I'VE GOT YOU IN MY SIGHTS: DEVELOPING A NOVEL METHODOLOGY COMBINING COGNITIVE TASK ANALYSIS AND EYE TRACKING

Developing a Novel Methodology Combining Cognitive Task Analysis and Eye Tracking

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Abstract

Video games cognitively challenge players to perform multiple cognitive activities at once. Game researchers and designers need to understand how players are interacting in the game environment, and new methods that provide actionable and focused feedback would provide the greatest benefit. This paper presents an efficient and novel approach (*The Tracer Method*) to address this issue, and describes its initial demonstration. *The Tracer Method* builds upon previous research (using only process tracing methods and static environments) to evaluate the combination of the two Human Factors methodologies, Cognitive Task Analysis (CTA) and Eye Tracking (ET), in a fast-paced first-person shooter: *Overwatch.* Both the CTA method and ET provided a level of validation between the data, however, this overlap was significantly lower than previous research. *The Tracer Method* findings do indicate that integration of the two methods provides new and useful information that either method alone would not be able to elicit.

Extended Abstract

In Human Factors Psychology, there are many methodologies to unpack cognitively complex decision making in dynamic and difficult environments. Cognitive Task Analysis (Crandall et al., 2006) and Eye Tracking (Duchowski, 2002; 2003) are two heavily used methods across many different domains (i.e. military and aviation). Cognitive Task Analysis (CTA) is a set of methodologies used to unpack experts' cognitive processes during complex tasks. Typically, the output of CTA encompasses designing guidelines to decrease errors while increasing performance, and improving training for novices. Very few studies have used CTA in games, and those that have explicitly used process tracing methods to: unpack learning in gameplay (Shute & Kim, 2011) and develop game design requirements (Boyle et al., 2012; Gallagher & Prestwich, 2013). Eye Tracking (ET) is a technique to record and measure eye movements as they interact with elements in an environment or task. Typically, ET measures fixations and saccades across Areas of Interest (AOIs), which have been mostly used to evaluate usability (Duchowski, 2002; Duchowski, 2003; Jacob & Karn, 2003; Poole & Ball, 2006). ET has been used more commonly than CTA in video games, focusing on using ET as input for game control (Leyba & Malcom, 2004) or to evaluate player strategies in game (Alkan & Cagiltay, 2007; Almedia, 2009; Almeida et al., 2011, El-Nasr & Yan, 2006; Renshaw et al., 2009). Some research has investigated the combination of the two, and none have investigated them in the context of a video game (Cooke & Cuddihy, 2005; Cooke, 2010; Elling et al., 2011; Elling et al., 2012; Rhenius

& Deffner, 1990). Previous research has focused on process tracing methods (e.g. concurrent verbal protocol) and static tasks (e.g. navigating a website). Cooke (1994) articulates that these previously used methodologies (e.g. process tracing) are unable to capture all of the knowledge associated with completing a task or making a decision. The information that they do capture may not even be actionable. To date, there has been no research investigating any other Cognitive Task Analysis method (i.e. Critical Decision Method) and Eye Tracking, thus, this would be the first study to do so.

The goal of this paper is to describe *The Tracer Method*, a novel methodology combining Cognitive Task Analysis and Eye Tracking that addresses previous limitations (Cooke, 1994; Elling et al., 2011; 2012) while expanding the focus to investigating new information, and exploring new application areas to: informing game design and eSports. To evaluate *The Tracer Method*, we evaluated the overlapping, different, and new information elicited from Overwatch. Overwatch was chosen as the first demonstration environment for several reasons: 1. The complexity mirrors real world, 2. There are interdependent teammates, 3. Cognitively difficult tasks with various pressures occur throughout the game, and 4. The game exhibits qualities of Naturalistic Decision Making (Zsambok & Klein, 2014).

