AFRL-RH-WP-TP-2015-0028

HUMAN-MACHINE TEAMS: THE SOCIAL FRONTIER (Briefing Charts)

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December 2015
Interim Report

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NOTICE AND SIGNATURE PAGE

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
07-12-15	Interim	30 Jan-31 Aug 2015

4. TITLE AND SUBTITLE
Human-Machine Teams: The Social Frontier (Briefing Charts)

5a. CONTRACT NUMBER
In-House

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Charlene Stokes-Schwartz, Ph.D.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
H0FY (5328S010)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
In-house, 711 HPW/RHXS

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Materiel Command
Air Force Research Laboratory
711th Human Performance Wing
Human Effectiveness Directorate
Human Centered ISR Division
Human Trust & Interaction Branch
Wright-Patterson Air Force Base, OH 45433

10. SPONSORING/MONITORING AGENCY ACRONYM(S)
711 HPW/RHXS

11. SPONSORING/MONITORING AGENCY REPORT NUMBER(S)
AFRL-RH-WP-TP-2015-0028

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution A. Approved for public release.

13. SUPPLEMENTARY NOTES
88ABW-2015-6261; Cleared 31 December 2015

14. ABSTRACT
This interim report summarizes the program road map, experimental studies, and preliminary data analysis results to date. Several intriguing empirical findings have been generated thus far, indicating that implicit social dynamics of human-machine teams (HMT) can be explicitly shaped during training, resulting in a significant impact on machine trust, reliance, bonding/cohesion, and perceived ability to cope with stress during a simulated ISR task. Such social dynamics (e.g., climate management) can be shaped with minimal design investment, and minimal user cognitive resource requirement as the effects are largely implicit.

15. SUBJECT TERMS
human-machine teams

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT:	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON (Monitor)
U	U	U	SAR	35	Charlene Stokes-Schwartz, Ph.D.
					19b. TELEPHONE NUMBER *(Include Area Code)*

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18

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Human-Machine Teams: The Social Frontier

American Psychological Association (APA) Convention
Toronto, Canada
7 August 2015

Charlene Stokes, Ph.D.
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Overview

Objective: Improve calibrated trust and optimal reliance on autonomous systems through a deeper understanding of the inherent *social cognitive underpinnings* of Human-Machine Teams (HMT).

Approach: Empirical studies fusing social psychology and team research and theory in an HMT context – lab and applied studies.

Impact: The largely unconscious, social-emotional aspects of interaction have been relatively neglected, leaving a wide and critical gap in our understanding of HMT.

> This understanding has tremendous potential for HMT success, as future interactions will increasingly include features of social exchange relationships where trust, affect, and other social factors are even more relevant than before (Lee,2012).

Accomplishments: Establishment of multimodal HMT research laboratory as an AFRL resource housed at Yale University, Phase 1 data collection complete.

NOTES

- **Uniqueness/Impact: Incorporation of social psychological processes/theory and team research/understanding for optimization of autonomy/HMT.**
- **Traditional focus is on the "Intelligent Machine" with assumption that a "capable" tool with efficient & intuitive interface will be accepted/trusted.**
- **The increased intelligence/autonomy of future systems inevitably leads to increased social interaction capability, which demands greater attention to a "social cognitive" approach that views cognition and social-emotional systems as an inseparable whole.**
- **Air Force Application: Novel training paradigms and interface design guidelines.**
- **Wide application potential in that calibrated trust and appropriate reliance is critical for all autonomous systems.**
- **"The single greatest theme to emerge from Technology Horizons (2010) is the need [for]….far greater use of autonomous systems in essentially all aspects of Air Force operations…Achieving these gains will depend on development of entirely new methods for enabling trust in autonomy."**
- **Future human-machine interactions are more likely to include features of social exchange relationships where trust is even more relevant than before (Lee, 2012).**

AF Relevance

- **“The single greatest theme to emerge from “*Technology Horizons*” is the need [for]….far greater use of autonomous systems in essentially all aspects of Air Force *operations…Achieving these gains will depend on development of entirely new methods for enabling “trust in autonomy”*** *(Technology Horizons, 2010).*

- **AFRL HMT Goals** *(Overholt & Kearns, 2013)***:**
  - **Calibrated trust, common understanding, shared perception, flexible decision-making.**

Research objective: Improve calibrated trust and appropriate reliance on autonomous systems through a deeper understanding of the inherent *social cognitive underpinnings* of HMT.

DoD Relevance

Addresses Technical Challenges called out in:

- ***Human Systems Priority Steering Council (PSC):*** HMT, Adaptive Aiding, Intuitive Interaction for future interface design.
- ***Autonomy PSC*:** Natural, cognitively compatible, and effective multi-modal interactions between humans and autonomous systems for rapid coordination and collaboration.
- ***Data-to-Decisions PSC*:** Given massive amounts of data from sensor and open-source assets (ISR human-centric problem), interface tools must detect and proactively respond to the users information needs.

