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Identifying Problem Frames in Design Conversation

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Abstract: Design thinking concepts such as framing, storytelling, and co-evolution, have been widely identified as part of design activity though generally have been evidenced from manual coding of design conversations and close reading of transcripts. The increase in easy-to-use computational linguistic methodologies provides an opportunity not only to validate these concepts, but compare them to other kinds of activity in large datasets. However, the process of systematically identifying such concepts in design conversation is not straightforward. In this paper we explore methods of linguistic analysis for revealing problem frames within design process transcripts. We find that frames can be identified through n-grams with high mutual information scores, used at low frequencies, along with subsequent lexical entrainment. Furthermore, we show how frames are organised in primary and secondary structures. Our results represent a step forward in computationally determining frames in datasets featuring design, or design-like activity.

Keywords: framing; design conversation; linguistic analysis

1. Introduction

Research in design thinking has steadily revealed a number of key concepts through which designers practice the activity of designing. Summarising early work on studying designers in both professional and laboratory contexts Cross (1982) proposed ‘designerly’ thinking as a distinct form of intelligence. Lawson (2006) describes in more detail the relationship between design problems and design solutions, particularly in relation to past experience and discipline of practice. This foundational work has enabled consistent theoretical progress to be made through empirical studies of designing, notably through publications associated with the Design Thinking Research Symposium (DTRS) Series (Cross et al., 1996; McDonnell & Lloyd 2009; Adams & Siddiqui 2010; Christensen et al., 2017). These have revealed concepts such as: co-evolution (Dorst & Cross, 2001), storytelling (Lloyd & Oak, 2018), epistemic uncertainty (Ball et al., 2010), design fixation (Crilly, 2015), client-designer interaction (Lloyd & McDonnell 2009; Oak, 2009), amongst many others.

Alongside this, Schön's theory of reflective-in-action has gained increasing traction in design studies, providing a language with which to explore facets of design activity. One such facet is the idea of 'framing' in design, introduced by Schön in the context of architectural design (1983; 1984) and subsequently explored in other discipline and policy contexts (Schön & Reijn, 1994). The idea of 'frames' in cognitive and dialogic activity had previously been theorised in more general contexts (e.g. Goffman, 1974; Tversky & Kahneman, 1981), but the application to the design process opened up new ways of thinking about designing as an activity which has flourished in recent years (Dorst & Dijkhuis, 1995; Valkenburg & Dorst, 1998; Glock, 2009; Mabogunje et al., 2009; Paton & Dorst 2011; Secules et al., 2015; Dorst, 2015; Dong & MacDonald, 2017; Umney & Lloyd, 2018).

'Framing' as a concept enables both more nuanced analyses of design activity (e.g., Glock, 2009; Dong & MacDonald, 2017) and consideration of innovative practices outside of design (Paton & Dorst, 2011; Umney & Lloyd, 2018). It is a concept that practitioners intuitively recognise in a general sense, but theoretical and empirical questions remain. At what frequency and level does framing occur during processes of design? Is framing a second-by-second practice, occurring regularly through the process of design, or something that occurs much less frequently (but perhaps with greater significance)? Is framing a concept that can be identified in the talk of designers, or is it a concept more suited to interpreting what happens in a design process? If the former, what are the linguistic markers of framing in design conversation? If the latter, what associated concepts are used to interpret framing? Studies of designing (e.g., Glock, 2009) have been effective in using short episodes to show how framing takes place, but there remains a disjunction between practices of framing and the description of those practices. In this paper we aim to explore the above questions in a specific dataset of design activity.

2. Identifying framing in design activity

2.1 Definitions of framing

What do we mean by a 'frame'? Tversky & Kahneman (1981) in looking at how people make decisions, define it in a general but useful way. What they term a 'decision frame' is dependent on *"the decision-maker's conception of the acts, outcomes, and contingencies associated with a particular choice. The frame that a decision-maker adopts is controlled partly by the formulation of the problem and partly by the norms, habits, and personal characteristics of the decision-maker."* (p.453). Tversky & Kahneman's research is centred around frames that are perceived as either positive or negative. In general, the process of 'framing' - intentionally, or unintentionally - has a negative connotation; a frame channels and shapes communication in a specific way, exploiting the bounded rationality of humans for benefit.

