Quant-Ethico: An Approach to Quantifying and Interpreting Ethical Decision Making

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Abstract: Design researchers have previously sought to describe, model, and represent the cognitive processes of designers. In parallel, researchers in HCI and STS have identified a range of frameworks to describe the ethical and value-related character of design activity. We have identified a productive gap between these two sets of literature—namely, the role of analytic methods in describing ethical decision-making as one aspect of design complexity. In this paper, we describe and explore an approach for quantifying the ethical character of design decision-making, building upon existing critical approaches from HCI and STS literature. Through a series of visualizations at varying temporal scales and numbers of interlocutors, we seek to describe the ethical complexity of design activity, grounded in a set of ethically focused lab protocol studies. We describe the implications of our approach for mixed methods researchers, including the role of quantitative methods in describing temporal aspects of ethical design complexity.

Keywords: ethics; ethical complexity; protocol study analysis; quantifying ethics

1. Introduction

Design researchers have described and interpreted aspects of design cognition that are evident in design activity, using *in situ* and lab protocol studies to analyze specific aspects of design reasoning. In addition, design researchers have hypothesized connections among design activities, interweaving processes of idea generation, relations between design outcomes and design methods, designer's reflection in the process, and designers' collaborative abilities.

In parallel, researchers in Human-Computer Interaction (HCI) and Science, Technology, and Society (STS) have described the role and importance of ethics and values in design activity. Numerous scholars have proposed frameworks and methods to describe and activate value

commitments in design processes, both as a means of knowledge building (e.g., research through design (Zimmerman et al., 2007; Zimmerman & Forlizzi, 2014), critical design (Bardzell et al., 2012)), and as methodological or cognitive support such as value-sensitive design(Hendry et al., 2021), value levers (Shilton & Koepfler, 2013), and ethics-focused methods (Chivukula, Li, et al., 2021; Gray et al., 2023). These approaches to engaging critically with design activity are primarily oriented towards enhancing or enriching design practice, focusing primarily on the importance and need to engage with values as designers.

In this paper, we seek to synthesize these two strands of literature—enriching knowledge about design activity and engaging in ethical dimensions of design practice—to further research efforts in describing ethical complexity as one important element of creativity in design activity. Building upon previous work to describe the ethical character of design engagement in an HCI framing (Chivukula, Hasib, et al., 2021; Gray et al., 2021; Shilton, 2018), we use quantitative and qualitative analyses of design lab protocols to describe opportunities to bridge rich qualitative work and quantitative analysis to create knowledge that can support ethical design practice.

Our key contribution is to propose a set of quantitative approaches to describe and visualize aspects of ethical complexity. Through these analytic approaches, we seek to identify and evaluate ethical concerns and their temporal role in design processes. The outcomes of this method facilitate further description of: 1) the ethical valence of design activity, 2) critical moments in the design process that include ethical components, and 3) the mediating presence of designers' responsibility as one facet of ethical complexity. These outcomes and approaches have the potential to inform further research of ethical awareness and action in education and practice contexts.

2. Background Work

2.1 Mapping Designers' Cognition

Design researchers have analyzed and described designers' patterns of cognition when they engage in design activity using qualitative, activity-oriented, participatory, and quantitative approaches. One of the many methods to map cognition and the behaviors of designers is through lab protocol studies (Cross et al., 1996; Kan & Gero, 2017). These protocol studies enable researchers to describe, analyze, and model different aspects of design cognition, including externalizing design thoughts, idea generation practices, problem-solution framing, and interactions among designers. Kruger and Cross (2006) presented different kinds of cognitive strategies (solution-driven, problem-driven, information- driven, and knowledge-driven) used by designers and how these strategies shape design outcomes in terms of solution creativity and activities of iteration.

We build on a well-known method to visualize design activity and cognitive processes of designers known as *Linkography* (Goldschmidt, 1990), adding an ethical dimension to its mapping of design cognition. This method enables researchers to describe the inter-connectivity

of design ideas by forming links and visually coding creative relationships in group design activity. Linkography opened doors to computational exploration of design cognition as researchers have built to: conduct statistical analysis of design protocols to quantify idea generation (Kan & Gero, 2005), learn designer's reflection through the linking patterns between problems and solutions (Dorst, 2003), compare various design methods used to induce creativity in brainstorming (Hatcher et al., 2018), quantify elements of design cognition using lab protocols (Kan & Gero, 2017), and "measure" design action and processes (Gero & Milovanovic, 2020).

Previous work has explored how design thinking happens in teams (Cross & Clayburn Cross, 1995; Goldschmidt, 2016; G. M. Olson & Olson, 2000), particularly in relation to the use of sketching material as a means of externalizing design creativity. Menning et al. (2018) concentrated their study on "focus shifts" as teams sought to identify and solve issues while designing, proposing a computational modeling approach to identify how these shifts occurred rather than completely disrupting problem solving activities. In a similar way, other researchers have used quantitative or mathematical approaches to describe design outcomes and model differences in practices between expert and novice designers (Kavakli & Gero, 2002, 2003). Across these examples from the design literature, few researchers have engaged explicitly with ethical and value-centered dimensions of design cognition, and while some computational approaches to engaging with design complexity have been offered, none appear to focus on methodological inquiry relating to ethics.

2.2 Describing Ethical Concerns in Design

In the HCI and STS literature, researchers have previously argued for the importance of ethics and values in a design process. A range of existing design methods offer support for designers' engagement with values, as they are discovered, applied, and considered throughout a design process (Chivukula, Li, et al., 2021). Other means of foregrounding ethical concerns as part of a design process include knowledge-building activities such as critical design (Bardzell et al., 2012) which engage designers in reflection on social responsibility and the need for internal forms of critique on the role of design in society. In addition, Shilton has proposed "values-levers"(Shilton & Koepfler, 2013) as a means of encouraging ethical awareness and engagement in corporate contexts as a means of creatively engaging with design work, activating value-centered decisions while designing.

Shilton and other STS scholars have also engaged in ethnographic study of design processes in industry, describing how multi-disciplinary teams can influence ethical or moral decisions or actions (e.g.,(Chivukula, 2021; Shilton, 2018; Steen, 2015)). These ethnographic engagements most frequently take on a case study design, and provide deep insights into a single design context within or across a design project. Researchers have also identified the ethical engagement of practitioners more broadly, using the notion of ethical mediation and ethical design complexity to describe interactions among individual, disciplinary, and organizational factors (Gray & Chivukula, 2019; Wong, 2021; Wong et al., 2023).

