The Knowledge Handling Notation: building an interface to enable design conversation diagnosis

Andrea Scheer[1,2]

scheer.andrea@gmail.com

Axel Menning[1]

axel.menning@hpi.de

Elisabeth von Helldorff[1,3]

helldorff@schwarzplusweiss.de

Holger Rhinow[1,2]

holger.rhinow@hpi.de

Dr. Claudia Nicolai[1]

claudia.nicolai@hpi.de

1 Hasso Plattner Institute, Potsdam, Germany
2 University of Potsdam, Potsdam, Germany
3 University of Hildesheim, Germany

Abstract: *With the development of the Knowledge Handling Notation (KHN) we were able to provide a model for a notation that captures modes of knowledge handling and visualizes its dynamics in design conversations. The KHN functions as an interface between transcript and pattern analysis for researchers or coaches who aim at diagnosing knowledge handling in conversational interactions in general, and design reviews in particular. We applied the notation to different design review sessions and iterated on the coding, which is presented in a coding manual. A visualization of the coding shows the dynamics of the conversational interaction. We developed the Knowledge Handling Notation (KHN) by integrating Nonaka's concept of externalization and combination, enriched with sub-categories that account for transitions between those activities. In that, KHN maps out design conversations focused on the dynamics of knowledge handling and thereby serve as an orientation system for knowledge handling interactions in the context of design conversations.*

Keywords: design conversation dynamics, Interaction Dynamics Notation, organizational knowledge creation, Nonaka, pattern recognition, knowledge handling

1. Introduction

The main goal of our research is to enable design conversation diagnosis through carving out patterns of knowledge handling. The notation would serve as a first step to actually record modes of knowledge handling interactions and represent them in a visual model. In this research, we want to create an orientation system for knowledge handling analysis in the context of design conversations.

1.1 The importance of knowledge handling in design reviews

Design reviews are a form of design conversations which are characterized by a team interacting to solve a design challenge. Design review sessions primarily function as interactions that aim at sharing and creating knowledge, which is beneficial for the design project outcome. We consider the key activities of sharing and creating knowledge and the dynamics between them as knowledge handling. However, there is not much known about what actually happens during interactions in design reviews, or how participants perform knowledge sharing and creation. In perspectives of conversation analysis and team interaction dynamics, the knowledge handling process still seems to be a black box we would like to understand in order to find out more about the underlying key activities and dynamics of design reviews. A first step towards an understanding of knowledge handling in conversational interactions is to capture knowledge sharing and creating activities, as well as the dynamics that define the variety of conversational interactions with different participants. In Nonaka's (1994) words, "knowledge is a flow of information, and information is a flow of messages or meanings distributed" (p.15). In other words, knowledge is defined by a flow, or a dynamic of shared messages. We are referring to Nonaka (1994) and his SECI model, which gives a theoretical basis for an exploration of the modes of knowledge handling. In order to empirically capture underlying processes of interpersonal exchanges, and being able to 'see' the dynamics of different review conversations, we are referring to Sonalkar's (2012) Interaction Dynamics Notation as a methodological framework.

According to Sawyer (2006), reviews are "learning conversations scaffold by external representations"(p. 191). The goal of a design review is to advance the reviewee's external representation of the status quo of the design project, enhance his learnings with feedback from the reviewer and result into a new formulation of another external representation. The design review therefore is an important step in the iteration process of the design project. Design reviews can be regarded as transition elements to bridge design phases within the progress of a design project. They are distinct parts of the design process to consolidate concepts within the team as an alternative to testing scenarios. In the design process, insights are generated and presented for feedback in the design review. The team members share their insights by representing them in form of artifacts, performances or concepts and evaluate them when getting feedback of the reviewer. Discussing insights and feedback in the design review situation generates a refinement of the concept presented and leads to a progress in the design process, from one design phase to the other. In summary,

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design reviews process knowledge through activities or modes of sharing and creating. The modes occur to a different extent in different review conversations.

The description of the design review dataset states, "design review conversations are a common and prevalent practice to help designers develop design thinking expertise, although the structure and content of these reviews may vary"(Adams & Siddiqui, 2013). The design reviews presented in the datasets show a great variety of design review formats, from partner debriefs to mentoring reviews, from one-to-one sessions to team intern review scenarios. Within those formats, the style of the review seems to vary as well. From a first glimpse on the datasets, we recognized different modes of interaction. However, it is not clear how those modes are defined, how they occur and relate to each other. Therefore, in our research we are interested in finding out patterns of interactions related to knowledge handling. To be able to actually find patterns, we would need to record a design review in such abstraction that it is analyzable at a glance, but still providing enough information about the modes of knowledge handling. Here the question arises, how do we capture knowledge handling modes and the different dynamics of speaker interactions?

1.2 What happens in design review conversations?

What do participants of design review conversations actually do during the process of reviewing the status quo of a project? Looking at the video material given by the organizing committee of the DTRS 2014, we see participants interacting with each other, referring to artifacts and materials representing the status quo of a project, discussing this material in different levels of detail, asking and answering questions, assigning new tasks and refining the material or artifact. Through the interactions of the participants during design reviews, information (meanings or messages) flows between participants, and is built upon in order to adapt the status quo, and to assign new tasks. Knowledge is emerging through this flow of information. We refer to this process of knowledge sharing and creation as knowledge handling dynamics. Those dynamics are based on distinct sequences, which are determined by the interactions of the speakers. These interactions result in and are influenced by knowledge sharing and creating activities. The question is, how do we record the mechanisms of knowledge handling interaction modes?

In order to study knowledge handling in design conversations, we need to capture and visualize the interactions and their information flow as they occur from turn to turn over time. This is leading to our research objective:

How do we capture knowledge handling dynamics in design review conversations in order to build an interface that enables design conversation diagnosis?