In contrast, when we look at the design research literature, we see that the term framing is considered to be a much more positive process, something intentionally constructed by the designer. Schön (1984) writes: *"In order to formulate a design problem to be solved, the*

designer must frame a problematic design situation: set its boundaries, select particular things and relations for attention, and impose on the situation a coherence that guides subsequent moves" (p.182). For Schön a frame is an intentional construct that brings coherence to a problem situation through setting specific boundaries, relationships, and objects. A frame allows a designer to 'move' in exploring a problem situation. Similarly, Silk at al. (2021) write: *"intentionally altering the problem frame allows a designer to 'see', 'think', and 'act' to create a novel standpoint from which a problem can be tackled"* (p.7). For Stumpf & McDonnell (2002) frames *"operate as 'structures of belief, perception and appreciation […] informing the way designers justify their actions and use argument."* (p.8). The idea of frames as structures is a frequent definition. Lloyd & Oak (2018) write: *"frames serve to structure practices of design, and also how objects, including people, are perceived within those practices"* (p.93). Paton and Dorst (2011) distinguish the cognitive ('mental and meaning structures') and social ('symbolic') structures of frames.

We can begin to see a consensus forming and a vocabulary associated with framing begin to emerge. Associated terms include *'perception', 'contingencies', 'perspective', 'formulation', 'structure', 'appreciation', 'problem', 'boundaries',* and *'justification'*. Descriptions of framing are remarkably consistent, in fact. Frames are not objective, rational ways for assessing evidence and making decisions, but social or rhetorical constructions that allow different perspectives to be explored in designing. These perspectives include values, beliefs, propositions, objects, symbols, etc. and they are explored through a process of 'moving' or 'action'.

Can we distinguish frames in design conversation? With a consistent definition one might think it a relatively straightforward task to identify when framing is taking place in a design process. We might expect step changes in language, for example, relating to the specific words that participants use. This, however, assumes a mutually exclusive sequential relationship between frames (something that Valkenburg & Dorst (1998) assumed in their study of design teams). But as decisions occur at many different levels of importance in design processes, we might expect frames to be mutually dependent and nested. Perhaps more generic linguistic or para-linguistic markers might identify the initiation or continuation of a frame structure within a design conversation? Framing in designing remains a largely qualitative, even phenomenological, concept, but it is clearly key to the outcomes of a design process. In subsequent sections we begin to explore how to better quantify the concept of framing in design conversation as a basis for measures which could be used in large datasets of design activity.

2.2 Linguistic markers of framing: lexical entrainment

Research in conversation analysis has revealed that participants in a conversation tend to collaboratively and implicitly arrive at a common label for an object or concept (Brennan, 1996). The label may be proposed by one of the participants, but its use by others is provisional until it is adopted or shared by at least one other participant. This phenomenon,

called *lexical entrainment*, has been observed to be a predictor of success in student team projects (Friedberg et al., 2012), where successful student teams converge on a shared set of project-related terms introduced and adopted within the team. The phenomenon is also used in the domain of spoken dialogue systems including social robots as ways to have humans adopt specific vocabulary used in a transit query system (Parent & Eskenazi, 2010), or as a way to measure or aid in-group pairing between human and robot interlocutors (Brandstetter et al., 2017). Lexical entrainment is a more appropriate approach to identify frame creation in conversations compared to other approaches such as measuring conceptual or semantic relatedness as these methods are used more to determine engagement of a concept between interlocutors (e.g., Angus et al., 2012) or adherence of discussions to agenda items (e.g., Chandrasegaran et al., 2019). Such measures may include instances of problem framing but do not separate them from other forms of conceptual relatedness.

As a starting point for our study, we adopt this notion of lexical entrainment and apply it to design conversations. Our hypothesis is that the words associated with a (successful) frame will be repeated and adopted by other interlocutors in a design conversation. This has been shown to be the case in previous studies (Lloyd & Oak 2018), though the examples identified were selective and limited. In the following section we describe the data we draw on to explore lexical entrainment and other linguistic markers related to framing.

