Analytic Provenance in Pair Analytics

Richard Arias-Hernandez
Simon Fraser University
250-13450-102 Avenue
Surrey, BC V3T 0A3 CANADA
ariasher@sfu.ca

Brian Fisher
Simon Fraser University
250-13450-102 Avenue
Surrey, BC V3T 0A3 CANADA
bfisher@sfu.ca

ABSTRACT
Herbert Clark's Joint Action Theory (JAT) addresses the social and cognitive mechanisms that coordinate face-to-face conversation. A theory of analytical JAT can help to clarify provenance of analytical findings that emerge from collaborative processes. Our "Pair Analytics" (PA) method extends JAT to the analysis of collocated collaboration using VA tools. We find that PA/JAT is effective for studying the structuring and navigation of joint analysis, the management of joint attention, and cognitive workload in joint activities.

Author Keywords
Joint Action Theory, Pair Analytics, Visual Analytics, Onscreen Gesturing, Analytic Provenance.

ACM Classification Keywords
H.5.3 Group and Organization Interfaces: Theory and Models.

General Terms
Theory, Human Factors.

POSITION STATEMENT
Joint Action Theory (JAT), Herbert H. Clark's theory of language in use, is an established psycholinguistic framework that has been effective in bridging social and cognitive understandings of human communication [3,4,5,6,7,8]. For Clark, language use is an instantiation of a broader class of human practices called "joint activities". In joint activities, individual participatory "joint actions" are coordinated to produce the intended effect. This implies coordinating *content* –what the participants intend to do, and coordinating *process* –how each participant generates actions to produce the desired joint effect. From this perspective, language in use is understood as a social process, rather than as a mere exchange of information between speakers and listeners, whose function is to solve coordination problems in joint actions (e.g. turn-taking, accounting for delays, structuring and navigating the analysis, mutual monitoring of understanding and attention, etc.). This is our starting theoretical point to apply joint action theory to study analytical reasoning: how do humans use language and interactions with artifacts to solve coordination problems in collaborative, visual analytics?

We believe that a theory of analytical JAT is needed if we are to establish provenance for analytical findings that emerge from collaborative processes. We use JAT theory as a starting point to studying analytic provenance by documenting how we use language and interactions with artifacts to solve coordination problems in collaborative VA. We do this through use of Pair analytics (PA) [1]. PA generates protocol data about thought processes in collaborative interaction with VA tools. Loosely based on "pair programming" from "extreme programming" software development [10], PA combines a Subject Matter Expert (SME) and a Visual Analytics Expert (VAE). The dyad is given an analytical task, data set, and VA tool(s). The VAE has technical expertise in the use of VA tools, but less domain knowledge. The SME understands the analytic domain, but has less VA knowledge. The pair generates a human-to-human dialog that makes explicit the mental models and cognitive processes of SME and VAE as they coordinate collaborative analysis. The interaction of the dyad with the VA tool generates a human-data dialog in which software models may interact with human mental models -e.g. as visualizations created by the dyad result in unexpected outcomes. Video and screen capture data from PA sessions are analyzed with Joint Action Theory.

We conducted a pilot study in 2009 to test and refine the PA/JAT theory-method with four SMEs in aircraft maintenance engineering and two VAEs from our laboratory. Results from four sessions showed the advantages of PA over "thinking-aloud" protocols [9] or ethnographic methods [13]. PA is non-intrusive, taking advantage of the natural and continuous flow of speech used to coordinate joint action [6]. As a result there was no need for a researcher to prompt participants to keep talking, as in think-aloud protocols. This reduces interference with cognitive task performance. Second, PA provided an entry point to study individual cognitive processes, (e.g. cognitive workload) and social processes (e.g. on-screen coordination gestures for joint actions) in an "in-vivo" setting. Thus PA shares some of the advantages of ethnographic or field-study methods to study cognition in practice.

