-author to take a screenshot of the text and annotate it in lieu of physical pointing or out of a desire to preserve the pointing (and thereby also preserve part of the discussion) for later. Or after the discussion, when a plan has been made and discussed (co-constructively), and the co-authors proceed with their parallel and mainly co-ordinated drafting of the planned sections. Examples like these have sparked our interest the role of materials in these shifts, and what this may imply about how technology can be designed to more actively play a part in this; not least how multimodal interaction may support collaboration through increased material expressivity, as discussed in section 6.

Following on from Bardram’s theoretical basis, and to shift the focus to materiality in the context of collaboration, we pursue the cultural-historical tradition a bit further. Fundamental to this tradition is that human activity is mediated, both materially and communicatively, and that people do not just live in the world, they also communicate about it [19]. In discussing design representations, Ivarsson et al. [29] address multimodality and multimodal practices from the point of view of cognition and socio-cultural theory. In their analyses, they point to the role of language as a central mediator of human joint activity, and to the roles of multimodal, material objects (in their case, design representations) in the development of joint and situated practices. In [30], they go on to study how children develop skills in using a range of symbolic artifacts, intimately related to – and most often indistinguishable from – physical tools. From a similar background, Nicolini et al. [41] focus on shared objects as both material and symbolic and point to how objects serve both material purposes (i.e., material mediation), purposes of understanding (linguistic, hence communicative mediation), and purposes of negotiating and establishing (new) collaboration.

In this paper, we apply a similar basis in socio-cultural theory and multimodality: We address what kinds of collaboration unfold and are supported/not supported through material and communicative mediation, along with transitions between Bardram’s three kinds of collaborative activity and how these transitions are helped or hindered by the qualities of the technological mediation. Drawing on this framing, we use examples from previous empirical work to develop a theoretical framing of materiality and collaboration.

In the section below, we provide an overview of the theoretical framework and the empirical background, before we move on to a detailed analysis of four examples selected from our empirical material. In conclusion of this, we discuss how increased material expressivity can be achieved through multimodal interaction.

3 THEORETICAL FRAMEWORK

3.1 The Duality of Material and Communicative Mediation

The theoretical framework and method share their background with several of the works mentioned in the introduction, notably, the work by Bardram [2] and Ivarsson et al. [29, 30]. Specifically, it takes its starting point in Bødker and Bøgh Andersen [10] who use a combination of Pierce’s semiotics and activity theory to explore the integration of communication and physical activity in activities that are mediated by technology. This work was inspired by Christiansen [18] who theoretically explores the communicative side of mediated human activity while pointing out that human activity is the molar unit of bodily human life through which humans act and do together and, at the same time, come to understand – highlighting the dual relationship between physical and communicative doing. Ivarsson, Linderöth, and Säljö [29] point out how mediation implies that humans think and act through cultural artefacts that have evolved over time, and that such artifacts encompass both linguistic/communicative and material mediation. They discuss how Vygotsky called language ‘the tool of tools’, and how Cole [19] has pointed to linguistic and material tools being two sides of any mediation (see also [56]). With this framing, we can view material and communicative actions as occurring simultaneously rather than as mutually exclusive forms of joint activity [55], leading us to focus on the duality of material and communicative qualities of mediation.

Further use of activity theoretical HCI (see, e.g., [6, 8, 12]) lets us focus on users in a *mediated* relationship with other users and with objects [8, 9]. Tools are mediators that stand between users and other objects and help users act on the objects [4, 8]. Objects are shared in various ways and exist in the activity in various forms, both the materials from which an outcome is shaped, various states of this in the process, and the anticipated, understood, shared understanding of the outcome of the activity.

Recent research [1, 5] has had a starting point in common objects that are simultaneously material, social, and communicative and that mediate users' joint activity with a specific focus on the language and concepts related to co-operation and transfer of experiences across a community. Bødker [8] and Baudouin-Lafon [4] have both offered attempts at understanding the connection between objects and mediators in cases where some or both of these are digital. Bødker [8] distinguishes between objects that are handled *in* the mediating artifacts, and objects that are handled *through* those artifacts. When looking at activity as mediated by multiple artifacts at once (see below), this is not an either/or; rather, some mediation happens through, and some in, the mediating artifact. Beaudouin-Lafon [4] uses the term *instrument* to embrace both the physical/material means of interacting with objects and the logical/virtual ones, fundamentally pointing out that material mediation is an element of all computer mediation, whether the objects are in the mediator or not, i.e., whether the object itself has a material manifestation outside the computer or not. Similarly, material mediation plays into communicative mediation, such as when individually colored telepointers in a shared document show collaborators *who* is working *where*; with aspects like position and color having both material ("Somebody is writing in *this* line") and symbolic purposes ("The orange telepointer *is Charlotte*").

Objects and artifacts exist together, and people rarely only engage with one at the time. Hence, Bødker and Klok-mose [12] talk about artifact ecologies, and Bødker and Bøgh Andersen [10] exemplify how multiple mediators for specific activities may be connected across the material and the communicative: Bødker and Bøgh Andersen [10] develop detailed analytical accounts of mediation, and how material and communicative mediation are constantly at play in their specific empirical settings. Material and communicative mediation supplement and substitute one another, such as in the joint navigation of a ship between a captain and a pilot. By pointing out that mediation is multiple, heterogeneous, and dynamic, and consists of webs of mediators [10, p. 374], Bødker and Bøgh Andersen propose that the development of instrumental skills goes hand in hand with the formation of successive concept formation (see also [13]).

In summary, common objects and mediators are both *material*, *social*, and *communicative*, because common objects and mediators stand between people, both materially and communicatively, and mediate their joint activity (see [1]). Bødker and Klok-mose [14] point towards the use of conceptual blends to address mediation as material and communicative and to constructively focus on combining the two. Conceptual blending helps address how people together combine known material and communicative mediators with a view to current and future activity.

In their analytical accounts, Bødker and Bøgh Andersen [10] execute a careful mapping of many different elements of multiple mediation, emphasizing activities, actors, mediators, objects, and interpretation, filled in with components of the working process. In their mapping, the same filler can play more than one role at a time, and it can change roles during the work process. This enabled them "*to describe co-occurring mediators; chains of mediators; leveled mediators; focus shifts; and, finally, the interplay between instrumental and semiotic activities.*" We have appropriated this filler-model to focus also on the community (see Figures 1–2 for background and 4–9 for detailed analyses).

