Research Tool to Quantify Interaction Dynamics Through Time

Bradlyn Walker
Georgia Institute of Technology
Atlanta, GA 30332 USA
bradlynmwalker@gatech.edu

Nicholas Davis
Georgia Institute of Technology
Atlanta, GA 30332 USA
Ndavis35@gatech.edu

Jordan Movish
Georgia Institute of Technology
Atlanta, GA 30332 USA
jordan.movish@gatech.edu

Brian Magerko
Georgia Institute of Technology
Atlanta, GA 30332 USA
magerko@gatech.edu

Abstract

Open-ended improvisational creativity is difficult to measure and quantify due to dynamic and fluid nature of creative collaboration. Existing methods provide a means to record and analyze individual events within a creative collaboration, but they often do not account for the fine-grained temporal dynamics of the interaction (e.g. the rhythm of interaction, structure of turn taking, and manner of executing actions). To address this gap in research methods, we previously introduced the creative sense-making (CSM) cognitive framework and sense-making curve coding tool and demonstrated their utility for quantifying interaction dynamics in co-creation. In this paper, we describe the design considerations for this new interaction coding tool and offer some design improvements based on usage of the tool that was previously reported.

Introduction

The concept of open-ended improvisational creativity involves a feedback loop between an agent and their current creative environment during which meaning emerges as the agent notices patterns and regularities in the environment (Davis et al. 2016). This dynamic process of meaning construction through interaction is referred to as *sense-making* (Jaegher and DiPaolo 2007; De Jaegher, Di Paolo and Gallagher 2010). When multiple agents engage in this sense-making process together in a way that is mutually influential (i.e. *participatory sense-making)*, the process becomes co-creative in the sense that ideas can mix, combine, and transform in novel and unexpected ways leading to *emergent creativity* (Sawyer and DeZutter 2009). Analyzing this process of co-creation is difficult as there are limitless options for interaction in an open-ended and naturalistic creative context. Individuals can choose many different productive and creative paths to follow for several reasons that are difficult to precisely quantify since they occur in rapid succession in real-time.

To help understand and model this co-creation process, we have developed a technique to quantify interaction dynamics of open-ended improvisational creative contexts in real world scenarios (Davis et al. 2017; Davis et al. 2015). Many research methods employed to observe open-ended creative processes focus more on the content of the actions between environment and agent rather than *how* those actions were performed (e.g. the rhythm of interaction, turn taking structure, and the granular temporal dynamics describing the manner of action execution). To address this issue, we introduced a new cognitive framework called creative sense-making (Davis et al. 2017), which includes an interaction coding technique and tool that enables analysts to record continuous data describing interaction dynamics throughout improvisational creative collaboration.

This paper overview the current design of the tool and offers some design improvements based on usage reported on previously (Davis et al. 2017). Similar methodologies for quantifying creative sense-making are described and contrasted to our research requirements. User needs are described for coding in this new environment. Finally, future design iterations are proposed based on evaluation and feedback from analysts who have used the tool.

Related Work

There are several methods useful when analyzing the interaction dynamics of open-ended creative improvisation. Perhaps the most closely related domain is interaction analysis, which lays theoretical foundations for coding interpersonal behaviors and actions into predefined categories. A rough summary of events is logged either during or right after the experiment has finished. A detailed transcription of content logs follows after researchers determine which hypotheses have substance from the data (Jordan and Henderson 1995). This can also be visualized through a node based network connecting agents and interactions (Bourbousson and Fortes-Bourbousson 2016). The type of data we are trying to capture are the events that happen during creative improvisation by agents interacting with their environment and each other, and therefore would need to be recorded in a similar fashion.

Protocol Analysis is another relevant research method which entails the transcription and coding of verbalized thought processes by participants in order to gain insight into their thinking (Nguyen and Shanks 2009; Kim, Jin and Lee 2006). This is important in creativity related research as think-aloud tasks provide insight into participants' rationales as a form of self-reported data. While this data can provide much insight, it is difficult to precisely reconstruct a quantitative model of moment-to-moment interactions from it.