2. Conceptual Framework

Despite the importance of design reviews, their inner conversation dynamics are still ill defined. The quality of design reviews, and there for the handling of knowledge within them, depends on several structural factors. Intuitive (Cross, 1995) and reflective (Schön, 1983) modes as well as co-evolution processes (Reyman et al.) and team dynamics challenge a direct establishment of diagnostic methods. The research goal of investigating the dynamics of review conversations and capturing knowledge handling processes requires a combination of frameworks: a theoretical framework that describes the underlying activities of knowledge handling, and a methodological framework that empirically captures the interactions of those activities.

The theoretical framework is embodied in Nonaka's theory of organizational knowledge creation (1994). Nonaka (1994) proposed "a paradigm for managing the dynamic aspects of knowledge creating processes" (p.1). In his paradigm two dimensions (the ontological and epistemological dimension) are said to be in continuous social interaction through four sequential modes of knowledge conversion: socialization, externalization, combination, and internalization (SECI model). The epistemological dimension of the SECI model is based on Polanyi's (1966) dimensions of tacit and explicit knowledge, whereas the ontological dimension defines the grade of social interaction between team, department, or company. Externalization and combination were considered useful for our purpose of understanding the dynamics of knowledge handling activities, since those modes describe activities of sharing and creating explicit knowledge on a theoretical basis. However, it is important to recognize that all four modes of the SECI model are involved in Nonaka's paradigm, as he puts it „[organizational knowledge creation] hinges on a dynamic interaction between the different modes of knowledge conversion" (Nonaka, p. 20). For our purpose of understanding and visualizing the dynamics of knowledge handling only the modes dealing with explicit knowledge (externalization and combination) are considered. The modes dealing with tacit knowledge (socialization and internalization) evolve through activities dealing with experiences (Nonaka, 1994), but are less visible from a researchers point of view as they deal with implicit knowledge. We extracted the two modes of externalization and combination from the SECI model to serve as theoretical framework describing knowledge handling. However, those modes do not work as a method to empirically capture those underlying activities in order to enable a visualization of the dynamics between them.

The methodological framework we refer to is the Interaction Dynamics Notation (Sonalkar, 2012, Sonalkar, Mabogunje & Leifer 2013). Through Nonaka's description of externalization and combination we are able to better understand the underlying modes of the knowledge handling process. Still, we cannot capture them in conversational interactions, nor do we 'see' the dynamics between them. Sonalkar (2012) introduced an Interaction Dynamics Notation (IDN) providing a visual representation to capture concept generation activities in engineering design teams. IDN identifies eight patterns of interaction: transitions between ideas and facts, the presence

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of periods of sustained idea expressions, the occurrence of improvisation behavior, question asking and humor in periods of sustained idea expression, the existence of blocking behavior, the presence of interruptions, and the resumption of concepts in conversation (Sonalkar, 2012). The notation is based on video interaction analysis based on Jordan/Henderson (1995). In IDN, a descriptive visual model of the unfolding interaction is generated through a coding of observable speaker expressions. Thus, the IDN is able to empirically capture interactions and enable a visualization of its dynamics. However, IDN is focusing on idea expression and generating activities as key activities in the concept generation phase of a design team, and not on knowledge handling. That is why we developed a notation that focusses on capturing and visualizing knowledge handling dynamics.

3. Methodological Framework

Our goal is to create an instrument that actually enables pattern recognition in design conversations. To accomplish this goal, the instrument would need to be a model of a design conversation that is not as detailed as the conversation itself, but offers enough information for pattern analysis focused on knowledge handling. Hence, we began with studying the given design review datasets based on Grounded Theory (Glaser, 1986). As Martin & Turner (1986) state, "A key element of Grounded Theory is identifying a slightly higher level of abstraction – higher than the data itself." We set out to develop a notation through iteratively identifying coding levels for knowledge handling.

In order to develop a notation that captures knowledge handling dynamics, which would then enable a visualization of the knowledge handling process, we examined three design review datasets from several disciplines as well as from different stages in the design process. Our strategy was to capture knowledge handling by coding Nonaka's modes of externalization and combination, as well as speaker expressions that seemed to have an impact on those modes. Each speaker expression is regarded as a result from the preceding, and influencing the following act. Therefore, we coded expressions according to their impact in the following response. It is not coded according to what the speaker might intend, which would have been hard to analyze, but what the responder got out of it. We added sub-categories that account for transitions between sharing and creating activities, as well as interruptions and changes of the topic.

Steps of developing the Knowledge Handling Notation:
- examining the datasets and randomly choosing three sets from different disciplines (engineering, choreography, service learning)
- independent coding of transcripts through the research team according to Nonaka's modes of externalization and combination
- double-testing and discussion of coding
- adding sub-categories that account for transitions between externalization and combination

- iterating steps 2-4 three times and specifying the codes through discussion
- describing the iterated specifications in a coding manual (Figure 2)
- final independent coding of the transcripts using the coding manual
- final double-test
- prototyping a visual representation of the results

The proceedings of the steps are discussed more in detail below.

We used transcripts of three design review conversations provided by the DTRS 2014 committee. The datasets were chosen randomly from three different disciplines (service learning, engineering, choreography) to try to capture knowledge handling in a variety of design review conversations. Interaction analysis (Jordan/Henderson) was used to capture knowledge handling interactions. A repeated viewing of the transcripts of the different design review sessions with several rounds of identifying and discussing modes of externalization and combination helped to become familiar with the knowledge handling phenomenon. The researcher team consisting of three independent researchers and two mentors went through the transcripts in several iterative rounds and checked the video material in cases where the transcript was not sufficient to take a decision on defining the situation regarded. Design reviews as described in the introduction chapter cannot be planned ahead of time as its constituting acts are influenced by and result in each other. Therefore, we went for a turn-by-turn approach, coding the main expression of each turn of a participant represented in the transcript.