2.3 Bridging Quantitative and Qualitative Approaches

In online ethnographic research, Geiger and Ribes (2011) have shown the value of trace data in thickening and enriching insights located through qualitative means, representing other potential forms of engagement with quantitative approaches. Gui et al. (2017) and Crowston et al. (2010) have also demonstrated explicit bridging work between qualitative and computational approaches, using automated coding of data through Natural Language Processing and qualitative thematic analysis to train computational topic models (Gui et al., 2017) to scale up the amount of data being used to support research insights. From a computational perspective, Chen et al. (2018) have described several approaches for connecting ML and social science practices, including leveraging ML to identify where there is ambiguity in the coding process as a promising approach outside of automated coding of data, demonstrating the value of both human and computational actors.

However, relatively little creatively-focused work has been done to bridge this divide in the study of ethics, which is the focus of this paper. In particular, little work has sought to interpret and analyze design activities through ethical lens at a more granular level. Thus, we seek to build new knowledge about ethical complexity, building on a legacy of design cognition research and engagement with ethical concerns. In this paper, we introduce a set of quantitatively-focused approaches to describe and interpret the ethical dimension of design activities, and propose opportunities to bridge qualitative and quantitative paradigms.

3. Method

We take on a quantitative analytic approach, using a series of data visualizations to engage with and quantify data collected through a set of lab protocol studies. The protocol allowed us to capture interactions between participants during ethically-nuanced design activities, including access to speech acts, non-verbal cues (e.g., gesture), and design materials (e.g., sketches, wireframes, whiteboard interactions). We conducted interaction analyses (Jordan & Henderson, 1995) of these data using a quantitative approach to interpret and understand ethical complexity through a series of visualizations. In particular, we map these data across temporal and interlocutor dimensions to describe ethical awareness, action, and sensemaking through a set of visualizations. We seek to answer the following research questions:

1. What insights can visualizations at varying levels of temporal granularity offer researchers in characterizing the ethical valence of design decision-making?
2. How do multiple interlocutors engage in ethical or unethical decision making?

3.1 Data Collection

Lab Protocol Design

We used a cognitive lab protocol study approach (Jiang & Yen, 2009) to record the interactions and discussions among student designers as they sought to address an authentic design task. We conducted four sessions of lab protocols with three participants each, resulting in twelve participants. Each set of participants worked as a team to address a design task during a one-hour session. The team engaged in the following activities: a task was introduced (5 mins), the team worked to address the design task (45 mins), the team presented their solutions to the researchers (5 mins), and the researchers asked follow-up questions based on their observations (5 mins).

The lab protocol was focused on an altruistic design task to redesign the donation experience of a charity foundation, asking the participants to maximize the conversion rates on this site "*by whatever means necessary*," with the goal of increasing donations for the charity in the wake of a natural disaster. We provided the participants with wireframes of the existing website, sketching tools, paper and whiteboard markers and encouraged them to redesign or alter any element of the existing website to reach the goal. We video recorded each of these sessions and transcribed the recordings to produce transcripts with participants and their respective speech acts. We de-identified the transcripts and assigned participant IDs. A letter is used to indicate the participant in each session (A, B, or C), while a number is used to indicate the session (01, 02, 03, or 04). For instance, P02C indicates the third participant in the second protocol session.

Participants

The protocol participants were majoring in User-Experience (UX) Design or Interaction Design, including a mix of undergraduate and graduate students. In order to participate, students must have previously taken a minimum of one UX-focused course, or have experience as a designer in an industry context as an employee or intern. This ensured that our participants were aware of typical design principles, design processes, and experiences in engaging with industry-focused work.

3.2 Data Analysis

Unitizing and Characterizing Speech Acts

We first cleaned the transcripts to correct inaudible instances, add paralinguistic elements (e.g., gesture), confirm timestamps, and document interactions with physical materials in the space. We then unitized the speech acts by conversational turn, indicated whenever a different participant started speaking, after a pause of more than three seconds from the previous conversational turn, after return from a period of group silence, or after a decision grounded in a generated solution was made. These elements of the interaction analysis

method (Jordan & Henderson, 1995) allowed us to document and clarify the interaction setting, and confirm timestamps that would facilitate temporal forms of analysis. Accurate timestamps in the transcripts were essential as our visualization analyses included a temporal axis over which the value relationships were plotted.

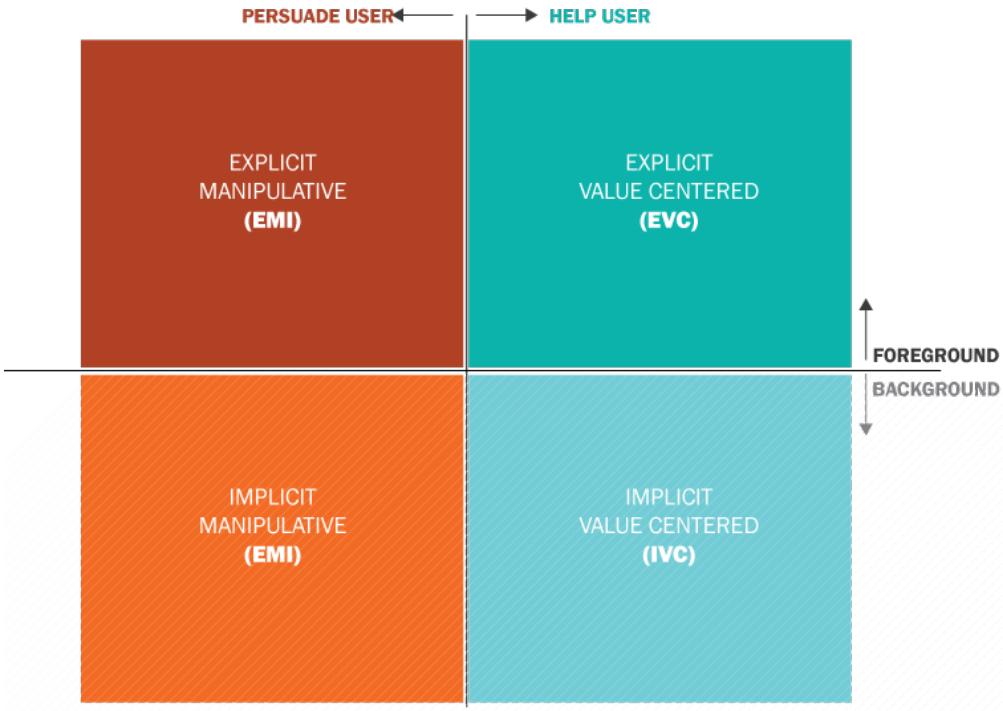


Figure 1 Analytic schema describing the value codes.

