A TYPOLOGY OF AFFORDANCES: UNTANGLING SOCIOMATERIAL INTERACTIONS THROUGH VIDEO ANALYSIS

Completed Research Paper

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Abstract

In this study we untangle the sociomaterial interactions between developers, users, and artifacts by analyzing what types of affordances occur in the interactions between actors and artifacts in the context of group generativity. Hereto, we conducted an in-depth ethnographic and interaction analysis of video data of the interactions of groups of people with each other and with a set of self-developed applications for supporting generative activities. On the basis of our findings, we propose a typology of affordances. Given that affordances are by definition sociomaterial, studying affordances helps us to provide empirical insights into sociomateriality. Furthermore, this typology of affordances enables us to empirically analyze the role of materiality as well as to theoretically explain how materiality affects the way people act and interact with each other and artifacts. Finally, important theoretical and methodological implications for the literature on sociomateriality are discussed.

Keywords: Typology of Affordances, Video, Interaction Analysis, Ethnographic Analysis, Sociomateriality, Generativity Support Applications

Introduction

While approaching a door with a doorknob, you recognize instantly and automatically that the doorknob is there to grasp, to turn or to pull in order to open a door[1]. In a similar vein, when you approach a chair, you recognize instantly and automatically that you can sit on it. Now imagine a door without a doorknob—either because it broke off or because it is an exit which is not supposed to be used—you may have to think for a second before knowing what to do in order to open the door or not to use it at all. Or alternatively, imagine an old chair stored in your basement where you are looking for a box located on top of a shelf. Rather than sitting on the chair, you will use it to stand on, as a sort of ladder for grabbing the box.

Such properties of material artifacts that are recognized and perceived and which contribute to the kind of interaction that occurs between an actor and the artifact are called affordances (Gibson, 1977). As such, affordances are preconditions for activity. As the above illustrations show, affordances are not an outcome of the artifact alone nor of the actor alone, but of the interaction between the actor and the artifact. Hence, affordances are by definition a sociomaterial construction and therefore studying affordances—through untangling the complex interactions between multiple social actors and material artifacts—is one potential approach to empirically analyzing sociomateriality (Leonardi and Barley, 2008).

In this paper, we analyze the interactions of different actors—developers and users—and a particular class of artifacts—Generativity Support applications. Generativity Support applications aim to enhance people's generative capacity, that is, the ability to produce new configurations and possibilities, to reframe the way we see and understand the world and to challenge the normative status quo in a particular task-driven context (Avital and Te'eni, 2009).

In order to understand the complexities and idiosyncrasies of these interactions between actors and artifacts, we conducted an ethnographic and interaction analysis of a set of videos from nine groups of people using these Generativity Support applications across two settings. Our main research questions underlying this study was: *What types of affordances occur in the interactions between actors and artifacts in the context of group generativity?*

Our motivation for answering these research questions is threefold. First, it helps us to provide an empirical illustration of the concept of sociomateriality, which in the literature up to date has been explored mostly conceptually. Second, we want to empirically address a number of theory building challenges regarding sociomateriality as distinguished by Leonardi and Barley (2008), most importantly, to develop a typology of affordances as well as to bridge activities of development and use. Third, it allows us to explore visual media-based methodologies for capturing the dynamics and complexities of sociomateriality in practice (Avital and Cyr, 2011).

However, given that the interactions between actors and artifacts that make up affordances are difficult to disentangle once established (Leonardi and Barley, 2010), we studied affordances in the context of the development and implementation of a set of novel applications—Generativity Support applications. When a new artifact—like these Generativity Support applications—is implemented, no affordances have yet emerged or been established prior to the interaction between actors and artifact. Hence, the context of this study provides an opportunity for studying how the social and the material become constitutively entangled and what types of affordances emerge and evolve (Orlikowski, 2007; Leonardi and Barley, 2010).

Based on the findings from the video analysis, we propose the following typology of affordances regarding the interactions between developers, users and artifacts:

1) *Designed affordances*—the set of affordances that is perceived and recognized by developers. Hence, it includes those sociomaterial activities that are purposely designed by developers, regardless of whether these are subsequently recognized and enacted by users when interacting with the artifact.

[1] See Johnson and Latour (1995)

2) *Improvised affordances*—the set of affordances that is perceived and recognized by users and therefore emerges while using the artifact. Hence, it includes those sociomaterial activities that were improvised by users, despite the fact that these were not previously recognized and designed by developers.

3) *Emergent affordances*—the set of affordances that is neither anticipated and designed by developers nor actively recognized and improvised by users in use, but which nonetheless has an impact on the interactions between artifacts and actors. Hence, it includes those sociomaterial activities that emerged from artifacts, despite the fact that these were not consciously recognized by developers and users.

Building on our findings, this study provides the following contributions. First of all, to the literature on sociomateriality, we contribute empirical findings regarding the constitutive entanglement of the social and the material while bridging the activities of development and use. Second, we demonstrate the relevance of materiality by showing the similarity of outcomes that emerges across social settings in which different actors interact with the same artifact. Third, we develop a typology of affordances which can support future studies aiming to capture the role of materiality and which can help us understand better how technology affects the way people do things and the way they interact with each other and technology (Leonardi and Barley, 2008). Finally, this study provides some insights into the complex methodological issues associated with studying sociomateriality and affordances by showing the potential of visual media-based methodologies for capturing the constitutive entanglement of the social and the material in practice.