Definitions

- **Team:** "A distinguishable set of two or more people/agents who interact dynamically, interdependently, and adaptively toward a common and valued goal/object/mission, who have each been assigned specific roles or functions to perform" *(Salas et al., 1992).*

- **Trust:** Willingness to be vulnerable to the actions of another based on positive expectations *(Mayer et al., 1995).*

- **Trust Calibration:** Achieved when users' subjective trust match the objective automation reliability *(Parasuraman, & Galster, 2013).*

- **Emotion:** Valenced state of cognitive appraisals used in an automating and biologically mediated effort to impose meaning on a perceived situation and aid in judgment an decision-making *(Lerner et al., 2014).*

- **Emotional Literacy/Intelligence:** The capacity to reason about emotions (in self and others) and use emotional information to guide thinking and behavior *(e.g., Mayer, Salovey, & Caruso, 1997).*

- **Social Cognition:** Cognition of social objects such as people, relations, groups, and the self *(Fiske & Taylor, 1991; Malle, 2003; Schneider, 1991).* General cognitive structures do not easily identify or distinguish social objects from non-social objects *(Malle, 2003)*.

NOTES

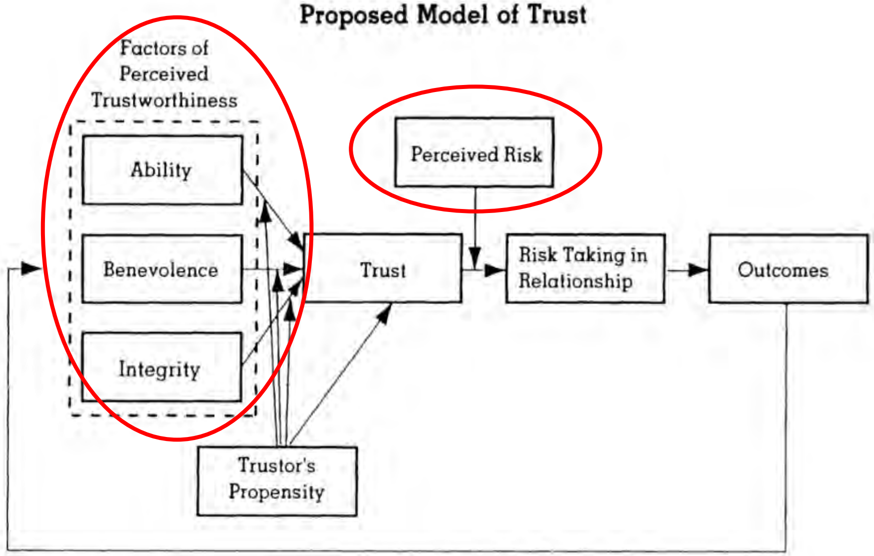
- HRI Paper: Emotion, on the other hand, is a conscious valenced state of cognitive appraisals directed at a specific object in an automating and biologically mediated effort to impose meaning on the currently perceived situation [26, 34, 46]. Lerner and colleagues [34] further distinguish between integral and incidental emotions, where integral emotions arise from the situation or decision at hand, and incidental emotions affecting the situation through carryover. The carryover associated with incidental emotions is largely unconscious. Lastly, mood is a generalized background feeling of longer duration and lower intensity that is not directed at a specific target. However, mood can operate as a filter or disposition toward particular emotions [21].

- Research has linked emotion and cognition, operationalized as judgment and decision-making, through the appraisal process (see [14], for a historical review). Appraisals are direct, immediate, and intuitive evaluations of the environment that result in action tendencies [14]. Emotions play an integral role: appraisals are triggered to account for qualitative distinctions in emotions, and the resulting action tendencies are experienced as emotions.

- [34] Lerner, J. S., Valdesolo, P., and Kassam, K. 2014. Emotion and decision making. Annu. Rev. Psychol., 66:33, 1-33.

Trust Models

FIGURE 1
Proposed Model of Trust



Mayer et al. (1995)
- Organizational lit.
- Most heavily supported

<u>Emotion/affect at play:</u>

*automatic, unconscious, impose meaning, and influence judgement decision-making

Lee & See (2001)
- Trust in Automation
- Control Theory

Emotion/affective climate management opportunity

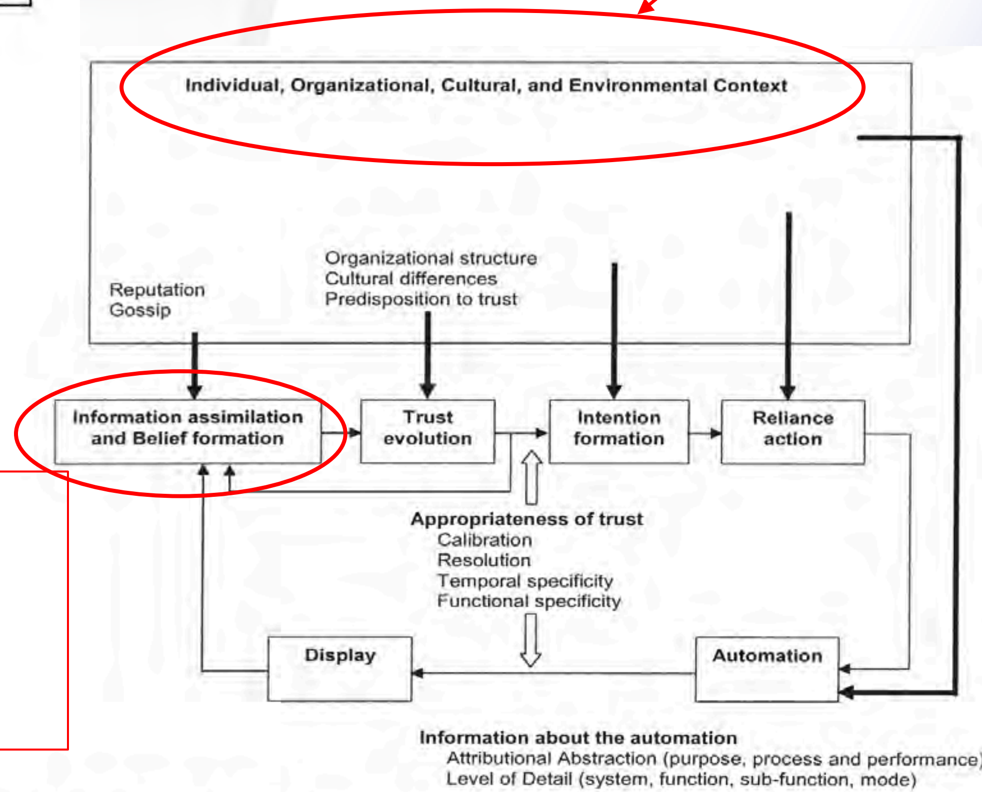
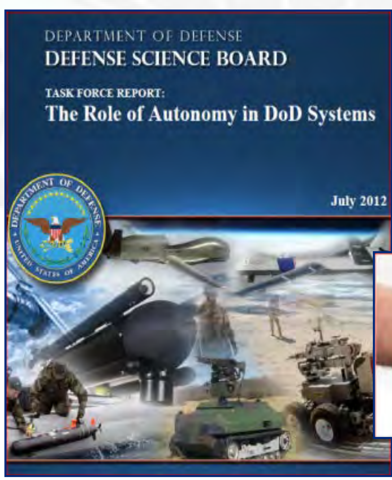