Application of Value Codes

Aftering unitizing the speech acts, we evaluated each speech act and conducted a deductive analysis approach to identify the valence of the intent of the speech act as either value-centered or manipulative, building upon previous work by Chivukula, Gray, and Brier (Chivukula et al., 2019). We described the intent of the designers, rather than only their explicit awareness and articulation of ethically-centered design interaction. *Value-centered behaviors* were oriented towards helping or advocating for users, while *manipulative behaviors* aimed to trick users or otherwise value shareholders over user value (Chivukula et al., 2018). These characteristics of valence are described in Figure 1.

According to this schema, we defined four value codes that capture the attitude and intention of the designers across a spectrum of value-centeredness to manipulation. Based on the context in which the speech act emerged, we have further divided this axis to identify if the designer's awareness of this valence was *explicit* (foregrounded) or *implicit* (backgrounded). The four value codes are: Explicit Manipulative Intentions (EMI), Explicit Value Centered (EVC), Implicit Manipulative Intentions (IMI), and Implicit Value Centered (IVC). An example of an explicit intention is ``*Maybe instead of donate, we can use more persuasive term"* (EMI; P01B) where the participant was very upfront with their intention of using a persuasive

term. An example of an implicit intention was *"once we get to the billing information, before that, we should have an option for like, do you want to do it by credit card? Do you want to use a bank account? Do you want to use another service, like PayPal or whatever?"* (IVC;P01A). An implicit intention would not be characterized as such without a previous or successive explicit intention around why such an indication is made. In continuation, the explicit intention was about *"some people don't want their credit cards to be on file, so there's, you know, privacy concern also, because the thing is uh, organizations like PayPal, Venmo, whatever, they actually provide you with certain kind of uh fraud protections, so if all of this does end up being a whole fake thing"* (EVC;P01A). Here, the participant explicitly calls out for ``privacy'' and implicitly provides various options of payments to safeguard users from privacy fraud. Figure 2 provides a table of the descriptions of these value codes. We observed that some speech acts do not have a direct or indirect value relationship, but are nevertheless important as a part of the conversation. We coded these acts as Neutral, represented by "N."

Quantification of Ethical Valence

After coding the speech acts based on this schema, we attributed each code with a score to quantify the results. The scores are mapped to the implicit and explicit nature of the speech act with a magnitude of 1 or 2, respectively. The value-centered and manipulative nature of the speech act are represented with a positive and negative sign, respectively. This results in the following valence scores: EVC = 2, IVC = 1, N = 0, IMI = -1 and EMI = -2. A combined table for applying these codes and scores to speech acts are summarized in Figure 2.

Value Codes	Description	Score
EVC	*Explicit Value-centered* – Inclination towards user values over stakeholders; Explicitly mentioned in the dialogue along with human values.	***2***
IVC	*Implicit Value-centered* – Inclination towards user values over stakeholders; Implicitly mentioned in the dialogue and analysed by the researcher.	***1***
EMI	*Explicit Manipulative* – Inclination towards stakeholder values over users; Explicitly mentioned in the dialogue.	***-2***
IMI	*Implicit Manipulative* – Inclination towards stakeholder values over users; Implicitly mentioned in the dialogue and analysed by the researcher.	***-1***
N	*Neutral* – neither towards user or stakeholder	***0***

Figure 2 Value codes, descriptions, and valence scores

After applying scores for ethical valence, we used several additional descriptive statistical measures to characterize session data. These measures used in our analysis include: ethical

valence score, mean ethical valence score, sum of ethical valence scores, time intervals, and horizon. The definitions are as follows:

- **Ethical Valence Score (EVS):** The value code score given to each speech act. These values can be only -2, -1 ,0 ,1 , or 2.
- **Mean Ethical Valence Score (mEVS):** The average ethical valence score over a defined time interval (e.g., entire session, 10 minutes, 2 minutes) for each participant.
- **Sum of Ethical Valence Scores (sEVS):** Sum of the ethical valence scores over a defined time interval for each participant.
- **Horizon:** The neutral line in the visualization which represents either no coded design activity or a neutral valence score.

Interpreting the Data

With chronologically coded transcripts, we attached an ethical valence score to each speech act. Through iterative generation of hypotheses regarding ethical complexity, informed by qualitative and critical analyses of the protocols, we identified two main analysis approaches to inform two potentially generative interpretations: aggregated and temporal. *Aggregated sensemaking* focuses on describing the ethical stance of all the participants by visualizing the frequencies of each value code throughout the entire design activity (t = 45 mins). *Temporal sensemaking* focuses on visualizing how the ethical valence of participants changed with respect to the time component. Both of these analysis approaches inform the following sections, where we describe means of analyzing value awareness and action over time at multiple time scales, and within and across interlocutors.

4. Aggregated Sensemaking

In this section, we seek to identify the frequencies of value codes for each participant throughout the design protocol activity. This depiction of aggregated sensemaking facilitates identification and interpretation of the overall ethical character of each participant's design moves, including relative frequencies of value-centered and manipulative moves.

The distribution of value code frequencies is presented using a bar graph on either side of the horizon, as presented in Figure 3. The frequencies of value-centered codes, EVC and IVC, are represented along the positive axis above the horizon and frequencies of manipulative intentions codes, EMI and IMI, are represented along the negative axis below the horizon. Speech acts coded as neutral are represented in green, allowing for comparison of overall aural presence in the design activity.