In their understanding of theories of interaction as generative (i.e. analytical, critical, and constructive) Beaudouin-Lafon et al. [5] ask a number of questions that help us address material and communicative qualities of mediation: Analytically, how are material and communicative qualities of mediation supported in the joint activity? Critically, what helps or hinders material and communicative qualities of mediation in collaborating around common objects? Constructively, how may concepts and objects be used to better support collaboration around common objects, e.g., through conceptual blending? We use a similar conceptual framing to distinguish between material mediation, i.e., material qualities that help transform the object of work from working material into outcome; communicative mediation,

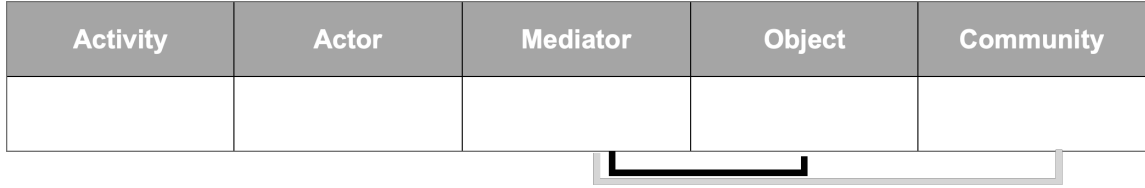


Fig. 1. The mapping of [10] adjusted with our focus on the community. The connectors indicate that the activity of the actor is mediated towards the object (material mediation – dark gray) and/or the community (communicative mediation – light gray).

i.e., communicative qualities that mediate the coordination and communication between actors in the joint activity; and their joint anticipation of future outcomes.

3.2 Kinds of Collaborative Activity

Bardram and Houben [3] propose the idea of collaborative affordances, further explored by Avdic et al. [1]. One of the collaborative affordances identified by Bardram and Houben [3], mutual awareness, is a matter of how collaborators may orient themselves towards each other, mediated by the material and communicative mediators available.

In another strand of work, Bardram [2] (as well as Borchorst and Bødker [15]) differentiates between three different forms of collaboration in joint human activity: *Co-ordinated* collaborative activity captures the normal and routine flow of interaction where the various actors act upon common objects, with their individual actions only externally related to each other. The participants follow their scripted roles, each concentrating on the successful performance of their assigned actions. In *co-operative* collaborative activity, the actors focus on a common object and share the objective of the activity. In *co-constructive* collaborative activity, the actors focus on re-conceptualizing their own organization and interaction in relation to shared objects, hence negotiating their joint activity. These three forms of collaborative activity point to various ways in which communication and joint actions go hand in hand, even when the (shared) understanding of artifacts, objects, and purposes differ and shift in the activity. Where Bardram [2] looks mainly at actors carrying out different, although interdependent, activities, our effort here is to address shifts of collaborative ‘mode’ within activities, and to focus in particular on how such shifts are mediated.

Awareness is one area where considering ways of coordinating and taking heed is relevant. Tenenberg et al. [54], with a somewhat similar theoretical background, discuss awareness with their starting point in a critique of the awareness concept in HCI often being framed with a focus on individuals, similarly to what we have noted about materiality above. They point out that “*awareness is a collective accomplishment, requiring and presupposing that actors take heed not only of what is external and public, but also of what is internal to one another.*” In terms of awareness and how participants orient to one another, the differences lie between co-ordinated activities, where awareness of the activity of other users primarily lies in external and public scripts, synchronization of actions (operations), and changes of the objects; co-operative activities, where awareness is to the joint balancing of actions and outcomes of one’s partner with one’s own actions and outcomes, and to influencing each others’ actions and outcomes with regard to the common tasks; and co-constructive activities, where awareness is connected to re-conceptualization of objects and negotiation of the joint activity internally in the community of actors.

We summarize the distinctions between the three types of collaborative activity (Figure 2) as follows: The differences lie in how stable (versus negotiated) the common objects of work are to participants. In addition, there are differences in the degree to which the means used to communicate and collaborate around the activity, and shared objects, are

Activity	Actor	Mediator	Object	Community
Co-ordinated activity	-externally related -focusing on performing assigned actions and roles	-scripted roles -individual tools	-each actor may not be aware of common objective of their activity	- no particular attention from individual to others to
Activity	Actor	Mediator	Object	Community
Co-operative activity	- each individual has to relate the joint task to the individual aim	-negotiated	-actors focus on a common object and share the objective of the collective activity - the object is stable and generally agreed upon	- common aims and tasks are placed above individual actions and their aims
Activity	Actor	Mediator	Object	Community
Co-constructive activity	-actors focus on reconceptualizing their own organization and interaction in relation to shared objects	-means/tools/routines are reconceptualized as is interaction and communication between participants	-object unstable and collectively constructed	- actors together in the activity

Fig. 2. Summarizing co-ordinated, co-operative, and co-constructive activity. The distinctions between these three types of activities lie in how stable versus negotiated the common objects of work are to participants, and in the degree to which the mediating tools and process, along with the shared objects, are negotiated.

in flux and negotiated. Whether, and how, participants are part of an activity is important. Is it only through the actions on the objects, or beyond that with an internalized, joint motive of the activity? Pointing towards the inclusion of both communicative and material or instrumental mediation, Bardram [2] (see also [15]) distinguishes between communicative, instrumental, and scripted collaboration, stating that “*coordination of collaboration takes place through communication, including indexical, symbolic, iconic, and conceptual communication*” [2, p. 49]. Instrumental coordination refers to how actors coordinate activity through their primary artifacts. Scripted coordination is made possible when all involved actors share what Bardram others call secondary artifacts, e.g., scripts and rules [2, p. 51].

3.3 Summarizing the Framework

In short, our starting point is that communication and division of work is mediated by the (digital) material, even in cases where the technological mediation seems to have been intended mainly to mediate material production, such as the production of text through a text editor. The theoretical framework presented above provides an analytical lens on why and how material qualities of mediation help or hinder communicative mediation, and vice versa. Below, we explore further how the duality between material and communicative mediation unfolds. By considering this as a duality, we mean to analyze the material and the communicative mediation separately to then address the tensions and transitions between them.

We look at this issue in combination with questions relating to what kinds of collaboration are unfolding and supported/not supported and, not least, transitions between the three kinds of collaborative activity and how they are helped or hindered by the qualities of the technological mediation. Different kinds of collaboration, and transitions between them, are connected with shared objects and material mediation, and with communicative mediation: For example, when a table of contents is a result of co-operative activity in a group who then shift to co-ordinated writing

of sections, whereby the table of contents changes from being the object of work to structuring the text (material mediation) and dividing the writing activity between members (communicative mediation).

4 THE EMPIRICAL BACKGROUND

Our empirical background is in two empirical studies we conducted of collaborative writing among university students and among university researchers. Both studies addressed the multiplicity of tools that co-authors use [33]. *Study A* was a mixed methods study [35, 36] with 32 participants: 11 research staff (postdocs, assistant professors, associate professors, and professors), 8 Ph.D. students, and 13 master’s students, spanning a total of ten nationalities (all Western and primarily Northern hemisphere). The study took its outset in writing projects that the participants were currently undertaking or had recently engaged in, within areas related to information studies, computer science, and interaction design. This covered a total of 18 projects, which included scientific articles, books, co-authored master’s theses, and a student project report. The data collection consisted of interviews and visualizations of document activity in project documents. While the participants spanned four different universities, the projects involved collaborators from beyond those universities. *Study B* was a co-design study [34] that built on the mixed methods study. It involved 13 participants, some of whom had also participated in Study A. Among the new participants, all had similar occupations and domains of work to those in Study A.