Figure 1. The interaction of context, agent characteristics, and cognitive properties with the appropriateness of tru

Teaming Skills for HMT

Team Skills: Social-emotional nontechnical skills that promote communication and team effectiveness.

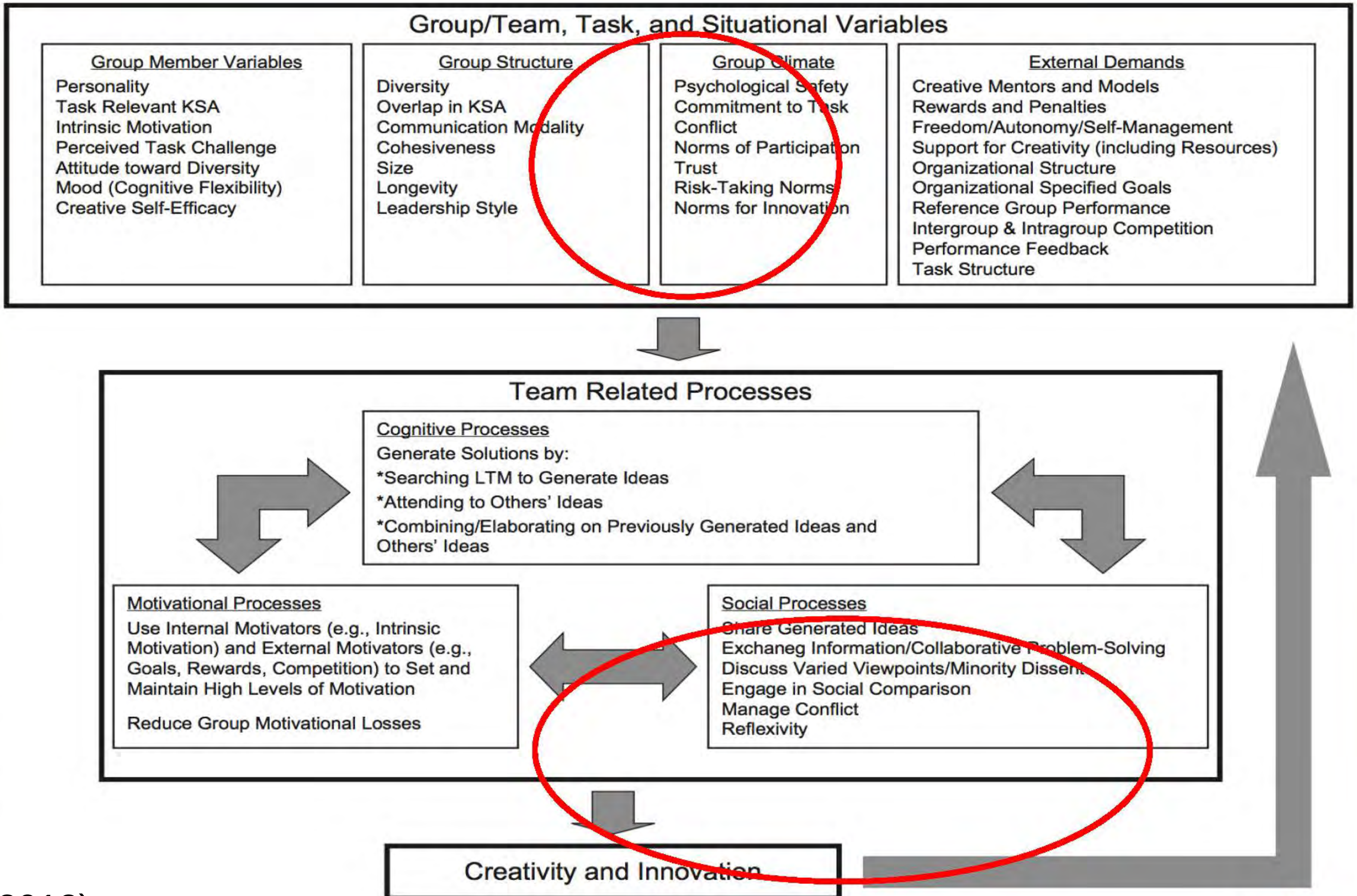
- **Fundamental aspect of human teams…absent in autonomy.**
- **Promote psychological safety, conflict resolution, cohesion, trust, and task focus** *(Paulus, Dzindolet, & Kohn, 2012).*
- **Fostered through collective learning (joint training) to including team building exercises and ongoing performance feedback on individual and group goals** *(Cannon-Bowers, Salas, Tannenbaum, & Mathieu, 1995. Kozlowski & Ilgen, 2006).*



