Tracing Interdisciplinary Design Conversations: An Architect-Tech Designer Conversation Analysis by Text Visualization

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Abstract

With the increasing convergence of digital and architectural practices, a common interdisciplinary encounter of today is between architects and tech designers. Tech companies, startups, designers, and entrepreneurs are increasingly interested in homes, offices, infrastructures, and cities as sites of deployment; and architecture offices and architects in return engage with software, sensors, robots, and devices as their instruments. The mutual interest in each other's work and artifacts start to bring these two figures more often in conversations, debates, or collaborations within labs or projects. Because of different knowledge backgrounds and discourses, an interdisciplinary conversation can at times involve low levels of engagement as well as exchanges and gaps. Producing insights on these between the disciplinary discourses of architects and tech designers is a crucial first step towards constructing a more productive communication between the two groups, which could help to produce distinct perspectives, artifacts, and knowledge out of their collaborations. This paper reports on a case study of an interdisciplinary conversation between two architects and a tech designer. Within the case study, we investigated the engagement, exchanges, and gaps between these actors' disciplinary discourses by text processing and visualization. By doing this through text processing and visualization, we also explored the potential of these methods in understanding these conversational dynamics. The case study and visualizations revealed that, even though the architects and the tech designer engage through a sharing and exchange across their discourses, there are issues in the qualities of that sharing and exchange.

Glossary

Content words: *Content words are the words in a sentence that contain semantic information and cumulatively form the contentful part of a discourse, such as nouns, verbs, or adjectives. In this project, we use content words to evaluate contentful contribution to a discourse.*

Disciplinary words: *Words that belong to or stem from a certain disciplinary or professional terminology. Disciplinary words can also be present in daily language. For instance, "ramp" when it is used by architects is an architectural word, as opposed to what it means in another daily conversation.*

Function words: *Function words are the words in a sentence that maintain the syntactic structure but do not contain semantic information, such as prepositions, pronouns or conjunctions. Function words are considered as "language style markers", and similarities and differences in rates of function word use is a way of analyzing language interaction (Ireland and Pennebaker, 2010; Gonzales et.al., 2010).*

Inter / dual-disciplinary words: *Interdisciplinary words are the words that are present in multiple disciplinary or professional terminology. An example is "design" that exists both in architecture and engineering. In this project, we take the interdisciplinary words together with, what we named as "dual-disciplinary" words. Dual-disciplinary words are the words that may or may not be disciplinary, but have different meanings or connotations in different disciplinary domains. An example would be "program" which means programming a computer by coding" in computer science versus "building programming by organizing the floor areas and layouts for different uses" in architecture.*

1. Introduction

An inherent quality of professional and academic work is its interdisciplinary nature. In various work practices such as the ones in architecture, design, or technology design, this quality is related to the involvement of various professions that participate. In these practices, one may see people from different knowledge backgrounds communicating and collaborating to tackle the complexities of large technical projects. In academic research, this quality is associated with various disciplines that engage for knowledge production. Examples are academic collaborations in which we see people from different fields communicating and collaborating to produce a combined body of knowledge.

With the increasing convergence of digital and architectural practices, a common interdisciplinary encounter of today is between architects and tech designers. Tech companies, startups, designers, and entrepreneurs are increasingly interested in homes, offices, infrastructures, and cities as sites of deployment; and architecture offices and architects in return engage with software, sensors, robots, and devices as their instruments. The mutual interest in each other's work and artifacts start to bring together these two figures more often around a table. We see them in conversations, debates, or collaborations within labs or projects.

But, how effectively do architects and tech designers communicate? How do they engage through their discourses in a conversation? And what could textual data, and visualization tell us about this engagement that we will not otherwise get by reading or listening to their conversations?

An Interdisciplinary conversation can at times be complicated because of different knowledge backgrounds and discourses involved. It can involve low levels of engagement or gaps between different discourses. On the other hand, these conversations can also involve exchanges and abridging between different discourses. Understanding and producing insights on engagement, exchanges, and gaps between the disciplinary discourses of architects and tech designers is a crucial first step towards constructing a more productive communication between the two groups. Such communication could help to produce distinct perspectives, artifacts, and knowledge that would not stem from a singular disciplinary perspective.

This paper reports on a case study of an interdisciplinary conversation between two architects and a tech designer. Within the case study, we investigated the engagement, exchanges, and gaps between these actors' disciplinary discourses by text processing and visualization. By doing this through text processing and visualization, we also explored the potential of these methods in understanding these conversational dynamics. The rest of the paper presents the case study. It is organized in sections that discusses the related work, method and framework of analysis, findings, the contribution of the work, and future steps.

2. Related work

Language and conversations have been used as a material for analyzing social interactions in different fields. Part of the researchers focus on everyday language use and exchange to investigate and understand social interactions and use computational analysis of text. The work has produced analytical frameworks for linguistic analysis as a predictive method for understanding aspects of social interaction. For instance, psychologist and communication researcher Amy Gonzales and her colleagues (2010) use language style matching (LSM) to calculate verbal mimicry in the context of small group discussions to predict group cohesiveness. In another study, psychologists Molly Ireland

and James Pennebaker (2010) focus not on group dynamics, but rather on mimicry in both everyday and professional writing tasks. In their work, they explore language style matching between a writer, and the language style that writer was recently exposed to. Similarly, psychologists Cindy Chung and James Pennebaker (2014) use 'computerized text analysis' to study the relationship between language use and psychological processes. In their work, they use Linguistic Inquiry and Word Count (LIWC), a framework for analyzing the social dynamics in a conversation. These studies are important in terms of the conceptual frameworks they provide to analyze conversations. However, even though these studies adopt computational analysis of conversations and text processing, they do not necessarily use visualizations as a method of analyzing conversations.

Researchers also look at the role of language in collaborative practices. For instance, human-computer interaction researchers Iris Howley and Carolyn Penstein Rose (2016) designed SouFLe, a framework as a linguistic analysis approach for studying small groups, to explore computational modeling of conversation dynamics and automated coding of conversation of collaborative learning. In another study, human computer-interaction researcher Mika Yasuoka (2009, 2015) explored and described in detail the role of language in pulling closer diverse knowledge bases and practices in collaborative design discussions. Yasuoka also used a conversation analysis tool next to qualitative observation in analyzing communication breakdowns and mutual meaning-making by language during the meetings of a software design project in Japan. The tool allowed to visualize key expressions and co-occurrences between programmers', an interaction designer's, and a client's discourses. The first study focused on collaborative conversations in a pedagogical setting, and did not use visualizations as part of their method. Yasuoka's work did an analysis in the wild looking at interdisciplinary conversations, and network visualization is a key part of her methodology.

In our study we take text visualization as a method to analyze aspects of interdisciplinary conversations. We borrow concepts from LIWC framework and situate text visualization as a key part of interdisciplinary conversation analysis. In that sense, our study examines some of the analytical concepts in linguistics literature through visualizations. In our study, we also expand Yasuoka's work by visualizing a larger set of dimensions of an interdisciplinary conversation, and use a variety of visualizations including network graphs. We also analyze conversations in English than Japanese, between different design actors including architects and tech designers, and therefore an engagement between different architectural and technological design discourses.

3. Framework and Method

3.1 Conceptual and technical framework

The conversation we chose is titled "Architecture and Technology" which took place in Venice Biennale in 2014. This was a conversation between German architect and journalist Niklas Maak, renowned Dutch architect and founder of the Office for Metropolitan Architecture (OMA) Rem Koolhaas, and American computer engineer, tech designer and entrepreneur Tony Fadell, who was one of the designers of Apple iPod and iPhone, and founder of Nest Labs, that developed smart thermostats at that time. Triggered by the programmable and self-learning thermostat designed by Tony Fadell and his company Nest, the conversation was an exchange of perspectives on the digitalization of architectural elements.

To analyze this conversation, we identified a list of questions. These questions include:

- What are the lengths and patterns of exchange between the actors in the conversation?
- What are the actors' weights in the conversation?
- What are the actors' weights of contentful contribution?
- What is the degree of engagement by language between actors?
- Whose disciplinary vocabulary has more weight in the conversation? What are the disciplinary words of importance?
- How do the discourse of actors differ? How are actors' disciplinary vocabularies?
- What are the words that are shared or exchanged between these disciplinary vocabularies? In other words, what are the words that bring actors with different knowledge backgrounds and discourses closer?
- How engaged or connected are the actors through discourse?

To investigate, we operationalized key dimensions in a conversation based on linguistics and other relevant literature. The key dimensions include:

- **Actor-time:** This dimension shows who speaks on a particular moment in the conversation as well as patterns and lengths of interaction between the actors.
- **Number of words-time:** This dimension shows an incremental count of words by each actor on a particular moment in the conversation. It also shows how the weight of each actor according to the number of words changed throughout the conversation.
- **Contentful contribution by actor-time:** This dimension includes a comparison of counts between content words by each actor. It shows how the weight of contentful contribution by each actor changed throughout the conversation.
- **"Language style matching":** Language style matching is rating the function word use in actors' discourses as a factor of engagement (Gonzales et.al., 2010; Chung and Pennebaker, 2014).
- **Frequent words by actor:** This dimension is about each actor's frequently used function, content, and disciplinary words.
- **Word sharing and exchange:** This dimension is about examining the key words or expressions shared or exchanged across actors' discourses. It shows the words through which actors converge in a conversation.

On the technical side, we used the Youtube transcript of the conversation, did data cleaning and corrections along with a qualitative reading. Then we used NLTK / Python for text processing and extracting data related to these dimensions listed, and HTML and D3.js to create our interactive narrative with visualizations.