Study A focused on co-authors’ habits of switching between writing tools, such as drafting in a separate application from the one in which the shared writing was taking place. It addressed participants’ motivations and strategies for choosing when and how to use which technology, and Study B was built around these concerns. We identified four kinds of motivation for transitioning between different tools in collaborative writing [36]: the need for particular features, the need for an undisturbed space, the need for particular visual characteristics or for reduced visual distraction, and the need to reach and communicate with collaborators. While our previous analyses focused on practical and emotional motivations for these transitions, the motivations often also relate to material aspects of the activity, and it is exactly our wish to understand this better that has led to the present paper. For example, while the desire to work in a personal document rather than the shared one might be motivated by avoiding interference from collaborators, our previous analyses did not leave room to understand how material and communicative aspects of the mediating environment prompted such interference in the first place (see subsection 5.4). Moving from a shared document to a separate, personal draft also means moving one’s activity away from the primary environment for co-constructive work. Using Bardram’s framing of different levels of collaborative activity helps us express how these transitions are prompted by material and communicative aspects and how the transitions affect the collaborative situation/mode, and thus enables us to show that the consequences are not just experiential but also practical.

Furthermore, in our original analyses, we found the writing to be *multi-mediated* in more than one sense: Not only do co-authors use a number of different tools to enable the writing; the writing and surrounding processes are also mediated by the very text being written, such as when details in the text are used to discuss and structure the division of work in the future writing [36]. This means that material characteristics of both the tools and the text influence the way writing activities take place.

We use these observations as an outset for further extending the focus on materiality and collaboration. It is these meetings between the material and the communicative/coordinate mediation that we need to understand and articulate better. As a whole, writing a scientific article is a co-constructive activity, in which reflexivity and articulation contribute to the creation of meaning and a joint outcome that is new; and not a routine reproduction of existing thoughts, ideas, or materials. As we will further discuss in the analysis, scientific writing takes place also at a practical level, in an

that are physical and not interactive. Kosner (2012) is critical towards this way of connecting materiality to physicality in CSCW and to the elevation of artifacts over materials as well. Dourish (REF), who also considers material properties and collaboration, discusses how interactive technologies have human-made material qualities and demonstrates how these are used for collaboration, e.g., in his discussions of color to mediate *sared* use in spreadsheets.

The current paper picks up on this collaborative aspect with a focus on how communication and division of work is mediated by (digital) material(s) and tools. Collaboration and sharing is, certainly, a matter of doing, but it also entails communication and learning, and we look into better understanding how sharing, and developing, joining, and overlapping uses may happen.

Bardram (1998) uses Raiethel's work (REF) to differentiate between three different levels of collaboration in human joint activity: Co-ordinated, co-operative and co-constructive collaborative activity. These three levels point to how communication and joint actions go hand in hand in communication and doing, between the shared understanding of artifacts, objects, and purposes and the understandings of individuals. Where this work seems to mainly be looking at different activities, our effort here is to address shifts of 'mode' *within* collaborative activities and, in particular, how such shifts are mediated – for instance, when a suggested change in a document pulls the coauthors out of their co-operative work and into a

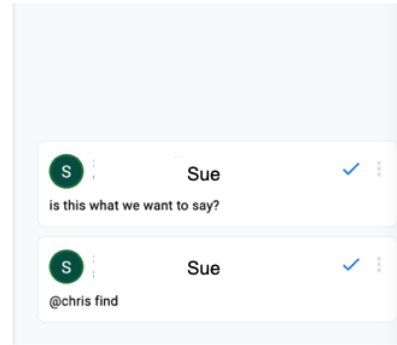


Fig. 3. Using a version of our own paper for illustration, this figure illustrates the co-writing set-up (*NOTE: constructed example, for illustration purposes*). Two pieces of the text in the document are highlighted. Each comment has “Sue” as the author. The first comment is addressing the contents and message of the document being written; the other is an example of a comment referring directly to a co-writer and what they need to do (find a particular reference). We are using this made-up example for illustration to not reveal details of the actual documents that were produced in the studies, and as a consequence also to be able to use one example to summarize our observations in a succinct way. The example mimics actual situations from the analysed material. This means that the names are invented and (as indicated) the text an old version of this paper.

interplay with actions of planning and coordination as well as direct actions and operations on the text as material [36], which happen in co-ordinated and co-operative activities.

4.1 New Analysis

To produce the present analysis, we went through the anonymized interview transcripts and identified latent [17] mentions of material and communicative/collaborative mediation, and of transitions between levels of collaboration. We present quotes that exemplify these in the analysis below. We also examined the documents shared with us in Study A and examples presented by participants in Study B. Unfortunately, presenting concrete examples from this examination would not be meaningful, as the consent given by participants would require anonymization of the content to a point where essential aspects (in particular, names and concrete text) would be lost. Instead, we provide more generic descriptions of the different examples and, in the case of Figure 3, have constructed an artificial but representative illustration. The analysis illustrates how communication is integrated with text and material production, and how different tools and materials are used, in both planned and improvised manners, to mediate these processes.

5 WRITING TOGETHER — ANALYSES

In the following, we dig deeper into the material and communicative mediation of human collaborative activity and use the theoretical framework above to exemplify unfolding activities and the roles of material qualities of the mediation in them. To understand the role of materiality in the examples we discuss, and as outlined above, we will address both *the material* and *the communicative* aspects of those examples in order to tease the two apart. We will combine this with a focus on how and when the material and communicative aspects matter to the three kinds of collaborative activity and shifts between them.

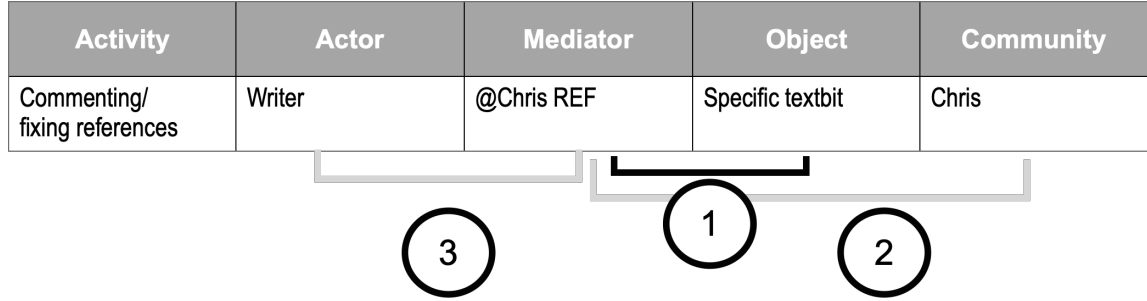


Fig. 4. Mapping of material and communicative qualities of “@Chris REF”. 1 illustrates how the reference is placed in the document (material quality), 2 shows the communication with Chris through the reference (communicative quality), and 3 shows how, if Chris is the writer, the comment may actually be a communication with himself later. (material mediation – dark gray) and/or the community (communicative mediation – light gray)

We return to, and draw examples from, the two presented studies of collaborative academic writing, *Study A* (mixed methods study) and *Study B* (co-design study). We present our observations using a mix of interview quotes (from Study A) and constructed examples that summarize observations and findings from across the two studies. The names used for the interview quotes are pseudonyms assigned by the authors.

