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Remote Communication, Collaboration and Cognition

Jocelyn Lomer, cereno

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Abstract

As operators search for hydrocarbons in increasingly remote and hazardous locations, so communications between the rig and head office become more challenging. The electronic media we use currently - email, telephone, electronic data transfer – all filter information, inhibiting collaborative cognition. This in turn can lead to misunderstanding of pivotal information, increasing risk to equipment, people, and indeed business value.

In this paper we will describe how the use of fully collaborative technology, backed by wide ranging psychological research into how people communicate and collaborate both in a face-to-face setting and in a variety of remote situations, can be used to optimise collaboration in the most challenging situations, reducing risk, and significantly increasing rapid, accurate decision-making in the field.

The Digital Oilfield is a reality, and the most significant change taking place is in the way in which people work in a collaborative environment. While there has been significant research into how different disciplines can work together, very little, if any, has gone into the way in which we collaborate remotely, and how that can be improved.

Our research, extending the findings by the Universities of Cambridge, Kings College London, and Surrey, demonstrates conclusively that the provision of a remote collaborative environment that most closely resembles a face-to-face meeting - natural, intuitive, and able to handle complex tasks - improves knowledge sharing and interpretation, expands thought and memory processes, and in so doing, adds significant, measurable value to remote operations.

Introduction

With the rise of Internet connectivity there are a plethora of new remote meeting technologies delivering different benefits as well as constraints becoming available on the market. This has the effect of building on existing confusion about the psychology of communication and the role of electronic media in defining the quality of the human machine interface. A generic category loosely defined as 'social media' adds to the confusion since the different social media platforms are widely different in their capabilities.

This paper seeks to define the ideal human/machine interfaces and separately to identify the constraints delivered by electronic media, and how implementing these technologies will deliver competitive advantage by efficiently linking their expert personnel as though they were in the same room.

The new technologies described inhabit a different space to current methods and will allow a new way of working and innovations that have not been possible before, because the systems create a rich workspace that is ideal for idea generation delivering innovative work practice.

Organisations embracing these Intelligent Energy technologies are likely to experience increased operational efficiencies as well as an exciting new innovation capability that is becoming increasingly important as the global business environment changes ever more rapidly.

Statement of theory and definitions

The media naturalness hypothesis (Kock, 2005) argues that, other things being equal, a decrease in the degree of naturalness of a communication medium (or its degree of similarity to the face-to-face medium) leads to the following effects in connection with a communication interaction:

1. Increased cognitive effort,
2. Increased communication ambiguity, and
3. Increased physiological arousal.

Therefore the closer the electronic medium emulates a real face to face meeting with stimuli the better the cognition. In order to achieve the optimum environment the electronic medium should deliver:

1. a high degree of co-location, which would allow the individuals engaged in a communication interaction to see and hear each other;
2. a high degree of synchronicity, which would allow the individuals to quickly exchange communicative stimuli;
3. the ability to convey and observe facial expressions;
4. the ability to convey and observe body language; and
5. the ability to convey and listen to speech.

Clearly many existing systems such as the telephone drastically fail in matching these criteria and similarly most desktop systems are unable to deliver communicative stimuli in a rich way such as synchronous document exchange in a real face to face meeting. Most social media have a very weak performance against these criteria.

In the future we can therefore expect the human/machine interface to the 'cloud' to closely resemble a real meeting, but unlike video-conferencing it will allow a high level of document exchange and collaboration especially where the matters are complex and the grounding of ideas manifests itself by building on existing documents and concepts.

Human communication and collaboration and effective group performance is a complex matter involving many intangible elements. Intuitively it is clear that remote team effectiveness will be radically affected by the remote communication medium and the constraints it applies to cognition.

Human collaboration and human interfaces to machines

Human evolution: how the human mind has evolved

Darwinian evolutionary theory postulates that homosapiens evolved from a common primate group. Twenty five million years ago ape like creatures started to evolve. Somewhere around ten million years ago our ancestors diverged from the gorilla ancestor and started to evolve from being herbivorous to carnivorous, becoming erect and evolving toward a savannah dwelling hunter gatherer. (Morris, 1987)

During this period of ten to seven million years ago the forest dwelling ape further evolved toward a highly social hunting ape and had also to develop strategies and communications to survive. With stone based weapons becoming available, our ancestors had to evolve more sophisticated collaborative strategies and communications in order to survive. Right at the earliest part of human evolution collaboration had been important in order to thrive.