"For the operator, autonomy is experienced as human-machine collaboration, which is often overlooked during design."

Hancock et al. suggest that training methods should be employed in human-machine systems to “adequately prepare an individual for the coming interaction” (p. 525 [22]). The ‘partners’ must be introduced and get acquainted, possibly through team building exercises. Team building is one of the most effective group development interventions in organizations and sports [6, 7]. There is a strong social emotional component to team building. Targeted social emotional learning (SEL) programs have a rich history in the education domain [28]. Findings have shown SEL to improve academic performance, social interactions, classroom behavior, mental and physical health, and lifelong effectiveness [4]. Thus, beyond the task or hard skill aspects, team-oriented training (in any domain) should include soft skill elements such as fostering a team culture, establishing means of communication, development of respect and transparency, and development of shared mental models [3, 4, 7, 9, 22]. Mention of such factors is largely absent in HCI and related fields, and to our knowledge, no empirical investigations exist.

Human Team IPO Model



Team Effectiveness*

Paulus et al. (2012)
*modified

NOTES

- **Innovative teams critical given complexity of today's societal, scientific, and technical problems**
  - **Role of conflict and diversity unique to innovative teams.**
  - ****Analyst Subject Matter Expert (SME (Valarie) customizing tools end up being so much work to understand (include operational perspective)**
  - **Considerable evidence exists on the benefits of team training and team building on human performance [6, 7]. However, in a human-machine system context, the benefits may be multiplicative. On the human side, beyond the necessary skill development, added benefits of team building may include: fostering a team culture, establishing means and preferences of communication, development of respect and transparency to include setting the emotional climate, and development of shared mental models (real or perceived). As discussed throughout this paper, such social and affect-laden factors have implications (direct and indirect; explicit and implicit) for the effectiveness of the human-machine system. For example, the occurrence of conflict or disagreement between humans and automated aids is a robust predictor of disruption or failure in the human-machine system [8, 42]. Conflict is also a major player in human team models, and team building or soft skill development the primary mitigation strategy [7, 43].**

- **On the machine side, training programs provide**

  - **increased opportunities for an intelligent system to learn and adapt to its user, and for customization by the user. Leveraging such social learning mechanisms, common to developmental psychology, offers a more efficient (and possibly necessary) way to build adaptable machines. As the machines acquire new knowledge autonomously, they “become increasingly more complex and capable without requiring additional effort from human designers.” This iterative design strategy often improves human-machine system effectiveness [16]. It can be assumed, but remains to be tested, that the increased effectiveness is in part attributable to increased feelings (primarily implicit) of acceptance, trust, cohesion, transparency, and reduced feelings of conflict, competition, rejection, and the list goes on.**

HMT: Notional Representation

(Stone/Overholt, 2012; Kearns, 2015)