The paper is organized as follows. The next section presents a brief review of the relevant literature on sociomateriality, in which we focus on the notion of affordances in particular, and highlight the contributions of this work. This is followed by a theoretical exploration of generativity and Generativity Support applications in order to describe the research context. We then discuss the research design that was used in this study. Subsequently, we present our main findings regarding the affordances of design and use of Generativity Support applications. Finally, we discuss our findings and propose the typology of affordances as well as explore the theoretical and methodological implications of this study and future research directions.

Theoretical Underpinnings

Affordances and Sociomateriality

Sociomateriality is a recent theoretical approach to understanding the relationship between humans and artifacts, which assumes a constitutive entanglement of the social and the material in practice (Orlikowski, 2007; Suchman, 2007). Sociomateriality builds upon previous concepts that have addressed the importance of materiality (see Orlikowski, 2007), such as actor-networks (Callon, 1986; Latour, 1992, 2005), sociotechnical ensemble (Bijker, 1995), mangle of practice (Pickering, 1995), object-centered sociality (Knorr Cetina, 1997), relational materiality (Law, 2004), material sociology (Beunza et al., 2006).

Sociomateriality presumes that actors and artifacts are not self-contained, independent entities that influence each other through impacts or interactions, but rather they enact each other in practice (Barad, 2003). This implies a shift from focusing on how artifacts influence humans to examining how artifacts are intrinsic to everyday (inter-)actions. However, aiming to understand these sociomaterial assemblages by reconciling materialism with a focus on agency provides four challenges for theory building (Leonardi and Barley, 2008), which are addressed simultaneously in this empirical study, namely:

1. *Acknowledging materiality's relevance*—We focus on the sociomaterial assemblages that emerge in the course of generative processes and pays specific attention to the relevance of materiality—in the form of Generativity Support applications—in these processes

2. *Developing typologies of constraints and affordances*—We develop a typology of affordances related to the constitutive entanglement of (groups of) actors with Generativity Support applications.

3. *Bridging activities of development and use*—We analyze simultaneously the affordances of Generativity Support applications that are recognized by designers as well as the affordances of these applications that are recognized by users.
4. *Shifting to studies of constructionism*—We build on constructionist insights by revealing the similar outcomes that emerge across settings—i.e. across experimental groups—with the same technology.

By addressing these four challenges for theory building simultaneously, the findings of this study can provide relevant insights for the sociomateriality literature. However, before going into the context and design of this study, we will first explore in more detail the concept of affordances, which is fundamental to this study.

The term affordance refers to the actionable properties between an artifact and an actor (Zhang, 2008). Hence, affordances are based in the material properties of the artifact and the actor in their interaction and exist whether or not it is being perceived and recognized (Gibson, 1977). For the property of an artifact to be in the category of affordances it has to be a property that interacts with a property of an actor in such a way that an activity can be supported (Greeno, 1994). This implies that affordances are preconditions for activity.

Hence, affordances are by definition a sociomaterial construction and therefore studying affordances—through untangling the complex interactions between multiple social actors and material artifacts—is one potential approach to empirically analyzing sociomateriality (Leonardi and Barley, 2008). We empirically untangle the complex interactions between developers, users and a particular class of artifacts—Generativity Support applications—in order to understand how each contributes to the whole and to distinguish different types of affordances that constitute these sociomaterial interactions.

Generativity and Generativity Support Applications

Generativity refers to the ability to originate, produce or procreate. The concept of generativity has been used effectively in multiple social science disciplines in order to refer to the drive to revitalize or rejuvenate; the production of novel configurations and new possibilities; as well as an attempt to challenge the normative status quo (see Avital and Te'eni, 2009; Van Osch and Avital, 2010).

In the context of Generativity Support applications, the notion of generative capacity is particularly important which refers to one's ability to produce new configurations and possibilities, to reframe the way we see and understand the world and to challenge the normative status quo in a particular task-driven context (Avital and Te'eni 2009). Hence generative capacity refers to the ability of a person or a group to generate creative ideas that lead to innovation or produce overall value.

Avital and Te'eni (2009) introduce the concept of generative fit to refer to a feature of a system that enhances one's generative capacity. Generative fit therefore is the main feature underlying Generativity Support applications. Based on the concept of generative fit, Avital and Te'eni (2009) offer three broad design directives for generative designs—evocative, adaptive and open-ended. For each of these design directives, they propose a set of operable features that contribute to the overall generative fit of a system. In this study we analyzed the interactions between groups of people and two different types of Generativity Support applications that were based on two design features proposed by Avital and Te'eni (2009), namely:

1) **Visualization:** the system should incorporate human-centered visualization tools that enable seeing multiple dimensions, such as visual representations and digital images. Visualization provides the ability to seen an object from multiple perspectives and to search for new insightful points of view, hence, can thereby enhance one's generative capacity.
2) **Integration:** the system should incorporate human-centered integration tools that enable linking, aligning, and re-contextualizing interdependent and seemingly unrelated domains, objects or processes. Integration provides the ability to overlay or merge views and to promote system-wide boundary crossing and cross-fertilization, hence, can thereby enhance one's generative capacity.