The ongoing evolution of the human species has resulted in a complex web of communication methods for humans in co-located groups. That is, hearing and speech have evolved along with complex facial expressions and other body language gestures that convey complex messages. The human face has twenty two muscles solely dedicated to expression. At the same time our brains have evolved in a certain way that allows improved processing if the signals are delivered in a certain way, for example using visual reasoning in Computer Aided Design.

The evidence for these evolutionary theories comes from archaeological sites from 2 ½ to 2 million years ago which deliver evidence of hominids as social hunter gatherers. Sites in the 2.0 to 1.5 million years ago period such as Olduvai Gorge indicate home based hominids living socially, delivering division of labour, hunting and cooking which in turn implies early collaborative activity to ensure survival. (Kinzy, 1987)

The psychology of human communication

Recent advances in cognitive psychology are helping to unravel the complexity in human communication, how our primary senses collect information, and how this information is processed.

It is not just the way that the external channels of speech and hearing have evolved that influences the efficacy of our communications, collaborations and cognitive absorption. Important signals that include eye gaze, gestures, facial expressions, body language etc. also deliver important messages. The human mind itself has evolved in a particular way and is constrained in the amount of material it can process. This is particularly critical in the area of working memory, where the human mind can only process a limited amount of information at one time. For example if you are computing by long division 1132 divided by 48 in your head, humans are unable to calculate another similar sum simultaneously, although they might be able to drive a car whilst performing the calculation. (Baddeley & Hitch, 1976)

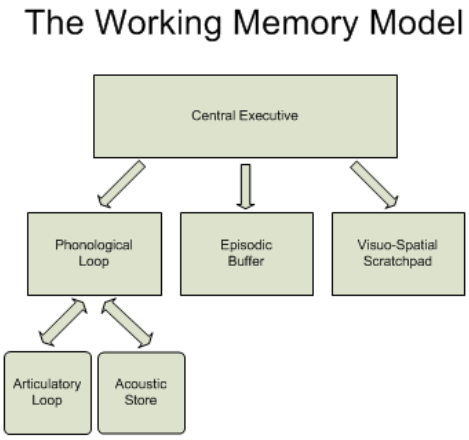

Fig a.The Working Memory Model

Based upon experiments in the Baddeley and Hitch model the central executive manages the Phonological loop which handles verbal information, the Visuo-Spatial sketch pad which deals with information as the name describes. The articulatory loop deals with the decay of information and the fact that mental repetition holds - for example - a telephone number in working memory for a longer period. All these resources are managed by the Central Executive. The Episodic buffer was recently introduced to explain remembrance of more meaningful episodes.

These elements are key to human cognition and if they are blocked with unnecessary computation we are unable to deliver new ideas. The ideal would be to have a clear, stimulated phonological loop, as well as visuo-spatial stimuli from artefacts.
A good example of working memory performance is if we were navigating a new long distance route by car, our minds would be full of computations on how to get there, whereas if we have a Satnav to execute the navigation computations for us, then our working memory is free to come up with some interesting ideas. In the driving analogy the visuo-spatial model is still able to operate in parallel to the numerical computations since it utilizes the visuo-spatial sketchpad. In the same way human/machine interfaces must be designed to free the mind for idea generation, however many web-based collaboration systems actually block the working memory while the operator is trying to figure out how to work the system.