5.1 Example — Comments

Comments are examples of a simple feature of most document editors that is often used to diligently cross between material and communicative mediation: We have seen comments used to flag a missing reference to be added later (using the text “REF” or similar), sometimes directly requesting that a co-author fix a reference (e.g., “@Chris REF” – see Figure 4 and the highlighted text in Figure 3). In particular, the generic “REF” may be found both within the actual text being authored and in separate comments in a document’s side pane. While the “@Chris REF” can be seen as purely a matter of delegated and co-ordinated activity, the “REF” without a specified recipient may serve that same role (simply as a request for someone to fix later) *or* it may be part of a co-operative activity that involves identifying the appropriate reference for the text being written. See also a researcher, Carl’s, description of these sorts of comments, and his clarification that in the collaboration he is describing, they are not targeted to anyone in particular:

Carl: [...] and then there are comments that are absolutely necessary, and for those, we often use macros, where we create a macro with the initials [and] a specific color. [...] Because then it shows up in the PDF in bright colors, and then you can see that this is something you must deal with [...]. **Interviewer:** So, it’s a comment from you? Or do you use it to address other people?

Carl: No, but actually a comment that: “Here, we’ll have to reference [‘McGregor 2001’],” or something along those lines.

Whereas in-text comments are often ad-hoc – or sometimes agreed-upon – conventions in the group of co-authors, using comment functionality as it is offered by most text editing tools is a matter of utilizing elements of the tools that have been designed specifically for communication (with others or as an author’s personal notes for later – see Figure 5). The material aspects of built-in comment features usually show up as the comments visually being linked to a particular place and context in the text, for instance through a colored line connecting the comment to a point in the text, whereas the communicative aspects are the explicit or implicit references happening between co-authors. In

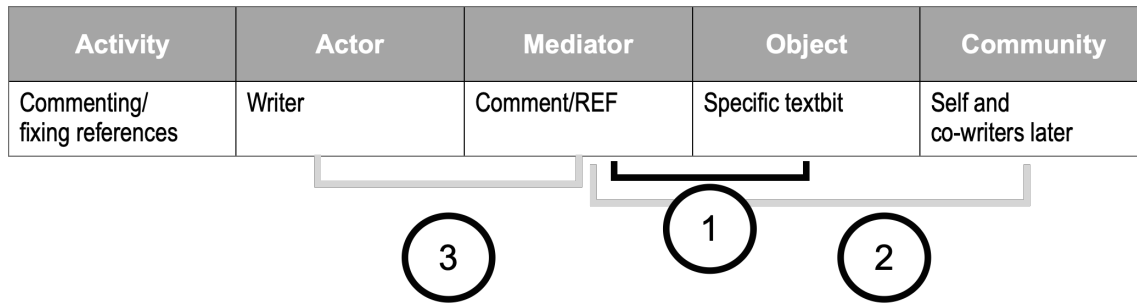


Fig. 5. Mapping of material and communicative qualities of “REF”. 1 and 3 are similar to Figure 4, while 2 points differently at a mediation with the community. This kind of activity may be co-ordinated or co-operative (material mediation – dark gray) and/or the community (communicative mediation – light gray).

any circumstance, these comments persist past other changes in the document. They are visible and/or searchable and remain until removed by an author.

Comments come in many forms, sometimes with contents related to the developing meaning of the text, other times mainly as reminders for oneself or to draw co-writers’ attention to certain matters or tasks to be done. With persistence over time, they are also, at times, just reminders of matters to be sorted later, collaboratively or by individual authors. Or even to preserve awareness of the fact that a task has been completed.

In the empirical material, we found several examples of how co-authors were commenting with the purpose of planning. A comment like “Sue will do this” left in the margin of a document most often requires little reflection or coordination; it expresses the need for action that an author (Sue) can carry out independently of their co-authors. In some cases, such a comment came out of a co-operative activity, in which authors agreed that Sue should take on the task, and in that case serves as a reminder that enables co-ordinated activity in which authors can work independently of each other. Or, as in other examples, Sue had independently decided to take on the task, in which case the comment takes on a co-operative purpose as it is used to communicate this to her co-authors. And it may even serve as a reminder for Sue herself to return to the text; that is, it may not necessarily have any collaborative purpose. In either case, a shift has happened from one kind of activity (co-operative) to another (co-ordinated); or, perhaps more correctly, a link has been made between two kinds of the ongoing activity.

In the following example, Carl describes how he uses different means for creating a comment, depending on whether it is a minor remark or to-do; something he wants to call attention to; or something that needs further discussion.

Carl: [There] are comments where I, for example, put a percentage sign¹ and write [my initials] and then write some text so people can see that it’s a message from me, or write “to-do” or something. Then there are the comments that go into the PDF, that have, sort of, a stronger signal because you can see in the PDF all the time that something needs to be done here. But then there’s also, in ShareLaTeX², where [...] you can highlight some text, and then you can add a comment in the margin, and then some colored highlight appears based on your user. And then you can, kind of like Google Docs, comment on it. And that’s actually mostly if there’s a need for some kind of discussion.

¹Putting a percentage sign’ refers to the % symbol, which instructs the LaTeX compiler that the text following the symbol is not to be rendered in the compiled PDF

²ShareLaTeX was an online LaTeX editor that has since merged with the Overleaf LaTeX editing platform.

Activity	Actor	Mediator	Object	Community
Commenting	Co-writer	I thought we meant X not Y	Text content	Co-writers

Fig. 6. This type of communication may move the activity from co-ordinated to co-constructive because it entails a possible negotiation of the contents and purpose of the writing (material mediation – dark gray) and/or the community (communicative mediation – light gray).

Carl’s description brings out how the different kinds of comments, among other things, rely on different levels of material salience. He went on to clarify that he only rarely uses margin comments because, if used too frequently, they turn the document messy because of the colorful highlights that “put question marks around the text.” Thus, that level of salience is reserved for when there is a need to invite co-constructive discussion, whereas other kinds of comments are tied to other levels of activity.

The different steps taken along the way in the collaborative writing process can contribute to multiple of these levels of activity, and to shifts between them. Commenting – in-text or through a comment feature as described above – is often used among collaborators in the space between material production and communication with collaborators, and for authors themselves as reminders for later. Some of these are elaborate and focus on actual exchange of the material; some focus on coordination and serve as reminders or prompts for (even trivial) actions to happen in the future. That is to say, some comments are part of the (potentially intricate) work of creating meaning; whereas others mainly help co-operation or may even just support co-ordinated activity. In some cases a comment may move the activity from a lower level to the co-constructive level, for instance, if a discussion about the article’s main message ensues from someone saying: “hold on a minute; [...] the last time we were writing this, we were saying something else,” as it happened for Emma, a researcher who participated in Study A (see Figure 6 and subsection 5.3). After such a discussion, the comment may become a to-do that enables co-ordinated activity, and yet later on, when someone replies: “done,” it serves a co-operative purpose by encouraging co-authors to respond to the new update.