Event-based behavioral coding also serves to categorize participant interactions either based on predefined options or emergent patterns akin to Grounded Theory, in which meaning and patterns are derived from the actions happening in the environment (Strauss and Corbin 1997). Discrete behaviors can be recorded in a dynamic linear fashion so long as they are easily definable and noticeable physiological events. However, this method struggles to capture the minute cognitive events that are manifested in these larger behavioral events.

Ethnomethodology arose in response to recognizing the importance of these fine-grained contextual details of the interaction. In this approach, analysts capture interactions at a highly granular level, which can be arduous as the number of minute events recorded in a small amount of time can make coding large data sets particularly time-intensive (Garfinkel 1997). Conversation analysis (CA) is one method that has been employed in ethnomethodological studies describing the fine-grained dynamics of open-ended interaction through linguistic and paralinguistic study. This also includes the concept of constructive dialogue modelling which attempts to understand and represent the willingness to cooperate and participate in turn-taking in conversation between participants. An example of this includes an individual's likelihood to repeat usage of a particular communication type if it is successful in reaching a cooperative goal, often found in open-ended creative collaboration. CA methodology often makes use of an audio or video recorder to collect richer data to be analyzed later. Similarly, analysis of sense-making benefits from video recording to capture the different interactions between an agent and their environment that can be analyzed through the CSM tool. In the context of creative sense-making, we look at these methods as a representation of the qualitative coding scheme the CSM tool uses to quantify interaction.

More recently, a new cognitive science research method called perceptual crossing has gained traction as a means of quantifying participatory sense-making by observing how participants make sense of a one-dimensional virtual environment. Often done through the use of avatars (Froese and DiPaolo 2011; Auvray, Lenay and Stewart 2009), participants are signaled through stimuli when avatars cross over another object in the virtual space. Both players must interact with the environment to distinguish between static objects and other agents in a process of *participatory sense-making.* This interaction dynamic is a fundamental part of creative improvisation where feedback between actors and their environment can lead to states of coupled interaction, i.e. both individual's actions are mutually affecting each other. Perceptual crossing demonstrates the analytic power of using continuous interaction data to model participatory sense-making, but the virtual environment is too constrained for use in creative collaboration and co-creation.

Creative Sense-Making

Creative sense-making (CSM) the continuous cycle of performing creative actions, then modifying schemas about the environment based on the effects (Davis et al. 2017). It is seen as a form of experiential learning in which agents gradually develop a more accurate model of their environment through experimental interactions. This framework is based on the cognitive science theory of enaction and involves analyzing the dynamics displayed by an agent interacting with their environment and how this creative engagement leads to agents working within or updating their generative model. Through this, the agent establishes meaning and derives patterns about the world around them and can create within this paradigm or perform an action to modify it. When another agent, whether human or AI, becomes part of the agent's sense-making process, it can become *participatory sense-making.* The environmental co-creator not only provides new sources of feedback for the agent, but takes in information from the agent as well. This results in recursive, yet open-ended co-creation leading to a rich, novel environment that the agent can interact with and modify through the sense-making process.

Quantifying creative sense-making requires analysis of the agent's cognitive states as they act within, or reframe their environment. The technique involved with analyzing these behaviors involves coding for what Glenberg refers to as *clamped* and *unclamped* cognition (Glenberg 1997). Within CSM, clamped cognition is defined as "The process of maintaining or slightly refining the selected generative model assuming that it is the most accurate representation of the environment (Davis et al. 2017). In clamped cognition, agents perform creative actions with a high level of cognizance of the current state of the environment, i.e. the agent has already made sense of their environment. Unclamped cognition is "the process of changing or replacing the generative model by exploring and reflecting on the environment from different perspectives. It generally occurs during task onset and after surprises during the task" (Davis et al. 2017).