After each researcher coded independently first, the team double-tested the categories and found it necessary to add sub-categories to differentiate between different turns that were consisting of expressions that were neither regarded as externalization, nor as combination but still had an impact on the knowledge handling process. The sub-categories emerged while discussing those expressions in the research team and examining its effects on the following turn.

In three iteration cycles of independent coding closely followed by a shared discussion of the decided codes, the notation emerged and was more and more refined during each cycle. Through those regular discussions we came up with a shared understanding of the selected categories and described those in a systematic coding manual (see Figure 2). We assigned symbols to each mode of interaction that would be able to be used with a keyboard as well as analogue note taking. The researcher applied the manual to go through a final coding. See Figure 1 below for an excerpt of a final coding after double testing:

time stamp:	0:05:00

o externalization	Claire: Like I said, I just kind of started out as making it like, ah, the door and then like the, the screens were kinda like what I focused on. So it's like I kind of like felt like a door is like accessibility. So like my door was just like a push door that they could actually push through, but it can be locked. Like they can push through it, but they can't push like from the inside out, unless like they're like – it's like – I don't know. It's just the way I thought of it.
/ none	Female: I like that idea.
oo combination	Naomi: oh, and then, um, so my idea with this, it looks like it's actually the other yellow one, yeah, same idea. But, basically, like just having a ramp kind of wrap around an entire space just, you know, like going around –
oo combination	Joel: Like a spiral.
/ none	Naomi: Yeah.
//o deviation and externalization	Jordan: So I'll just piggyback of that 'cause of the yellow one. I was kinda hesitant about putting it up there 'cause I don't know like making the right – no, no, no. Not 'cause I can't draw, but like the regulations of like–
time stamp:	0:06:00

Figure 1. Excerpt from 2_SL_BrainstormRev transcript including assigned codes based on the coding manual

At this point, we reached a level of the notation that fully accounted for what we identified as essential in order to visualize the dynamics of knowledge handling: a coding for the modes of externalization and combination, as well as important transitions that seemed to "trigger", "interrupt" or "deviate" interactions in the design conversation. The full specifications and all sub-categories are captured in the KHN coding manual, which is described in the following chapter.

In a last step, we created a first prototype of a visual representation of the final coding (see Figures 3-6). We were eager to 'see' the whole conversation at a glance in order to check the use of KHN as an instrument to diagnose knowledge handling dynamics of design conversations in a visual representation. The visual representation prototype is described in chapter 4.2 below.

4. Results

4.1 The KHN coding manual

The notation is a visual representation of knowledge handling interactions in design conversations (see Table 1). It consists of 6 symbols, 2 of which are defined by the modes of externalization and combination of Nonaka's SECI model (Nonaka, 1994). The other 4 evolved during the attempt to code preceding and following modes of externalization and combination. The unit of analysis for the notation was a speaker expression that could be isolated in time in the transcript of the design review conversation. This expression was assigned a symbol for a mode of interaction when it influenced the content of the ongoing interaction. It was assigned *none*, when it did not influence the content of the ongoing interaction. Even though the coding symbols were fixed, the parameters were redefined through iterative application and discussion with the research team. The coding manual represents the final, collectively agreed on set of codes and descriptions. Table 1 below shows the manual of the coding symbols, including descriptions of different forms and functions, as well as examples derived from different design review conversation datasets.

Table 1. The Knowledge Handling Notation (KHN) and its specifications in the coding manual

Symbol	Mode of Interaction	Form	Function	Examples
Basic Categories (influencing the content of the ongoing interaction)				
o	externalization	statements, presentations, need articulation, storytelling of experiences, representations e.g. artifacts, metaphors, analogies	articulation of data/ information, knowledge of an individual or group of persons, getting to a common ground, informing	"That's good because there was probably half of them will be afraid of heights." (that they will be afraid of heights is known before the meeting) "And they'd just be incorporating like different aspects to make it easier for them, too." (describing what she observed) "It become more like an – education ramp for the kids. And I think that's what they want. You want it to be more educational." (describes his idea he generated before the review and refers to his observations)

oo	combination	new/ jointly generated models, manuals, description, solutions, standards, ideas and thoughts that evolved during the team meeting articulated by one or more individuals, design principles	editing/ refining/ changing articulated information, data or knowledge by one or more individuals	"Is then the other like protection for these ramps?" (ramps have been described before) "Like a spiral." (something has been described before) "Yep. I had, I had an idea. I'm gonna draw it real quick, like a, um, maybe like a covering over a section of the ramps. Like I like the – you talked a lot about the lattice idea, making that like a little housing section you have to go through." (describes an idea that just evolved during the conversation with others, based on an articulation of someone else)
Sub-Categories (influencing the basic categories)				
//	deviation	new sentence/ statement/ question that is not related to the preceding topic, changing topic	cut of topic and start of another topic or semantic sequence	"Then we can finish here. Let's jump to, um, Mike's idea." "Ok. By the way, Decke is your Grandpa?" "We also found that folding space to be interesting. … ." (the preceding topic was not about the folding space or any other formatting)
[ ]	interruption	verbal interruption of a speaker without changing the topic	expression that adds to an externalization or combination by another person than the speaker	a: Mhmmm. And when Paul was here he was saying the pods actually still used too much detergent __. b: Really? a:Too much detergent. And I am really, I can't figure out why they don't just…. ."