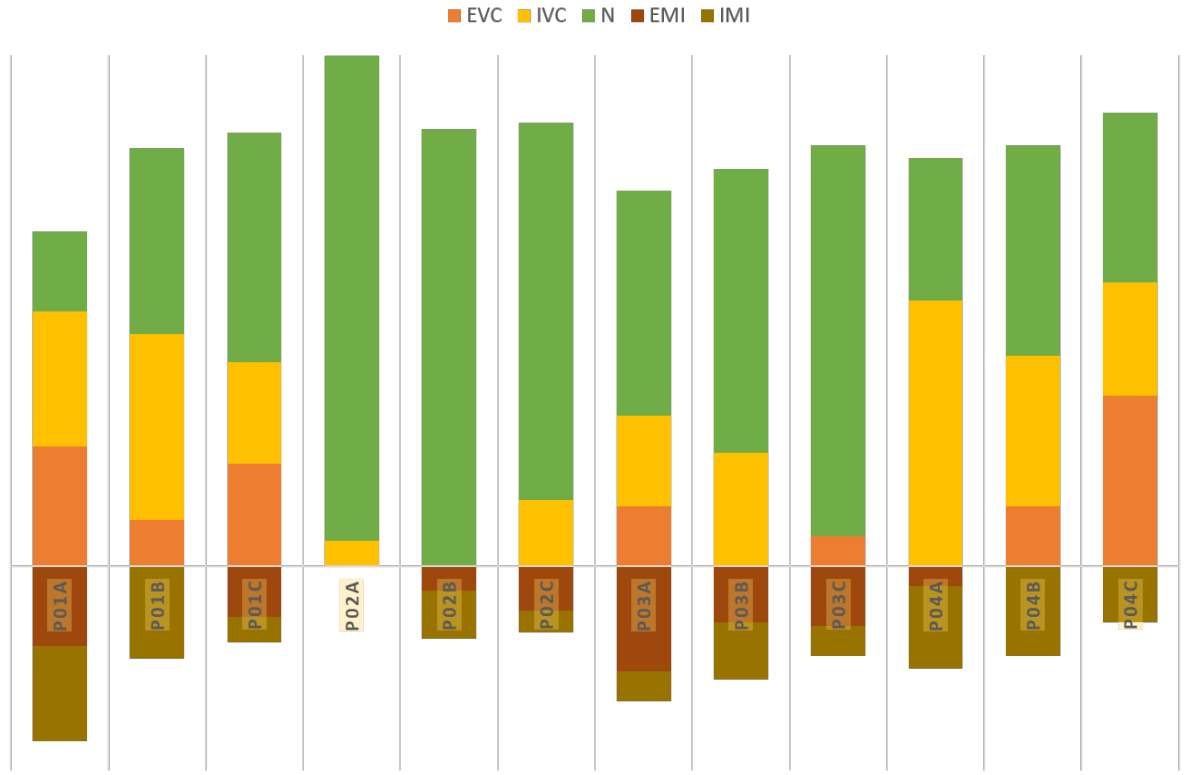


Figure 3 Frequencies of value code (EVC, IVC< N, EMI, IMI; details in Figure 2 describe the value codes) speech acts per participant across all protocols illustrating Aggregated sensemaking of ethical valence. Refer to Figures 1 and 2 for value codes.

The variation of value code patterns in these distributions facilitate qualitative analysis of the potential ethical roles of each participant. This role can be defined according to each participant's overall ethical stance on a spectrum from being manipulative to value centered. For example, as depicted in Figure 3, participant P01A had almost equal frequency of speech acts above and below the horizon. This indicates that the design activity of this participant incorporated instances across the spectrum of ethical valence, from value-centered to manipulative. A similar pattern of balanced valence can be seen with P03A, but with different frequencies.

While these overall frequencies provide a high-level overview of participant behavior, insights can be drawn from this analysis to identify leads for further qualitative inquiry. For instance, at a high level, we can readily identify patterns of ethical valence across multiple participants. Participants P01C and P04A show a more value centered and less manipulative valence; P02C and P03B show implicit value-centered nature and manipulative nature almost equally around the horizon; P01B, P04B and P04C are less value-centered and more explicitly manipulative. While the granularity of this chart cannot comprehensively identify the context of meaning of this ethical valence, a researcher might use insights drawn from this chart to identify and interpret specific examples of speech acts from one or more participants, providing a detailed account of their ethical stance in a design process, contextualized through a broader evaluation of their ethical valence distribution. The number of neutral

codes at the top of the bar allows access to the instances where the participant did not actively make ethically-focused judgments. The evaluation of these different distributions has the potential to spark questions such as: *In what instances in the design activity was the participant trying to manipulate the user? Where did the participant choose to stay neutral? Where did the participant choose to value the user through their design decisions?*

5. Temporal Sensemaking

In this section, we seek to identify the change in ethical valence scores of the participants over a period of time. In contrast to aggregated sensemaking (as in Section 4), temporal sensemaking facilitates evaluation of ethical character on the participant level in the context of the progression of design activity across the temporal dimension. This approach allows investigation into the variation in valence scores as design activity progresses, resulting in both an overall trend line for each participant, and easy comparison among participants' valence scores at specific moments in the design process.

Table 1 Different levels of interpretations for temporal sensemaking

Analysis	Combination of ethical valence and time	Results	Variables for plotting
Macro temporal (Figures 4 and 5)	Across all participants from all the protocols	Overall Shifts in ethical focus throughout the course of a design process	Line Graph: sEVS vs. 10 min Time Intervals per each participant
Micro temporal (Figure 6)	sEVS Across the three participants from one protocol	Overall shifts in ethical character (holistic) and instances of rapid ethical engagement patterns (episodic) within a group of designers	Line Graph: sEVS vs. 2 min Time Intervals + Average per each participant in a group
Meso Temporal (Figure 7, right)	Per Each participant in a protocol	Overall engagement with ethical valence during decision making	Plot graph: EVS vs. every Time mark per each participant in a group

The ethical valence scores of the participants were plotted across the time axis, with three different levels of temporal granularity. These three levels of temporal-participant visualization—Macro, Micro and Meso—each offer different perspectives on the ethical complexity, involving different combinations of participant and protocol data (Table 1). These graphs provide information regarding two different aspects of ethical complexity: 1) the concentration of value centered conversations across the entire duration of the design activity, and 2) the variation of the participant's ethical valence scores over time. These three levels of data visualization will be described in the following subsections:

5.1 Macro Temporal Analysis

In the macro visualization of temporal data, we sought to describe the overall valence score through time for all the participants in all protocols (n=12) and/or participants in one protocol (n=3). We have divided our data into chunks of 10 mins intervals and calculated the Sum of Ethical Valence Scores (sEVS) of each participant for each interval. The graph provides insight into how value-centered or manipulative conversations occur across time and how participants shift their ethical focus throughout the course of a design process. At this level of data granularity, comparisons among participants is also relatively easy to accomplish, quickly validating hypotheses regarding ethical roles of participants that might have been prompted from an aggregate analysis (Figure 4) treating each participant as a unit of analysis. The plots for this relation are presented in Figure 4 and 5.