Situating reasoning, deliberation, and reflection in the text through material placement allows authors to make clear, across work sessions, which bits of thinking or which plans affect which parts of the text. A comment like “Sue will do [Z]” or “hold on ...” is at once communicative – expressing ideas and division of work – and material in (among other things) its placement, which serves as, e.g., a reminder or an anchor for discussion by materially highlighting that HERE is something that needs to be discussed or something that needs to be done. As an example where authors draw on the material presence and placement of comments to infer that a task has been completed, without this being specified in the communicative contents, consider Ryan and Tom’s explanation of how their group, comprising three university students, draws on comments as a material signal:

Ryan: If I’ve written something, it’s pretty obvious that if Tom has commented on it, that means he just went over it ... you know? So, in that way, it’s pretty [easy to see], usually, who’s been over it last. [...] You can also see that if Tom has left a comment, [...] and then, if [Calvin] has commented on what Tom has started, well, then you know that [Calvin] is the one who went through it last. So, if you think about it, it’s pretty transparent, really, when we use comments as much as we do, who’s been over the text.

Tom: Yes. It's true. It's that thing, where you can see this trail of comments, then you know ... as long as there's just one or two comments, you know you've been over it.

Materially, the comments make visible to Ryan that his co-writers have given his text a look. His co-writers' names on the comments add communicative mediation on top of this, letting him know who went over the text last, and in some cases allowing him to infer that everyone has had a look (see also [54]) and, hence, it might be time for him to go through the feedback.

In the studies, we have seen many different commenting practices that would support all three kinds of collaborative activity, and we have seen that the specific material anchoring of comments is, at times, also a hindrance to a discussion, i.e., to co-constructive activity.

5.2 Example – Plans

Written plans are, similarly, often used in ways that provide a material coupling between the thinking and the material production of text: A group of authors may begin by producing an outline or a to-do list, perhaps in the document itself or perhaps elsewhere. This to-do list serves, from the outset, a communicative purpose. In collaborative scientific writing, most often plans and to-do lists are developed and negotiated in the group in co-constructive activities and are then used to divide work to reduce complexity and move, at least for some time, to co-operative or even co-ordinated activity, until eventually this division of work and of contents breaks down and needs renegotiation (see, e.g., Figure 6 and the related example above). Additionally, the plans are used by the co-authors as each does their part (Figure 7). In some cases, this co-operation and co-ordination is helped by material cues, such as colorful highlights. Below, two members of a four-person group of university students describe how color coding was used both for assigning areas of responsibility and for communicating/remembering the state of the text for later:

Henry: We used to make a, sort of, bullet point form first. [...] We actually ended up color-coding it. So that, in the top of our document, we had a color code for each of us. And then we highlighted every bullet point in that color, so that we could see who was meant to take care of what.

Steven: We did the same when we were dividing up literature to read for the different projects. We've been color-coding that, too.
[...]

Interviewer: So, how long have you used those color codes? You know, is it something that's just meant for those to-do lists, or does it sit in the document; does anyone clean it up at any point?

Steven: You know, I think we've always used color codes in some way, also within the document itself. It hasn't so much been to specify what areas of responsibility people have, but then it's just as much that ... then we have a yellow section, if you're a little unclear on whether it's crisp enough. And a red one if you're, for instance, going: "If we need to shorten this report, this is one of the places where we could cut some bits," and stuff like that. Color coding, we've always used. But it's primarily been in, like, delegation; you know, bullet point lists or literature lists, or stuff like that, that we've used it.

In many instances, the to-do list is also integrated into the actual material text. As the text grows from the plan, disconnects begin to arise; a key point might flow naturally from a newly written paragraph, but making that point here means that another planned paragraph no longer has an obvious entry point. One researcher we spoke to managed this by creating a tool of their own that split the document into two columns: the left column would take up one third of the page and contain bullet points describing the arguments they were planning to make, and the other would take up two

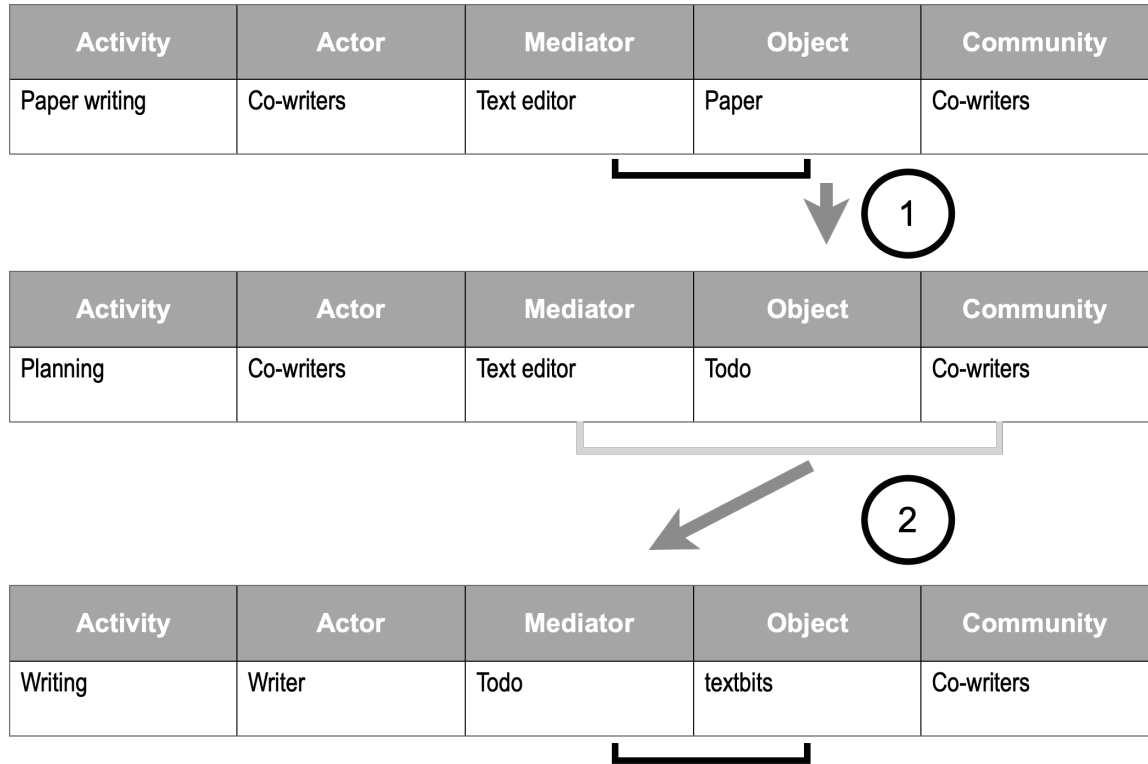


Fig. 7. The collaboration on the text is first on the paper as material and future outcome, then the mediation shifts (1) to a communicative one with the production of the to-do list. Once the to-do list has been created, that itself acts as a mediator for each collaborator to do their part of the writing, producing their textbit – i.e., we are back to material mediation (2) in which the todo list forms a basis for working on the textbits as material. The arrows describe the transformations, in the latter case also how the to-do list moves from object to mediator (material mediation – dark gray line) and/or the community (communicative mediation – light gray line).

thirds to contain the corresponding paragraphs. This combined material proximity and communicative correspondence would change the way the idea was accessible in relation to the text production and help them keep the argument in mind while writing. But while workarounds like these are possible, especially for people with the skills to program or otherwise create or modify their own tools, they leave something to be desired. For instance, (why) does the plan need to take up one third of the space that is meant for the text? In addition, this type of solution makes it difficult for co-authors to share how they work on, and with, plans in connection to the text and the writing. It seems that a solution like this is mainly useful in a co-ordinated kind of activity where the division of work is clear and each co-author simply has to do their part.