3. Conversational data for study

3.1 Design Thinking Research Symposia (DTRS)

Over nearly 30 years, the Design Thinking Research Symposium (DTRS) series (Cross, 2018) has conducted four shared data workshops, generating data from design activity in a number of different contexts including: think aloud protocols (DTRS2: Cross et al., 1996), designer-client discussion (DTRS7: McDonnell & Lloyd, 2009), design education (DTRS10: Adams & Siddiqui, 2010), and co-creation (DTRS11: Christensen et al., 2017). A central research thread of these workshops has been to consider the function of different words and the structure of different word forms in evidencing specific ideas about what constitutes design activity. Textual data has formed the basis of this inquiry. We build on one particular published paper from the DTRS series that focuses on the role of storytelling in design conversations (Lloyd & Oak, 2018). This paper analyses the communication flow during the co-creation sessions of DTRS11 highlighting specific examples of storytelling and framing. We use this engagement as a starting point for the present exploration, and hence we make use of the DTRS11 dataset, in the form of transcripts, as a reference with which to explore concepts of framing.

3.2 A description of DTRS11

DTRS11 comprises 20 collaborative sessions, taking place over a period of 6 months in 2015 and of varying length (up to 45 mins). The sessions were aimed at designing a new accessory

for the luxury car market in China. The first sessions feature a small number of designers designing two participative co-creation workshops based in China. Once these workshops have taken place, they are followed by sessions that analyse what came out of the two co-creation sessions and finally, sessions that begin to develop possible accessories as a result. In total these data consist of 175,000 words and a total time of around 12 hours. Further details are in Lloyd & Oak (2018).

3.3 Identifying frames using framing terms from the literature

An analysis of prior literature on linguistic expressions of framing gives us a good overview of words or phrases used by researchers in design theory to describe instances of framing. However, terms used to *describe* framing do not necessarily correspond to terms used *during* framing. Framing words from literature identified from twelve papers that study framing in design during situations such as designer-client interactions, analysis of co-creation sessions, or student-instructor interactions are listed below:

> see, look, interpret, explore, surprise, novel, understand, problem, solution, different, new, structure, reframe, example, precedent, think, view, propose, picture, perspective, analogy, metaphor, context, sense, express, experience, aspect, terms, shift, transform, novel.

However, other than the word '*think*', none of these words is present in the example of framing below from Lloyd & Oak (2018):

> E It is a more complex thing, it is an eco-system of story, but we need a base story. It's just, I **think** just having this as one part of the story and having kind of the 'car-take responsibility of me' story, those need to go together […] the whole thing around the me-time and stuff is an important part, but we just, as Kenny is saying, it is almost exhausted…
> K Yeah, but I also agree that it might be really interesting for accessories…
> A Exactly, because it's exhausted within the rest of the company. Or, not exhausted because it's going on right now so it is super relevant…
> K Yeah, but I also **think** it's not necessarily, at least for me it's not super sexy. I **think** it's very easy, it goes in the practical way, that it's gonna solve some very…
> E Yeah, calendars, and alarm clocks and like, whatever…
> K And maybe that's alright, but then we need to maybe spice it with the sexy commitment (laughs)…
> E Yeah…
> K No not sexy commitment, but with the global awareness responsibility…

Examining the use of the word 'think' (rendered in bold in the above text), we see it being used as a hedging term, to soften language in deference to social ties (Glock, 2009), and not as a framing term. The frame that is introduced here—'sexy commitment'—is used as a shorthand for the notion of making responsible consumption desirable to the consumer.

We conducted further verification of the occurrence of terms used to describe framing—the list shown above—using two approaches. First, we used the words to form a new dictionary category in the Linguistic Inquiry and Word Count (LIWC) software tool (Pennebaker, 2015).

LIWC is a specialist dictionary for studying the grammatical, linguistic, and socio-psychological dimensions of textual data, has been used for more than twenty years to analyse a wide range of textual datasets. Prior use of LIWC's dictionaries to analyse design conversation is described in Lloyd et al. (2021) and Salah et al. (2022). This approach did not help identify instances of verbal frame creation in the datasets. We also extended this dictionary using Empath (Fast et al., 2016), a tool that works similar to LIWC, but allows the generation of custom dictionary categories using machine learning from seed terms that the user considers to be associated with the intended category.

The optimal approach to using Empath to generate words relating to a hypothesised category is to use a small number of seed words. We used the following words from the above list of framing terms: *'interpret', 'problem', 'solution', 'reframe',* and *'metaphor'.* Again, no instances of framing were identified using this dictionary. Our conclusion was that focussing on words used in, or derived from, academic studies to describe framing were simply different from actual practices of framing. The following sections describes the development of a different approach.