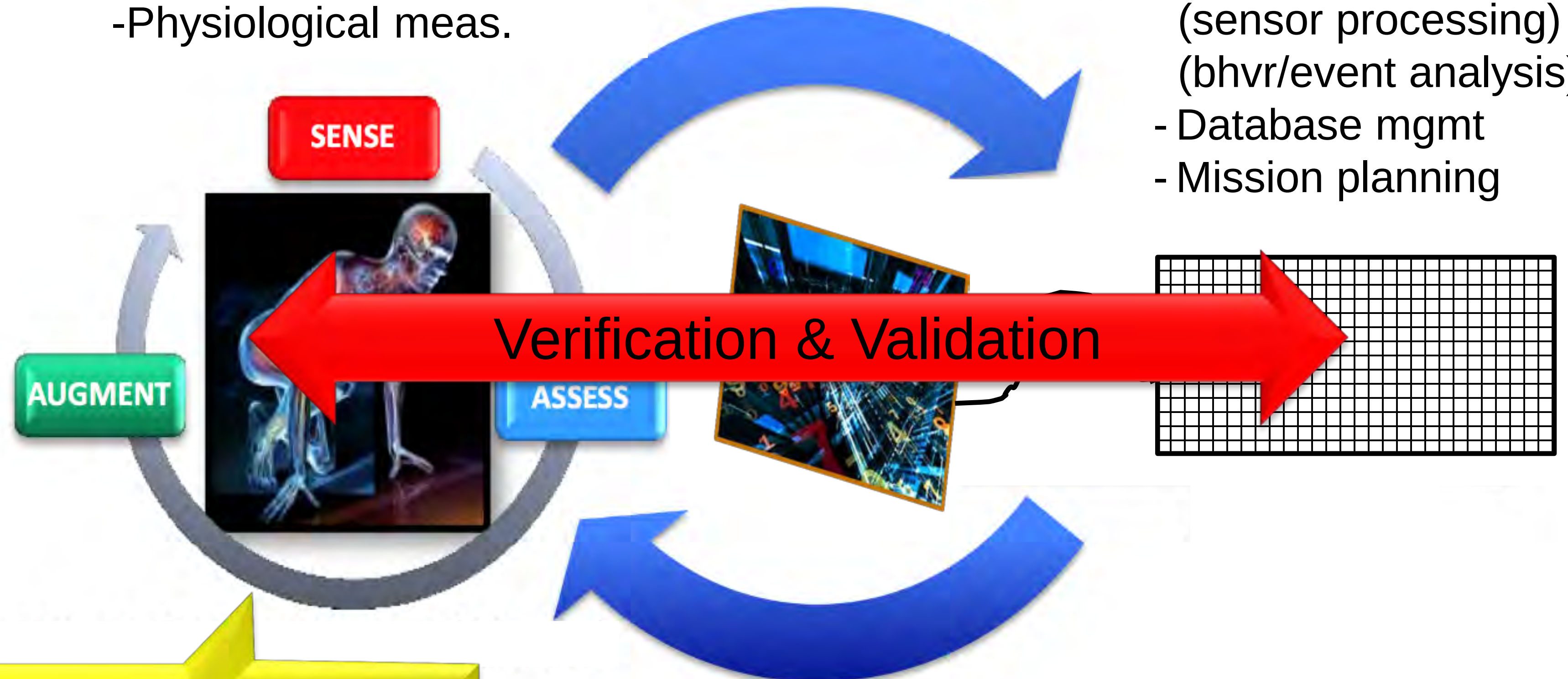
Human State Sensing

-Task performance

-Physiological meas.

Intelligent Machine

- Event monitoring
  (sensor processing)
  (bhvr/event analysis)
- Database mgmt
- Mission planning



Social processes & team dynamics critical:

- **Trust & affect/emotion**
- **Team training**
- **Climate mgmt**

Human-Machine Translator

- Cognitively/socioemotionally compatible
- Common/team understanding
- Natural interface
- Control

- **This HMT Notional Representation is a blending of Stone/Overholt's (2012) model of human and machine control loops and Kris Kearns' (2015) notional representation of HMT.**
  - **The Yellow box highlights my contribution/research focus.**
- **Novel aspect: Incorporation of social processes and team research/understanding for optimization of autonomy/HMT.**
  - **Traditional focus is on the "Intelligent Machine" with assumption that a "capable" tool with efficient & intuitive interface will be accepted/trusted.**
  - **The increased intelligence/autonomy of future systems inevitably leads to increased social interaction capability, which demands greater attention to a "social cognitive" approach that views cognition and social-emotional systems as an inseparable whole.**
  - **Establish emotional climate (team bonding) during training in order to facilitate trust and augmentation in operation.**
    - **Hancock et al. suggest that training methods should be employed in human-machine systems to "adequately prepare an individual for the coming [social] interaction" (p. 525 [22]).**

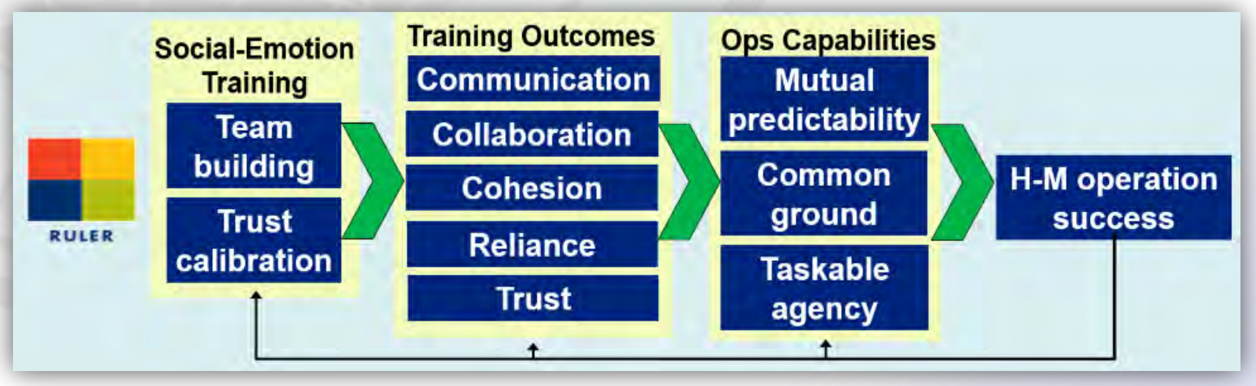
➢ **Quantified self/warrior and technology advances moving us closer.**

➢ **but…how will users feel about being so intimately connected to a machine?**

➢ **How should that *unique relationship* be developed and managed?**

Targeting Social/Team Dynamics: Training Focus

- **<u>Human team analogy</u>: Foster team skills during training to calibrate trust and develop mutual awareness – *capitalize on human social nature*.**
  - **Empathetic social support in a robotic agent improved subject motivation and performance (Saerbeck et al. 2010).**
  - **Minimal cueing of social norms/categories predicts attitudinal/behavioral responses in relation to computers (Nass et al.): Trustworthiness[1], Perceived intelligence[1,2], Reliance/compliance[2], Self-disclosure[4], Reciprocation (+/-)[3], Persuasiveness[1], Performance[5], Positive Affect[5]**
- **<u>RULER</u>: Evidence-based social-emotional training paradigm that develops social cognitive skills to improve self-awareness, wellbeing and interpersonal interactions.**