The importance of context

Intelligent perception and constructive perception is where a mind reacts to external stimuli to assess a situation and to decide an action. Humans accept visual sensations from multiple sources, apply knowledge and cognitive processes to come to a conclusion. Clearly, if involved in a design project where stimuli are constrained to a single document, the resultant conclusions and decisions are likely to be of an inferior quality. These human factors imply that an ability to see the broader context will result in improved conclusions, and additionally, if we are collaborating successfully, then the ability to "ground" the meeting, (that is to apply common references), with multiple documents and to allow collaborative turn taking, is an ideal that is delivered by a face to face meeting with papers on the table. A comprehension of these social behaviours allows us to conceive the complete ideal, which is to allow these behaviours with an electronic interface. (Brennan, 2005) (Ashdown,2004)

The importance of turn taking and grounding
Grounding is a particularly important concept in communication and collaboration - in fact normal communication is actually a collaborative activity. Therefore a dialogue between speaker A and B is likely to progress as follows:

Speaker A: Let us go for a walk in the Park
Speaker B: Ok, you mean Hyde Park?
Speaker A: Yes

Turn taking by the various parties and a tacit agreement to collaborate to move the conversation forward with the references has been clearly established. In order for the communication to proceed the references need to be fully grounded, and then a collaborative exchange proceeds in which both parties agree to continue the conversation. (Clarke and Wilkes-Gibbs, 1986)

Frequently, visual media are part of the collaboration and in that case the same process applies. For example in the design of an oil rig, a referencing of the particular design piece in question is prerequisite in having an error free collaboration and successful turn taking will establish the reference point for the collaboration to continue.

In general, humans like to avoid undue mental effort and the concept of "least cognitive effort" is important in grounding. Common ground needs to be established so that the participants are building the conversation from that established base whether in conversation or in design innovation, and without this type of affirmation, progressing the dialogue or job is likely to be problematic. A rich workspace for collaborative grounding allows common understanding to be established quickly, and the probability of communication errors markedly reduced. If the human/machine interface of a remote collaboration system does not allow free and easy turn taking with immediate graphical reference, then that collaboration has been constrained.

Collaborative psychology

Research has shown that physical proximity increases the likelihood of collaboration due to various factors. It is easier to initiate conversations if in close proximity and the frequency of meetings is likely to be higher. These and other social factors explain why close proximity encourages collaboration. Extrapolating these concepts to a remote meeting requires the medium used to be as easy to use as possible and ideally in an always on or 'touch of a button' mode for connection.

The concepts of cognitive effort and collaborative effort are important, and if grounding is difficult (for example at the beginning of a project), teams will often select face to face meetings, with remote media cutting in during the roll out stage. Again remote media must minimise cognitive effort. (Kraut et al., 2002)

The evolution of electronic media for communication and collaboration

Historically, sound and light have been used in immediate remote communications - for example communication drums, watch towers in Europe and reflections in arid areas - all of which been important in the delivery of remote communications. Advances in the comprehension of electricity in the 18th and 19th century has given rise to a plethora of new communication media, commencing with Morse's electric telegraph in the mid 19th century. Since then technological advances have been huge, particularly in the 1960's with the advent of the first fax machines and personal computers. Further developments in micro-processor and router technology allowed the development of the World Wide Web in the late twentieth century. Consistent improvements in access to the global population and to the World Wide Web are currently underpinning huge political and social change, coupled with an exponential rise in innovation due to the connection of global experts.

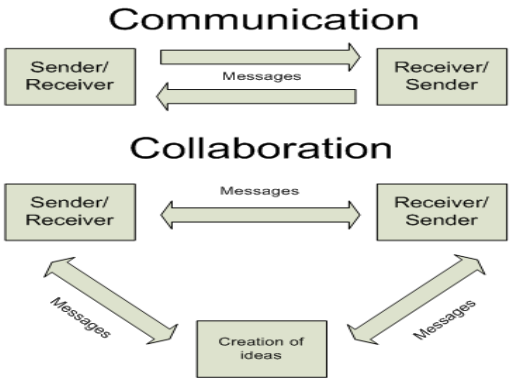

Fig b. Collaborative Teams deliver Innovation

These days innovations are no longer created by individuals, they are created by collaborative teams, because the level of complexity required by the average project requires multiple experts to deliver their opinions. In the context of remote

communications, a workspace is prerequisite to provide the reference upon which to collaborate. Referring to Fig b, the fundamental difference between communication and collaboration is that a workspace is required for complex collaboration where a task is being worked upon.