As aforementioned, we empirically analyze sociomateriality in the context of nine groups of people using a set of self-developed applications. The implementation and use of novel Generativity Support applications that are unknown to the users provide a context and opportunity for studying how the social and the material become constitutively entangled and what types of affordances emerge and evolve (Orlikowski, 2007; Leonardi and Barley, 2010).

Research Design

In order to reveal the different types of affordances so as to understand the constitutive entanglement of humans and artifacts in practice, we relied on an ethnographic and interaction analysis of a set of videos about groups of people that interacted with each other and with the different Generativity Support applications in the course of solving a challenge (also see Appendix 1). In what follows we will describe the study context and our approach to data collection and analysis in order to show the potential of video data for capturing and untangling the constitutive entanglement of the social and the material in practice.

Study Context

The video data that was analyzed for this study was recorded during a set of group experiments that were conducted in order to test the effect of Generativity Support applications on group generativity. Given that these experiments represent merely the context in which the videos were recorded, a detailed description of the experiments in beyond the scope of this paper, hence, we will only briefly explain the nature of these group experiments.

The nine group experiments which provide the context for this video-based analysis of sociomateriality were conducted in two different settings. The first three experiments were conducted with members from C'MM'N—a community for sustainable personal mobility. The remaining six experiments were conducted with children from a primary school in Israel. During these experiments, each of the nine groups had to solve one challenge that was closely related to their field of practice (see Appendix 2) and which stressed the importance of solving the challenge as a group through employing the corresponding artifact. In order to solve this challenge, each group had to interact with three applications[2]; two self-developed Generativity Support applications (i.e. manipulations) vis-à-vis a Baseline application that set the benchmark (i.e. control), namely:

- *Visualization application*—an application that offers generativity support to users by providing **images** (i.e. visual representations) of objects or settings that are related to their specific task-context. These images trigger new ideas or configurations by providing users with new insightful points of view thereby potentially enhancing their generative capacity.
- *Semantics application*—an application that offers users generativity support by providing **eliciting sentences** that are based on templates of solutions structures that are composed with nouns and verbs taken from the textual task. These sentences trigger new configurations or possibilities by providing users with novel and unusual combinations of words through linking and aligning interdependent domains, objects or processes, thereby potentially enhancing their generative capacity.
- *Baseline application*—a barebones application that offers users no generativity support in relation to their specific task-context, hence, does not thereby enhance their generative capacity. It merely provides an overview of the experimental task that needs to be conducted; hence, it has no designed functional material properties.

Additionally, in order to adapt the abovementioned applications to (1) the specific research subjects (car enthusiasts versus children) as well as (2) the specific challenge (electric car development and survival in the wild), two different versions of the applications—a digital and a physical version respectively—were developed. The digital version included software representations of the *Visualization*, *Semantics* and *Baseline applications* and the physical version included wooden board games of the three applications.

[2] See Appendix 3 for the different sequences in which the groups interacted with the three applications

The underlying rationale for developing two different versions of the applications was twofold. First, as abovementioned, we wanted to adapt the materiality to fit the nature of both the research subjects and the challenge. The C'MM'N community already employs a software application for collaboration, hence, a digital software version of the three applications would fit with the research subject as well as the challenge of developing and using electric cars (see Appendix 2). The children, however, were not used to working with software applications in their daily school activities and the nature of their challenge—survival in the wild—is incompatible with a digital application, hence, we provided them with wooden board games. Second, the two different versions—digital and physical—are based on the same underlying design principles and features; hence, this allowed us to observe whether the same design principles can be adequately translated and embedded in different types of materiality.

Because the experiments included the interaction between different groups of people in different settings with a set of novel artifacts, Generativity Support applications, these experiments provided a good opportunity for us to understand the emergence and evolution of affordances by moving within and between a number of social settings and groups (Leonardi and Barley, 2008).

Data Collection

As aforementioned, the video data was collected during the nine group experiments in order to record the interactions in the groups and with the different applications, resulting in over twelve hours of video data. Even though the researchers were also present during the group experiments and wrote down field notes on a regular basis in order to capture observations, impressions, feelings, hunches and questions (Myers, 1999), we decided to videotape all group experiments to allow for a more in-depth analysis of activities and interactions.

Video data is especially powerful for multifaceted qualitative analysis; hence, it offers several advantages over other forms of data in particular for analyzing the complex sociomaterial interactions between actors and artifacts. First, one of the strongest arguments in favor of videotaping is that human activities unfold so fast that it is impossible to capture their complexity by observation alone (Jordan and Henderson, 1995). Field notes only provide a partial record of observed activities and words cannot capture the full complexity of what actually occurs during these activities. Instead video preserves these activities and allows for careful viewing and analysis (Blomberg et al., 1993). Second, video records also allow researchers to analyze the same activity from different perspectives. In particular because our perspectives and interpretations during initial observation may be heavily influenced by the emotions we experience at that moment (Schultze, 2000), the ability to view and re-view videos allows us to correct potential erroneous characterizations and interpretations (Suchman and Trigg, 1990).