5.3 Example – Hidden Abstracts

In the preceding examples, the comments' communicative and material aspects go hand in hand to shift the activity in a certain direction. However, material and communicative aspects of the same action can also contribute to each

their kind of shift. The following example illustrates how the communicative function of an activity can be of one kind, while the material function contributes to shifting it between yet different kinds.

When studying collaborative academic writing, we spoke with a group of researchers who were writing an article together and had been struggling to align on the message. To achieve some clarity, they decided to externalize their thinking by each writing an abstract in their shared document. In order to not get influenced by each other's thinking before having a chance to finish their own, they took turns writing their abstracts in the document and, once done, changed the font color to white to make the text invisible. This allowed them to postpone the reveal of all five abstracts until their next joint meeting:

Emma: I think we knew that we had different perspectives, so we agreed that we should each write an abstract to show what we thought the article should be. [...] Sandra did it first, then just changed the text to white, so you couldn't see it [...] so that her abstract wouldn't, then, affect what I wrote, for example. And then, so then I did it, too, and then everybody did it, and then I think we didn't change the text color until our next meeting when we were all there in person. [...] I think we highlighted the key sentences from each of the abstracts that we all thought were, like, the strongest or most important out of those. *(Emma goes on to describe an unsuccessful attempt at combining all the abstracts into one)*

Interviewer: [...] Still, reading the other people's abstracts, did that make you think anything about the abstract you had written?

Emma: [...] It highlighted that, how differently I was thinking about it.

The ability to manipulate the material appearance of the text – the text color, in this case – helped the group collaborate in a different way, by letting them alter the pacing at which they shared their thinking with each other and at which they allowed each person's thinking to influence that of the others.

The activity of aligning the message can be viewed as co-constructive (see Figure 8), as it involves collectively re-conceptualizing and (re-)constructing the object of work, with the outcome of deliberation being, potentially, highly open-ended. The communicative side of the invisible abstracts is what they communicate about the authors' ideas and understanding of the article's meaning, i.e., it is part of the co-construction of the article. However, the purpose of hiding the abstracts was quite the opposite, namely to not influence how the object of work was perceived and, instead, allow each author to work in a co-ordinated fashion, where they would not be influenced by whatever their co-authors were writing. Thus, while the abstracts communicatively served a co-constructive purpose, their material (non-)appearance temporarily made the abstract-writing activity a different kind. We have to note, however, just how reliant this mediation was on the co-authors "behaving" and not peeking at the text. Had one author desired true control over when their abstract was shared with the others, they would have had to move to a different tool and copy-paste the abstract in at the right moment in time. While that would likely have been nothing but a mere nuisance, it goes to show the limitations (but also a kind of flexibility) of the tools available to these authors.

5.4 Example – Tool Choice

In general, users' tool choices and practices are connected to their material experiences of different tools and features, when they make choices focused on close collaboration. This happens, e.g., when choosing Google Docs over other tools when prioritizing live collaboration, and later when prioritizing other needs, such as transferring from Google Docs to more heavy-duty document preparation tools like Microsoft Word or LaTeX when needing to use conference templates and do reference management [36]. While rooted in particular priorities, co-authors' choices extend beyond

Activity	Actor	Mediator	Object	Community
Co-ordinated activity – writing separate messages	-co-writers	-their own visible abstract	-own abstract	- the others

Activity	Actor	Mediator	Object	Community
Co-constructive activity – aligning messages	-co-writers	-invisible abstract	-re-conceptualizing paper message	- co-writers

Fig. 8. Invisible abstracts play a role as material mediator in dividing the writing up abstracts between co-authors, and at the same time the role of communicative mediator in the co-construction of the message of the paper (material mediation – dark gray) and/or the community (communicative mediation – light gray).

those priorities, seeping into the entire flow of work and influencing the way collaboration takes place. For example, a group of university students described to us how something as minuscule and innocent as the squiggly red line that tells (or rather, shows) you that the text contains a spelling error could make one of them throw away all social etiquette [35] (Figure 9) and correct the typos of his co-author even while that person was still typing – sometimes causing enough of a row that they would have to pause the collaboration and take a break. In the quote below, Andy and Paul have just recounted such an incident, and Andy is explaining his frustration, while Mike and Paul defend their case (although Mike ends up seeing Andy’s point of view).

Andy: It just totally interrupts your work if you’re sitting there typing, and you’re completely aware that there is a spelling mistake or something, but you just have this wording you just think is good ... and then someone just starts correcting, and then it’s like ... then you start looking and then you forget that wording.

[...]

Mike: There’s just something about red lines under words that’s also just annoying to look at.

Paul: Yes! [...]

Interviewer: So, what is it that it does to you if Paul goes and corrects one of your red lines?

Andy: But that’s when I lose focus from what I’m writing. [...] It’s like, almost, poking someone on the shoulder. [...]

Mike: I don’t correct red words to be annoying. It’s really just to think: “Maybe I can just quickly help remove this red line.” And then [Andy] can maintain focus on what [he’s] doing now. Then it’s sort of been cleaned up behind [him]. But ... But it’s also just so noticeable that that red line disappears out of your ... you know, even if you’re not directly focused on it, but ... it’s probably actually more distracting, really.

Something to notice in this conversation is how the experience is not solely rooted in the material presence of the red line: The *material change* that occurs when the word is corrected and the red line disappears intensifies the material

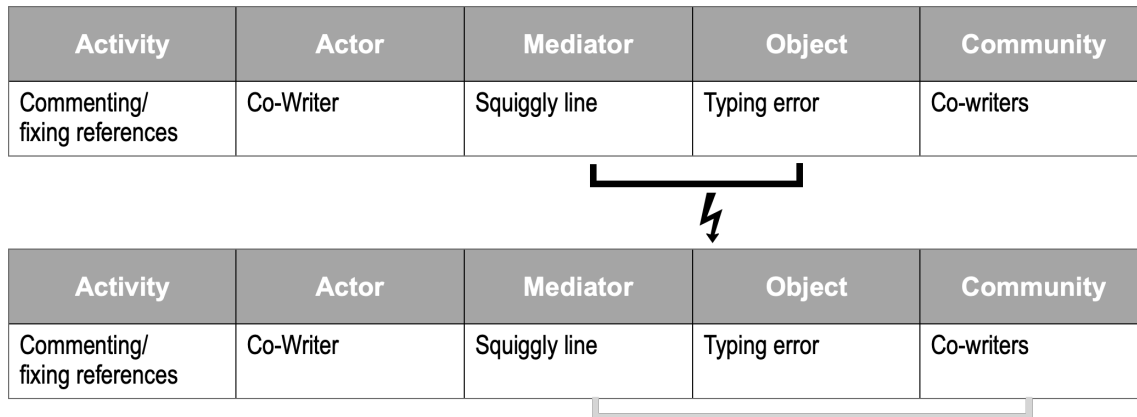


Fig. 9. The squiggly line causing breakdown in communicative qualities by what was intended as a simple material quality. The lightening expresses the tension or conflict between the two (material mediation – dark gray) and/or the community (communicative mediation – light gray).

experience. Paul, for instance, experiences a form of relief or satisfaction, and Andy gets distracted. Andy, in fact, compares it to the *physical* sensation of being poked on the shoulder.