3.2 A mixed-method approach

The study is built on a mixed-method approach that includes computational and qualitative evaluation of the conversation. Next to the computational approach, qualitative evaluation is important to contextualize the textual data analysis as well as what visualizations reveal. For instance, analysis and visualizations can point out which actor's discourse has been dominant in the conversation. But it is also important to explain why that is the case based on qualitative evaluation. To maintain the level of detail in that qualitative evaluation, the scope of analysis is limited to one conversation as opposed to a corpus of conversations.

By limiting the scope of analysis to a single conversation, the study constantly keeps in sight the specificity of the conversation data and specificity of actors and their discourses coming from architecture versus computer engineering background. For instance, parallel to visualizing the sharing or exchanges of disciplinary words in the conversation, the study also captures and describes the instances of those exchanges. Further, working with one conversation also allowed us to consider the specific connotations of words in context while taking the words as data points. For instance, “ramp” when it is used in this conversation is an architectural element, a term, as opposed to what it means in another daily conversation.

4. Analysis and insights

4.1 Role, weight, and contribution in the conversation

Part 1
The conversation has its distinct parts in terms of actor engagement as the actor-time heatmap shows. It starts with a 4.5-min (9:04 to 13:45) and a 3-min (15:17 to 18:22) dialogue between Maak and Fadell (Figure 1).

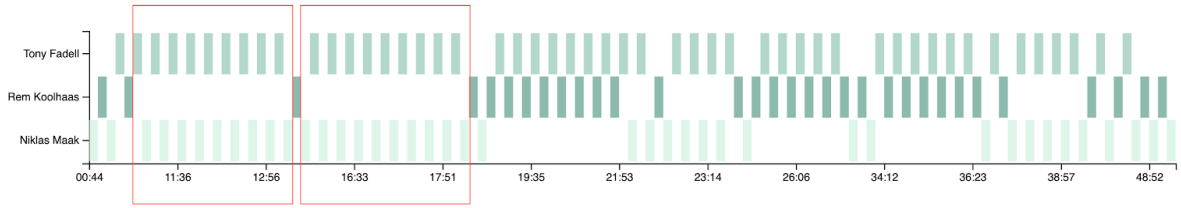

Figure 1: Actor-time heatmap showing the first and second dialogue of Part 1

In these two early engagements, Maak asks questions to make Fadell describe the Nest thermostat and how it works. Fadell explains the distinct features of the device compared to a conventional thermostat which are sensing the inhabitants' heating and cooling patterns, learning from it, adapting to automatically set the temperature for different rooms in different times. With that, the thermostat helps save energy.

In these parts, Maak also provokes Fadell with questions focusing on issues of privacy when a home device is able to track the inhabitant's habits in order to learn and adapt. He also questions the idea of a private company —Nest, later acquired by Google— keeping the data and setting the standards of heating and cooling energy consumption to reduce the carbon footprint. Fadell assures the private companies interest in reducing carbon footprint by saving energy in residential heating and cooling. He also assures that the data is only used for the improving the product, and giving users feedback on their energy consumption.

Within the first dialogue, Fadell has more weight in the discourse as the number of words-time bar graph shows (Figure 2). But Maak has more contentful contribution with two fifths of his discourse made of content words. Within the second dialogue, Maak has slightly more weight, but the contentful contribution is even with almost two fifths of each actor's discourse being contentful.

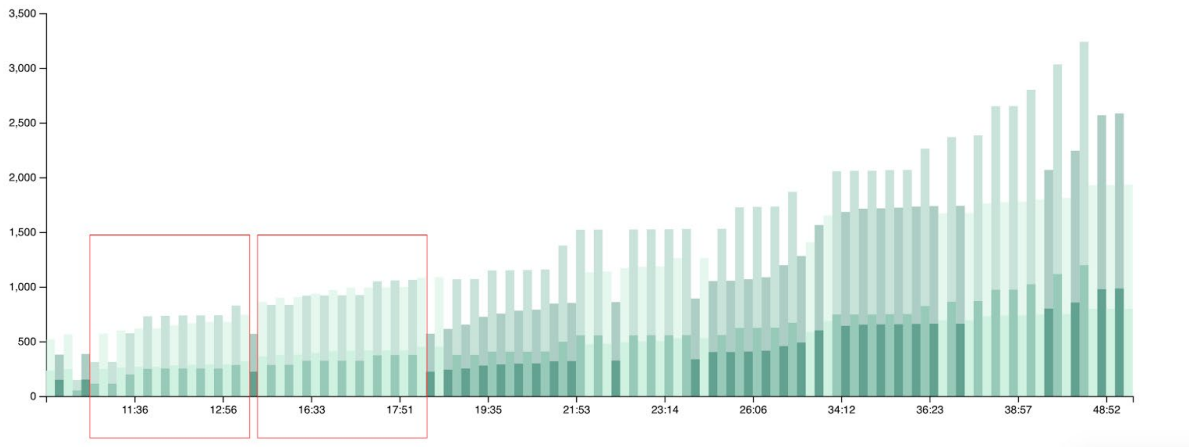

Figure 2: Number of words-time bar graph with the first and second dialogue of Part 1 highlighted

Part 2

These two dialogues are followed by a 4-min (18:24 to 22:35), a 4.5-min (23:53 to 28:25), and a 2.5-min (34:12 to 36:25) dialogue between Koolhaas and Fadell (Figure 3).

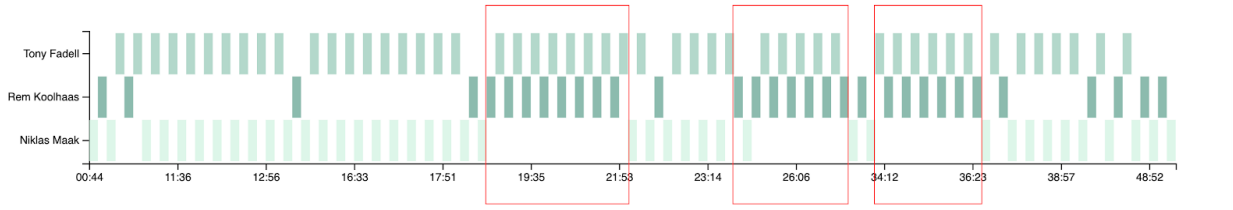

Figure 3: Actor-time heatmap showing the first, second, and third dialogue of Part 2

4-min dialogue

In the first 4-min dialogue, Koolhaas pauses the topic of "privacy" that Maak opened, and continues to question the designer of the thermostat on the persuasive aspect of the technology. He points out that the thermostat implicitly imposes a sense of responsibility on the users, and questions the applicability of the device in other cultures other than the United States. Fadell emphasizes that the device is not necessarily imposing any sense of behavior, but rather informing the users on their energy consumption. He mentions that this aspect is already embraced by people by mentioning that the Nest thermostats are active even in the countries that they are not officially sold. He also describes the adjustments in the product to fit it into the UK market.

4.5-min dialogue

Maak intervenes here to continue on the "persuasive technologies" by giving examples from cars, and insists on questioning Fadell on how he makes sure that the thermostat is not imposing on the self-determination of the users. This starts off the second 4.5-min dialogue between Koolhaas and Fadell. In this dialogue, Koolhaas balances Maak's interrogation by mentioning that it is hard to control how the vision that creates these products are taken and used. Fadell picks on that, and brings the notion of "transparency" as an essential way to ensure ethics in digital technologies. Koolhaas responses to that with the cynicism that exists against "transparency" as a promise. He also differentiates between a smart phone as a standalone mobile device that could be thrown away, and a learning thermostat that is embedded in architecture and not easy to escape from.

2.5-min dialogue

At this point, an exchange between Maak and Koolhaas redirects the conversation into the ways these embedded technologies re-shape social priorities towards comfort, security, and sustainability as well as architecture and cities. This exchange produced another question for Fadell on how technologies will work in forms of inhabitation other than the single-family home, such as the mass housing in large cities in Asia. Fadell re-emphasizes the importance of data for improving individual decision-making and collective behavior towards a more environmental way. Koolhaas challenges Fadell's constant emphasis on improvement and, noting transgression as an inherent human tendency, asks Fadell to speak to its absence in his story. It is here that the third 2.5-minute dialogue between the two begins. Fadell responds by stating the necessity of inspecting the designers of feedback algorithms, and transgression as a freedom of choice. He once again clarifies that his motivation is about providing information towards a more conscious resource consumption.

The weights of actors' discourses within these dialogues is changing as one can track in the number of words-time bar graph (Figure 4). Fadell has more weight within the first 4-min dialogue and has slightly more contentful contribution with almost two fifths of his discourse being contentful. Whereas Koolhaas has a slightly more weight within the second 4.5-min and has slightly more contentful contribution with two fifths of his discourse being contentful. Within the third 2.5-min dialogue, it is again Fadell who has slightly more weight and a contentful contribution, with almost two fifths of his discourse as contentful.