Third, particularly in the context of analyzing affordances, videos are a powerful tool for capturing the (subtle) entanglement of humans and artifacts, that is, the dynamics and idiosyncrasies of sociomateriality in practice. In particular for conducting the type of analysis that we performed in this study, namely interaction analysis, videos represent the only form of data that allow for a close and repeated interrogation of sequences of interactions by multiple viewers (Jordan and Henderson, 1995). Fourth, video data preserve the context as well as the content of the experimental sessions, allowing for a contextually rich interpretation of findings. Despite these advantages of using video data, it needs to be noted that the behavior of the experimental groups could have been influenced by the camera's presence during these experiments. Nevertheless, as also suggested in previous research (Blomberg et al., 1993), we observed that the camera quickly becomes part of the background and only occasionally surfaces in the participants' awareness.

Data Analysis

The results from the video data were analyzed using a combination of ethnographic and interaction analysis (Suchman and Trigg, 1991) based on multiple viewings of the video data in order to capture the (subtle) entanglement of humans and artifacts. *Ethnographic analysis* involves the careful study of activities and relations between activities in a complex social setting in order to develop descriptive accounts of human activities (Myers, 1999). *Interaction analysis* refers to the in-depth investigation of the interactions between people with each other and with objects in their environment (Suchman and

Trigg, 1991; Jordan and Henderson, 1995), in this case the digital or physical Generativity Support applications. An integration of ethnographic and interaction analysis allows us to what types of affordances occur in the interactions between actors and artifacts in the context of generativity.

The focus during the video analysis was on affordances, that is, on characteristics of the system that interacted with characteristics of the groups in order to produce generative outcomes. This focus on sociomaterial interactions would not have been possible in analyzing text-based data. However, because of the rich and processual nature of the video data, we were able to analyze in-depth the interactions within the group as well as between the group and the different Generativity Support applications. Hence, the videos allowed us to analyze every detail of the content and context of these sociomaterial interactions.

In the course of the data analysis process, the videos were viewed and re-viewed, transcribed and noted independently by the two researchers. Furthermore, the researchers independently logged the data immediately after it was collected by annotating it with general descriptions of activities and by highlighting specific parts of the video that were particularly relevant for answering our research questions. In the course of producing these content logs, we also used the field notes that were taking during the experiments.

Nevertheless, in order to produce adequate and detailed activity and interaction logs of the videos (Mackay, 1989), it was necessary to re-view the videos multiple times. Developing in-depth insights regarding the complexities and idiosyncrasies of sociomateriality can only be developed through careful and repeated analysis (Suchman and Trigg, 1990). The final content logs were discussed and integrated by the two researchers. Subsequently, the researchers identified and selected important video sections for later careful analysis that addressed the specific research question.

These important sections were again viewed and re-viewed for investigating different types of human activities—e.g. conversations, nonverbal interactions and the use of artifacts—with the aim of identifying routine practices across settings as a basis for developing a typology of affordances. Finally, we developed a short video of important results which we showed to our research participants in order to ask for their reflections and feedback with respect to our research findings.

Results

In what follows, we will answer the research question underlying this study, namely: what types of affordances occur in the interactions between actors and artifacts in the context of group generativity? Hereto, we provide a rich description of the affordances that emerged and evolved for each of the three applications—*Baseline, Visualization*, and *Semantics*—across the two settings and within the nine different experimental groups. Given the limited space, we can only partially capture the richness of the data through a textual description. Therefore, we augment the textual descriptions with a video encompassing a set of short clips **3** (see footnote) from different sociomaterial interactions in groups. These clips visualize our findings and capture the complexities and idiosyncrasies of affordances that cannot be adequately reflected in words (also see Figure 1).

[2] Please visit: http://vimeo.com/22888764 (password: icis2011)

Figure 1. Sociomaterial Interactions

Baseline application

As aforementioned, the Baseline application was intentionally designed to serve as a benchmark for the two Generativity Support applications. Therefore, the artifact did not purposely offer users generativity support but rather provided users with a mere description of the experimental task (i.e. the challenge) and the possibility to list their ideas. As such, the Baseline application had no other designed functional material properties in relation to the specific experimental task, that is, for affording idea generation.

The results from the video analysis show that the groups used the Baseline application as intended by the developer. Therefore, the actions of the groups during the session using this application were restricted to generating and listing ideas based on the description of the challenge as afforded by the Baseline application.

Despite the fact that users interacted with the artifact in the same way as was intended by the developer, the video data reveals that the Baseline application did instigate some sociomaterial dynamics that the developer did not foresee and the groups of users did not perceive consciously. First of all, in all nine experimental groups we found limited group structure or group coherence. In the C'MM'N groups—in which people were seated on chairs that were put in a circle—this was evident by the fact that people were leaning back in their chair instead of leaning to the front to be involved with each other and with the artifact. In the Survival groups—in which children were seated on a carpet on the floor—this was evident by the fact that children would sit in a row instead of a circle and would sit up straight, being neither involved with each other nor with the artifact.

Second, all nine groups displayed low positive energy compared to the other sessions with the Visualization or the Semantics application. This was evident from the fact that participants were not joking and laughing and not displaying positive emotions or energy.