Another group of university students felt similarly to Paul and Mike, with one group member describing how the red line had compelled her to alter her choice of words:

Sarah: Google Docs did something weird the other day, where I'd written [...] "bought". And then it said it was a [spelling] mistake. [But] I'd spelled it correctly, and I also Googled it, and I really had spelled it correctly, and it kept saying it was a mistake, [...] and you couldn't change it. [...] And then I just had to go change all the words to "purchased". Because it annoyed me so much.

These examples show how material experiences can exert influence over both the social situation and decisions about the object of work. More pertinently for this paper, they show how those material experiences shift the nature of the activity, for example by spurring a renegotiation of roles and relationships to the object of work.

People's tool choices result in marked differences in their working practices due, at least in part, to material characteristics of those tools. As another example, while LaTeX can be edited in a basic text editor and can thus allow authors to focus on content and ignore the look and feel of the document, WYSIWYG editors like Word confront authors with the appearance of their document from the get-go. Multiple study participants who used a WYSIWYG editor described drafting in a plain-text editor as a strategy for breaking writer's block by escaping the distraction of a formatted document [36]. Even if this drafting is an individual strategy and a solitary task, this pattern of temporarily working elsewhere indirectly influences the way collaboration happens, for instance by making it necessary to explicitly clarify what the co-author is working on, as it is not visible to collaborators.

As the material characteristics of technological mediation influence the way work happens, tools can have material effects and lead to practices that manifest materially. For example, when using a local LaTeX editor rather than a cloud service, many authors in our studies would use version control systems designed for software development in order to share the LaTeX code files. The diff'ing functionality used by such systems to detect changes in the code usually highlights changes on a line-by-line basis (i.e., confined by line breaks), and so even minor changes can cause the diff overview to appear as though a whole paragraph or section has been changed, even if the only change was the

correction of a single typo. To avoid the system making a hiccup every time two authors had changed separate parts of the same paragraph, some of the authors we interviewed would break up the text so that each sentence was on a separate line. Below, Carl describes how this material manifestation, in turn, influenced communicative aspects, as the line-by-line structure made it easy for him to mold the text by moving around sentence-level units.

Carl: I have this principle where I make a line break after each period, because then I can always comment a sentence out (*referring to the use of the percentage sign % to exclude text in the LaTeX code from the compiled PDF*). And I use that a lot. Also because then it's very easy to move sentences around, if they're all broken into lines in the editor.

When the text is broken up sentence-by-sentence, the sentences come to stand out as units to be moved around, encouraging this form of editing in addition to finer-grained editing within sentences, and more structural editing at the level of sections and paragraphs.

Tool choice in very detailed ways matters to how collaboration happens and can happen. The empirical examples show many such details, as well as how the material and the communicative mediation happening through the tools are deeply connected: E.g., as we have seen, a squiggly red line intended to help correct spelling had rather severe impacts on how co-authors collaborated. Most of the details in the case of tool choice address co-operative and co-ordinated activities (and shifts between them), but it seems quite likely that also in the formulation of a collaborative writing project (co-constructive activity), the decision of the tool setup could seriously impact (and vice versa) the content of the writing.

As a final remark, a closer look at Andy's experience with the squiggly red line also brings out that conclusions about the level of activity may depend on the person whose perspective you take on. From Andy's perspective, there is a tension between the co-ordinated situation in which he alone is working (and focusing) on a piece of text and expects Paul and Mike to focus on other parts of the document, and what Mike turns into a co-operative situation where he and Andy are both editing the same piece of text. However, what constitutes co-ordinated versus co-operative activity may, in fact, not be clear-cut: Paul and Mike may not see their actions as changing the activity's co-ordinated nature. When Mike outlines the situation in the end, he focuses on the objective of the work (producing versus polishing text) rather than on the object (this piece of text versus another one). Although he ends up sympathizing with Andy, Mike's original reasoning is based on a different perception than Andy's of how individual activities are separated.

5.5 Summary

In the above examples, we have seen how the materiality of text matters to the communication and coordination among co-authors. Comments, plans, and to-do lists were at times part of the text, and often they were extended to actually become text. In this way, they were both mechanisms of coordination and part of the material and also transitioned between the two. As part of this, the ability to perform material modifications, such as font color, deeply influenced how the text was used in co-constructive activity. Both in-text comments and comments outside the text were used as signs that something needed to be done (and sometimes also what and by whom), and hence as mediators of the communication between collaborators, drawing on material anchoring to locations in the text.

We have also seen that co-authors' choice of tools depends on both material and communicative needs, like being able to manipulate and/or ignore the text's formatting (material) or controlling the timing of when co-authors can follow along with what one is working on (communicative). Conversely, tool choice also stimulate actions and practices, like when authors structure text line-by-line in the process of appropriating collaboration tools designed for software

development; and how this new material appearance of the text influences how some authors perceive and choose to shape the text.

We have discussed examples of how computational material restricts activity, like when people move text out of the collaborative tool because they are bothered by seeing co-authors' activity. We also recounted how a red line, intended for authors' spell-checking, was distracting to writers and resulted in social tensions, hence causing disruptions and breakdowns in the collaborative activity.

The squiggly red line and the generic "REF" are both examples where something visual (and linguistic) is used to indicate very basic information about a place in the text/material objects, where future action of some kind will be needed later. Both in-text comments and comments outside the text are similarly used as signs that something needs to be done, though at times with more communicative content. This indicates to us that more flexibility and diversity in the modalities used are not only possible but would also be an improvement. E.g, the squiggly red line causes disturbances mainly because it is visible in the peripheral view of collaborators, and it is a good candidate for a feature to experiment with using other modalities. There is a similar potential for comments that direct a specific collaborator's attention towards a piece of text. In the case of the hidden abstracts, the coloring is also a very basic way of utilizing color, and it seems even in this case that a richer, more flexible set of modalities could be useful.

The duality of the material and the communicative roles of the shared text stands out clearly in the analysis, and the framework has helped us show that communication and coordination do not only happen around common objects such as a text but also, in very particular and sometimes idiosyncratic ways, through it. Since communication is also, at times, a matter of distraction, we have also identified situations where the shared objects were used to delimit communication and transform the activity from one kind to another. This is the most surprising finding of the analyses and leads to further attention also to possible modalities.

6 TOWARDS MULTIMODAL MATERIAL MODIFICATIONS

The empirical examples show the way materiality can be, and is already, used as part of collaboration. Why, then, are our current possibilities for material engagement/modification so restricted? As our empirical material shows, we see resourceful authors working out ways to deal with this, but we also see many frustrations. In our view, a large number of these challenges and frustrations are caused by a lack of material expressivity.