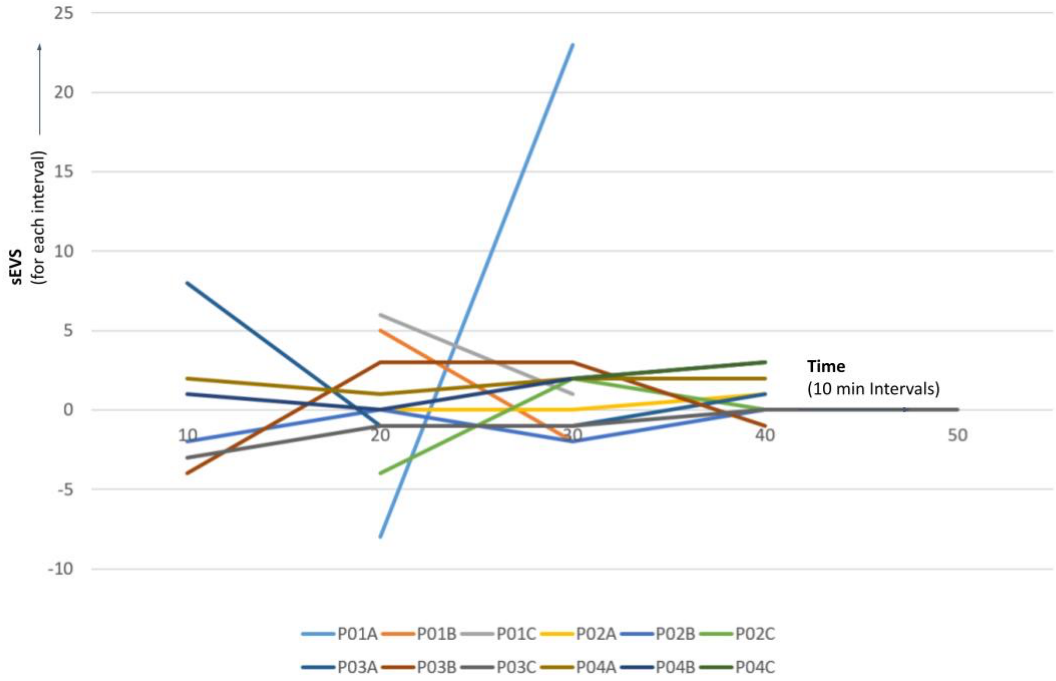
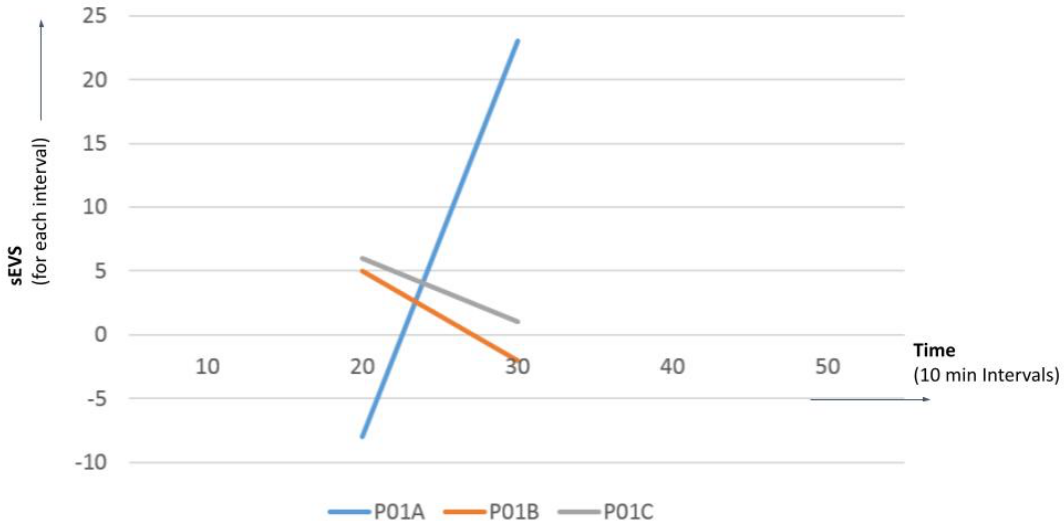


Figure 4 Macro view of sum of ethical valence scores (sEVS) across all participants per 10 mins time intervals.

Macro analysis allows pinpoint specific time intervals of value-centered or manipulative valence during a design activity (which could be further investigated using micro temporal analysis in Section 5.2). By comparing the participant trend lines in Figure 5, we can readily identify that the participants concentrated their ethics-focused decision making in the intervals of 10 to 30 mins with P01A always on an opposite side of the argument compared to P01B and P01C. For example, in the interval between 10 mins to 20 mins, P01A took a manipulative stance (negative sEVS) in generating solutions while the other two participants were arguing for a more value-centered approach. This design interaction then transitioned to a more value-centered direction, led by P01A, in the next interval from 20 mins to 30 mins. A holistic level of analysis allows insight into each designer's role in either leading or

driving the ethical valence of the design process and moments of ethical tensions during decision making in a team. However, it is difficult to describe which specific speech acts drove changes in ethical valence, beyond an overall trend line.



Till	10	20	30	40	50	Average	Std.Dev
P01A		-8	23			7.5	21.92031
P01B		5	-2			1.5	4.949747
P01C		6	1			3.5	3.535534
Average	NA	1	7.333333	NA	NA		
STD.Dev		7.81025	13.6504				

Figure 5 Macro temporal Analysis within one group of participants: View of sum of ethical valence scores per 10 mins time intervals including all participants from one protocol.

5.2 Micro Temporal Analysis

In the micro visualization of temporal data, we sought to describe the patterns of interaction across the three participants from a specific protocol during a specific portion that indicated ethical decision making. The specific portion could be identified using macro temporal analysis (as in Figure 5), which was identified to be between 10 mins to 30 mins. We plotted a portion of the same data as above that particularly indicated ethical valence or variance in sEVS, using 2 min intervals from the transcript to describe interactions on a more granular level alongside the mean of the three participant's EVS (mEVS) across that interval (Figure 6).

Figure 6 Micro temporal Analysis: Micro view of sum of ethical valence scores per 2 mins time intervals within the ethical valence discussion (identified in Figure 5) including all participants from one protocol. Also identified are the Patterns of Ethical Valence- 1) Anti-Horizon, 2) Syn-Horizon, 3)Transverse and 4)Lateral.

To further demonstrate the interpretive potential of the micro temporal analysis approach, we located four evident patterns (as marked in Figure 6) in the visualization, here illustrated only using data from Group 1. These patterns, while not exhaustive, show the variation of ethical valence scores with respect to time, relation to another participant, and the horizon as:

1. **Anti-Horizon:** Participants are at differing levels of ethical valence, with participants divided across both sides of the horizon (Figure 6 [1]). This pattern aids in evaluating critical moments where the participants are demonstrating a lack of ethical consensus and a deeper discourse analysis will help understand the roles or conflicts in ethical decision-making.
2. **Syn-Horizon:** Participants are synchronized in ethical valence directionality with all the participants on the same side of the horizon. This pattern aids in evaluating instances of resonant ethical valence, potentially indicating areas of consensus-building. Specifically helps identify when all the participants are synchronized below the horizon, representing a shift towards manipulative intent, as in Figure 6 [2].
3. **Transverse:** Participants' overall ethical valence is shifting across the horizon. This is tracked by the mEVS shifting signs over multiple time periods, or the sEVS of all the participants changing signs as shown in Figure 6[3]. In either direction, this pattern and further qualitative analysis helps identify the drivers for pivoting in either a positive (value-centered) or negative (manipulative) decision making direction.