The pilot study found at least three socio-cognitive phenomena of collaborative VA through JAT analysis [1,2]:

CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.

The pilot study also showed that at least three socio-cognitive phenomena of collaborative visual analytics can be studied by using pair analytics and joint action [1][2]:

(1) Structuring and navigation of joint visual analysis: analysts structure and navigate visual analysis by using vertical and horizontal verbal markers and on-screen gestures. "Vertical markers" are verbal gestures, such as "okay," and "all right," that signal transitions between different analytical tasks. "Horizontal markers," such as "yeah" and "mhmm," on the other hand, are used to signal continuation within a singular analytical task [3]. By using vertical and horizontal markers, analysts create an ad-hoc structure of an analysis and navigate through it in an orderly fashion [1]. Analysts also use interactional strategies, such as "saving-state-of-the-analysis" as vertical markers to signal transitions (and milestones such as insights) between different phases of the analysis.

(2) Management of joint attention: Gaze, finger-pointing and mouse-point are gestures used by the analysts to direct joint attention, when used by a speaker, and to confirm that joint attention is in place, when used by a listener.

(3) Use of "self-talk" with on-screen gesturing to visually inform about progress on the execution of a cognitively demanding task during the visual analysis: Pauses in joint visual analysis were accompanied by "self-talk" of participants on-task: The social substratum of pair analytics demands that participants inform each other about problems that they encounter in their interaction, such as cognitively demanding tasks (e.g. retrieving information from memory, understanding some questions, solving problems, etc) [12]. When facing these challenges, participants delay their responses to the requests from the other participants and resort to the use of fillers, such as "uh," "um," and self-talk to account for longer delays [12]. This is a natural strategy used by people in conversational settings to "save face" [11]. We are currently studying and categorizing "self-talk" occurrences in pair analytics as indicators or cognitive workload.

Details of these socio-cognitive phenomena and processes as well as more details on the method and the theory will be provided during the workshop.

REFERENCES

1. Arias-Hernandez, R., Kaastra, L.T., Green, T.M., and Fisher, B. Pair Analytics: Capturing Reasoning Processes in Collaborative Visual Analytics. In *Proc. HICSS-44*, IEEE Computer Society Press (2011)
2. Arias-Hernandez, R., Kaastra, L.T., and Fisher, B. On-screen Gesturing in Collocated, Collaborative Visual Analytics. Technical Paper, 2010. SCIENCE Lab, Simon Fraser University.
3. Bangerter, A. and Clark, H.H. Navigating joint projects with dialogue. *Cognitive Science*, *27* (2). 195-225.
4. Clark, H.H. Coordinating with each other in a material world. *Discourse studies*, *7* (4-5). 507-525.
5. Clark, H.H. Pointing and placing. Kita, S. ed. *Pointing: Where language, culture, and cognition meet*, Psychology Press, 2003, 243-268.
6. Clark, H.H. *Using language*. Cambridge University Press, Cambridge [England]; New York, 1996.
7. Clark, H.H. and Brennan, S.E. Grounding in communication. Resnick, L.B., Levine, J.M. and Teasley, S.D. eds. *Perspectives on socially shared cognition*, American Psychological Association, Washington, DC, 1991, 127-149.
8. Clark, H.H. and Krych, M.A. Speaking while monitoring addressees for understanding. *Journal of Memory and Language*, *50* (1). 62-81.
9. Ericsson, K.A. and Simon, H.A. *Protocol analysis: Verbal reports as data (Rev. ed.)*. MIT Press, Cambridge, 1993.
10. Gallis, H., Arisholm, E. and Dyba, T., An initial framework for research on pair programming. In *Proc. ESEM*, IEEE Computer Society (2003).
11. Smith, V.L. and Clark, H.H. On the course of answering questions. *Journal of Memory and Language*, *32*. 25-38.
12. Hutchins, E. *Cognition in the Wild*. MIT Press; Cambridge, MA, 1995.