4. Method

Based on observations from prior studies of framing in design and other scenarios (Section 2.2), we examine the possibility of computationally identifying framing-related terms by identifying uncommon phrases that appear in the design discourse captured in the current dataset and examining their entrainment between interlocutors. To do so, we start with the following assumptions:

Framing-related terms are compound: In a design conversation, a speaker may employ domain-specific terms that may not be commonly used by the remaining interlocutors. This does not necessarily mean that a frame is introduced. On the other hand, a frame may be introduced by combining a set of common terms. For instance, Lloyd and Oak (2018) in their analysis of DTRS11 data identified framing terms such as '*sexy commitment*' and *'Mercedes guy'*. While the individual terms *'sexy'*, *'commitment'*, *'Mercedes'*, and *'guy'* are not uncommon terms, their use as bigrams (a pair of consecutively occurring words) is uncommon and could be indicative of frame creation.

Framing-related terms are invented or introduced during the conversation: Not all compound words need be related to framing. For instance, such phrases as 'at the same time', 'or something like that', or 'a little bit' are quadgrams (or 4-grams) and trigrams that are often used in regular English conversation. On the other hand, phrases such as 'points to magic chart', 'domestic robot', and 'body and mind' are phrases that—depending on their frequency of use and the general context of the conversation—may be indicative of framing.

To computationally identify—or at least filter the terms to manually verify—instances of framing, we first identified all possible *n-grams*, or groups of *n* words that consecutively appear together in the dataset. We capped the value of n to 4, partly by trial and error for

the given dataset, and partly because long and specific strings of consecutive words when introduced as a frame tend to be shortened upon entrainment by others (Brennan, 1996). We thus look at all occurrences of bigrams, trigrams, and quadgrams within the text simply by assigning a moving window of two, three, and four words respectively and assigning all words occurring within the window as an n-gram. The window is then moved by one word to resume the count. Thus, the phrase *"something wicked this way comes"* contains five words, four bigrams ("something wicked", "wicked this", "this way" etc.), three trigrams ("something wicked this" etc.), and two quadgrams. All identification of n-grams is performed within speech terms, i.e., the window is not allowed to span two or more speech turns.

We then counted the occurrences of each such n-gram in the data. N-grams that occur only once are easily eliminated as simply occurring by chance, while n-grams occurring more than once merit closer inspection as they may relate to phrases that are repeated. Within this, there are (a) word sequences that may occur together by chance, (b) word sequences that occur together as common idioms or phrases, and (c) new word sequences characteristic of framing.

We use the notion of mutual information (Tremblay & Tucker, 2011) to eliminate words that occur together by chance. Mutual information is a measure that weighs the probability of the occurrences of two words being dependent on each other. The generalization of the idea for n words is given by the formula:

$$MI(w_{1\text{-}n}) = \log_2\left(\frac{p(w_{1\text{-}n})}{\prod_{i=1}^{n} p(w_i)}\right)$$

Here, $w_{1\text{-}n}$ refers to the n-gram formed by stringing together words $w_1, w_2, \ldots, w_n$, and $p(w)$ refers to the probability of that word occurring in the corpus, which in this case is the DTRS11 dataset. Thus, the mutual information score $MI(w_{1\text{-}n})$ for an n-gram $w_{1\text{-}n}$ is high for words that occur together a significant number of times when compared to the frequencies of occurrences of the constituent words by themselves. For instance, the words "sexy" and commitment" may occur separately in a discussion a number of times, but if they occur together (i.e., "sexy commitment") consistently by more than one person, they are likely to hold a specific meaning to the interlocutors.

5. Results

A sample set of bigrams, trigrams, and quadgrams are shown in Table 1, with corresponding frequency of occurrence and mutual information (MI) scores. Each category has ten n-grams, five of which are the most frequent (see rows 1–5), and five with the highest MI score (rows 6–10). We disregard *hapax legomena*—terms that appear only once in the data—as a term has to be introduced and then adopted for it to be considered an instance of lexical entrainment.

From the top half of the table, we can see that the most frequent n-grams tend to be phrases commonly used in the English language, with a significant use of pronouns. Although these may have significance in themselves (Pennebaker 2011), they have lower mutual information (MI) scores as the words constituting the phrases are themselves quite commonly used outside these phrases. Note the decrease in frequencies as we move from bigrams to quadgrams: the likelihood of any two words occurring together tends to be higher than that of any four words occurring together.