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> (o/oo)	trigger	W-questions, yes/no- questions, open ques- tions, refer- ences to pro- totypes or artifacts through presentation or testing	asking for more information, data, knowledge {trig- gering externali- zation (>o)} OR asking for rela- tions, coherences, new ideas, effects, or other elements that ask for com- bination of knowledge {trig- gering combina- tion (>oo)}	"So keep on going. Just who draw the next, just talk about that." "Now, was that something you got off the web or is that some- thing you found at the - were these statistics you were able to just grab from general?" "Come on, be more specific."
Category with no influence on the content of the ongoing interaction				
/	none	opinions/ add ons/questions that do not trigger exter- naliza- tion/combinat ion e.g. rhetor- ical question, closed ques- tion, organization- al/ not con- tent related topics	no other item applies	"Yeah." "I like that." "Don't you think it's nice?" "Mhmmm."

The manual defines the modes of interaction in terms of form and function in the conversation. Thereby, it provides information about our interpretation of the modes of *externalization* and *combination*, as well as the added sub-categories *deviation*, *trigger*, *interruption* and *none*. The examples provided are extracted from different datasets of design review conversations.

a.) Basic Categories

The basic categories are representing those SECI categories dealing with explicit knowledge, which can be "seen" and analyzed in design conversations. In our under- standing those modes directly relate to knowledge handling in a conversation, as an individual needs to externalize its knowledge in order to share it with other individ- uals of the design team. Individuals can combine knowledge to create new knowledge for the sake of the advancement of the design team. In our description of the basic categories, we refer to Nonaka's (1994) words, *externalization* is „the conversion of tacit knowledge into explicit knowledge"(p.19), and *combination* „the

process of creating explicit knowledge from explicit knowledge"(p. 19). We found that the conversion of tacit knowledge into explicit knowledge can be realized in the form of statements, external representations, need articulations, or storytelling of experiences. Those are formats that are articulated by an individual and refer to implicit experiences or flow of information, which is transformed into explicit knowledge. Metaphor and analogy are means to transfer tacit knowledge indirectly to explicit articulations (Nonaka, 1994). Combining explicit knowledge with explicit knowledge into new knowledge can be realized through models, manuals, or other representations that represent explicit knowledge in a more generalized manner, thereby editing and advancing it. The research team further decided to not code the other two modes of Nonaka's SECI model, e.g. internalization and socialization, as those refer to tacit knowledge creation of the individual speakers and cannot be captured through the use of transcripts as easy as the modes referring to explicit knowledge. With real time coding or video analysis, this might be more convenient.

b.) Sub-Categories

The sub-categories of (a) *deviation* and (b) *interruption* refer to cuts of the flow of interaction through (a) expressions that open up a new topic for the conversation, and (b) a verbal expression of a speaker without influencing the topic or content.

The sub-category *trigger* is important when it comes to expressions preceding and *triggering externalization* or *combination*. A *trigger* occurs in the form of different types of questions or references to prototypes or other artifacts. *Externalization* is triggered, if a speaker asks for more information for a general understanding. *Combination* is triggered, if a speaker asks for complex relations, coherences, new ideas or effects.

c.) Category with no influence on knowledge handling

Last, but not least the category *none* is referring to all expressions that do not seem to relate to a knowledge handling process. Those are opinions, questions, statements that do not affect activities of knowledge handling like sharing or creating knowledge. Rather they have a more rhetorical character or relate to organizational topics.

	Claire: Like I said, I just kind of started out as making it like, ah, the door and then like the, the screens were kinda like what I focused on. So it's like I kind of like felt like a door is like accessibility. So like my door was just like a push door that they could actually push through, but it can be locked. Like they can push through it, but they can't push like from the inside out, unless like they're like – it's like – I don't know. It's just the way I thought of it.	Female: I like that idea.	Naomi: oh, and then, um, so my idea with this, it looks like it's actually the other yellow one, yeah, same idea. But, basically, like just having a ramp kind of wrap around an entire space just, you know, like going around –	Joel: Like a spiral.	Naomi: Yeah.	Jordan: So I'll just piggyback of that 'cause of the yellow one. I was kinda hesitant about putting it up there 'cause I don't know like making the right – no, no, no. Not 'cause I can't draw, but like the regulations of like–	
	o	/	o	o o	/	//o	
time stamp 0:05:00	externalization	none	externalization	combination	none	deviation and externalization	time stamp 0:06:00

Figure 2. Example of the visual representation of a design review conversation through on KHN - excerpt from 2_SL_BrainstormRev transcript

The episode in Figure 2 begins with an *externalization* by Claire based on an idea that was sketched out on a post it. It is followed by an expression that does neither influence the first speaker's, nor the following speaker's content. A third speaker, Naomi adds her idea to the general question about accessibility, Claire's expression has also responded to, through another *externalization*. This is then followed by a *combination* through refining the ideas that were externalized by the two speakers before. Jia is joining the ideas expressed before with his own knowledge, thereby specifying them. The *combination* is followed by an expression that has no influence on the content of the following interaction. The episode ends with a *deviation* by a fifth speaker, Jordan, who is not adding to the specified idea, but rather suggests a new perspective, that of regulations. The *deviation* is influencing the preceding expression in that it ends a further exploration of that idea, and it opens up a new episode with an *externalization*. The implications of these results will be explored in the discussion chapter.

4.2 Visualizing knowledge handling dynamics

With the coding manual the first part of our research question is answered: with the KHN we are able to capture modes of knowledge handling interactions in design conversations, and design review conversations in particular. In order to make knowledge handling dynamics of the coded design review conversations visible, we developed a prototype of a visual representation that could function as an interface between the video material or transcript and conversation pattern analysis to enable design conversation diagnosis.

