Hyperscanning Reveals Trustworthy Man-Machine Teaming

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Abstract — Hyperscanning is a social neuroscience methodology by which multiple individuals can interact with one another while their brains are simultaneously scanned. Hyperscanning technology permits the study of the brain that underlie social interactions. The hypothesis states [1] that interpersonal interactions between people involve brain activity that is not seen during non-interactive, isolated behavior. At its center is the understanding that human-to-human interactions evoke unique responses in our brains. If these responses are synchronized, then performance increases. It has been found in Hyperscanning studies that classification of human trust, cooperation, coordination and leadership is possible, in some cases even under high threat situations. This methodology is put forward to study human to human and human to machine harmonization and interactions. The take away for the ITEC audience is that understanding social interactions between humans may be the prerequisite for developing and enhancing true trustworthy man-machine teaming.

1 Introduction and background

We are at the beginning of a new technical (r)evolution towards systems with autonomous functions. Based on AI, machine learning and deep learning frameworks and techniques the technical and operational potential is considerable. In space, air, land, maritime, cyber domains autonomous functions are envisioned a key technology in operational theatres [2]. The roadmap towards full autonomy faces many challenges. A step-wise implementation expects to see changes in human interactions with systems that evolve with increasing autonomous functions. From human-in-the-loop to human-on-the-loop, and finally human-out-of-the-loop across a variety of military tasks.

Man-machine harmonization and teaming is becoming a challenge in itself. From both a system and human factors perspective concepts such as trust, cooperation, coordination and even leadership between man and machines will become more important than ever. Do human ‘operators’ trust systems that make decisions on their own, do we allocate specific tasks to systems because they may do a more efficient job, who leads, follows, coordinates subsequent activities and tasks? And vice versa, do systems trust humans regarding their (moral)judgment and decision-making capabilities, which may be characterized by various perceptual and cognitive biases [3]? We suggest that human performance envelop constructs such as trust, cooperation, coordination and leadership should be viewed from both the system and human perspective.

In this work in progress paper we focus on human behavior analytics since it becomes important to have a clear understanding in human behaviors during interactions with systems with incremental autonomous functions. Most man-machine studies focus on a single operator interacting with a system [4]. We are interested in teams that operate and interact in time-critical situations in particular in command and control settings.

2 Technical Approach and methods

One may examine and quantify concepts of mutual trust, cooperation, coordination, and leadership in various (combined) ways. For example, using qualitative studies e.g. introspective interviews or semi-structured questionnaires and/or analyzing observable behavioral metrics. We have an interest to look at the potential of examining neural activities and relate those to performance metrics. Hyperscanning technology permits the study of the brain that underlie social interactions. Hyperscanning is a method by which multiple individuals can interact with one another while their brains are simultaneously scanned. The hypothesis states that interpersonal mutual interactions between people involve brain activity that is not seen during non-interactive, isolated behavior [5]. At its center is the understanding that human-to-human interactions may evoke unique synchronized responses in our brains. Interestingly, these responses have not been reported during human-system interactions. On the other hand, it is assumed that human to human interaction is likely to be comparable to human-computer interaction. Here its argued that systems that team with humans need to provoke certain type of responses to synchronize. The reason is simple, namely entities ‘in sync’ perform better [6]. Several hyperscanning architectures have been employed using EEG, fMRI and fNIRS brain activity recordings. To qualify and quantify inter-brain coupling for hyperscanning studies various analyzing techniques are

used viz. correlation analysis, coherence analysis, Granger causality modelling, graph models, including Graph theory [7, 8].

3 Innovations, research findings, etc

It has been found in hyperscanning studies that classification of human trust [9], cooperation, coordination and leadership is possible, in some cases even under high threat situations. For example, inter-brain activity coherence was found between participants that indicated better cooperation performance. [10]. Second, looking at interpersonal neural synchronization (INS) of gamma band oscillations it was that found that INS was enhanced when people are under high threat; increased gamma interbrain synchrony is associated with higher coordination [11]. Third, it has been shown that INS is significantly higher between leaders and followers than between followers and followers, suggesting that leaders emerge by synchronizing their brain activity with that of the followers [12].