Unfortunately, currently available media deliver constraints upon remote communication. As advised by Clark and Brennan (1991) eight criteria have been identified:

1. Complete co-presence – many media effect constraints so that the participants cannot see or hear what the other parties are doing and looking at
2. Visibility - the media may allow visibility without showing what the parties are looking at
3. Clarity - constraints are applied by some media where audibility is ill-timed, blurred or fading
4. Co-Temporality - no delays in communication such as are provided in e-mail and text
5. Simultaneity - Parties are allowed to speak at precisely the same time e.g. a facial reaction to a speaker's utterance
6. Sequentiality - the taking of conversational turns that are not interrupted by time or interruption e.g. E-mail and letters
7. Reviewability - the difference between speech and recorded utterances
8. Revisability - allowing collaborators to revise and repair before delivery

It is clear that many human/machine interfaces do not match these criteria.

The rise of the Internet

Since 1994 there has been an exponential growth in the use of the Internet and the IP protocol, and this has become the global standard for access to end users.

It is estimated that 39% of the world's 7.1 billion people are connected to the Internet, and have the capability to communicate with each other. The richness of these communications is only constrained by the bandwidth and the quality of the 'human /machine' interface. That is, if we have adequate bandwidth, which is constantly improving, then the only remaining constraint is the human/ machine interface.

Put simply, we are moving toward a virtual world where the recent West teaches East paradigm is rapidly eroding, and we are moving toward a world where local innovators solve local issues and may then sell them back to more developed economies. Strategically, the richness of the communications channel will be of key importance to the survival and growth of global businesses.

New types of human /machine interface/social media

In 1843 Samuel Morse delivered the first long distance electric telegram. At this stage, this electronic medium filtered out all but the simplest message, such that only one of the eight criteria mentioned previously is met. Therefore it can clearly be seen that all electronic media constrain communication in some way. Similarly, Bell's telephone in 1876 gave rise to new ways of communicating remotely, yet constraints of co-presence, visibility of objects, reviewability etc. are all apparent. The telephone effectively makes us 'blind' because we cannot see the other end.

Moving to the 21st century, Social Media means different things to different people. These new media are evolving very quickly and they are all fundamentally human/machine interfaces to the cloud or telecommunications networks. Some of the largest public players are perceived to be Facebook, LinkedIn, YouTube, Instagram, Twitter etc., yet all of these have quite different characteristics. The question: 'Is Skype social media?' results in quite different answers. Social media is a highly subjective category.

All these media have strengths and weaknesses, but ultimately connect people and data in some way that adds value. However, if the question is asked: 'Can you have a meeting between up to nine sites while simultaneously sharing a table full of complex content documents?', the answer is negative with any of the aforementioned social media by any subjective definition.

All electronic media constrain communication, while desktop collaboration, video communication and all web conferencing, impose constraints, as the ideal human/machine interface is a natural meeting with reference points, which in the context of a modern meeting will include multiple documents serving as a collaborative reference.

Building on Kock's hypothesis, , the closer we can make the interface to a real meeting the better the cognition. The better the cognition, the less room there is for error.

In order to overcome the limitations of weak interfaces and weak solutions for managing complex problems, the nuVa collaboration environment has been developed following extensive research.

The research and development of nuVa technology based on human psychology

Constraints of existing electronic interfaces and the design of nuVa

I have described how conventional communications have the effect of stripping out information and therefore reducing cognition, which in turn increases risk in all but the simplest tasks.

A DPhil research degree was sponsored at the University of Cambridge by Thales Research and Technology (Ashdown, 2004) additional research was delivered by Kings College London as well as MIT and Surrey University in England. Detailed research into human machine interfaces was undertaken and complex software engineering delivered to achieve the result. The specific objective in researching the nuVa advanced collaboration technology was to create the optimal interface for the paperless office, to be utilised by the truly remote worker and to fully emulate a face to face meeting in a similar environment.

As a direct result, the concept of a virtual space, emulating a real meeting with papers in the horizontal plane and video in the vertical plane was developed. This environment allows the human behaviours of a real meeting such as gesturing, and other body language communications to be visible, as well as the synchronous referencing required in complex tasks. The environment overcomes the constraints of typical workspaces, it recognises the ongoing supremacy of paper with its associated affordances, the cognitive benefits of alternative interaction including bi-manual input and the required synchronous shared task space that is required for remote collaborative work.