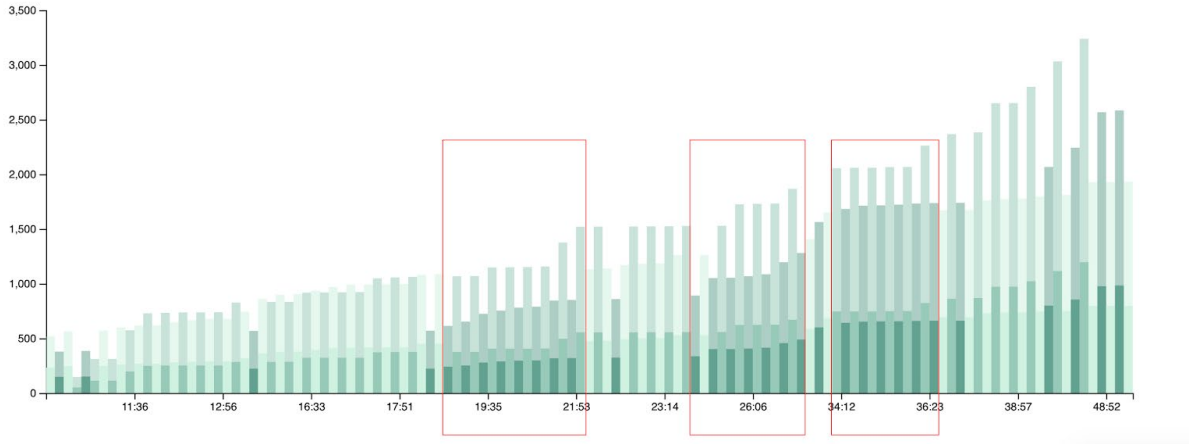

Figure 4: Number of words-time bar graph with the first, second, and third dialogue of Part 2 highlighted

Part 3

These three dialogues are followed by a 2.5-min (37:05 to 39:39) dialogue between Maak and Fadell and a 9.5-min (39:39 to 49:00) ending conversation between the three actors (Figure 5).

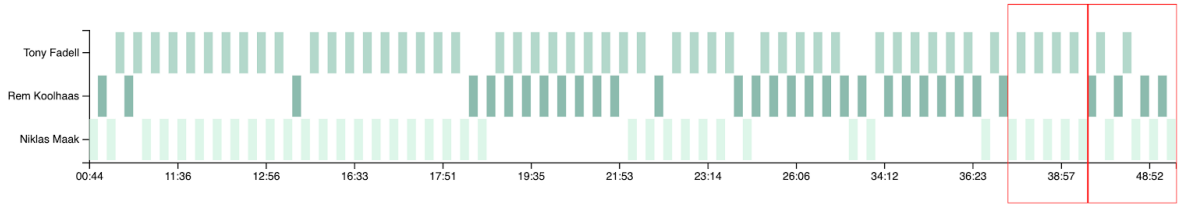

Figure 5: Actor-time heatmap showing the first and second dialogue of Part 3

2.5-min dialogue
In the first 2.5-min dialogue, Maak opens up a conversation around the notion of "discomfort" and points out the hidden merits of discomfort that have also been reflected in literature. He then provokes Fadell to discuss the notion by asking if the Nest Thermostat could be programmed to create discomfort. Fadell responds by stating the possibility and ties the notion to the conflicts on the comfortable temperature between spouses, which he half-jokingly mentions that the Nest thermostat can address.

9.5-min dialogue
The final dialogue opens by Maak directs the question of "discomfort" in architecture to Koolhaas. Koolhaas responds by telling a historical story about two architects: a utopian creating discomfort as a heroic yet failed design experiment, and another resolving discomfort by making handicapped access accepted in the United States. He asks Fadell about his utopia. Tony mentions that he is not technoutopian and asserts once again the role of the technology designer in providing information for more responsible living. Rem brings about the potential of collaboration between architects and tech designers, not necessarily on the single elements, but increasing "the intelligence of the whole". Tony agrees and appreciates.

The conversation ends by Rem's closing statement on the dilemma between the necessity to be constantly rational within the technological discourse and the merits of the irrational, based on the example of Venice as the beautiful outcome of an irrational decision of building a city on water. He finishes with a subtle critique on technology design not being able to produce "a profoundly creative dimension that could really transform beyond improvement", the dimension that he hopes that the collaboration between architects and tech designers can produce.

The weights of actors' discourses within these dialogues is also changing (Figure 6). Fadell has more weight within the first 2.5-min dialogue, but Maak has a slightly more contentful contribution than Fadell with more than two fifths of his discourse being contentful. Within the closing conversation, Koolhaas has the most weight, but Fadell and Maak has slightly more contentful contributions with almost two fifths of their discourses made of content words.

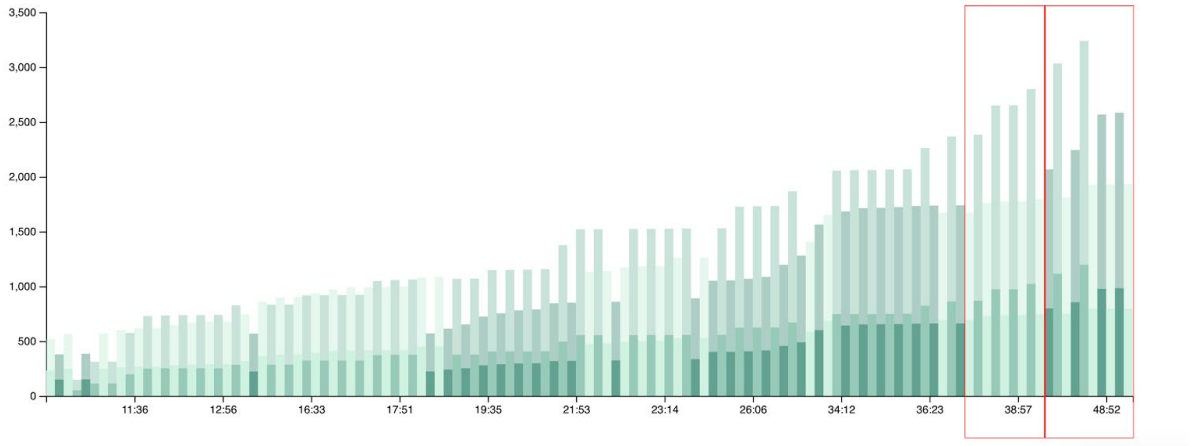

Figure 6: Number of words-time bar graph with the first and second dialogue of Part 3 highlighted

Overall

As the summary of the conversation shows, each part is a dialogue between the tech designer and one of the architects. Because of that, the tech designer Fadell has a continuous participation in the conversation while the architects Maak and Koolhaas almost take turns in engaging with the tech designer. Because he has to continuously participate, Fadell's discourse has the most weight in the overall conversation in terms of the number of words (Figure 7). This is followed by Koolhaas and Maak. Maak has the least weight, but he has the highest percentage of content (content words) in his discourse (41%), followed by Koolhaas (38%) and Fadell (37%) (Figure 7).

Overall, 38% of the conversation discourse is contentful. Even though Fadell has the lowest percentage of content in his discourse, the highest contribution to the overall contentful discourse comes from him (40%). This is followed by Koolhaas (33%), and Maak (27%).

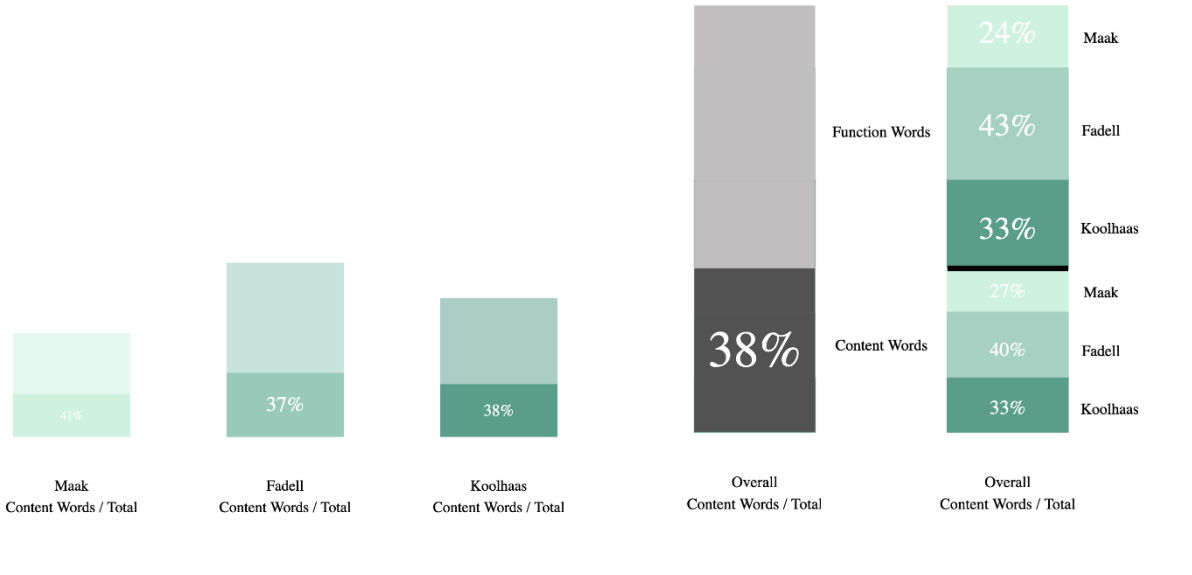

Figure 7: Content words / total words bar graphs

4.2 Engagement by language style matching

Language style matching is a linguistics concept used in social interaction analysis (Gonzales et.al., 2010; Chung and Pennebaker, 2014). It uses the degree of match between the number of function words in actors' discourses as a factor of engagement in a conversation.

The first three actor-word network graphs reveal the set of function words shared between each pair of actors (Figure 8). The size of the point cloud indicates that Koolhaas and Fadell, aside from having more and longer dialogues through the conversation previously mentioned, also shared more function words across their discourses. These graphs also show each function word as nodes and its frequency of use by each actor links with different thicknesses (Figure 8). The actor-actor network graph displays, even though Koolhaas and Fadell shared more function words, when the frequency of function words considered, they have a slightly lower degree of engagement through their discourses than the other pairs (Figure 9). Whereas, despite having less and shorter dialogues through the conversation, Maak and Fadell had a slightly higher degree of engagement through their discourses.