Third, the Baseline sessions involved only limited discussion between members of the group, rather the participants had the tendency to formulate and list solutions individually rather than by means of group interaction. Fourth, all nine groups displayed an early loss of concentration and engagement with the experimental task, which did not happen in the other sessions using the Visualization or the Semantics application. Hence in almost in all cases, experimental groups ran out of ideas before the end of the session.

Therefore, in short, it appears that the lack of designed functional material properties related to the group experimental task affords limited, that is, constrains group structure and coherence, low positive energy and emotions, limited interactions and discussion, and constrained idea generation.

Table 1. Observed Affordances during Baseline Application Sessions

	C'MM'N Car Challenge	Children Survival Challenges
Designed by the developer	Computer application that provides challenge description and affords the activities of reading the challenge and listing generated ideas. It lacks designed functional material properties for affording particular generative activities.	Piece of paper that provides challenge description and affords the activities of reading the challenge and listing generated ideas. It lacks designed functional material properties for affording particular generative activities.
Improvised by the users	Not observed	Not observed
Emerged from the artifact	The lack of designed functional material properties (digital) afford: - limited group coherence and little engagement (both with each other and with the artifact) - low positive vibe, energy or emotions - limited interaction and discussion - constrained idea generation as evident by the fact that groups stopped before end of session	The lack of designed functional material properties (physical) afford: - limited group coherence (people sit in row, not in circle) - low positive vibe, energy or emotions - limited interaction and discussion - constrained idea generation as evident by the fact that groups stopped before end of session

Visualization Application

As aforementioned, the Visualization application was purposely designed to afford generativity support by providing images of context-related objects or settings in order to trigger new ideas. Therefore, the artifact had particular designed functional material properties in relation to the specific experimental task, that is, for affording idea generation.

The results from the video analysis show that the groups largely used the Visualization application as intended by the developer. So all groups used the images for generating ideas, however, it was clear that toward the end of each Visualization session, users would make less use of the provided images and increasingly generate ideas without explicit reference to these images. In other words, the afforded material properties of the Visualization application—that is the images for evoking idea generation—were perceived and used only for some time.

At the same time that the users stopped to actively interact with the images for idea generation, some of the users increasingly started interacting with the images in unintended ways. Rather than using the images as a source of inspiration, some of the participants in the C'MM'N groups engaged in active storytelling and joking in relation to the images. Similarly, the children in the survival groups engaged in building houses or using the image-blocks as domino stones. However, these unintended activities of storytelling and playing as afforded by the Visualization application in both experimental settings frequently resulted in further idea generation.

In addition to interacting with the artifact in ways intended by the developer as well as in unintended ways, the video data reveals that the Visualization application afforded some unanticipated sociomaterial dynamics that were neither consciously recognized by the developer nor by the users. First of all, in all nine experimental groups we observed strong group structure and coherence compared to the Baseline application. This coherence emerged instantly when the groups were endowed with the artifact. In the C'MM'N groups this was evident by the fact that people started leaning toward the screen and each other in order to be more involved with the artifact and the group. In the Survival groups this was evident by the fact that children would no longer sit in a row but formed a circle and bended over the artifact as if to immerse the artifact into the group.

Table 2. Observed Affordances during Visualization Application Sessions

	C'MM'N Car Challenge	Children Survival Challenges
Designed by the developer	Computer application that retrieves images from internet based on search strings regarding objects from the challenge description and which thereby affords generative activities	Wooden game that provides (1) cubes with images regarding objects from the challenge description and (2) empty board for arranging cubes and which thereby affords generative activities
Improvised by the users	Toward end of the session, participants stop using the images as intended and instead engage in activities of storytelling and joking as afforded by the images in the application. Yet, these unintended activities also result in idea generation.	Toward end of the session, children stop using the images as intended and instead engage in activities of playing (e.g. building houses or domino) as afforded by the image cubes. Yet, these unintended activities also result in idea generation.
Emerged from the artifact	The designed functional material properties (digital) afford: - strong group coherence (circling around the screen) - moderate group discussion and interaction - storytelling, positive vibe and energy and excitement - unconstrained idea generation as evident by the fact that groups had to be interrupted (because of end of session) even though they were still proposing new ideas	The designed functional material properties (physical) afford: - strong group coherence (circling around the board) - moderate group discussion and interaction - playfulness, positive vibe and energy and excitement - unconstrained idea generation as evident by the fact that groups had to be interrupted (because of end of session) even though they were still proposing new ideas

Second, in addition to the increase in group coherence, the Visualization application also affords high positive energy compared to the Baseline session as evident from the fact that participants were telling stories, making jokes, and displaying a lot of positive emotions or energy.

Third, the Visualization application also afforded increased discussions and interactions between members of the group. Rather than formulating and listing solutions individually, solutions were discussed in the groups and individual members would build on each other's ideas to create more complex constellations for solving the group challenge. Fourth, rather than a loss of concentration and engagement, as was the case during the Baseline session, all groups ran out of time while using the Visualization application and had to be interrupted at the end of the session.

Therefore, in short, it appears that the designed functional material properties related to the group experimental task afford the emergence of strong group structure and coherence, high positive energy and emotions, increased interactions and discussion, and unconstrained idea generation compared to the Baseline application.