Seventeen experienced Overwatch players with at least 50 hours of playtime participated in the study. The study involved two sessions. In the first session we interviewed participants about general Overwatch strategies using two CTA techniques: Task Diagram and Critical Decision Method. In the second session, participants played 1-2 games of Overwatch while having their eye movements tracked. After the games, participants were interviewed regarding one of the games they had just played, using Critical Decision Method (Hoffman et al., 1998; Klein et al., 1989). The CDM data (decisions, cues, and courses of action) were coded using both top down and bottom up techniques. The ET data involved overlaying AOIs based on the Overwatch UI, segmenting out each 20 second decision window (10 seconds before and 10 seconds after decision), and coding 1,766 fixations on the reticle. Finally, *The Tracer Method* involved coding cues for mappability (ET), if the cues were confirmed with ET, and any cues that were not reported in the CDM but were fixated on in the ET data.

Using this new method, we found an overlapping percentage of 35-59%, compared to previous research having between 77-98% overlapping information (Cooke, 2010, Rhenius & Deffner, 1990). We also found new information using this technique: 1. 96 potentially valid bottom up cues from ET (within decision window), 2. Common transitions between areas of interest that relate to task diagram output, 3. Reticle fixation cues distributed across decision types, and 4. AOI centrality that related to specific viewing patterns. The findings from each individual submethod (CDM and ET) found consistent results with past research from other domains (e.g. 39 critical decisions compared to 33 from Crandall & Getchell-Reiter, 1993). With eye tracking, it was not surprising that in *Overwatch*, a FPS, the majority of fixations occurred in the reticle area. However, *The Tracer Method* was able to tease apart the individual fixations and determine the type of information that was being elicited. The method was also able to demonstrate the range of decisions and cognitive activities that occur in a FPS game, which on the surface seems reactive. There has been no past research on gaze/visit patterns on Overwatch.

Overall, *The Tracer Method* combines two methodologies that provide important independent insight. CTA provides understanding of game sense or expertise knowledge/cues, while ET provides behavioral data based on a participant's interaction with the environment. Combined, these methods support each other: CTA providing context and focus and ET providing validation and scope. This study builds off of past research by investigating a highly dynamic and complex environment (past: website vs. current: video game), using a different CTA technique, and investigating both different and new information instead of focusing on overlapping information. For game design, this methodology could be very useful in several ways: evaluating user interfaces in less time (focusing on 40-80 seconds of gameplay vs. 30 minutes), providing useful information across different game versions (e.g. conceptual to alpha), and understand how players are using the game environment (via "cognitive playtest"). For eSport training, the output can help develop scenarios to allow players to train on specific valid cues or types of decisions. It can also help develop decision making measures to evaluate and recruit individual players (e.g. Wagner, 2006). Finally, it can help train "novices" or new teammates to understand and gauge the flow of the specific team.

The Tracer Method is the first documentation of a combined methodology using CDM, and exploring within the context of a video game. This method is efficient, flexible, and focused to the specific problem or goal. We are not the first to suggest the compatibility of these methods (Rhenius & Deffner, 1990), but we are the first to fully expand upon the added value. The alliance of these methods is fully supported, however, more research is needed to evaluate and further develop *The Tracer Method*. The world could always use more METHODS!

References

Alkan, S., & Cagiltay, K. (2007). Studying computer game learning experience through eye tracking. British Journal of Educational Technology, 38(3), 538-542.

Almeida, S. de J. (2009). Augmenting video game development with eye movement analysis. (Master's thesis, Universidade de Aveiro).

Almeida, S., Veloso, A., Roque, L., & Mealha, O. (2011). The eyes and games: A survey of visual attention and eye tracking input in video games. Proceedings of the SBGames, 1–10.

Boyle, E., Van Rosmalen, P., MacArthur, E., Connolly, T., Hainey, T., Johnston, B., Pennanen, T. (2012). Cognitive task analysis (CTA) in the continuing/higher education methods using games (CHERMUG) Project. In Proceedings of the 6th European Conference on Games Based Learning: ECGBL (p. 63). Academic Conferences Limited.

Calderwood, R., Crandall, B. W., & Klein, G. A. (1987). Expert and novice fire ground command decisions (No. KA-TR-858 (D)-87-03F). KLEIN ASSOCIATES INC YELLOW SPRINGS OH.