By processing the analysis of design conversations on a rather basic level of detail, one is able to code speaker interactions during a design project. With the help of a visual representation of that coding, one is able to 'see' the dynamics of the design team conversation. We propose color-coding of individual expressions by bar chart

diagram in addition to the symbolization through the coding with KHN coding manual as visual indicators.

The visualization aims at providing information about
- the turns of speaker expressions through a color-code
- the frequency of the modes of interaction of knowledge handling through the symbols of KHN coding manual
- the share of speaking time of every individual in the conversation through the length of the bar chart

Further design requirements of the visualization include
- being easy to read and understand
- giving an idea of the dynamics of the conversation at a glance without even understanding the coding manual
- applicable digital and analogue by using video tapes or transcripts of design conversations

Working with spreadsheets allows an easy application digitally as well as analogue. Furthermore, they can be arranged in a linear format to account for the dynamics of the conversation. Every speaker of a session is tagged with a color. A number is added to the color also representing a speaker in order to make sure the speakers can be differentiated even with black and white printing. Furthermore the visualization represents *combination*, *externalization*, *triggers* of *combination* and *externalization* as well as *interruption* and *deviation*. Expressions that are not related to any of these categories are marked as empty.

Rules for reading the visual notation
- The notation is read from left to right.
- The horizontal axis represents the time elapsed from left to right.
- Speakers are tagged with a color. Students in shades of brown, red or yellow. Advisors in shades of green.
- The symbols for *combination*, *interruption* and *deviation* are exaggerated for a better readability. The symbols are as follows:

Externalization: o

Combination: oooooooo

Trigger externalization: >o

Trigger combination: >oo

Deviation: /////////////

Interruption: [⬛⬛⬛⬛⬛⬛]

None: (left empty)

The examples shown hereafter were picked out of the design review datasets that have been coded with KHN coding manual. The choice aims at showing a great variety of possible readings.

The following two excerpts from the datasets of choreography and industrial design review conversations are examples of representations of the knowledge handling dynamics in a conversational episode. The excerpts illustrate how the different dynamics of design conversations can be compared. Examining Figure 3 and Figure 4, one can recognize a significant difference in the sequence of the episodes at a glance. Figure 3 shows a moment of *combination* as a result of an *interruption* followed by a *trigger of externalization*. Figure 4 shows no *combination* at all but a tight conversation with an advisor (green) whose most expressions are *trigger for externalization*. However, further analysis on a bigger set of data would be necessary to actually point out patterns and give implications.
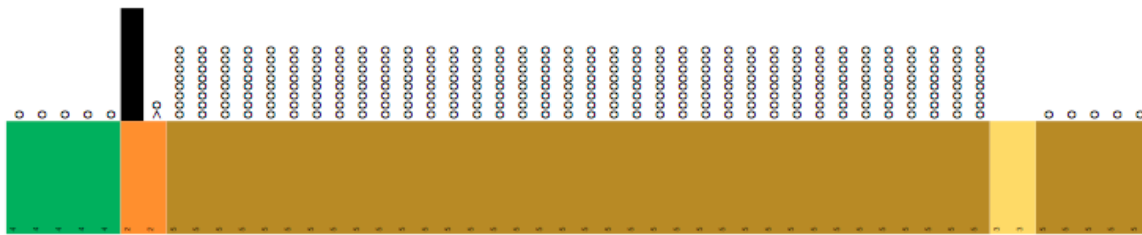
Figure 3. Example of KHN Visualization - excerpt from the choreography dataset
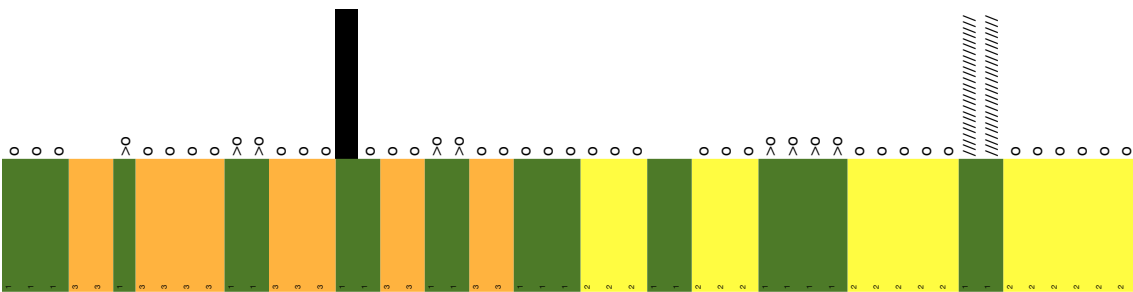

Figure 4. Example of KHN Visualization - excerpt of the industrial design dataset

Figure 5 illustrates the knowledge handling dynamics, leaving out the individual color code. This prospect eases the analysis of knowledge handling dynamics, leaving out the frequency of speaker turns. Especially, when looking for patterns of knowledge handling modes, it can be useful to detach the occurrence of modes from the actual speaker expression.