To better understand the role unclamped cognition plays during sense-making, we can analyze physiological manifestations of cognitive states utilized during sense-making, or the lack thereof. In this state, the agent is either modifying their schemas through direct manipulation of the environment or disengaging from the environment altogether. Unclamped cognition can also be marked as either partial (e.g. the agent is on "standby", or is unsure of their next action), or full (active reframing of environment or complete disassociation with creative process). This new interaction coding technique and tool enables us to begin identifying interaction trends and classifying different types of sense-making and participatory sense-making strategies quantitatively.

Analysts employ behavioral markers to determine each participant's cognitive state and sense-making activities through time, which produces what we call a sense-making curve the has the potential to reveal interaction trends and classify different types of sense-making and participatory sense-making quantitatively. Determining these interaction trends utilizes a similar procedure as identifying buy, sell, and hold patterns in stochastic stock market analysis. The tool is used to help quantify changes in behaviors during interaction using mathematical techniques similar to stock market analysis (e.g. pitches up in the curve and the magnitude of the vector segment have semantic meaning). This allows us to analyze distinct cognitive states and temporally extended sense-making processes, the ways in which these states manifest, and the magnitude thereof.

Sense-Making Curve Tool Design

Accurate measurement of creative sense-making requires a tool with four key features: continuous collection of interaction data, rapid state switching between interaction codes, low time-cost, and the ability to establish IRR. Creative sense-making requires being able to determine relative change from previous states of cognition, thus data collected should be continuous over a single session as we

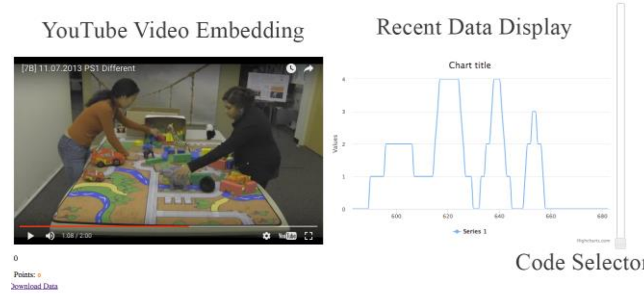

Figure 1: Screenshot of the sense-making curve tool.

are interested in looking at behaviors over the duration of the experiment to identify distinct periods of clamped/unclamped activity. The tool must also facilitate quick, rapid coding. Periods of clamped/unclamped cognition are unstable in both frequency and duration; the tool must necessarily be robust enough to code these changes rapidly yet flexible enough to facilitate ease of use.

The prototype sense-making curve tool (as seen in Figure 1) is a qualitative video coding web application that allows for continuous coding of researcher video data uploaded to YouTube. The advantage of using YouTube is that it is a free service that allows researchers to store videos online in a place that does not rely on the resources of the tool.

Quantifying the creative sense-making process requires development of a tool with several specific properties. Overall, the tool must be demonstrated as reliable and accurate in its coding process. Coding should easily be consistent throughout the duration of an experiment session, and fairly consistent among raters. There are also pragmatic design considerations about how much time is required to code video with the tool. since the coding of qualitative data has historically been a time-intensive process, we sought improvement on these processes through the implementation of this tool. It was designed to minimize amount of time needed to code a video, as behaviors being coded can change quickly and unpredictably. The system's code application mechanism was designed to the overall coding time by continuously sampling the current coded value the user selected with the code selectto, which can be rapidly changed in the moment using the up/down arrow keys). While this approach does rely on the analysts reaction time, this approach has demonstrated reliability among multiple analysts (IRR=.71), ensuring consistency in coding and subsequent analysis of multiple sessions (Davis et al. 2017).

Usage of the sense-making curve tool has led to the discovery of additional constraints from a usability perspective. Before the coding process even begins, the tool needs to provide enhanced confirmation to users of video selection upon launch before coding begins. As the launch page for the tool only asks for the unique video ID, analysts need cognitive support for coding videos within the application domain. As coders often work with tools in different application domains where the categories listed below may not always apply, the coding scheme must be generalizable enough as to be as consistent as possible across all domains in which it might be used. Analysts wanted more instantaneous input when coding; controls and coding should be more intuitive in real time in order to minimize cognitive load. Quick rewinding and control of video playback speed should be salient and easily accessible to minimize distractions from coding activity.