Cooke, L. (2010). Assessing concurrent think-aloud protocol as a usability test method: A technical communication approach. IEEE Transactions on Professional Communication, 53(3), 202-215.

Cooke, N. J. (1994). Varieties of knowledge elicitation techniques. International Journal of Human-Computer Studies, 41(6), 801–849.

Cooke, L., & Cuddihy, E. (2005, July). Using eye tracking to address limitations in think-aloud protocol. In Professional Communication Conference, 2005. IPCC 2005. Proceedings. International (pp. 653-658). IEEE.

Crandall, B., & Getchell-Reiter, K. (1993). Critical decision method: a technique for eliciting concrete assessment indicators from the intuition of NICU nurses. Advances in Nursing Science, 16(1), 42-51.

Crandall, B., Klein, G. A., & Hoffman, R. R. (2006). Working minds: A practitioner's guide to cognitive task analysis. Mit Press.

Duchowski, A. T. (2002). A breadth-first survey of eye-tracking applications. Behavior Research Methods, Instruments, & Computers, 34(4), 455–470.

Duchowski, A. T. (2003). Eye tracking methodology. Theory and Practice, 328.

Elling, S., Lentz, L., & De Jong, M. (2012). Combining concurrent think-aloud protocols and eye-tracking observations: An analysis of verbalizations and silences. IEEE Transactions on Professional Communication, 55(3), 206–220.

Elling, S., Lentz, L., & de Jong, M. (2011, May). Retrospective think-aloud method: Using eye movements as an extra cue for participants' verbalizations. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 1161-1170). ACM

El-Nasr, M. S., & Yan, S. (2006). Visual attention in 3D video games. In Proceedings of the 2006 ACM SIGCHI international conference on Advances in computer entertainment technology (p. 22). ACM.

Gallagher, P. S., & Prestwich, S. (2013). Cognitive Task Analysis: Analyzing the Cognition of Gameplay and Game Design. Paper presented at Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC). Orlando, FL.

Hoffman, R. R., Crandall, B., & Shadbolt, N. (1998). Use of the critical decision method to elicit expert knowledge: A case study in the methodology of cognitive task analysis. Human Factors, 40(2), 254–276.

Jacob, R. J., & Karn, K. S. (2003). Eye tracking in human-computer interaction and usability research: Ready to deliver the promises. Mind, 2(3), 4.

Klein, G. A., Calderwood, R., & Macgregor, D. (1989). Critical Decision Method for Eliciting Knowledge. Retrieved from http://services.lib.mtu.edu:2188/stamp/stamp.jsp?arnumber=31053

Leyba, J., & Malcolm, J. (2004). Eye tracking as an aiming device in a computer game. Course Work (CPSC 412/612 Eye Tracking Methodology and Applications by A. Duchowski), Clemson University, 14.

Overwatch. (2016) [Video Game]. Irvine, California: Blizzard Entertainment

Poole, A., & Ball, L. J. (2006). Eye tracking in HCI and usability research. In C. Ghaoui (Ed.), Encyclopedia of human-computer interaction.. (pp. 211-219). Pennsylvania: Idea Group Inc.

Renshaw, T., Stevens, R., & Denton, P. D. (2009). Towards understanding engagement in games: An eye-tracking study. On the Horizon, 17(4), 408–420.

Rhenius, D., & Deffner, G. (1990, October). Evaluation of concurrent thinking aloud using eye-tracking data. In Proceedings of the human factors society annual meeting(Vol. 34, No. 17, pp. 1265-1269). Sage CA: Los Angeles, CA: SAGE Publications.

Shute, V. J., & Kim, Y. J. (2011). Does playing the World of Goo facilitate learning. Design Research on Learning and Thinking in Educational Settings: Enhancing Intellectual Growth and Functioning, 359–387.

Wagner, M. G. (2006, June). On the Scientific Relevance of eSports. In *International Conference on Internet Computing* (pp. 437-442).

Zsambok, C. E., & Klein, G. (Eds.). (2014). Naturalistic decision making. Psychology Press.