Figure 5. Example of KHN Visualization – Modes of Interactions only

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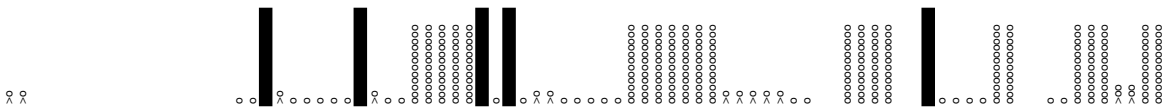
Using the visual representation prototypes to compare the three coded datasets first findings emerged. We found it striking that every combination was a result of a period of externalization. As a result there is a higher quantity of externalization than combination in a design review conversation. Regarding the color-coded turns it is possible to make out different styles of reviewing. Whereas one group arranged the review session in a monologue of the reviewer, the other one had a lively dialogue. The first started combinations quite late in the process, while the latter early began to trigger and combine. The advantage of the visualization is that these insights can be gained quickly when looking at the conversation at a glance. The reading of transcripts would provide the same information, but in a more time consuming way.
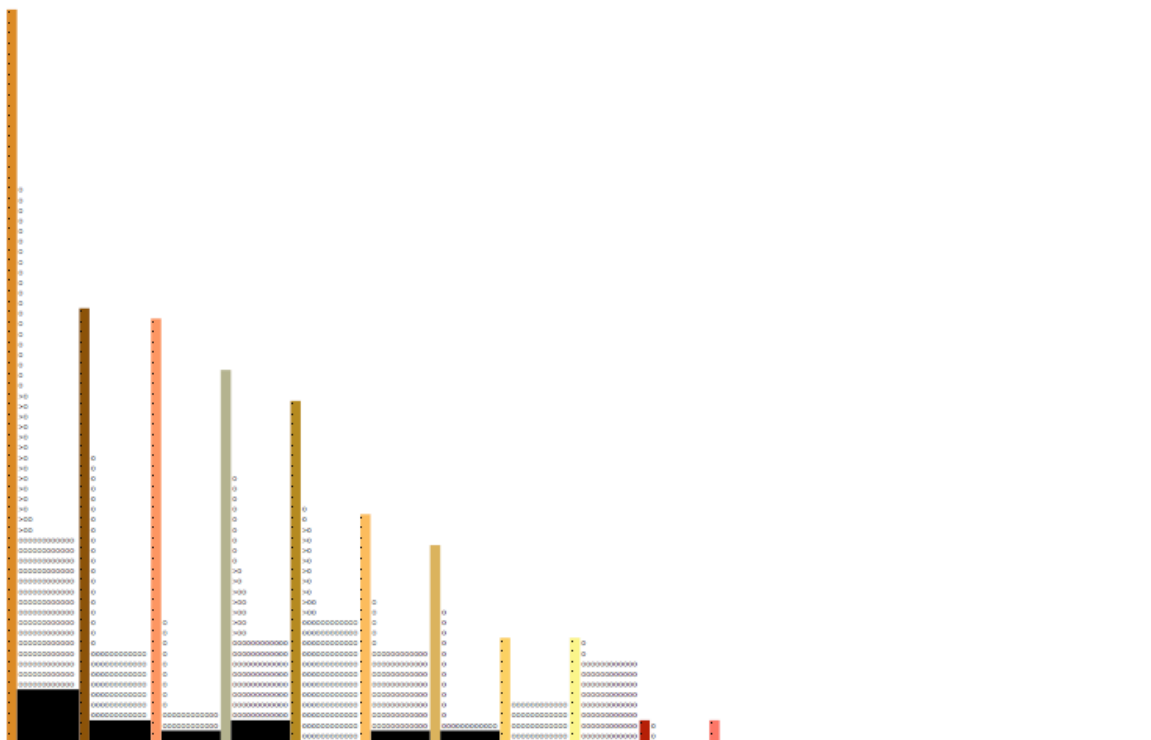

Figure 6. Example of KHN Visualization - Individual Knowledge Handling Performance

The last picture, Figure 6, provides an overview of the personal performance of each speaker of a design conversation. It shows the individual talking time in relation to the others, as well as the amount of knowledge handling modes detected in the sum of the individual expressions. The order of symbols in Figure 6 was chosen to realize an easy readability.

5. Discussion

We set out to capture knowledge handling dynamics in design review sessions with the premise that key activities of speaker interactions are sharing and creating knowledge. We developed a notation that would capture knowledge handling dynamics and created a first prototype of a visual representation that would enable design conversation diagnosis. In this research, we iterated the coding specifications and generated a coding manual to strengthen the notation and make it easy to apply on design conversation transcripts. In a second step, we prototyped a visual representation of the coded material to test readability and possible pattern recognition of knowledge handling dynamics in design conversations.

In further research, we aim to analyze the visual representation towards a diagnosis of interaction patterns in design review conversations. A first evaluation of KHN as an instrument to capture knowledge handling dynamics and enable a design conversation diagnosis is discussed below.

1. *The KHN coding manual records knowledge handling in design conversations*

The KHN captures modes of interactions based on externalization and combination of Nonaka's SECI model that hint towards knowledge handling dynamics in design conversations. The coding manual specifies the form and function of the assigned codes. With the manual, researchers are able to code a design conversation mainly based on transcripts and video material. The decision to code speaker expressions in terms of the impact they had on the response, rather than on their intention of the speaker was inspired by IDN. However, we found that the response to an expression might differ to its intended impact. For example, a *trigger* that resulted in a *combination* could have been an intended *trigger for externalization*. In fact, we think it would make a difference in the diagnosis of a design conversation if the speaker actually intended the response he actually got or not. Nevertheless, from a researcher's perspective it is challenging to analyze the intention of a speaker.

When coding the design review datasets, we recognized that most of the conversation expressions could be coded with our manual, leaving only few expressions to *none*. This actually implies that at least in the case of design reviews the main interaction is focused on sharing and creating knowledge.

Last but not least, we compared KHN coding with the Interaction Dynamics Notation (IDN) as we recognized similarities in at least a few categories of IDN. The IDN categories *interruption* and *deviation* were especially useful to divide interruption of a speaker turn (*interruption*) and interruption of the content flow (*deviation*). However, our notation comprised of categories that were not used by IDN like *externalization* and *combination* of knowledge, as well as *trigger*. On the other side, IDN com-

prised of categories that focus on concept generation and were not used in our notation, e.g. *move*, *block*, *support of block,* and *humor*.