From the bottom half of the table, we can see that the n-grams with high MI scores, i.e. formed of words that do not appear frequently by themselves, occur rarely, with frequencies of 2 or 3. Note the gradual increase in MI scores as we move from bigrams to quadgrams. This makes sense: as the number of words in an n-gram increases, the denominator in the formula decreases, thus increasing the MI score.

Table 1. A sample set of n-grams with frequencies and Mutual Information (MI) Scores.

	Bigram	Count	MI Score	Trigram	Count	MI Score	Quadgram	Count	MI Score
Most Frequent	I think	1291	5.35	a little bit	240	14.06	and stuff like that	69	14.81
	kind of	911	5.66	we need to	226	9.11	and so on and	43	11.55
	this is	684	4.17	and I think	164	7.51	at the same time	37	18.87
	and then	643	3.90	but I think	144	8.57	and I think that	35	11.11
	of the	557	2.33	I think that	135	8.01	we want them to	35	14.97
Highest MI Score	horizontal sweep	2	16.44	dependent versus independent	2	29.05	short term medium term	2	38.36
	pedestrian airbags	2	16.44	wish I'd known	2	28.89	dependent versus independent like	2	35.59
	frying pan	2	16.44	her communicative load	2	27.00	eating salmon in Norway	2	35.47
	steering wheel	2	15.86	motion graphic design	2	26.94	I wish I'd known	2	34.51
	cup holder	2	15.86	till eleven fifteen	2	25.28	seen my tea collection	2	34.35

We examined the top N bigrams, trigrams, and quadgrams with high MI scores and determined whether they were uttered by the same person or by different people. In the case of the former, we do not consider it to be a successful act of framing: perhaps a frame was proposed, but it was not adopted by the other interlocutors. We then examine the contexts in which the remaining n-grams appeared.

5.1 Preliminary findings

After performing the filtering described in the previous section, we iteratively worked on filtering the N-grams based on the number of unique speakers who used the phrase (three or more), and the number of times the terms appears across all sessions of the DTRS11 dataset (10 or more). A sample of the n-grams in descending order of MI score is provided in Table 2.

As discussed earlier, the longer the n-grams, the less frequent they are, and the more likely they are to be reduced to shorter phrases if they are entrained. On the other hand, shorter n-grams tend to occur more frequently by chance and thus need a higher threshold of appearance to be considered a candidate for a framing instance. Table 2 thus shows bi-, tri-, and quad-grams in decreasing order of MI score but using increasing thresholds of frequency. The starred (*) items in the table are instances of anonymization (the name of a city was replaced with a descriptive yet anonymous "Chinese city from phase 1") and of parenthetical notes by the transcriber (points to magic chart, points to whiteboard etc.). The remaining phrases are a mix of commonly occurring phrases in the English language (e.g., *a little bit*, *half an hour*, *come up with*, *hundred percent*), common phrases specific to the topic of discussion (e.g., *co-creation*, *status symbol*), and finally, uncommon phrases that have the potential to be instances of framing. These are shown in bold font in Table 2, and include such phrases as *"sexy commitment"* (Lloyd & Oak, 2018), and others like *"endure now, benefit later"*, *"one plus ten thousand"*, and *"table of old friends"*.

Table 2. N-Grams spoken by more than one interlocutor, in decreasing order of MI Score

N-gram Type	N-Gram	MI Score	Frequency	Unique Speakers	Filtering
quadgram	**endure now benefit later**	32.36	4	3	Frequency > 3
	one plus ten thousand	29.62	9	3	
	city from phase 1*	28.91	9	3	
	table of old friends	26.89	4	3	
	points to magic chart*	26.37	19	4	
trigram	half an hour	20.09	16	4	Frequency > 15
	points to whiteboard*	14.69	34	3	
	in Chinese city*	14.42	25	5	
	come up with	14.26	35	7	
	a little bit	14.06	240	10	
bigram	magic chart*	11.68	47	4	Frequency > 25
	status symbol	11.06	32	6	

	co creation	10.82	76	5
	hundred percent	10.77	33	4
	sexy commitment	10.53	28	5

Note: Bold text above indicate potential instances of framing, while starred text (*) indicate instances of anonymisation or notes from the transcriber.