Semantics application

As aforementioned, the Semantics application was purposely designed to afford generativity support by providing eliciting sentences about context-related objects or settings in order to trigger new ideas. Therefore, the artifact had particular designed functional material properties in relation to the specific experimental task, that is, for affording idea generation.

The results from the video analysis show that all groups largely but not entirely used the Semantics application as intended by the developer. In other words, the afforded material properties of the Semantics application—the eliciting sentences for generating ideas—were perceived and used only now and then. In particular, toward the end of the session, users would make less use of the provided sentences and increasingly generate ideas without explicit reference to these sentences. The fact that sentences were employed less frequently than the images in the Visualization application can most likely be explained by the complexity of the application. All groups indicated that the Semantics application was difficult to understand and use. Also the results from the video analysis show that some form of training would have probably improved the interaction between the groups and the artifact.

Similar to the session using the Visualization tool, users in both the C'MM'N and the children groups stopped to actively interact with the sentences and rather start discussing important words from the sentences—the key nouns and verbs from the challenge. Nevertheless, these unintended activities as afforded by the Semantics application in both experimental settings frequently resulted in additional idea generation.

In addition to interacting with the artifact in ways intended by the developer as well as in unintended ways, the video data reveals that the Semantic application afforded some unanticipated sociomaterial dynamics that were neither consciously recognized by the developer nor by the users. First of all, in all nine experimental groups we again observed strong group structure or group coherence similar to the Visualization application that emerged instantly when the groups were endowed with the artifact. In the C'MM'N groups this was evident by the fact that people again would lean toward the screen and each other in order to be more involved with the artifact and the group. In the Survival groups this was evident by the fact that children would again form a circle and bend over the artifact as if to immerse the artifact into the group.[4]

Second, similar to the session using the Visualization application, the Semantics application afforded high positive energy as evident from the storytelling, joking, and high levels of positive emotions or energy in all groups.

Third, the Semantics application afforded increased interaction and discussion, even more than during the session using the Visualization application. To a larger extent than with the Visualization application, individual participants would use each other's sentences to build more complex stories in relation to the group challenge. This increase in discussion compared to the Visualization session may be explained through the fact that discussing is a verbal activity based on combining words. Therefore, the activity of combining words and sentences for discussion is better afforded by the generativity support of the Semantics application, which is word-based (eliciting sentences) than by the generativity support of the Visualization application, which is image-based. Fourth, similar to the Visualization session, all groups ran out of time and had to be interrupted at the end of the session.

Therefore, in short, it appears that the designed functional material properties related to the group experimental task afford the emergence of strong group structure and coherence, high positive energy and emotions, and unconstrained idea generation, similar to the Visualization session. Furthermore, the Semantics application affords even more intense interactions and discussions than observed during the Visualization session.

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[4] Note that each session is separated from the next session by a period of approximately 5-10 minutes in which each individual group member fills out a survey and in which new instructions are provided, hence, the group structure was not carried over from the previous session but had to emerge again

Table 3 Observed Affordances during Semantics Application Sessions

	C'MM'N Car Challenge	Children Survival Challenges
Designed by the developer	Computer application that randomizes objects from challenge description into five tactics (sentences) and which thereby affords generative activities.	Wooden game including (1) cubes with objects from challenge description and (2) a wooden board with five tactics (sentences) for placing the cubes and which thereby affords generative activities.
Improvised by the users	Throughout the session, but in particular toward the end, participants use words referring to objects rather than the complete sentences for idea generation. Yet, these unintended activities also result in idea generation.	Throughout the session, but in particular toward the end, children use the words on the cubes rather than the complete sentences for idea generation. Yet, these unintended activities also result in idea generation.
Emerged from the artifact	The designed functional material properties (digital) afford: - strong group coherence (leaning forward toward the screen) - intense group discussions and interaction - positive vibe and energy - some confusion about the usage of the tool	The designed functional material properties (physical) afford: - strong group coherence (circling around the board) - intense group discussions and interaction - positive vibe and energy - some confusion about the usage of the tool

Discussion

Based on the rich descriptions and videos of the interactions between developers, users and artifacts, we develop a typology of affordances. This typology of affordances is based on the idea that each artifact potentially holds many different (sets of) affordances. However, not all (sets of) affordances are perceived and recognized by the same actors and some affordances might not be recognized by any actor, but still affect the interaction between actors and artifacts.

The first set of affordances that we distinguish is perceived and recognized by developers, who draw on these affordances to develop an artifact that helps users to achieve a particular outcome, such as supporting group generativity. We refer to these affordances as **designed affordances,** because they are perceived and recognized by developers and intentionally used to bring about particular sociomaterial activities. Examples from our results include the listing of ideas during the Baseline session as well as the use of images and sentences for idea generation during the Visualization and Semantics session respectively. Note however that these designed affordances might or might not be recognized and enacted by users when subsequently interacting with the artifact, therefore resulting in used or unused designed affordances.