In addition nuVa technology delivers all the aformentioned Clarke & Brennan criteria, particularly through the use of the luxurious idea generating workspace which allows full synchronous collaborative capability.

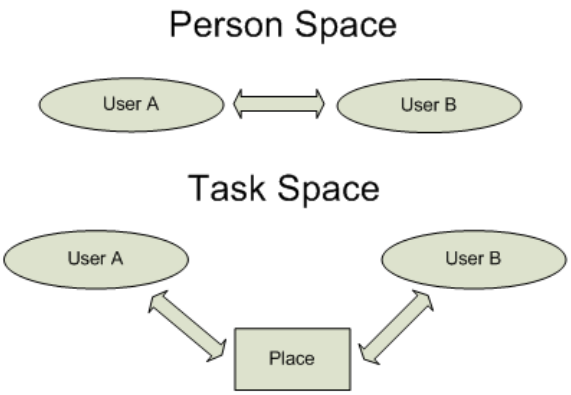

Fig c. Idea generation occurs in the task space

The nuVa device emulates a ‘real face to face meeting’, yet delivers a powerful workspace with papers on the table allowing collaboration. Following detailed research into how humans collaborate, this system was evolved as a direct result. It emulates a real meeting in that it delivers video in the vertical plane and papers and documents in the horizontal plane. The layout most matches the hypothesis that a real meeting delivers the best cognition, yet enhances that by the creation of the idea generating workspace.

The system also allows users to be able to view and manoeuvre papers simultaneously at both ends. The layout affords a comprehension of the five key criteria identified by the Natural Meeting theory and the closest possible match to a real face to face with a task space that allows sharing of complex ideas.

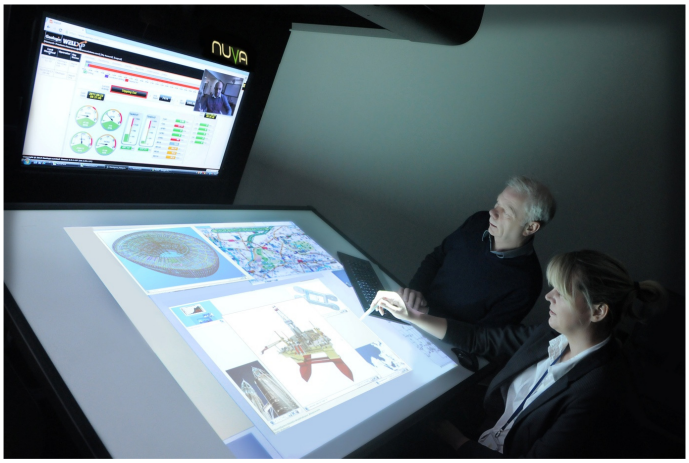

Fig d. nuVa being demonstrated as a 'mini CWE'. The sharing of well monitoring software, remote video and full real time document sharing allows access to remote experts and visibility of the full context for improved decision making.

The importance of cognition in emergency response and risk communication

Cognition of the event unfolding is of critical importance in disaster management. In this context it is the comprehension of the size of the risk unfolding that will in turn initiate the emergency response. Insofar as the emergency response is actually delivered by multiple agencies, then a common platform of understanding is vital to understand what is happening. In the disastrous incident of Hurricane Katrina for example,'It was not the communication of the upcoming hurricane that went awry, it was the cognition of the unfolding and expanding risk' (Comfort, 2007).

Furthermore, Comfort argues that the building of a common operating picture is essential in allowing the maximum amount of shared information among the various organisations, so that all parties readily understand the constraints on each other and the opportunity for collaborative action.

The principle of collaboration to mitigate a disaster is similar in concept to that of de-risking a complex Oil and Gas engineering project, i.e. collaborative activity in the light of organisational constraints is likely to deliver innovative and risk reduced solutions.

nuVa a design for collaborative cognition

Deployments of nuVa have recently taken place in a range of industries, including International Oil and Gas, International Oil and Gas Engineering, and International Gases and Chemicals.