4. **Lateral:** Participants are increasing the strength of the ethical valence over two or more two minute periods. The one side increase in this pattern demonstrates a commitment towards a more value-centered or manipulative direction without considering alternatives on the other side of the horizon as in Figure 6 [4]. Further qualitative analysis can evaluate the rationale the team is using to strengthen or support their ethical stance.

Figure 7 Comparing the granularity for analysis between Macro (10 mins intervals), Micro (2 mins intervals), and Meso (every timestamp) (left to right) analysis for one participant (P01A)

5.3 Meso Temporal Analysis

After comparing the interpretive potential of macro and micro temporal analyses, we explored the value of altering temporal granularity in different ways. In performing a meso temporal analysis, we investigated how the change in the time intervals might give more access into various aspects of the ethical complexity of the participants' decision-making process. As shown from left to right in Figure 7, these three visualizations compare the plots of sEVS of participant P01A for 10 mins, 2 mins, and EVS for every speech act.

By isolating a single participant across multiple time scales, we are able to evaluate how an individual participant engaged with ethical valence—both as a general trend line (Figure 7, left), and as a deliberative process (Figure 7, right). It is also possible to evaluate these moments of ethical engagement in relation to the horizon, indicating the range of considerations as well as the final outcomes. This meso analysis builds upon the previous two forms of analysis by exposing the temporal noise with different intervals for each participant. For instance, by comparing the left and right graphs, we can describe how participant P01A continuously and rapidly shifted from being value-centered to manipulative in the beginning of the discussion—a detail which would be easily lost at the macro scale.

6. Discussion

Across this range of quantitative methods and visualizations, we have identified analytic approaches to engaging with ethical concerns using qualitative and quantitative insights to inform deeper engagement with ethical design complexity. In the following subsections, we will evaluate the insights that these analyses can offer in relation to the ethically-nuanced

roles that designers take on, and the impact of these analyses in bridging the quantitative-qualitative divide in future ethics-focused research.

6.1 Identifying Designers' Ethical Roles

Through this quantitative approach to visualize designer interactions, we have described various ways in which a designer's ethical engagement can be identified and interpreted (Sections 4 and 5). The range of interpretations allow us to compare and contrast designers' characteristics in the same protocol as well as in relation with all the participants who were trying to solve the same task. Within the same protocol, we are able to describe the most influential participant(s) in the design conversation (e.g., Figure 4 and 5), characterize each participant's ethical stance in comparison with other participants (e.g., Figure 7), and highlight moments of conflicts between participants during the design process (e.g., Figure 6).

The different stances taken by designers in solving the same problem provide an opportunity to identify several characteristic types of designer roles in relation to ethical engagement. As qualitative researchers who engaged first-hand in observations of these protocol study sessions, we realized there were substantial differences in the roles of different participants, including how they tried to solve the problem and engaged in discussion to generate solutions. However, using the visualizations and quantifications of ethical valence, we were able to create a clearer and more precise portrait regarding the role of each participant. We leverage this analysis alongside the ethical framework of virtue ethics (Hursthouse & Pettigrove, 2022) to highlight the ethical, moral, and value-based intentions of the designers. Through our initial analysis of the roles through macro temporal graphs, we analyzed four different roles designers could take during ethical decision making as illustrated in Figure 8.

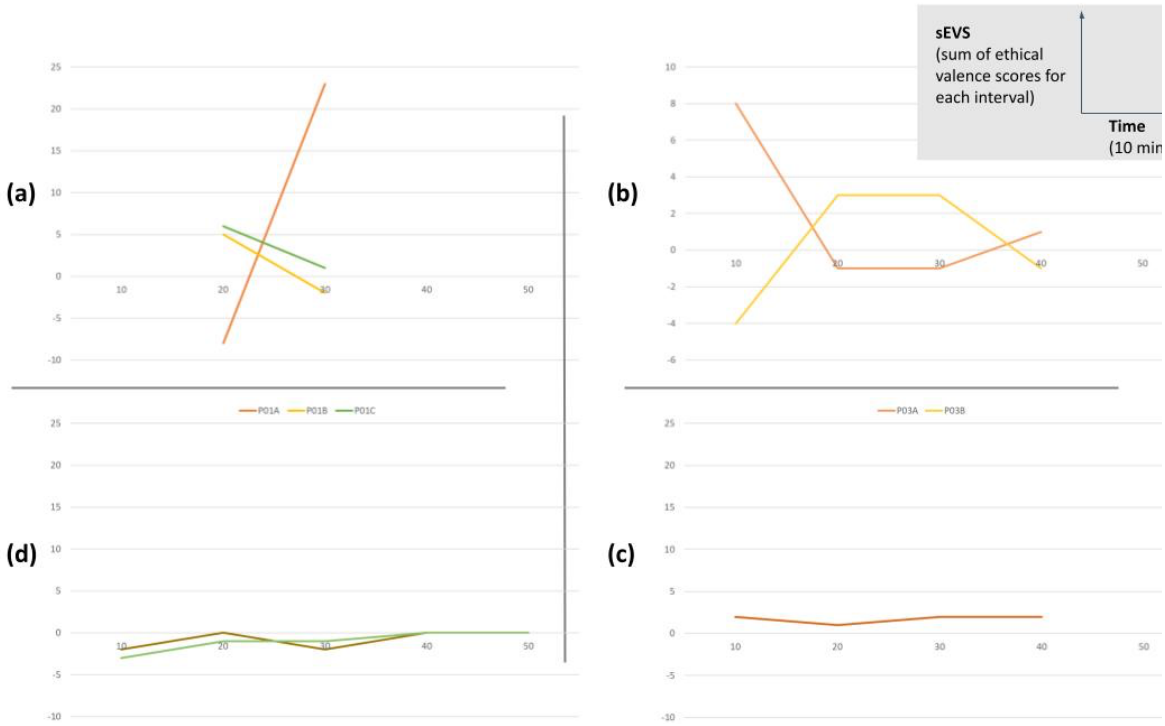


Figure 8 Identified ethics-focussed roles from quantitative analysis using Macro temporal Analysis (clockwise)- (a) Ethical Inverter (b) Ethico-Gemini (c) User's Advocate and (d) Stakeholder's Pet

a) **Ethical Inverter:** This role represents a designer that tries to contradict the other designers on the team and is always on the opposite side of the horizon from their teammates. As shown in Figure 8(a), P01A forms an intersecting plot with the other participants with EVS always on the other side of the horizon compared to others. The magnitude of the EVS of P01A lets us understand the intensity of how this designer was trying to invert the conversation against the wishes of the other two designers across the design activity.

b) **Ethico-Gemini:** This role represents a pair of designers who were actively mirroring each other's ethical valence throughout the session. Their plot, shown in Figure 8(b), reveals that this pair of designers were in conflict regarding the ethical character of their decisions throughout the design activity.

c) **User's Advocate:** This role represents a designer that is always above the horizon, actively attempting to engage in value-centered decision making. As shown in Figure 8(c), the designer was trying to engage in the task from a user-focused perspective rather than attending primarily to stakeholder needs.

d) **Stakeholder's Pet:** This role represents a designer that tries to manipulate the users to reach the stakeholder's goals by "whatever means necessary" (w.r.t our protocol study and design brief given). The plot of this designer is always below the horizon with negative valence scores throughout the design activity.