The second set of affordances, that we refer to as **improvised affordances**, is perceived and recognized by users in use, despite the fact that these were not previously recognized and designed by the developers. This set of affordances also has an inherent flexibility; some people might recognize and enact it while using the artifact, others might not. Examples from our results include the usage of images and words for playing and story-telling rather than for idea generation during the Visualization and Semantics session respectively.

The third and final set of affordances, that we refer to as **emergent affordances**, is neither anticipated by developers in their design nor actively improvised by users in use. Nonetheless, the artifact has an impact on the sociomaterial fabric of interactions between artifacts and actors, despite the fact that these are not consciously perceived and recognized. Examples from our results include the augmented group coherence, positive energy, discussion and engagement during the Visualization and Semantics session compared to the Baseline session.

It is important to note that these three types of affordances encompass developers, users and artifacts. Hence, it is only as a result of the interaction between these actors and artifacts that these affordances emerge. Nevertheless, for each type of affordance—designed, improvised and emergent—one (f)actor of the interaction is more critical for the affordance, namely the developer, the users, or the artifact respectively.

Implications and Future Research

The insights from this study hold several implications for the literature on sociomateriality. First, we developed a typology of affordances which can support future studies aiming to capture and understand the significance of materiality as well as the various possible interactions between actors and artifacts. Future empirical studies on sociomateriality should try to validate this typology of affordances for other types of material artifacts and in other settings. As our results show, technologies have the power to influence the way people interact with each other, to change people's way of doing things as well as the relationships that they have (Leonardi and Barley, 2008) and our typology of affordances can support the study hereof.

Second, the findings illustrate that affordances do not merely enable actions, they can also constrain action. Hence, future research should not only look at the power of technology to influence what people do and their interactions , but also how technology constraints what people do and the ways in which people interact. Consequently, future research should pay attention to how technological affordances—because of their ability to enable and constrain simultaneously—affect the composition of groups, the structure of organizations, and how these become interwoven with dynamics of power in organizations.

Third, the findings show that, although affordances are considered possibilities for goal-oriented action (Markus and Silver, 2008), material objects do not merely afford cognition and action, but also affect. Given that technologies impact the way people interact, affordances—in the context of intersubjectivity—also enable and constrain the way people express and share emotions. Therefore, although traditionally we think of affordances as enabling functional—i.e. goal-oriented—actions and interactions, material objects may also afford affective and empathetic actions and interactions.

Fourth, through developing this typology we provided an empirical illustration of the sociomateriality concept by revealing the similarity of outcomes that emerge across social settings—the C'MM'N groups and the groups of children—in which different actors interact with the same artifact. Third, our typology of affordances can bridge the activities of development and use in analysis and theory-building. Therewith we can overcome the existing separation between developers and users in technology studies which has hitherto limited our ability to unravel the relationship between the material and the social (Leonardi and Barley, 2008).

Finally, this study provides some insights into the complex methodological issues associated with studying sociomateriality by showing the potential of video data in this context. We argue that future studies on sociomateriality should draw on video data instead of or in addition to other traditional data sources for the following reasons:

- *Richness of video data*. Videos allow you to observe the complexities and idiosyncrasies of affordances as well as to analyze actual activities and interactions beyond what people say, by capturing what they actually do and how they do it. Furthermore, video data preserves context as well as content allowing for contextually rich interpretations.
- *Dynamic nature of video data*. Videos allow you to capture a process—which is essential for understanding the emergence and evolution of sociomaterial fabrics—whereas photos only capture snapshots.
- *Multiple viewing*. Videos allow the researcher to watch sociomaterial processes and activities repeatedly, from different perspectives and by multiple viewers. This helps us to become aware of things that we did not observe initially or to correct erroneous interpretations that were based on initial observations alone. Every video is full of details that can only be captured through multiple

viewings of the same video. Furthermore, multiple viewings of the same video help researchers to counter and overcome personal biases that affect initial observations.

- *Communication mechanism*. Videos or small fragments of video data can be used to communicate research findings that are dynamic, rich and/or subtle. Therefore relevant video fragments can be used as a powerful augmentation to traditional forms of communicating the researchers' experiences as well as research findings through text.
- *Feedback mechanism*. Videos or small fragments of video data can be used as a reflective tool in order to confront research subjects with seemingly contradictory actions and behaviors as well as to allow them to reflect on the accuracy of the research findings.
- *Enhanced reliability and validity*. The previous advantages collectively enhance the reliability and validity of research findings.

Conclusion

In this paper, we presented the results of a mixed method study for untangling the sociomaterial interactions between developers, users and artifacts in the context of Generativity Support applications. Based on our findings, we propose a typology of affordances for disentangling these complex sociomaterial interactions, including three types of affordances, namely: designed, improvised and emergent. We argue that this typology of affordances is useful for capturing both the significance of materiality as well as the various possible interactions between actors and artifacts in the context of sociomaterial activities. Furthermore, understanding the different types of affordances of a particular technology can help us better predict how technology will affect people's way of doing things and the relationships that they have (Leonardi and Barley, 2008). These insights are relevant both for those studying sociomateriality as well as for those designing, developing and using technologies in practice.