<u>References:</u>

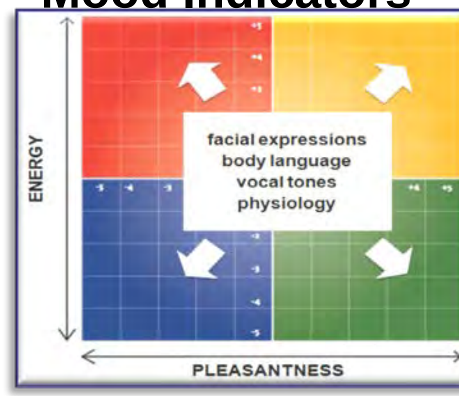
[1] Nass, Isbister, & Lee (2000); [2] Nass, Fogg & Moon (1996); [3] Fogg & Nass, (1997)[a]; [4] Moon (2000); [5] Fogg & Nass (1997)[b]

The RULER Approach

<u>Emotional literacy</u>: one's attitudes, knowledge, and expertise in applying five key emotion skills:

<u>R</u>ecognizing
<u>U</u>nderstanding
<u>L</u>abeling
<u>E</u>xpressing
<u>R</u>egulating

Mood Indicators



Team Model (Paulus et al., 2012): Addresses several of the input and process variables that have been shown to contribute to team effectiveness.

<u>Improves:</u>

- Engagement
- Performance
- Teamwork
- Job satisfaction
- Leadership skills
- Empathy
- Well-being
- Prosocial behavior

<u>Mitigates:</u>

- Stress
- Burnout
- Anxiety
- Aggression
- Depression
- Substance abuse
- Attention problems

Longitudinal and cross-sectional findings (Brackett, 2013)

NOTES

- **Quadrant is a self-report tool for emotion/mood, but many indicators of mood.**
- **RULER approach: skill-based approach to social emotional learning.**
  - **Used for all ages (pre-K to CEOs) to develop the skills needed to build better relationships and enable better decision making.**
  - **Develops social, emotional, and cognitive skills**
  - **Proactive versus reactive strategies**
  - **Enduring skills / lasting results**

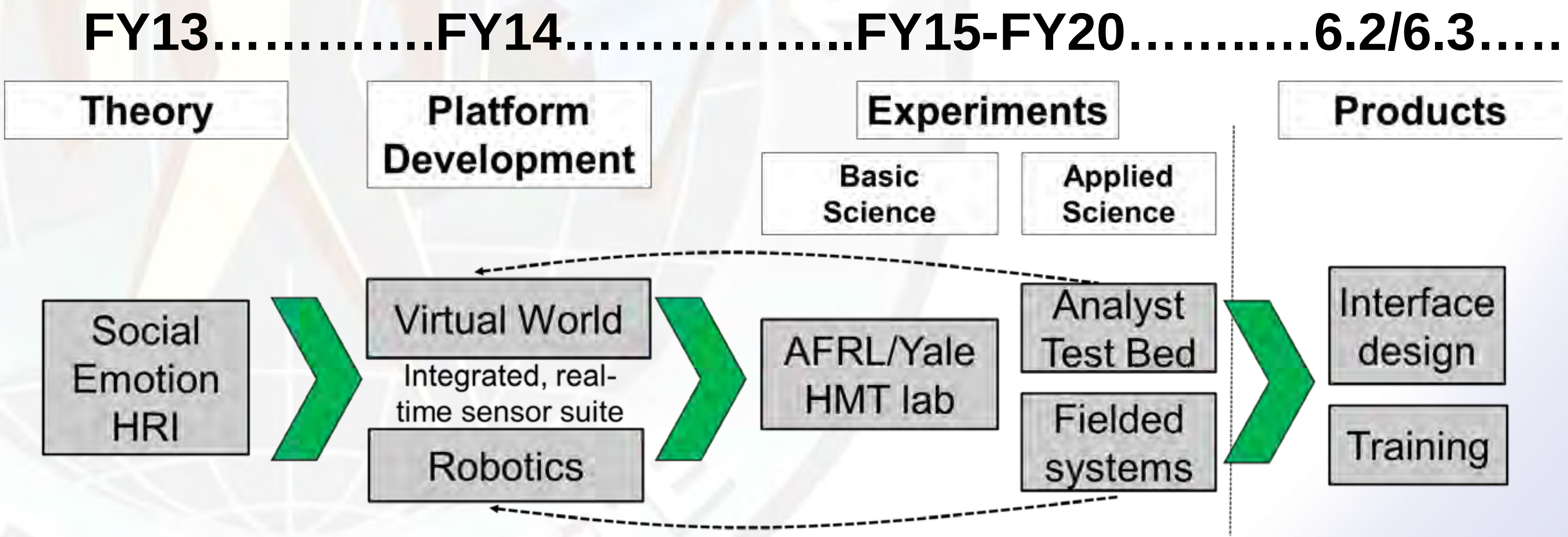
RULER Anchor Tools

1. **Charter** - Building culture and climate.
2. **Mood Meter** - Building self- and social-awareness.
3. **Meta Moment** - Building emotion regulation skills.
4. **Blueprint** - Building empathy and perspective taking.