We propose a multimodal approach to materiality, with an aim to support the combination of material and communicative qualities that support transitions between different collaborative activities. Multimodal material mediation, in this context, means to help users better make use of multiple modalities when shifting between modes of work [16], utilizing and innovating both hardware and software as needed. Traditional face-to-face communication methods rely heavily on our sense of sight, hearing, touch, and even smell, as well as on touching and physically structuring the world around us. For instance, when referring to a paragraph in a paper's analysis in order to propose a change to its discussion, you might point to the paragraph on a printed page and, as you explain your idea to a co-author, rest your finger on the paragraph to not lose sight of it whilst also scribbling a note on a print of the discussion and using your gaze to guide your co-author to look at a relevant figure.

Touch/haptics hold a great deal of promise, given that previous work has shown that touch is often used to express the diverse, private, and subtle nonverbal cues that are crucial for communication and collaboration [24, 27]. Let us take the examples of activities that occurred in the Comments and Tool Choice examples. Frustrations occurred here because of the lack of expressivity in terms of location/placement, and traces of past work. These material qualities naturally translate well to the haptic modality. One may take an idea like Hill and Hollan's metaphor of document 'wear' [26], in

which traces of writing and reading activity show up as darkened sections in a document’s scrollbar, and reintroduce the metaphor’s material nature through tactile sensations of wear: Imagine scrolling through a document and physically feeling signs of wear where your co-authors have done a lot of work, being able to feel which parts of the document may need more attention, shifting material qualities to communicative ones, while moving from co-ordinated activity to co-operative. Taking the metaphor further, imagine being able to ‘take your teammate by the hand’ and physically guide them to different locations in the text linked together by a comment (e.g., “this is related to that”); a design that would combine material and communicative qualities even more directly, mainly as a co-operative activity. Haptic guidance could, for example, pull the user’s mouse to the relevant locations in the text to contextualize the comment.

Difficulties in managing attention, and presence whilst shifting between different activity levels or between different apps, caused frustration in the Hidden Abstracts and Tool Choice examples. In a shared physical space, we gesture, direct, and obscure people’s views to manage their attention [22]; and we annotate and crumple pieces of paper to signal what should be, respectively, used and discarded. How might similar effects be achieved when relying on digital capabilities? Morris et al.’s [40] experimental designs give people a “personal space” on a shared interactive tabletop that not only enables a visual separation of content to communicate whether something is shared or personal but also affects users’ abilities to interact with content depending on where it is placed: physically moving a document from a personal space into the shared space gives everyone shared digital access rights to it – similarly to how doing so on a regular table could be a social signal that anyone may use or make changes to the document. Another way of using physical movement or positioning could be to use a tangible user interface (TUI) to provide a physical manifestation of how visible an author and their document are to co-authors. We might imagine allowing degrees of personal space and privacy by allowing the author to make small adjustments to the position of a tangible representation of the document – much like we do with our own bodies and physical objects – and reflecting those adjustments in the writing UI. For example, having the TUI face the screen, and hence be “visible” to the collaboration UI, could make the author’s activities in the document on the screen visible to co-authors. When positioned away from the screen, activities would be obscured to co-authors. Not only would such a TUI allow subtle control of visibility; it would also help authors have a peripheral sense of the visibility of their current activities, in a form similar to what one has when physically in a room with others [22]. Möllers and Borchers [39] have presented a simple version, where tangible filters obscure items on a tabletop when viewed from certain angles, allowing natural physical positioning to flexibly obscure content or make it visible, effectively giving users a material means to communicate the desired level of attention or involvement from collaborators. Examples like these combine material and communicative qualities better by rendering visible both the author’s individual activity on the material object, and their activity together with their co-authors.

Yet another challenge is maintaining a plan or negotiating the division of work alongside the production of the text. Multimodality offers a way to avoid the visual clutter experienced by authors in the Plan example, by adding a range of dimensions to the limited visual screen real estate. Pinelle et al. [46], for example, suggest that users may use force, as applied to a pressure sensor, to specify how freely available a digital object is for collaborators to interact with. We might, conversely, imagine tactile output to alert an author that the section they are currently proofreading is still another author’s work in progress (cf. similar coordination challenges discussed in [34]).

These speculations illustrate but a few of many opportunities for multimodality in material mediation for collaborative activities. Intended to inspire exploration, the presented ideas are deliberately optimistic and do not begin to unfold the complexities that would be associated with both their implementation and their impact on collaborative work. Some modalities may be better suited than others, and we know very little about the role of less commonly used modalities. And, of course, multimodality is not the only sensible avenue for material support of collaborative activity – it is,

however, relatively unexplored for this purpose, and so seems like a worthwhile direction to take. Further work is needed to establish the best ways to support mode shifts in different collaborative activities whilst ensuring that the material and communicative aspects are also supported by the multimodal modifications.

We also encourage others to apply the framework to other forms of collaborative activity, such as software development or highly visual work like collaborative video editing (where previous research has identified challenges in relation to mediating collaboration; see, e.g., [43, 49]), to tease out the intricacies of how material mediation manifests in different settings.

7 CONCLUSION

In this paper, we have addressed shifts within collaborative activities between different kinds of collaboration and we have offered a theoretical framing to identify how such shifts are mediated. We have used the conceptual framing to distinguish between material qualities that help transform the object of work from working material into outcome, and communicative qualities that mediate the coordination and communication between actors in the joint activity. Through this framing, we have pointed out that material expressiveness has a role to play among collaborators when they divide work and collaborate. We have illustrated this both when it comes to how collaborators choose tools, and how they define the objects that are shared in the activity.

We have chosen as our main case for analysis an activity where both mediation and objects are digital and contained in a suite of programs, in particular various forms of text editors. A case like co-writing illustrates well that a focus on material and materiality does not imply a focus on individual users and uses – on the contrary. Hence, we conclude that there is too little focus on the communicative side when discussing, analyzing, and designing material mediation.

By using interconnected terms like ‘material’ and ‘communicative’ qualities instead of, e.g., ‘feature’, we have widened the perspective on material expressivity, and it becomes more obvious how additional modalities could play a role in helping co-authors share and communicate about, e.g., places in documents where activity has happened or needs to happen, in less intrusive ways. Or how additional modalities may help co-authors guide each other to pay attention to parts of the common object or to leave parts of the common object alone.

We have focused on three kinds, or modes, of collaborative activity and transitions between them within the same activity, instead of focusing on shifts between different activities. This is slightly unconventional compared to the existing literature, and by shifting focus away from the differences between activities, our analysis brings out the common object itself as material and communicative. The transitions and tensions between the kinds of activities and the dynamic roles of the mediators and objects in these transitions and tensions further illustrate the multiplicity of artifacts involved in collaborative work [11]. In the current paper, we have not presented a further development of the interwoven material and communicative qualities as regards artifact ecologies. Looking further at the entire setup of tools, as a follow up to the Tool Choice example, is an obvious next step in future work.

In conclusion, the CSCW literature has had too little focus on the communicative side when addressing material mediation. Since the material is intertwined with people’s communication, no matter how the technology is designed, why not have a more explicit focus on the duality between material and communicative mediation when researching and building instruments of interaction? While the case of co-writing shows that communicative and material mediation go hand in hand, the empirical examples also point to a lack of material expressivity between people. Accordingly, we have outlined how multimodal interaction may support material mediation of collaborative activity in various ways.

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