6.2 Bridging Quantitative and Qualitative Approaches

While quantitative accounts of ethical engagement represent a new contribution to discovering and interpreting aspects of ethical complexity, we also connect our contribution with existing qualitative and critical analytic approaches in the mixed methods tradition. This bridging work is already evident in our approach, as we began with critical qualitative analysis to code our data and generate value codes. As we seek to link these quantitative approaches with the potential for deep qualitative insights, we highlight the identification of *"critical incidents"* that warrant further analysis. These critical incidents commonly involved instances of conflict among participants or shifts in participants' ethical valence through the design process, and while some of these incidents may have been captured through qualitative approaches alone, we see substantial value in using visualizations to identify new types of interconnected insights that might inform designer roles and industry practices.

There are definite limitations to our quantitative approach which are important to acknowledge. In its current form, our visualizations are built upon intensive qualitative coding to identify ethical valence, participants, design tasks, and other relevant information. However, these data in their coded form represent the first essential step to describe the architecture and ethical patterns, which could facilitate future training of machine learning models to inform a semi-automated quantitative framework.

7. Implications and Future Work

While existing frameworks for describing ethics allow for deep qualitative investigation, the quantitative methods we have proposed in this paper provide new tools to depict ethical complexity. We propose the use of this range of quantitative approaches to build insights regarding the ethical character of a design activity, including implications for the expansion of specific ethical roles that characterize ethical engagement in sociotechnical and design practices. A future line of research may further describe a designer's cognition with an ethical valence, leveraging the quantitative approaches explored in this paper to support more computational approaches in design ethics research. As design practices become increasingly intertwined with near- and long-term social impact, identification of static and dynamic roles, and the mediators among these roles, will be critical to informing ethically centered design practice.

Future work could leverage visualizations to identify critical incidents and inspire analysis into the role of designers and the emergence of ethical awareness and action. For instance, characteristic types of desired ethical engagement might be identified, leading to uptakes for design practice and education. The results from this paper could serve as a foundational framework, supporting the development of tools that can model how designers can learn and evolve their ethical decision making. Additional protocol studies may also be conducted with different kinds of tasks, exploring how the ethical valence of designers is shaped by design contexts and types of ethical challenges.

8. Conclusion

In this paper, we have identified a set of approaches to quantify ethical valence, facilitating the description and interpretation of ethical awareness among designers on temporal and participant levels across multiple time scales. These quantitative approaches have the potential to aid researchers in identifying and describing underlying patterns of ethical complexity, laying the groundwork for new mixed methods approaches to the study of ethics, as well as greater attention to the complex ethical roles that designers may take on in industry settings.

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5. References

Bardzell, S., Bardzell, J., Forlizzi, J., Zimmerman, J., & Antanitis, J. (2012). Critical design and critical theory: the challenge of designing for provocation. *Proceedings of the Designing Interactive Systems Conference*, 288–297. https://doi.org/10.1145/2317956.2318001

Chen, N.-C., Drouhard, M., Kocielnik, R., Suh, J., & Aragon, C. R. (2018). Using Machine Learning to Support Qualitative Coding in Social Science: Shifting the Focus to Ambiguity. *ACM Trans. Interact. Intell. Syst.*, *8*(2), 1–20. https://doi.org/10.1145/3185515

Chivukula, S. S. (2021). *Designing for Co-Creation to Engage Multiple Perspectives on Ethics in Technology Practice* [Purdue University Graduate School]. https://doi.org/10.25394/PGS.15036321.v1

Chivukula, S. S., Brier, J., & Gray, C. M. (2018). Dark Intentions or Persuasion? UX Designers' Activation of Stakeholder and User Values. *Proceedings of the 2018 ACM Conference Companion Publication on Designing Interactive Systems*, 87–91. https://doi.org/10.1145/3197391.3205417

Chivukula, S. S., Gray, C. M., & Brier, J. A. (2019). Analyzing Value Discovery in Design Decisions Through Ethicography. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, Article Paper 77. https://doi.org/10.1145/3290605.3300307

Chivukula, S. S., Hasib, A., Li, Z., Chen, J., & Gray, C. M. (2021). Identity Claims that Underlie Ethical Awareness and Action. *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, Article Article 295. https://doi.org/10.1145/3411764.3445375

Chivukula, S. S., Li, Z., Pivonka, A. C., Chen, J., & Gray, C. M. (2021). Surveying the Landscape of Ethics-Focused Design Methods. In *arXiv [cs.HC]*. Cornell University; arXiv. http://arxiv.org/abs/2102.08909

Cross, N., & Clayburn Cross, A. (1995). Observations of teamwork and social processes in design. *Design Studies*, *16*(2), 143–170. https://doi.org/10.1016/0142-694X(94)00007-Z

Cross, N., Dorst, K., & Christiaans, H. (1996). *Analysing design activity* (Vol. 11). Wiley.

Crowston, K., Liu, X., & Allen, E. E. (2010). Machine learning and rule-based automated coding of qualitative data. *Proceedings of the American Society for Information Science and Technology*, *47*(1), 1–2. https://doi.org/10.1002/meet.14504701328

Dorst, K. (2003). Exploring the structure of design problems. *DS 31: Proceedings of ICED 03, the 14th International Conference on Engineering Design*. https://www.designsociety.org/download-publication/23953/exploring_the_structure_of_design_problems

Geiger, R. S., & Ribes, D. (2011). Trace Ethnography: Following Coordination through Documentary Practices. *2011 44th Hawaii International Conference on System Sciences*, 1–10. https://doi.org/10.1109/HICSS.2011.455

Gero, J. S., & Milovanovic, J. (2020). A framework for studying design thinking through measuring designers' minds, bodies and brains. *Design Science*, *6*, e19. https://www.cambridge.org/core/journals/design-science/article/framework-for-studying-design-thinking-through-measuring-designers-minds-bodies-and-brains/04EC7F5384E423992E61CC8C65EA355F