Figure 8 : Actor-word network graph (function words) (top) and actor-word network graphs (function words) with word frequencies highlighted (bottom)

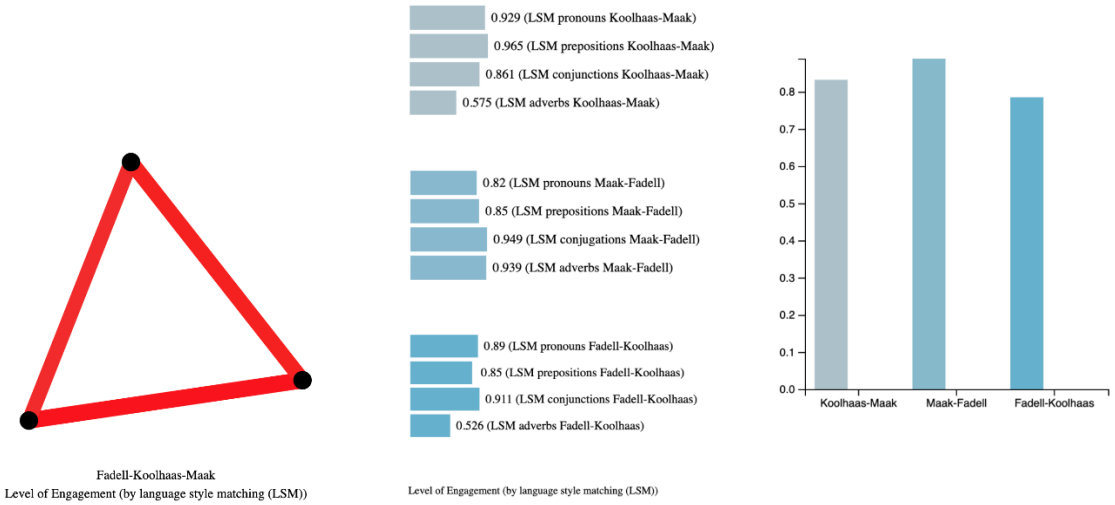

Figure 9 : Actor-actor network graph showing level of engagement by language style matching between actors (left) and bar graphs showing the breakdown of language style matching by category (middle and right)

4.3 Disciplinary words in the conversation

An analysis of the content words reveals the disciplinary words in the conversation discourse. Certain disciplinary words are specific to the technological design domain whereas certain words are to the architectural domain. Certain disciplinary words are inter-disciplinary that are present in both domains, or dual-disciplinary, that may or may not be disciplinary, but have different meanings or connotations in these two domains. These words represent the disciplinary vocabularies used by the two architects and the tech designer in this conversation.

The word tree map displays these vocabularies under three categories as colored clusters — technological as blue, architectural as yellow, and inter / dual-disciplinary as green (Figure 10). The sizes of the colored clusters indicate there are more inter / dual-disciplinary words used than the disciplinary words. To put it differently, an inter / dual-disciplinary discourse has more weight in the conversation compared to a technological or an architectural discourse. Between the disciplinary vocabularies, the technological has more weight than the architectural.

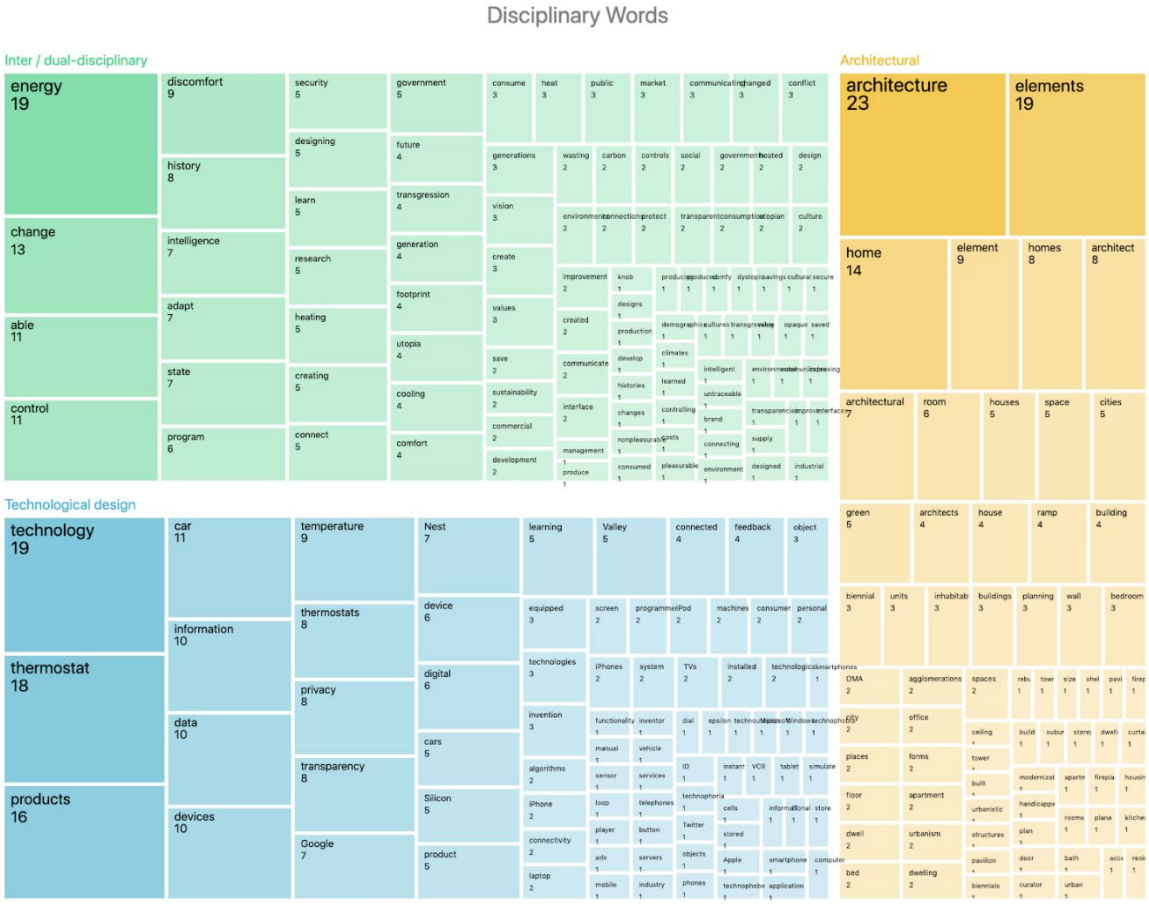

Figure 10: Word treemap showing disciplinary words

The tree map also shows the frequency of these words under categories, and the more frequently used ones, which may be called the words of importance. Some of these words hint at the primary subjects that the architects and the tech designer discuss around in the conversation. For instance, there are nine words of importance that are the inter / dual-disciplinary and used more than seven

times and more. Some of these words are "energy" (19), "control" (11), "discomfort" (9), and "adapt" (7). Within technological design vocabulary, there are thirteen words used more than seven times and more, including "thermostat" (18), "products" (16), "car" (11), "devices" (10), "data" (10), "privacy" (8), and more. This tells us that the technological design vocabulary is even more frequently used than the inter / dual-disciplinary vocabulary. Lastly, architectural vocabulary has seven words that are used seven times and more, some of which are "elements" (19), "home" (14), and "architectural" (7).

4.4 Difference in vocabularies and disciplinary words

Smaller nodes of the three actor-word network graphs represent the words in each actor's vocabulary in this conversation (Figure 11). Even though Fadell's discourse has the most weight in the conversation in terms of the number of words, Koolhaas used the highest number of unique words as the sizes of the "All Words" bars indicate. In other words, he used the richest vocabulary. Maak used the lowest.

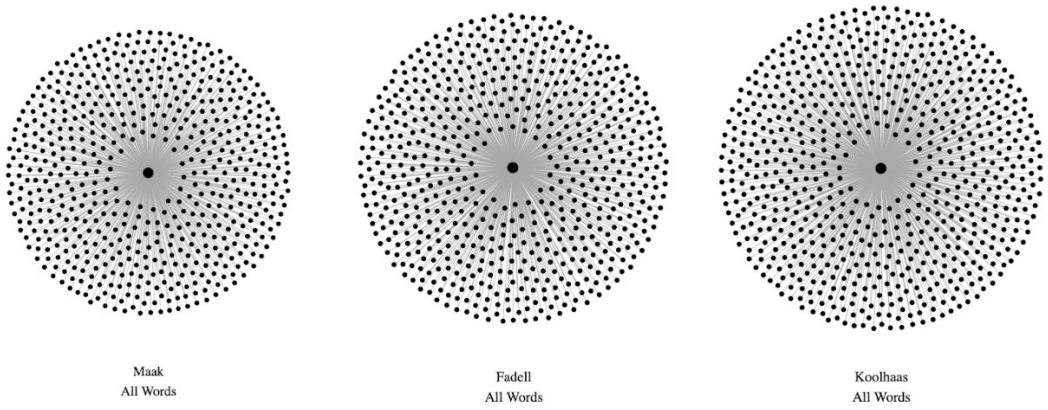

Figure 11: Actor-word network graphs representing the words in each actor's vocabulary

When content words are highlighted, the word nodes also show whether they are a non-disciplinary word (in dark-gray), a technological design word (in blue), an architectural word (in yellow), an inter / dual-disciplinary word (in green), or a function word (in light gray) (Figure 12). Across the actors, the percentage of content words within all words is almost even as the stack bars display (Figure 12). Koolhaas's vocabulary has a slightly higher percentage (72% + 4% + 3% + 6%) of content words compared to Fadell's (62% + 2% + 9% + 10%) and Maak's (59% + 10% + 7% + 8%). When the frequency of words is highlighted, the different thicknesses of links show the frequency of each word in the actor's discourse (Figure 13). Overall, it is the function words that are essentially more frequently used than the content words.