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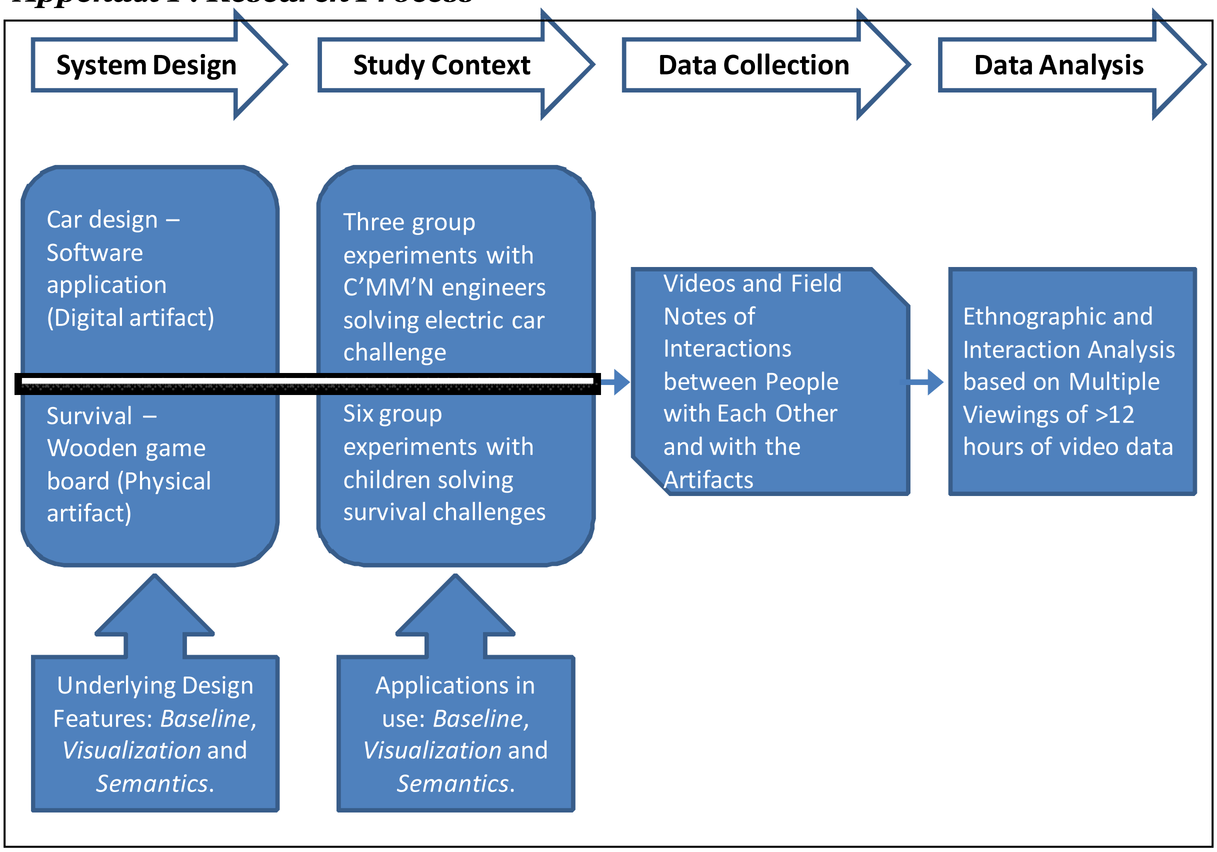
Appendices

Appendix 1 : Research Process



Appendix 2: Experiment Challenge

Challenge for C'MM'N community:
"The C'MM'N car runs on electricity. In order to run for one day the car needs to be either fully charged or the battery should be charged regularly. During their one month vacation, Family Jansen wants to use their car to travel from Amsterdam (Netherlands) to Rome (Italy). They also want to use their car for daytrips during their holiday in France, such as hiking, going to the beach, swimming, site seeing, shopping, cycling, fishing, etc. **How do we enable the Family Jansen to use their CMMN car for their one month trip without running out of electricity?** Imagine it is 2025 and many things are possible!"

Challenges for primary school children:
You all are campers going to the forest for the weekend. In the forest there are: trees, shrubs, and flowers. On the ground there are branches and leaves. A river with fish flows near the forest. In the forest are: wild animals and insects. The sun is shining, the wind is calm, and there are some clouds in the sky. You brought some things with you in your bag, including: blanket, clothes, bottle, comb, cup, knife, paper, rope, a band-aid and matches. You will now play three games together and in each game you will try to find as many solutions as you can to the following challenge.

Each team got one challenge from the following list:

1. Find ways to cross the river.
2. Find ways to protect yourselves from insects and wild animals.
3. Find ways to catch fish.
4. Find ways to get yourselves warm at night.

Appendix 3: Overview of Experimental Groups and Stages

	Experimental Groups	Stage 1 ⇨	Stage 2 ⇨	Stage 3
C'MM'N	**Group A**	Baseline	Visualization	Semantics
	Group B	Visualization	Semantics	Baseline
	Group C	Semantics	Visualization	Baseline
Children	**Group D**	Baseline	Visualization	Semantics
	Group E	Visualization	Semantics	Baseline
	Group F	Semantics	Baseline	Visualization
	Group G	Semantics	Visualization	Baseline
	Group H	Baseline	Semantics	Visualization
	Group I	Visualization	Baseline	Semantics