Which n-grams should we consider as frames? The profile information of MI score, frequency, and unique speakers gives some indications, but there are many n-grams that clearly relate to other things. What the analysis does reveal are likely candidates in the larger pool, that can then be verified by looking at the context of their usage in the data. Using this approach Table 3 summarises the profile information of several 'n-grams of interest' which we assumed as strong candidates to be considered as part of framing-related conversation.

Table 3. Potential framing-related N-grams and their categories (see Sec. 5.2).

N-gram	Frequency	MI Score	Unique Speakers	**Category**
me-time	34	7.02	6	Primary Frame (C2)
sexy commitment	28	10.53	5	
pockets of enjoyment	13	16.95	3	
conscious commitment	12	10.42	3	
one plus ten thousand	9	29.62	3	
green tires	5	11.66	3	Secondary Frame (C3)
sprinkle the king	5	17.45	2	
endure now benefit later	4	32.36	3	
awesomely humble	4	14.27	3	
lifetime companion	4	12.16	4	
comfort and convenience	3	15.40	3	
seamlessly integrated	3	14.71	3	
burger juice	2	14.12	1	

5.2 A model of frame-related conversation

From Tables 1-3 we can broadly identify three distinctive groups of n-grams that relate to framing-related conversation:

C1. ***N-grams with a suggestive propositional structure*.** These are high-frequency n-grams with low MI scores (in the top half of Table 1) that usually contain at least one pronoun, such as "*I think that*", "*we need to*", "*I don't know*" etc.

C2. ***N-grams indicative of framing.*** These are n-grams with high MI scores and moderate frequencies (≥ *4*) spoken by more than one person. These are terms such as "*one plus ten thousand*", "*pockets of enjoyment*", "*sexy commitment*" etc.

C3. ***N-grams indicative of "mini-framing".*** These are similar to category C2, but with frequencies of 2 or 3. They appear over a short interval of time in the conversation and are then discarded. Terms such as "*burger juice*" and "*elephant beetle*" from the dataset belong to this category.

The relationships between the three types of n-grams is interesting to consider with reference to the data. The C2 n-grams in Table 3 relate to a core idea that is repeated throughout all design sessions: the idea of a tension between social responsibilities (e.g. to the family, community, or society) and self-enjoyment. Of course, these are not necessarily in conflict, but they are constructed in this way by the design team using the C2 terms. The consensus is that being older (a target market for car accessories) brings with it more responsibilities, and hence more need for "*me-time*". C2 n-grams, then, set the overarching or primary frames for the design conversation.

In contrast the C1 n-grams, although distinctive, appear only fleetingly in particular parts of the conversation. Some of them can be related to the C1 n-grams (e.g. endure now, benefit later), but others (e.g. 'green tires') appear unrelated. Our explanation is that these are 'secondary frames', or in some cases, with only one unique speaker, unsuccessful secondary frames. Secondary frames tie together small units of conversation, often leading to further secondary frames, but disappearing quickly as the conversation progresses. Secondary frames have less traction and hence less lexical entrainment.

The final category are C1 n-grams that display different characteristics from C2 and C3 n-grams. They are much less distinctive in terms of MI, but have high numbers of repetition and unique speakers. They appear to be something like the glue that holds design conversation together, often moving it forward through propositional reasoning structures (e.g. 'this is', 'and then') and often involving pronouns. C1 n-grams fit within the frames of C2 and C3 then.

The structural relationship that we suggest for these categories of n-grams somewhat follows Schön's theory of reflection-in-action (1983) which posits moving experiments within constructed frames (naming, framing, moving, and evaluating) during designing. However, we don't want to over-fit our model for the time being. In the following section we give a concrete example of how the three n-gram groups outlined above cohere in design conversation.

5.3 An example of frames interacting

The relationship described in the previous section can be illustrated with an excerpt from the transcript where several n-grams of interest (Table 3) are highlighted. C1 is highlighted in grey, C2 in green, and C3 in blue. The participants in the conversation alight on the topic of how food can be eaten in a car as a self-indulgent pleasure. K starts by summarising a problem that the team think they've solved with an accessory unit:

> K: The problem by eating in a car is actually that you'll get food on your clothes and on the floor, I think that that thing [could solve that].
>
> A: [In that sense it's really unique] to eh-
>
> K: Accessory unit, yeah!
>
> E: Aprons!