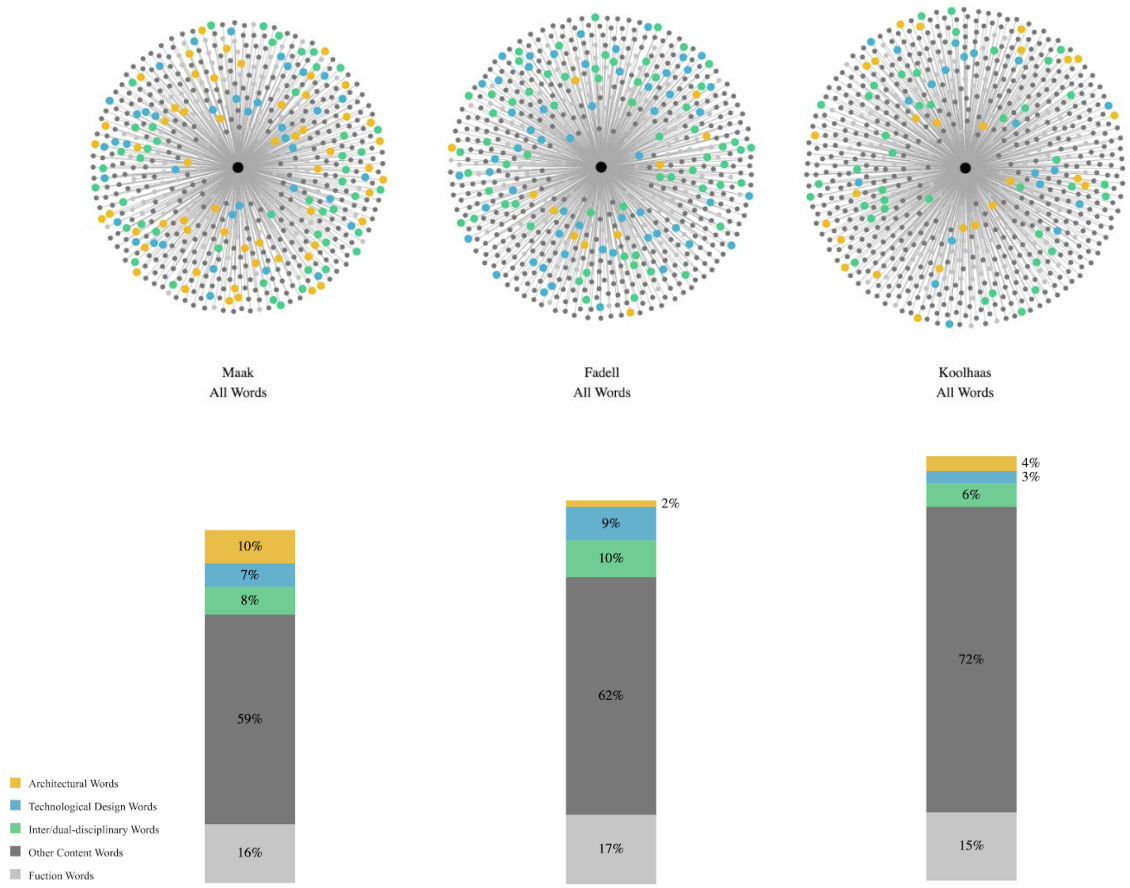

Figure 12: Actor-word network graphs with disciplinary words highlighted (top) and stack bars showing percentage of disciplinary words within the architects and tech designer's vocabulary (bottom)

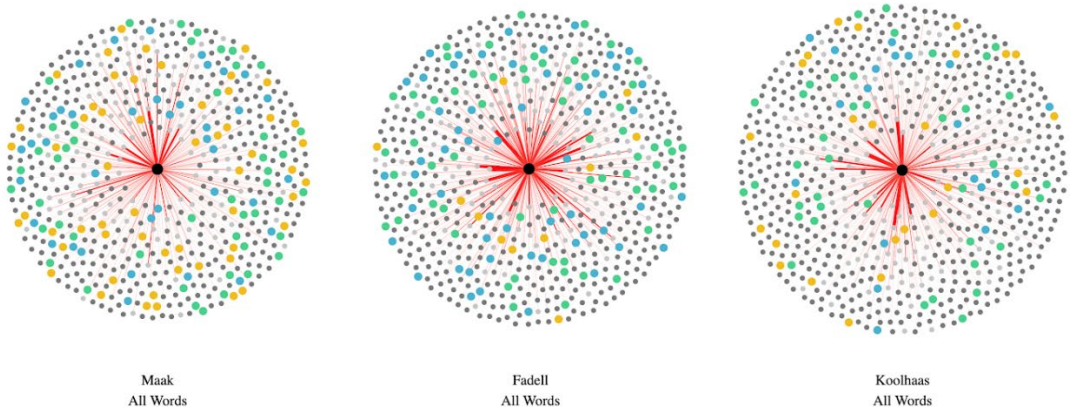

Figure 13: Actor-word network graphs showing disciplinary words and word frequencies for each actor

Disciplinary words by the architects and tech designer
Stack bars also show that actors use disciplinary words to different degrees (Figure 12). For instance, one-fourth of Maak's vocabulary is made of disciplinary words. The highest share within these disciplinary words belongs to architectural words (yellow), as it would be expected from the architect and journalist. Maak also used inter / dual-disciplinary words (green) as the second high, and technological design words (blue) as the third. The disciplinary vocabulary Maak used is pretty evenly distributed. He has a balance between the amount of unique architectural words, technological design words, and inter / dual-disciplinary words he used.

For Fadell, more than one-fifth of his vocabulary is made of disciplinary words. The highest amount of this vocabulary is made of inter / dual-disciplinary words (green). Fadell also used technological design words (blue) as the second high, and architectural words (yellow) as the third. The amount of inter / dual-disciplinary and technological design vocabulary Fadell used are pretty even. On the other hand, he did not use many architectural words.

Koolhaas has the richest vocabulary and a slightly higher percentage of content words in it compared to Maak's and Fadell's. However, only more than 10% of his vocabulary is disciplinary words, which is quite low compared to the other two actors. The highest amount of this vocabulary is made of inter / dual-disciplinary words (green). This is followed by architectural words (yellow) as the second high, and technological design words (blue) as the third. The amount of architectural and technological design vocabulary Koolhaas used are pretty even.

So, the case shows that the architects (by individual) used more technological design vocabulary than the technological designer used architectural. It also shows that there is a good amount of inter / dual-disciplinary words across each actor's vocabulary.

Frequently used disciplinary words by the architects and tech designer
Looking at the frequently used of these words foregrounds subjects that are featured in each actor's discourse and that helped to engage the actors' discourses (Figure 14). Maak, for instance, frequently referred to words such as "technology", "devices", "thermostats", "privacy", "Google" or "cars" from the technological design vocabulary (blue). Whereas Koolhaas referred to "car", "digital", and "transparency". "Technology", "thermostat", and "transparency" are the words that Fadell also used often. However, in addition, Fadell also frequently used words such as "products", "connected", "Nest", or "feedback". In that sense, the frequently used technological design vocabulary that architects used to engage with the tech designer is quite small and mostly made of the fundamental words that are part of the daily discourse. The frequently used words common in all three actors' discourses —"technology", "thermostat", and "transparency"— also point out certain primary subjects that all three actors touched upon in the conversation.

From the architectural vocabulary (yellow), Fadell used "home", "homes", and "elements" (architectural elements). "Home" or "homes" are also often referred to by Maak with a different word "houses", and "elements" are often used by both Maak and Koolhaas in the conversation. Essentially, Maak and Koolhaas frequently used more architectural words such as "architecture", "architectural", "architect", "building", "space", or "room". So, similar to architects in using less of the frequently used technological design vocabulary, the tech designer was also quite limited in engaging the frequently used architectural vocabulary, while conversing with the architects. The interesting point is the frequently used word "elements" common in all three actors' discourses also reveals another primary subject that all three actors touched upon in the conversation.