2. *The visual representation of KHN can serve as an interface between transcript and pattern analysis to enable design conversation diagnosis*

The notation is designed to capture modes of interaction in design conversations relating to knowledge handling, in order to enable a visualization of the dynamics of
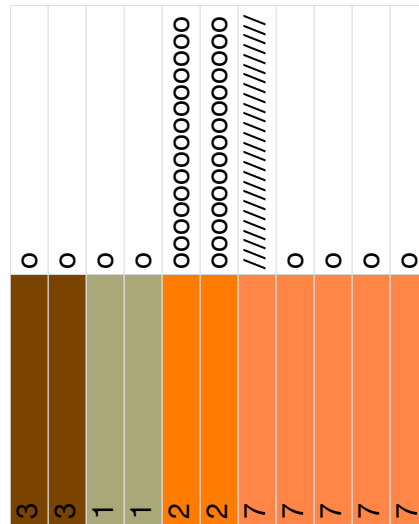
those interactions. This visualization works as an interface between transcript and pattern analysis that enables design conversation diagnosis through a visual recognition of patterns emerging.

The design review phase in the design thinking process is often facilitated in different formats, e.g. face to face discussions, Q&A patterns or a reporting format in which the reviewer checks and assigns tasks. In addition, we found that within these formats the style of the review also differs in terms of the frequency of interaction between reviewer and reviewee, as well as the knowledge handling dynamics and frequency of externalization and combination of knowledge in the design review conversation.

A KHN coded conversation can be condensed to the modes of interaction influencing knowledge handling in conversations. For example, excluding the *none* category of that design episode presented in Figure 2 before, we would get to a visual representation shown in Figure 7 below:

Figure 7. Example for a condensed visual representation of a design review conversation through KHN including color code

Figure 7 is a condensed version of the visual representation presented in Figure 1. It includes a color code that represents the speaker turns and a time stamp. This is just

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one phenomenon out of one coded episode. If we find such phenomena in further research on a bigger data corpus, one could hypothetically conclude the pattern that combination occurs after externalization happens; as if something needs to be externalized first to have 'material' for further combination. One could implicate that an intervention to foster externalization at the beginning of design conversations would lead to better combination. This shall be an example of the possibility of pattern analysis and conversation diagnosis in coded and visualized design conversations. A scientific pattern analysis on a bigger set of data is planned to be conducted in further research.

3. *KHN benefits design education and research on design conversations*

The potential use cases of KHN instrument are twofold. First, KHN enables pattern recognition through a visual representation which can be useful for further analysis of and research on design conversations. The application of our notation in the field is expected to yield insights into how design research can actually augment the performance of real teams engaged in design review conversations. Second, KHN can lead to coaching implications through an understanding of the dynamics of a conversation at a glance. In point 2 this chapter, we started to give a first glimpse on how the notation enables identifying team interaction patterns. This corpus of data will be further analyzed to discover interaction patterns that are fostering or hindering knowledge handling processes in design reviews. As demonstrated in the discussion above, once the patterns are visualized, we are able to give a concrete account of the dynamics of a conversation, not only hinting towards patterns of high performance, but also towards an understanding of how they relate to and interact with other patterns. We as a team of researchers recognized an increased awareness of the knowledge handling processes not only when analyzing the design reviews, but especially when being in review or feedback situations ourselves. Part of that was a higher awareness of when externalization took place, how well it took place and when there was a possible transition to combination of knowledge. We assume that by developing and applying the notation we improved in actually diagnosing and steering knowledge handling patterns in our own teams when coaching. Although we had a very intense phase of dealing with knowledge handling processes, we believe that already the visual representation of a design conversation gives an overview of the dynamics at a glance, thereby enabling coaches to steer the review for the better. This assumption also needs to be verified in further research.

Finally, the review analysis depicts that the different design review scenarios we have coded and analyzed, include bidirectional knowledge creation. This means that the sessions do not end with the reviewer expressing his thoughts towards the reviewee, but rather that they create a conversation about the presented subject, enabling both the reviewer and the reviewee to learn from each other. Although, this is dependent on the style of the review (see Figure 3 and Figure 4).

4. *KHN as an abstract model for design review conversations*

The notation abstracts the actual conversation represented in video material or transcript towards a model of knowledge handling interactions. In that, the KHN serves as an instrument to focus on the performance of knowledge creation in design conversations. Especially in design review conversations, in which the creation of knowledge is a main goal, such an instrument might proof useful for a better understanding of a design review process.

The engagement with the dataset enabled us to develop a model of interaction layers within design review conversations (see Figure 8 below).