Application in HMT

- Resonates with team building / non-technical skills, climate management, establishment of social norms.
- Approach affords an excellent training opportunity.
- Implementation/training is context specific.

HMT Program Road Map



Multiple studies including:

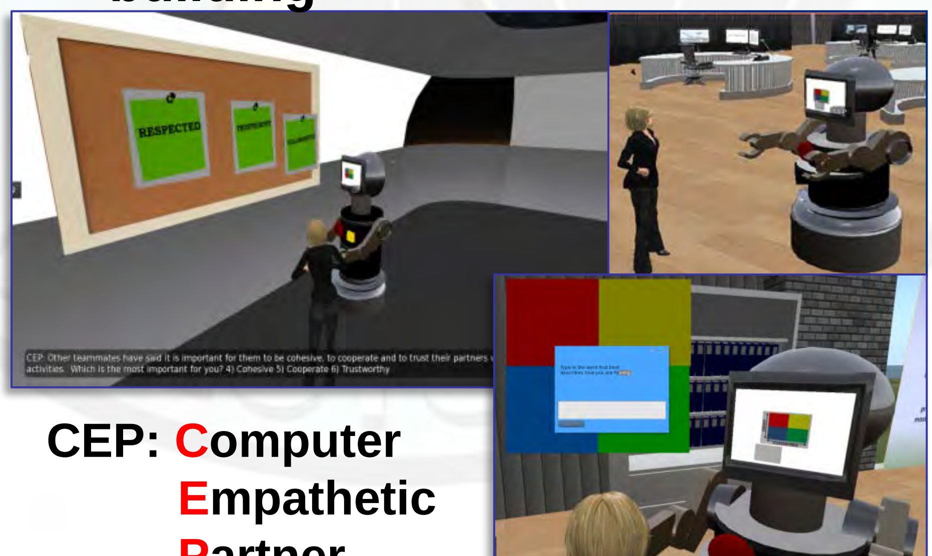
- AFOSR Grant (Study 1, FY14-16)
- Lockheed Martin CRADA (ISR setting)
- PER Lab, Italian Air Traffic Controller (EOARD)
- NSF funded collaboration with Yale Social Robotics Lab

Social Agent vs. Tool
(Study 1: AFOSR Lab Task)

Same ISR Ranking task across conditions

Experiment Condition:

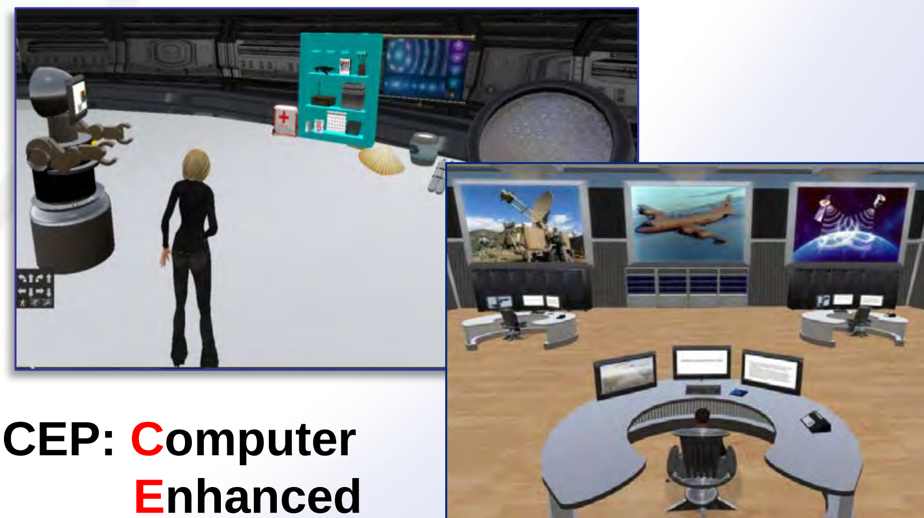
- Empathetic partner focus
- Social-emotional skill development (RULER) for team building



CEP: **C**omputer **E**mpathetic **P**artner

Control Condition:

- Tool focus
- Yoked control task – message processing



CEP: **C**omputer **E**nhanced **P**rogram

- **RULER: Large empirical base for performance, behavioral, attitudinal, etc. improvements in K-12 and in workplace (Salovey, Brackett, Rivers).**
    - **Our research program is to extend findings to military and HMT contexts.**

- **Primary Dependent vars: trust (self-report, physio) & reliance (behavioral)**

Expected Outcomes:

•Foundational scientific understanding of the *risks* and *benefits* associated with the social/emotional side of HMT.

•Including insight into how users feel and respond to increasingly intimate connections with machines – quantified warrior & sense-assess-augment.

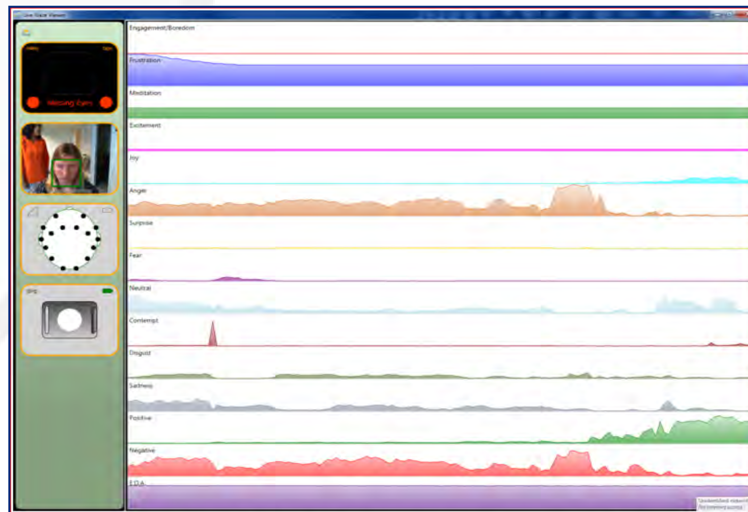
•Proof of concept for novel methods to optimize HMT interaction and performance through joint user-machine social-based *training*.