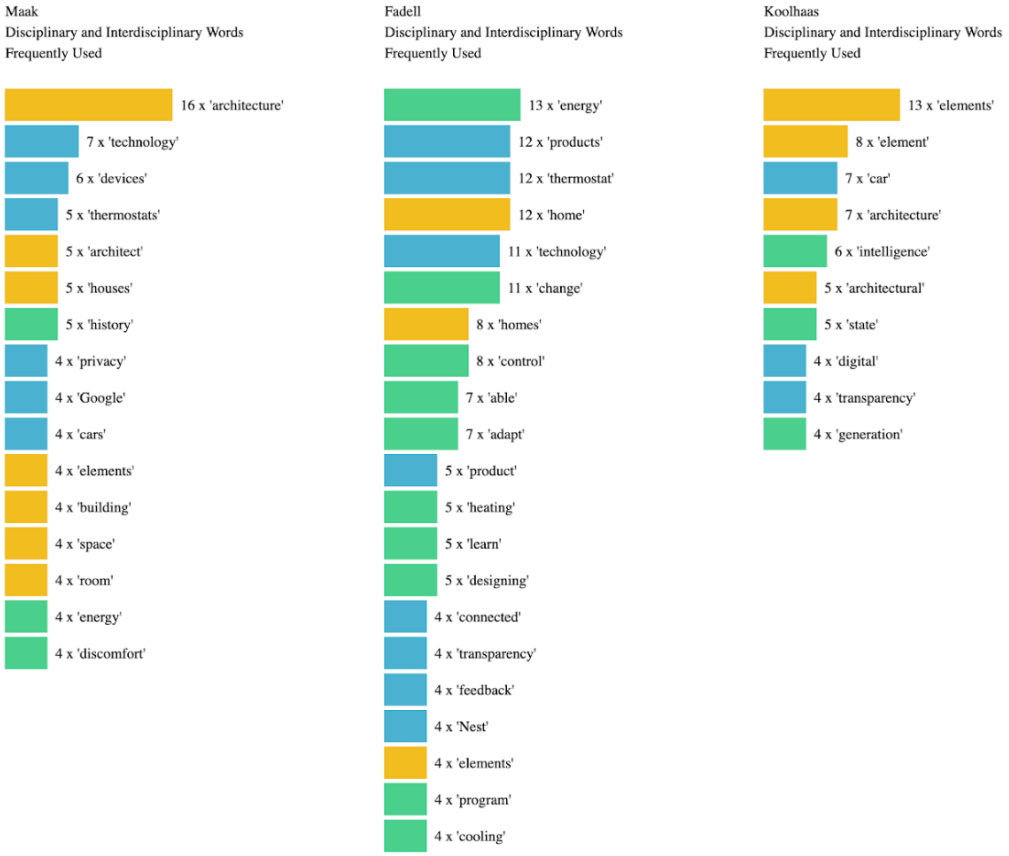

Figure 14: Bar charts showing the frequently used disciplinary words by each actor

There are inter / dual-disciplinary words not frequently used but still shared by actors. However, except "energy", which is often referred to by Fadell and Maak, the inter / dual-disciplinary words that are frequently used (green) are not shared. Koolhaas also used "energy" but not as frequently as the other two. From inter / dual-disciplinary vocabulary (green), Maak also used "history" and "discomfort". Fadell in many instances used "change", "control", "able", "adapt", "learn", "designing", "program", "heating", and "cooling". And Koolhaas frequently used "intelligence", "state", and "generation". So, interdisciplinary words, that have a place in both disciplinary discourses, or dual-disciplinary words, that are not disciplinary but have a different meaning in architectural versus technological design domain, are not frequently shared by the architects and the tech designer. Further, architects compared to the tech designer used less of this vocabulary frequently.

If shared more, these more frequently used disciplinary words could have potentially helped to abridge more the different discourses of the architects and the tech designer. Alternatively, they could have facilitated more instances where the actors could potentially realize these dual meanings and create ways to resolve these meaning conflicts.

4.5 Sharing and exchange between different disciplinary discourses

As described, the discourse of each actor is different in terms of the weight of disciplinary words. But each actor uses disciplinary words from the others' vocabularies. So, what is shared or exchanged?

Shared or exchanged

The actor-word network graph reveals the shared or exchanged content words (Figure 15). In the network, the size of the word point cloud linked to Fadell and Koolhaas nodes (F∩K) combined with the size of the word point cloud linked to Fadell, Koolhaas, and Maak nodes (F∩K∩M) suggest that Fadell and Koolhaas shared and exchanged more content words (F∩K + F∩K∩M = 174). This is compared to Maak and Koolhaas (M∩K + F∩K∩M = 158), and Maak and Fadell (M∩F + F∩K∩M = 156), which are almost equal. Accordingly, the number of links between Koolhaas and Fadell nodes to (F∩K) point cloud and from the same nodes to (F∩K∩M) point cloud also point out to a stronger discourse engagement based on the number of shared and exchanged words between the architect and the tech designer. This is in comparison to the same groups of links from the nodes of other architect Maak and the tech designer, and to the same groups of links from the nodes of the two architects. These two groups of links in comparison suggest an even engagement.

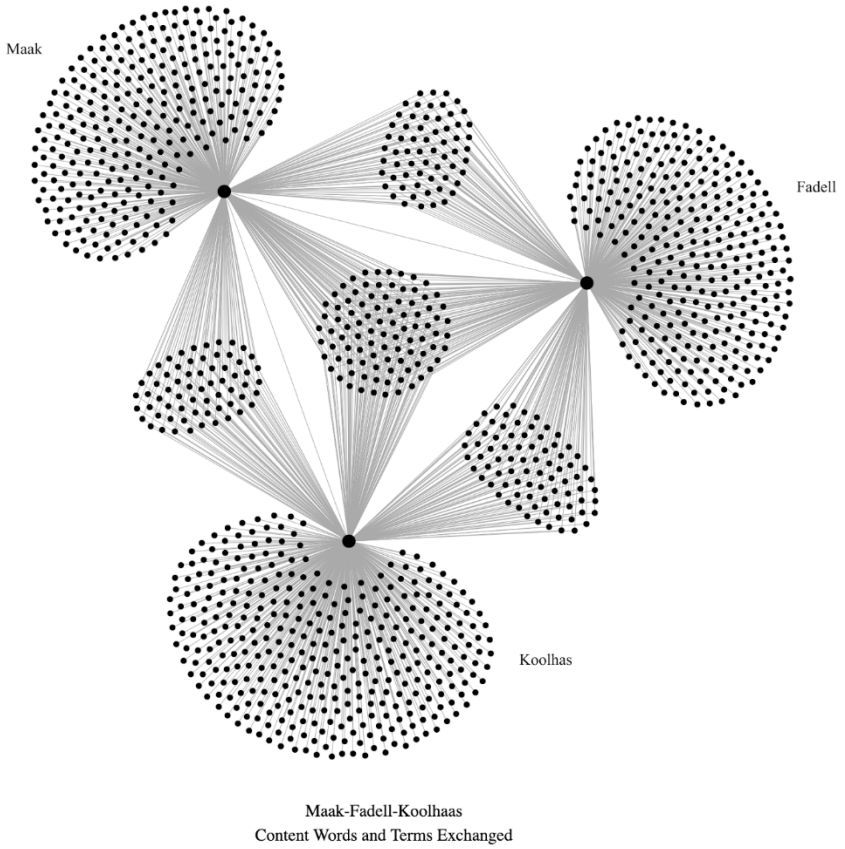

Figure 15: Actor-word network graph of content words shared or exchanged among the actors

When the weight of exchanged words highlighted and considered, the network also reveal a stronger engagement between Koolhaas and Fadell (see the links from Koolhaas and Fadell nodes to (F∩K) point cloud and from the same nodes to (F∩K∩M) point cloud), compared to the other architect Maak and the tech designer, and between the two architects (see the same groups of links of these two pairs) (Figure 16). The weight of exchanged words highlighted also reveals that the architect

Maak and the tech designer Fadell has a stronger connection than the two architects Maak and Koolhaas, even though both pairs shared and exchanged nearly the same amount of content words. If we consider by actor, the tech designer used "the shared and exchanged" words more frequently than the architects, as the links from Fadell node to (M∩F), (F∩K), and (F∩K∩M) point clouds indicate. Between the architects, it is Koolhaas who used them more frequently.

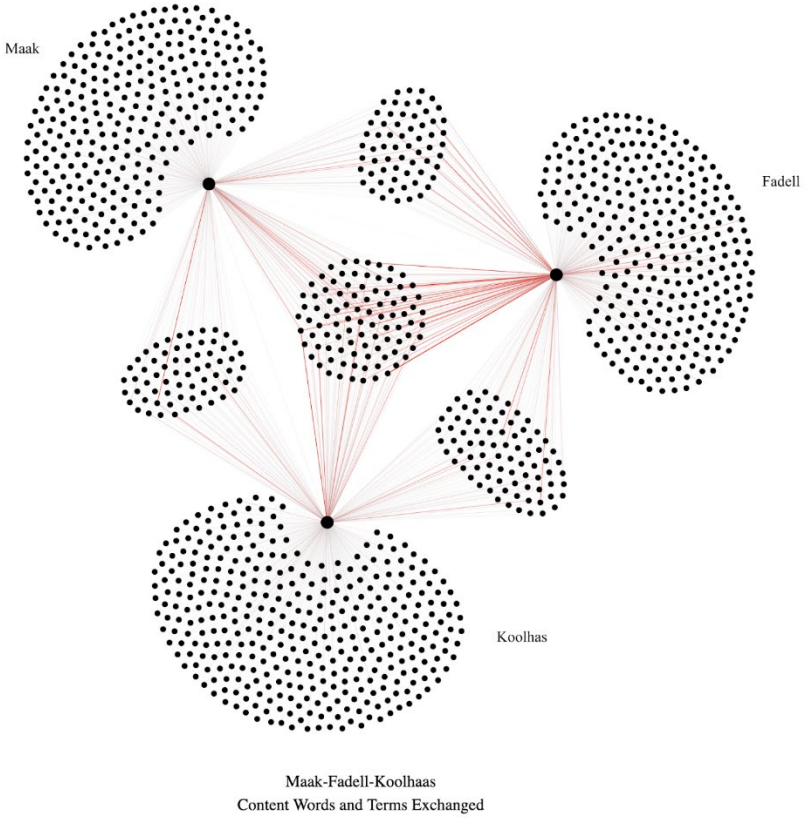

Figure 16: Actor-word network graph of content words shared or exchanged with frequencies highlighted

Architect 1 – Tech designer

Highlighting the disciplinary and inter / dual-disciplinary words reveal that Fadell and Koolhaas shared and exchanged the least amount of these words (see (F∩K) point cloud and (F∩K∩M) point cloud), even though they shared and exchanged the most content words (Figure 17). In other words, the architect and the tech designer has less of an engagement through disciplinary words. For instance, there is only one technological design word "(data) transparency" and one architectural word "(architectural) element" that actors exclusively exchanged (see (F∩K) point cloud). The architect picked on "transparency" as Fadell brought it into the conversation, and similarly, the tech designer adopted "element".