Improving Tool Design and Functionality

The software tool that was developed to apply the qualitative coding procedure of the creative sense-making framework has a lot of opportunity for improvement. As a first step, the tool can be hosted online and made publicly available. Along with the software, formal documentation describing the coding procedure for producing sense-making curves should be included in the online version. Eight users have extensively used the tool, and based on their informal feedback, the following changes would improve its ability to meet the requirements for accurate and scalable CSM data capture.

Being able to switch code applications using the keyboard would enable coders to more rapidly transition between different states. Some analysts may prefer the slider, but the numerical keyboard input should be introduced as an option to select codes. This feature may reduce the noise generated by the process of changing the slider from one code to another, increasing the overall accuracy of the technique.

Efficiency of the tool would increase if more than one participants of a video could be coded during a single coding session. For example, in the pretend play study, there were two individuals in the collaboration that needed to be coded (Davis et al. 2015). Currently, the tool only supports the creation of a single sense-making curve in a given coding session. Ideally, the tool would support multiple curves per session based on the number of people involved in the collaboration being analyzed. Analysts would still have to re-watch the video each time they created an additional curve, but creating a local repository of curves within the tool would be useful for later analysis. This change would involve being able to create multiple sense-making curves for each video and being able to export them with individual file names (or together in a combined excel file). Multi-participant coding would also facilitate data visualization within a given session.

The tool can implement the MatLab mathematical analysis techniques to perform the sense-making curve integrations and other classification techniques within the user interface of the coding tool. The web visualization environment D3 can be used to visualize the sense-making curve analysis from within the platform. This feature would allow users to code each participant in their data set and immediately visualize their creative trajectory curves and sense-making classifications. Exploring these charts with different information exploration techniques, such as increasing and decreasing temporal granularity and tuning classification parameters, can help quantify interaction dynamics of open-ended creative collaboration with minimal overhead.

Sense-making curves provide continuous data about interaction dynamics, but they do not contain any information about the type of actions that participants are engaging in during this time. This could be solved with a relatively simple technical addition to the tool that allowed users to associate text input (e.g. labels, tags) to different time segments of the sense-making curve. To reduce the amount of time it takes to tag events, the system could employ an autocomplete technique for typing tags as well as present the user with frequently used tags when they begin the event labeling task. This feature could combine the power of event-based coding with the continuous coding method of the sense-making curve. With this information, the system could classify interaction dynamic trends as well as quantify the number of particular events and their temporal relationship.

In some experimental setups, multiple cameras are used to capture interaction. In these cases, multiple camera angles may provide more perspectives to help analysts apply qualitative codes to the different participants in an experimental session. Users have requested a dual video stream environment where two angles from the same time periods can be simultaneously presented in the tool (similar to the popular 'YouTube Doubler' tool located at youtubedoubler.com) and coded using a single sense-making curve.

While the researchers are confident the tool demonstrates a sufficient level of validity and reliability, the preceding design suggestions point to the need to increase usability of the tool for analysts. As mentioned, variables such as the granularity of the analysis, amount of data captured, and speed of coding stand to benefit from a redesigned interface.

Conclusions

This paper presented the purpose for the development of a sense-making curve tool, coding, and analysis process. The tool defines a new way to code continuous open-ended creative improvisation that fits the demands of analyzing this process as an amalgam of several methods (e.g. Interaction Analysis, Event-Based coding, etc.). Comparisons to other relevant methods were described, as well as how they relate to accomplishing the goal of accurately capturing clamped/unclamped cognition during the creative process. Design features and constraints based on researchers needs and usability demands were described. The process by which analysts code videos was explained with a visual representation of the coding environment. An evaluation of the tool was provided, including the inter-rater reliability data from previous applications of this tool. Finally, future plans for tool functionality were discussed as well as the rationale for potentially implementing these changes using a low-fidelity mockup provided of what a future iteration of the tool may look like. Future efforts will entail analyzing how generalizable the tool is to other applications regarding open-ended improvisational creativity and collaborative creation.