Goldschmidt, G. (1990). Linkography: assessing design productivity. *Cyberbetics and System'90, Proceedings of the Tenth European Meeting on Cybernetics and Systems Research*, 291–298. https://ci.nii.ac.jp/naid/80005333113/

Goldschmidt, G. (2016). Linkographic Evidence for Concurrent Divergent and Convergent Thinking in Creative Design. *Creativity Research Journal*, *28*(2), 115–122. https://doi.org/10.1080/10400419.2016.1162497

Gray, C. M., & Chivukula, S. S. (2019). Ethical Mediation in UX Practice. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, Article Paper 178. https://doi.org/10.1145/3290605.3300408

Gray, C. M., Chivukula, S. S., Carlock, T. V., Li, Z., & Duane, J.-N. (2023). Scaffolding Ethics-Focused Methods for Practice Resonance. *Proceedings of the 2023 ACM Designing Interactive Systems Conference*, 2375–2391. https://doi.org/10.1145/3563657.3596111

Gray, C. M., Chivukula, S. S., Melkey, K., & Manocha, R. (2021). Understanding "Dark" Design Roles in Computing Education. *Proceedings of the 17th ACM Conference on International Computing Education Research*, 225–238. https://doi.org/10.1145/3446871.3469754

Gui, X., Wang, Y., Kou, Y., Reynolds, T. L., Chen, Y., Mei, Q., & Zheng, K. (2017). Understanding the Patterns of Health Information Dissemination on Social Media during the Zika Outbreak. *AMIA ... Annual Symposium Proceedings / AMIA Symposium. AMIA Symposium*, *2017*, 820–829. https://www.ncbi.nlm.nih.gov/pubmed/29854148

Hatcher, G., Ion, W., Maclachlan, R., Marlow, M., Simpson, B., Wilson, N., & Wodehouse, A. (2018). Using linkography to compare creative methods for group ideation. *Design Studies*, *58*, 127–152. https://doi.org/10.1016/j.destud.2018.05.002

Hendry, D. G., Friedman, B., & Ballard, S. (2021). Value sensitive design as a formative framework. *Ethics and Information Technology*, *23*(1), 39–44. https://doi.org/10.1007/s10676-021-09579-x

Hursthouse, R., & Pettigrove, G. (2022). Virtue Ethics. In E. N. Zalta & U. Nodelman (Eds.), The Stanford Encyclopedia of Philosophy (Winter 2022). Metaphysics Research Lab, Stanford University. https://plato.stanford.edu/archives/win2022/entries/ethics-virtue/

Jiang, H., & Yen, C. (2009). Protocol analysis in design research: a review. *Journal Paper*, *78*(24), 16. https://www.researchgate.net/profile/Ching_Yen/publication/325656426_Protocol_Analysis_in_Design_Research_a_review/links/5b1b58dbaca272021cf35e30/Protocol-Analysis-in-Design-Research-a-review.pdf

Jordan, B., & Henderson, A. (1995). Interaction Analysis: Foundations and Practice. *Journal of the Learning Sciences*, *4*(1), 39–103. https://doi.org/10.1207/s15327809jls0401_2

Kan, J. W. T., & Gero, J. S. (2005). Can entropy indicate the richness of idea generation in team designing. *CAADRIA05*, *1*, 451–457. https://www.researchgate.net/profile/John_Gero2/publica-

tion/285914264_Can_entropy_indicate_the_richness_of_idea_generation_in_team_designing/links/583d8c5e08aeda696806e459/Can-entropy-indicate-the-richness-of-idea-generation-in-team-designing.pdf

Kan, J. W. T., & Gero, J. S. (2017). *Quantitative Methods for Studying Design Protocols*. Springer Netherlands. https://doi.org/10.1007/978-94-024-0984-0

Kavakli, M., & Gero, J. S. (2002). The structure of concurrent cognitive actions: a case study on novice and expert designers. *Design Studies*, *23*(1), 25–40. https://doi.org/10.1016/S0142-694X(01)00021-7

Kavakli, M., & Gero, J. S. (2003). Strategic knowledge differences between an expert and a novice designer. In U. Lindemann (Ed.), *Human Behaviour in Design: Individuals, Teams, Tools* (pp. 42–52). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-07811-2_5

Kruger, C., & Cross, N. (2006). Solution driven versus problem driven design: strategies and outcomes. *Design Studies*, *27*(5), 527–548. https://doi.org/10.1016/j.destud.2006.01.001

Menning, A., Grasnick, B. M., Ewald, B., Dobrigkeit, F., & Nicolai, C. (2018). Verbal focus shifts: Forms of low coherent statements in design conversations. In *Design Studies* (Vol. 57, pp. 135–155). https://doi.org/10.1016/j.destud.2018.03.003

Olson, G. M., & Olson, J. S. (2000). Distance Matters. *Human–Computer Interaction*, *15*(2-3), 139–178. https://doi.org/10.1207/S15327051HCI1523_4

Shilton, K. (2018). Values and Ethics in Human-Computer Interaction. *Foundations and Trends® in Human–Computer Interaction*, *12*(2), 107–171. https://doi.org/10.1561/1100000073

Shilton, K., & Koepfler, J. A. (2013). Making space for values: communication & values levers in a virtual team. *Proceedings of the 6th International Conference on Communities and Technologies*, 110–119. https://doi.org/10.1145/2482991.2482993

Steen, M. (2015). Upon Opening the Black Box and Finding It Full: Exploring the Ethics in Design Practices. *Science, Technology & Human Values*, *40*(3), 389–420. https://doi.org/10.1177/0162243914547645

Wong, R. Y. (2021). Tactics of Soft Resistance in User Experience Professionals' Values Work. *Proc. ACM Hum.-Comput. Interact.*, *5*(CSCW2), 1–28. https://doi.org/10.1145/3479499

Wong, R. Y., Chong, A., & Aspegren, R. C. (2023). Privacy Legislation as Business Risks: How GDPR and CCPA are Represented in Technology Companies' Investment Risk Disclosures. *Proc. ACM Hum.-Comput. Interact.*, *7*(CSCW1), 1–26. https://doi.org/10.1145/3579515

Zimmerman, J., & Forlizzi, J. (2014). Research Through Design in HCI. In J. S. Olson & W. A. Kellogg (Eds.), *Ways of Knowing in HCI* (pp. 167–189). Springer New York. https://doi.org/10.1007/978-1-4939-0378-8_8

Zimmerman, J., Forlizzi, J., & Evenson, S. (2007). Research through design as a method for interaction design research in HCI. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 493–502. https://doi.org/10.1145/1240624.1240704

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