Instead the architect and the tech designer shared and exchanged more inter / dual-disciplinary words such as "market", "intelligence", or "interface". The interesting point with a dual-disciplinary word such as "interface" is the two different ways the tech designer and the architect uses it. Fadell uses the word to refer to a device to communicate, whereas Koolhaas uses it as a point of meeting.

Figure 17: Actor-word network graph of disciplinary words shared or exchanged between Koolhaas and Fadell with frequencies highlighted

Architect 2 – Tech designer

Highlighting the disciplinary and inter / dual-disciplinary words also reveal that Fadell and Maak (see (M∩F) point cloud and (F∩K∩M) point cloud) and Maak and Koolhaas (see (M∩K) point cloud and (F∩K∩M) point cloud) shared and exchanged almost the same amount of disciplinary and inter / dual-disciplinary words (Figure 18). Between the architect and the tech designer, and between the two architects, there is more engagement through disciplinary words.

Between Maak and Fadell, this is achieved via more technological words such as "information", "(machine) learning", or "data" as well as inter / dual-disciplinary words such as "footprint", "(energy) save", or "protect" (see (M∩F) point cloud). For instance, the architect has captured "(machine) learning" and uses the computing term accurately in his discourse. The architect and the tech designer were also able to gather around the popular scientific term "footprint". However, as the example of "protect" shows, there are also issues in meeting around the proper use of certain terms. Maak uses the word as in "protect(ing) the use of products" when he is referring to data protection, and Fadell uses it more accurately as "protect(ing) the data".

Similar to the exchange between Koolhaas and Fadell, Maak and Fadell exchange also shows that not many architectural words enter into the tech designer's discourse from this conversation. The

only three architectural words that actors exclusively exchanged are "house", "home", and "spaces" (see (M∩F) point cloud).

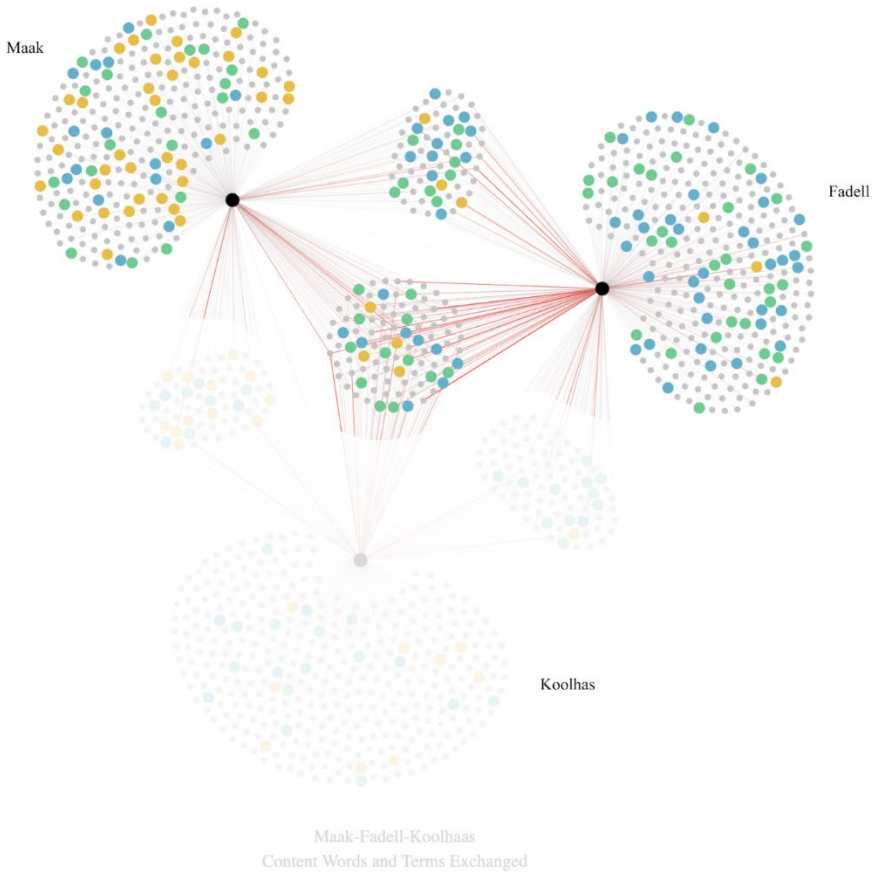

Figure 18: Actor-word network graph of disciplinary words shared or exchanged between Maak and Fadell with frequencies highlighted

Architect 1 – Architect 2

Between Maak and Koolhaas, the engagement through disciplinary words is achieved via more architectural words such as "room", "ramp", "floor", or "space" as well as inter / dual-disciplinary words such as "environments" or "state" (see (M∩K) point cloud) (Figure 19). Similar to the fact that not many architectural words enter into the tech designer's discourse from his conversations with Maak and with Koolhaas, not many technological words are used within the exchange between the two architects. As previously mentioned, this is not the case when, for instance, Maak was conversing with Fadell, but it is also the case when Koolhaas was conversing with the tech designer.

Figure 19: Actor-word network graph of disciplinary words shared or exchanged between Maak and Koolhaas with frequencies highlighted

Architect 1 – Architect 2 – Tech designer

Highlighting the disciplinary and inter / dual-disciplinary words also reveal the shared and exchanged disciplinary words among the three actors (Figure 20). In this conversation, it is inter / dual-disciplinary words such as "energy", "comfort", "utopia", "program", or "control", and technological words such as "device", "privacy", "products" or "car", than architectural words that abridge the architects' and tech designer's discourses (see (F∩K∩M) point cloud). However, as much as these words abridge, they also reveal gaps such as the differences in coding of these words by the two disciplinary figures. For instance, the notion of "privacy" enabled a conversation. But, the way architects code the word is more holistic, and related to the "privacy of space and life" or "individual privacy", whereas the way tech designer codes is more specific, and related to "data privacy", which is a subset within architects' holistic reference. With that kind of difference, the conversation remains as high-level rather than getting streamlined or specific.

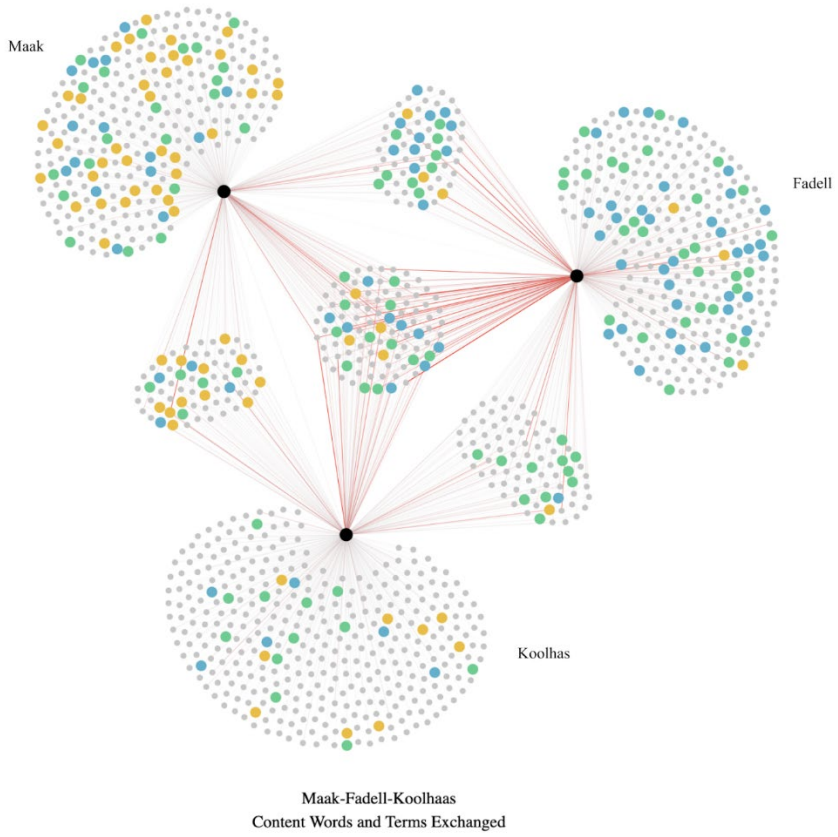

Figure 20: Actor-word network graph of disciplinary words shared or exchanged between the three actors with frequencies highlighted

Not shared or exchanged as potential

Aside from the shared or exchanged word point clouds, what do the isolated word point clouds (not shared or exchanged words) tell? They show that more disciplinary words that came into the conversation could have been exchanged to abridge the architectural and technological discourses. For instance, Fadell's contribution to the content involves more technological design (blue nodes) and inter / dual-disciplinary words (green nodes), but the majority of those words are not exchanged or picked by the other actors as Fadell's isolated point cloud reveals. Similarly, Maak's contribution to the content involves more architectural words (yellow nodes), but the majority of those words are not exchanged or picked by the other actors as Maak's isolated point cloud displays.