•Developing and managing the unique relationships envisioned for the future HMT.

Machine’s Perceptual System: A Multimodal Approach

Real-time integration of multiple sensors (sense) to understand (assess) and respond to (augment) user’s state.

- **Provides the machine input for compatible cognitive and social-emotional interaction.**
- **Affords individualized response.**



Attention Tool sensor integration

Our purpose is:

To *simulate* the intelligent machine partner of the future and develop an understanding of how users perceive and respond to this much more intimate coupling with machines.

Human-centric approach to facilitating augmentation.

Going beyond the rational model of calibrated trust, which assumes 1:1 relationship between autonomy reliability and user trust.

Social-emotional factors account for the variation.

Multimodal Approach

- **Multimodal approach to *sense-assess* optimizes machine learning algorithms to enable targeted *augmentation*.**
  - **Key for AI or personalized, intelligent agents….true, but….**

- **Our purpose is:**
  - **To *simulate* the intelligent machine partner of the future and develop an understanding of how users perceive and respond to this much more intimate coupling with machines.**
  - **Human-centric approach to facilitating augmentation.**

Methodology

- Between subjects manipulation (N=80):
  - tool vs. empathetic partner frame using RULER Anchor tools.
- Survey measures:
  - Trust propensity (including new measure of IT Trust Propensity)
  - Trustworthiness and Trust measures (Mayer et al. and others)
  - State Affect
  - Stress Appraisals
  - Sensor beliefs
- Behavioral measures:
  - Reliance
  - Communication (verbal & text)
- Physiological measures:
  - EEG, GSR, eye-gaze, pupil dilation

Preliminary Analyses

- IT Trust Propensity
- Trustworthiness & Trust
- Trust & Reliance
- Stress Appraisals – Coping
- Sensor beliefs

IT Trust Propensity Ex. (created)

"Generally, I trust technology."

"Technology helps me solve many problems."

Coping Ex. (Schneider et al.)

"How able are you to handle the burden of this task?"

Sensor Beliefs Ex. (created)

"The sensors contributed to CEP's understanding of me."

"The sensors made me feel more connected to CEP."

Example items (Mayer & Davis, 1999 - modified)

Ability: "I felt that CEP was very capable of performing its job."

Benevolence: "I believe CEP really looked out for what was important to our team."
"My needs and desires were very important to CEP."

Integrity: "CEP has a strong sense of justice."

Trust: I would be willing to let CEP have complete control over our task.

Mayer & Davis, 1999)

Ability

Instructions: Using the scale provided, please rate your agreement with the following items.

Scale: 1=Strongly disagree, 2=Disagree, 3=Neither agree nor disagree, 4=Agree, 5=Strongly agree

1. I felt that CEP was very capable of performing its job.
2. I had confidence in the skills of CEP.
3. I believe that CEP was well qualified.
4. CEP has specialized capabilities that can increase our performance

Benevolence (past/future tense below and can be modified for the other subscales from Mayer & Davis, 1999)

Instructions: Using the scale provided, please rate your agreement with the following items.

Scale: 1=Strongly disagree, 2=Disagree, 3=Neither agree nor disagree, 4=Agree, 5=Strongly agree

1. I believe CEP really looked out for what was important to our team.
2. My needs and desires were very important to CEP.
3. I think CEP went out of its way to help our team.

Integrity

Instructions: Using the scale provided, please rate your agreement with the following items.

Scale: 1=Strongly disagree, 2=Disagree, 3=Neither agree nor disagree, 4=Agree, 5=Strongly agree

1. I believe that CEP tried to be fair in dealings with me.
2. CEP has a strong sense of justice.
3. I liked the values of CEP.
4. Sound principles seem to guide CEP's behavior.

Trust (2nd administration)

If I had my way, I wouldn't let CEP have any influence over issues that are important to me.
I would be comfortable giving CEP a task or problem that was critical to our performance
I would be willing to let CEP have complete control over our task.
I really wish that I had a better way to keep an eye on CEP.

Sensors:

The sensors contributed to CEP's understanding of me. The sensors made me feel more connected to CEP.

Working Alliance Inventory: I feel comfortable with CEP. CEP helped me look at the tasks in a new way. CEP understands me. I believe CEP likes me. I believe CEP is genuinely concerned about how I feel. CEP and I respect each other.

Conclusion

Expected Outcomes:

- Foundational scientific understanding of the *risks* and *benefits* associated with the social/emotional side of HMT.
  - Including insight into how users feel and respond to increasingly intimate connections with machines – quantified warrior.
- Proof of concept for targeted methods to optimize HMT interaction and performance through user *training* and *interface design*.
  - Developing and managing the unique relationships envisioned for the future quantified warrior and human-machine teams.

Questions?