The accessory unit allows food to be placed on the steering wheel whilst covering the driver with a kind of apron. This leads to the following exchange where the convenience of eating specific foods is discussed:

> A: On the steering wheel like this, and then you're totally covered. (laughter)
>
> E: Or you by- bypass that, you just, you have this tube that you just suck on (laughter), and there's like, you see on this display,
>
> A: What it is that you're eating?
>
> E: The different foods and it says like meeeeee
>
> J: Ah, a final-
>
> A: No no, a different one. No it's a burger! (laughter)
>
> E: It's the burger juice!
>
> A: I would like the multi now.
>
> E: Yeah yeah, burger juice, fries juice, and then the smoothie juice afterwards.
>
> J: You can have burger and fries, combo, combo-set. I finally made a different name for me-time, sprinkle the king (laughter)
>
> A: Yeah it is actually
>
> [4 turns later in the excerpt]
>
> E: (..) I'm just an average king. (laughter) Magnificent!
>
> J: So going from a peninsula husband with the duty, we should call it king of the-
>
> K: Yeah, to sprinkle the king, yeah (laughter). So this is just peninsula husband, and this is sprinkle the king!
>
> J: Husband, that's the sprinkle the king, oh my God, full circle!

The C1 n-grams, highlighted in grey, appear regularly through the excerpt, holding the text together by mainly linking noun phrases. The C2 and C3 highlighted n-grams in the excerpt connect three specific phrases with high MI scores but differing numbers of speaker repetitions (lexical entrainment): *'burger juice'*, *'me time'*, and *'sprinkle the king'*. The bigram

'me time' links to several other distinctive n-grams, as described above and shown in Table 3, relating to the idea of contrasting individual indulgence with social responsibility. This bigram is triggered in turn 4 of the above excerpt when E says 'Meeee'. In the complete DTRS 11 dataset, '*me time*' is used 34 times in three separate sessions by 6 different speakers. This suggests that it is being used as a primary frame (C2) for this excerpt and for the design conversation more generally.

The remaining two n-grams are used only in the above excerpt. The bigram 'burger juice' originates from turn 3 ("you just suck") to represent the idea of a liquified burger, and is repeated only by E twice. This is an example of a secondary frame (C3), with unsuccessful lexical entrainment. In contrast the trigram 'sprinkle the king' - referring to something that the team experienced in a restaurant the previous evening - is repeated by three speakers in different forms. This is an example of a secondary frame (C3) with successful lexical entrainment.

6. Discussion & conclusion

Framing has become an increasingly popular topic when talking about design thinking but it remains a somewhat mysterious practice. Although there have been attempts to formalise framing, notably by Dorst (2015), the identification of frames in concrete contexts remains elusive. We have attempted in this paper to develop a more robust method for identifying 'framing talk' in design conversation.

We started by looking for patterns of word usage in design transcripts based on words used to describe framing in the literature. The computational linguistic tools of LIWC and Empath have been effective in our previous studies (Lloyd et al., 2021; Salah et al., 2022) but didn't reveal any significant patterns. We thus refocused our approach on using n-grams to engage more with the content of the transcripts.

Our n-gram analysis revealed a promising model for the identification of frames and other elements of design conversation. N-grams with high mutual information (MI) scores, high frequency, and larger numbers of unique speakers (suggesting lexical entrainment) indicate a primary frame within a design conversation, while high MI scores, lower frequency, and lower numbers of unique speakers indicate secondary frames, nested beneath primary frames. N-grams with low MI scores, very high frequencies, and very high unique speakers, display characteristics of moving the conversation along, through proposition and reasoning. These measures also helped us to verify hypothesised frames from previous studies based on the same dataset (Lloyd & Oak 2018).

Our measures indicate necessary conditions for frame identification, but are not sufficient. Manual verification of statistical n-gram analysis still needs to be carried out to interpret and confirm patterns of framing activity. Nevertheless, our method represents a significant step forward from a relatively small dataset. A clear limitation is that our study only considered text available in transcripts. Adding other modalities of behaviour (gesture, gaze, etc.) may

provide additional markers of framing conversation, and indeed using tools such as Language Style Matching (LSM) may be further ways to explore lexical entrainment in particular.

Through developing methods and showing examples, the contribution of this paper is in presenting a clear hypothesis for future work along with a concrete method for testing that hypothesis. We hope that other design researchers interested in exploring the language used in design conversation will use our findings to explore larger datasets of designerly activity, both within traditional design disciplines, and those other disciplines that have adopted practices of design thinking.

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