5. Discussion: Connection by discourse?

The findings of the study foregrounded the question on the quality of the connection by discourse. The actor-actor network graph set displays the connection between the three actors' discourses through the timeline of the conversation as the summary (Figure 22). Overall, there is only a subtle difference between the weight of sharing and exchange between the actors throughout the conversation. Based on the number of exchanged content words, and frequency of these words,

Koolhaas and Fadell has a slightly stronger connection by discourse. But that starts to be the case only within the 40th to 48th minute of the conversation. From the 16th to the 40th minute, it is Maak and Fadell whose discourses were more strongly engaged. Based on the number of exchanged disciplinary and inter / dual-disciplinary words, and frequency of these words, the result is different. Based on these parameters, Maak and Fadell have a stronger connection by discourse. This has been the case from the middle to the end of the conversation.

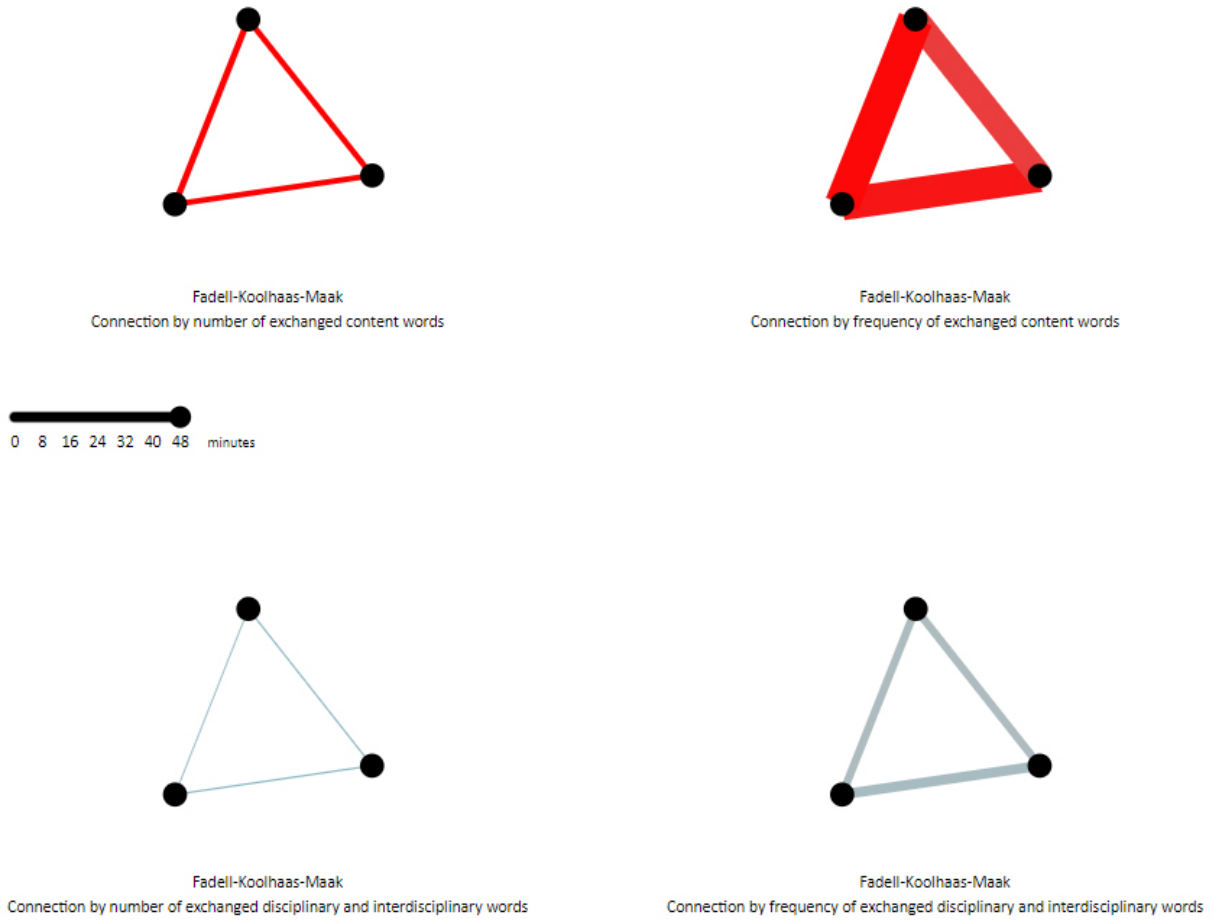

Figure 22: Actor-actor network graph set displaying the connection between the three actors' discourses through the timeline of the conversation

Either case tells us that there has been a stronger sharing and exchange between the architects and the tech designer compared to the two architects. This is positive. It suggests that the conversation had mostly been carried between the different disciplinary actors. However, as discussed based on the actor-word network graph, there are issues in the qualities of that sharing and exchange. These are also the insights our study has revealed. They are asymmetry between architectural and technological vocabulary shared or exchanged, the architects not adopting enough technological vocabulary (e.g. Koolhaas), and the tech designer not adopting enough architectural vocabulary (e.g. Fadell), ratio of shared to not shared or exchanged disciplinary words, and gaps between the architects and the tech designer because of the differences in coding word.

With these insights, we hope to urge the necessity for disciplines and disciplinary actors to engage more with the other discourses towards a productive interdisciplinary conversation. Such common discourse is essential to have a deeper and more meaningful discussion on a subject at the intersection of disciplines, such as “digitalization of architecture and cities”.

6. Future Work

A clear limitation of our study is that it relies on a single conversation. Even though the approach here is a mixed-method, and the purpose is not to reach generalizable results about interdisciplinary conversations, which may require multiple conceptual and methodological perspectives, the next step is to test the viability of our approach further. In other words, testing the viability and limitations of text visualization in understanding interdisciplinary design conversations further. The conceptual and technical framework we developed is suitable to analyze other interdisciplinary design conversations. So, one way to expand the work is to analyze other interdisciplinary design conversations to see if we reach similar insights. Another way is to explore the potentials to work on a larger data set of architect-tech designer conversation. That may also help to validate the insights that our single case study produced.

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Appendix

Architect 1 – Tech designer verbatim examples:

"Transparency"

Tony Fadell: (25:07) "…so I think these are questions that we have to continue to bring up and we have to have transparency so not just transparency through the products transparency through the companies that we work with but also through our governments…"

Rem Koolhaas: (25:53) "Can can can I have a show of hands who believes in transparency? Tony"
Tony Fadell: (26:06) "Yes, I see I see."

Rem Koolhaas: (26:12) "I think transparency is simply not strong enough as an argument to to counteract some of these questions."

"Element"

Rem Koolhaas: (06:07) "We began to realize that almost every architectural element was about to associate itself with digital technology traditionally architectural elements are mute and deaf in other words they cannot speak and they cannot listen but that is about to change."

Tony Fadell: (09:52) "…so going back to the elements going back to every single element as Rem has shown here and understanding what would it be when it's connected and green and creating a new thing and that's where we came on to the thermostat."

"Interface"

Tony Fadell: (09:19) "…and when I had this product [iPhone] in my hand and working with it I thought to myself how will the world change when the when the interface to your world will always be in your hand. How will the car change how will vehicles change how will the office change and how will homes change when this could be one of the primary interfaces to your to your home?"

Rem Koolhaas: (46:34) "For some reason in the last year there has been a lot of interaction and interface with Silicon Valley and us…"

Architect 2 – Tech designer verbatim examples:

"Learning"

Niklas Maak: (01:11) "…he's [Fadell] also the founder and CEO of Nest Labs a company that among other products designs and manufactures sensor driven learning devices like thermostats…"

Tony Fadell: (10:38) "But what we found was it's [Nest Learning Thermostat] not just beautiful object but it's a learning object and why is it learning because most people didn't know how to program a thermostat."

Niklas Maak: (43:21) "So so Rem what would be your utopia in the age of learning dwelling devices?"

"Footprint"

Niklas Maak: (15:56) "It's [Google buying Nest] much more than that but as it's much more than that it's very interesting because normally you know that Google is not primarily interested in the reduction of the carbon footprint but rather in the"

Tony Fadell: (16:05) "Actually"

Niklas Maak: (16:06) "Exploration of your digital footprint so"
Tony Fadell: (16:08) "It is actually very it's it's very interested in reducing carbon footprint and that's one of the one of the reasons why they were interested in us…"

"Protect"

Niklas Maak: (17:03) "How do you how do you protect the use of your products from a possibility to be spied out which is…"

Tony Fadell: (24:55) "And the Snowden the Snowden revelations have shown that no matter what we can do as companies and protect all of the data there still could be nefarious things going on that we are that are unbeknownst to us."

"Spaces"

Niklas Maak: (29:00) "But then what how do you react as an architect to these technological changes that also changed our idea and our conception of privacy and public life? Because you could argue that the bedroom equipped with iPhone and laptop is much more of a public space than other spaces in town…"

Tony Fadell: (45:26) "We had to take commercial technology and it became consumer. What we're doing now is really truly making consumer products and and personal products for people and now we're actually going back into the large office spaces and the government's and changing those products…"

Architect 1 – Architect 2 – Tech designer verbatim examples:

"Privacy"

Rem Koolhaas: (14:44) "…but that may be kind of simply a fundamentally different perception of the value of privacy between my generation and your generation

where my generation sees privacy something that it values and it's been educated but also used to keep privacy to keep things to themselves…"

Tony Fadell: (17:27) "…but in terms of privacy and security we are not a part of Google actually we might be owned by Google but our data and our data services are stored in a different location we have a separate management team a separate culture a separate brand for a reason. We believe your data is your data…"

Niklas Maak: (28:50) "…if they're sitting eight hours in their bedroom sitting with a laptop communicating through mobile phones and Twitter you could say the privacy is not given anymore anyway. But then what how do you react as an architect to these technological changes that also changed our idea and our conception of privacy and public life?