4 Lessons learned

Over the last decade the hyperscanning methodology showed to be a valuable paradigm to study social cognition. However, nearly all studies are performed in academic labs where controlled environments are key. Most of these studies is with dyads (2 persons mutually interacting). Notably hyperscanning fNIRS allows for investigations to examine brain activity in natural settings thereby increasing its applicability. We have planned series of experimental studies to examine the applicability of the hyperscanning approach in the military domain in more natural settings. We concentrate on teams of 2, 4, 8 people in interacting with systems that are assumed to evolve in autonomous functions. In particular, we take command and control environments as use cases.

5 Conclusions

This work in progress paper suggest a methodological framework to study team performance based on hyperscanning brain activity studies. We focus on psychological constructs such as trust, cooperation, coordination and leadership. We will examine human to human interactions as well as human to system interactions focusing on teams. In sum, we argue that understanding how humans synchronize may be the prerequisite for developing and enhancing true trustworthy man-machine teaming solutions.

References

[1] Hirsch, J. (2018). Two brain neuroscience: understanding our social selves. http://fmri.org/wp-content/uploads/2018/04/Professor-Joy-Hirsch-Yale-School-of-Medicine-Neuroscience-1.pdf

[2] European Defence Agency (2018) Remote Defence: Unmanned and autonomous systems take hold in military toolboxes. EDM European Defence Matters, Issue #16.

[3] Kahneman, D. (2011). Thinking, Fast and Slow. Macmillan. ISBN 978-1-4299-6935-2.

[4] https://man-machine-teaming.com

[5] Hirsch, J. (2017). The grand challenge to understand the brain: neuroimaging by functional near-infrared spectroscopy. In *Shimadzu Journal*, Volume 5, Issue 1. https://www.ssi.shimadzu.com/sites/ssi.shimadzu.com/files/Products/literature/Life_science/fnirs-article.pdf

[6] Szymanski, C. Pesquita, A., Brennan, A., Perdikis, D., Enns, J. Brick, T., Muller, V. Lindenberger, U. (2017). Teams on the same wavelength perform better: Inter-brain phase synchronization constitutes a neural substrate for social facilitation. Neuroimage, 152 (12017), 425-436.

[7] Duan, L., Dai, R., Xiao, X., Sun, P., Li, Z. and Zhu, C. (2015). Cluster imaging of multi-brain networks (CIMBN): a general framework for hyperscanning and modeling a group of interacting brains. Frontiers in neuroscience, Technology report published: 28 July 2015 doi: 10.3389/fnins.2015.00267.

[8] De Vico, F., Fallani, Richiardi, J., Chavez, M., Achard, S. (2014). Graph analysis of functional brain networks: practical issues in translational neuroscience. Published 1 September 2014. DOI: 10.1098/rstb.2013.0521.

[9] Akash, K., Hu, W., Jain, N., and Reid, T. (2018). A classification model for sensing human trust in machines using EEG and GSR. ACM Transactions on Interactive Intelligent Systems, Volume 8 Issue 4, November 2018 Article No. 27.

[10] Cui, X, Bryant, D.M., & Reiss, A.L. (2012). NIRS-based hyperscanning reveals increased interpersonal coherence in superior frontal cortex during cooperation. Neuroimage, 59 (3), 2430-2437. 2 Mu,

[11] Y., Han,S. & Gelfand, M.J. (2017). The role of gamma interbrain synchrony in social coordination when humans face territorial threats. Social Cognitive and Affective Neuroscience, 2017, 1614-1623.

[12] Jiang, J. Chen, C.Dai, B, Shi, G., Ding, G. , Liu, L. & Lu, C. (2015). Leader emergence through interpersonal neural synchronization. Proceedings of the National Academy of Sciences, 112 (14), 4274-4279.

Author/Speaker Biographies

Johan de Heer (PhD) directs the Thales Research & Technology organization in Hengelo. Focus is on Brain Computer Interface technologies, in particular understanding the value of bidirectional BCIs. bBCIs providing two-way communication and influence

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