References

Todd Lubbart. 2001. Models of the Creative Process: Past, Present and Future. *Creativity Research Journal.* 13, 3-4:295-308.

Keith Sawyer. 1992. Improvisational creativity: An analysis of jazz performance. *Creativity Research Journal*. 5, 3.

Brigitte Jordan and Austin Henderson. 1995. Interaction analysis: Foundations and practice. *The Journal of the Learning Sciences*, 4, 1, 39-103.

Jérôme Bourbousson and Marina Fortes-Bourbousson. 2016. How do co-agents actively regulate their collective behavior states? *Frontiers in Psychology. 7.*

Lemai Nguyen and Graeme Shanks. 2009. A framework for understanding creativity in requirements engineering. *Information and Software Technology.* 51,3, 665-662.

Yong Se Kim, Sun Tai Jin and Sang Won Lee. 2006. Design Activities and Personal Creativity Characteristics: A Case Study of Dual Protocol Analysis Using Design Information and Process. *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference.* 4: 181-190.

Ansel Strauss and Juliet Corbin. 1997. Grounded theory in practice. *Sage Publications.*

John Gero. 2011. Fixation and commitment while designing and its measurement. *Journal of Creative Behavior*. 45, 20

Tom Froese and Ezequiel Di Paolo. 2011. The enactive approach: Theoretical sketches from cell to society. *Pragmatics & Cognition.* 19, 1: 1-36.

Malika Auvray, Charles Lenay, and John Stewart. 2009. Perceptual interactions in a minimalist virtual environment. *New ideas in psychology* 27, 1: 32–47.

Erin A Carroll and Celine Latulipe. 2012. Triangulating the personal creative experience: self report, external judgments, and physiology. *In Proceedings of Graphics Interface* 2012, 53–60.

Kristiina Jokinen, Hirohisa Furukawa, Masafumi Nishida, and Seiichi Yamamoto. 2013. Gaze and turn-taking behavior in casual conversational interactions. *ACM Transactions on Interactive Intelligent Systems. 3,2.*

Nicholas Davis, Chih-Pin Hsiao, Kunwar Yashraj Singh, Brenda Lin, and Brian Magerko. 2017. *ACM Creativity and Cognition 2017.*

Harold A Linstone, Murray Turoff, and others. 1975. The Delphi method: Techniques and applications.Addison-Wesley Reading, MA.

John Gero. 1996. Creativity, emergence, and evolution in design. *Knowledge-Based Systems.* 9:435-448.

Arthur M Glenberg. 1997. What memory is for: Creating meaning in the service of action. *Behavioral and brain sciences* 20, 1: 41–50.

Harold Garfinkel. 1967. Studies in Ethnomethodology, *Prentice-Hall.*

R Keith Sawyer and Stacy DeZutter. 2009. Distributed creativity: How collective creations emerge from collaboration. Psychology of Aesthetics, Creativity, and the Arts 3, 2: 81.

Nicholas Davis, Margeaux Comerford, Mikhail Jacob, Chih-Pin Hsiao, and Brian Magerko. 2015. An Enactive Characterization of Pretend Play. *In Proceedings of the 2015 ACM SIGCHI*

Hanne De Jaegher and Ezequiel Di Paolo. 2007. Participatory sense-making. *Phenomenology and the cognitive sciences* 6, 4: 485–507.

Hanne De Jaegher, Ezequiel Di Paolo, and Shaun Gallagher. 2010. Can social interaction constitute social cognition? *Trends in cognitive sciences* 14, 10: 441–447

Davis, N., Hsiao, C. P., Popova, Y., & Magerko, B. (2015). An Enactive Model of Creativity for Computational Collaboration and Co-creation. *In Creativity in the Digital Age* (pp. 109-133). Springer London.

Nicholas Davis, Chih-Pin Hsiao, Kunwar Yashraj Singh, Lisa Li, and Brian Magerko. 2016. Empirically Studying Participatory Sense-Making in Abstract Drawing with a Co-Creative Cognitive Agent. *In Proceedings of the 21st International Conference on Intelligent User Interfaces, 196–207.*