Figure 8. Layers of Interaction in a Design Review
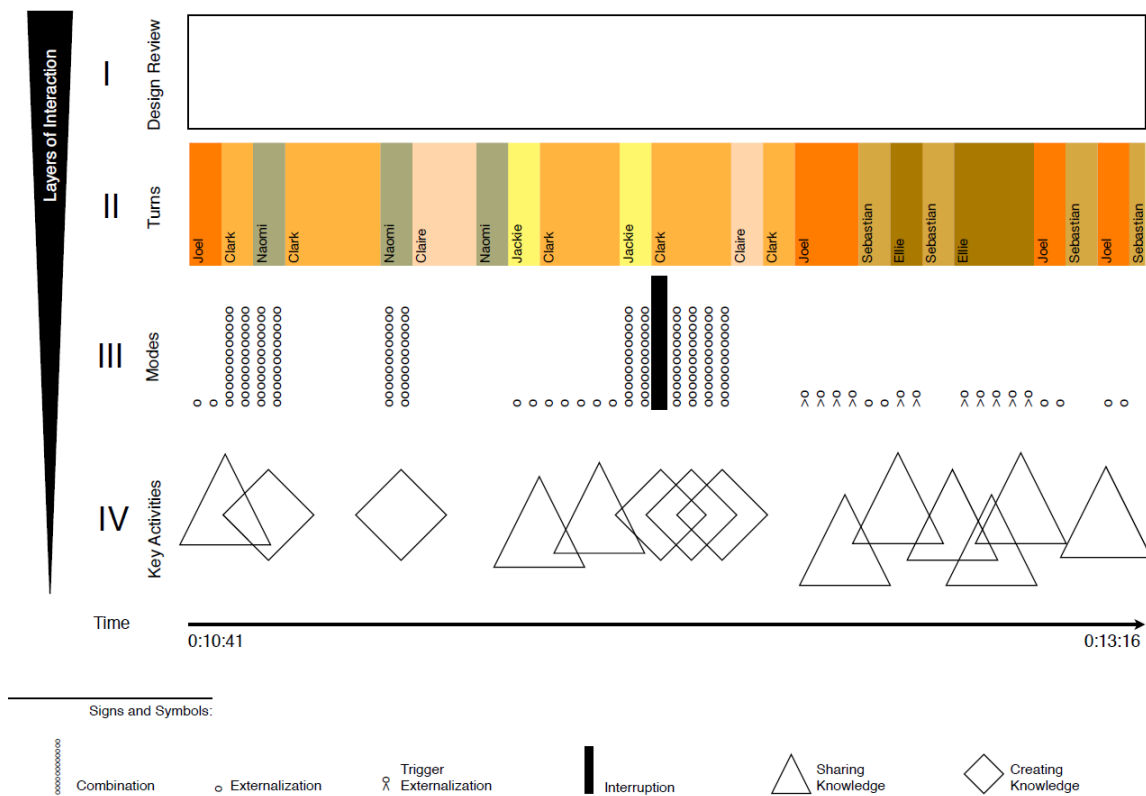
As described in 1.1, a design review still is a black box (I) when it comes to identifying the mechanisms that lead to knowledge and advancement of the reviewer and reviewee in a design review conversation. In order to enable an understanding of what actually happens during a design review conversation, we developed KHN as a model that focusses on knowledge handling. With KHN we were able to shed light on the black box of design reviews to a certain extend. We identified speaker turns (II), which are consecutive sequences of actions or expressions of one speaker and the reaction or response of another speaker. Each turn is defined by a mode of interaction (III), which we identified through coding of the speaker turns with KHN. With further research identifying patterns of modes of interactions we will be able to recall key activities (IV), which are proposed to be sharing and creating

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knowledge in the context of design review conversations. So far, with KHN we are able to set the stage for pattern recognition and the identification of key activities, as the notation combines a coding of knowledge handling interactions with speaker turns across time.

5. *Outlook for the KHN instrument*

For application in practice, we propose two alternatives that would benefit either the coaching of design teams (a) or further design conversation research (b): (a) real-time monitoring of a design team according to its effective knowledge handling in order to predict team performance and advise coaching accordingly, and (b) code-based sequence analysis as a post-process research method in order to further analyze patterns of knowledge handling in design conversations. A real-time coding was also tested during this research briefly and seemed to be promising.

Furthermore, the coding needs to be further tested in different design conversations and refined accordingly. For example, we consider that the expressions coded with *none* in this research, might actually be accounted for as *interruption* in future coding. Also, to account for a more detailed representation of a design conversation, we will build in codes that account for non-verbal and spatial interactions that might actually support knowledge handling. For that reason, we will expand the KHN with some more sub-categories that enable a better understanding of why externalization and combination occur, and how this can be fostered.

So far, the notation represents how one speaker expression leads to the next speaker expression across time. Hence, the notation is limited to show a linear interaction process, which does not fully account for the complex dynamics of a team conversation. For example, an expression might impact an expression further in the discourse than the directly following one. A non-linear visual representation needs to be developed in further research.

Finally, we plan to conduct KHN with more datasets including design reviews of different design teams, as well as in different phases of the design process. With an additional analysis the coded datasets, we might be able to not only diagnose knowledge handling patterns in design conversations, but also identify design phases that are prominent in knowledge handling.

6. Conclusion

In this research, we developed a tool or instrument to map out design conversations focused on the dynamics of knowledge handling. In particular, we created an atlas of symbols and codes to comprehensively record a design review conversation. However, the main goal of our research is to carve out patterns of knowledge handling in design conversations, in which the KHN is a first step to actually record modes of knowledge handling and represent them in a model that enables pattern analysis.

Hence, the KHN serves as an orientation system or atlas for knowledge handling in the territory of design conversations.

Acknowledgements

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Biographies

Andrea Scheer is a PhD candidate at the University of Potsdam and the Hasso Plattner Institute - School of Design Thinking in Potsdam, Germany. She holds a Master degree in education and linguistics.

Axel Menning is research assistant at the Hasso Plattner Institute - School of Design Thinking in Potsdam, Germany. He holds a diploma in cultural management.

Elisabeth Helldorff is a PhD candidate at the University of Hildesheim and the Hasso Plattner Institute - School of Design Thinking in Potsdam, Germany. She holds a diploma in Cultural Sciences and Aesthetics.

Holger Rhinow is a scholarship holder at the Hasso Plattner Institute in Potsdam, Germany. He studied Social & Media Sciences, and International Business & Administration in Berlin and New Zealand.

Dr. Claudia Nicolai is General Program Manager and Senior Researcher at the Hasso Plattner Institute – School of Design Thinking in Potsdam, Germany and visiting professor at the University of Arts Berlin and the Elisava School of Design and Engineering in Barcelona/Spain. She studied Business Administration, Economics and Social Science and received her Ph.D. in Strategic Marketing.