The findings from these pilots are as follows:

nuVa or other collaboration technology may be seen as an internal (internal/external) product. As such, full acceptance into the organisation should be planned so as to implement and market the product thoroughly within the business. It is just as necessary to market these internal products as it is an organisation's external products.

Refering to SPE 150112, (Ibrahim-zade, Moore-Cernoch, Overton) the rich nuVa interface might be used for CWE to CWE remote collaboration (ACE to ACE) or CWE to Advisor for 24 hour 'follow the sun' technical support.

Key project elements to consider:

Implementation deserves a limited project team that delivers a senior level sponsor and internal project manager to ensure end-to-end delivery, and all functions impacted by the new technology should be consulted. Following a thorough project managed approach will ensure the service is fully utilised.

The fit with any existing collaboration strategy needs to be assessed and designed. nuVa will allow new ways of working, for example outsourcing CAD to highly skilled people in developing countries, and therefore users are recommended to consider this element carefully for any new opportunities for accessing remote experts and the strategic organisation of the business that utilises expertise on a global scale.

It is recommended that open collaboration should not be confined to meeting rooms, but a space in open plan rooms should be allocated that is always accessible so that 'ad hoc' collaboration may take place internationally, thus delivering improved innovation.

Through the involvement of the project team, internal marketing must take place, there is after all little point in having a new facility if nobody knows about it. All relevant functions should be targeted with offers of training. The system is simple to use but two hours training will advance confidence in its use and deliver the required benefits to the business.

Some other pilot findings (nuVa with whiteboards)

With whiteboards set up in the rooms and meeting room tables and chairs, it was found that the environment was not conducive to facilitating the most efficient use of nuVa's capabilities. Due to the setup with meeting room tables and chairs, participants would naturally sit down and expect to be "presented" information rather than be engaged in the collaboration by coming to the whiteboard to move documents and annotate on them. Participants would prefer to "relax and watch".

The above behaviours have shown that it is important to consider the environment/space in which nuVa is located in order to enable its design "naturalness" and "intuitiveness" for virtual collaboration to be enjoyed by users – just like a real meeting. The traditional meeting room design is not conducive for such virtual collaboration and this needs to be addressed to reap maximum benefits and effectiveness.

Conclusions

In today's world the pace of change is ever faster, complexity increases by the day and global organisations must remain aware of risks to their reputation. At the same time world changing events are delivered by great teams, for example the incredible Apollo programme that put a man on the moon is a fine example of the power of the effective team. Modern technology is now allowing organisations to deliver a global virtual team of experts in an ever richer way.

With the cost of corporate network bandwidth declining rapidly as well as having 3 billion people connected to the Internet, the opportunities for innovative idea generation are rising exponentially and assuming adequate bandwidth, the only constraint on a massive rise in human innovation is the quality of the human/machine interface. For example with an organisation of 1,000 people each having 10 ideas over a period, then using Reed's Law the theoretical number of pairings for ideas reaches the astounding number of 49,995,000 possibilities! These capabilities if unconstrained by bandwidth or interface will propel organisations into completely new realms of innovative possibility.

In the near future 'recommender systems' are likely to be used to identify potential 'collaborative innovation teams'. Such systems employ knowledge in the databases and apply it back to relevant people. These systems, when working with the optimum human/machine interface, will create a very powerful new innovation capability using resources both internal and external to the organisation.

Building further on Ned Kock's hypothesis that emulating a real meeting delivers optimum cognition but also recognising that visual artefacts form important reference points for complex collaboration tasks, the nuVa technology reaches an advanced level in delivering the optimum human/machine interface to the collaborative 'cloud', as it most closely emulates a real meeting with people seen in the vertical plane and documents fully shared over all end points allowing simultaneous referencing and collaboration.

It has been shown that failing to meet the IDEAL natural meeting emulation human machine interface will result in:

4. Increased cognitive effort,
5. Increased communication ambiguity, and
6. Increased physiological arousal.

The factors above are highly significant and will literally affect every area of operations, including safety. The implications of improved cognition in the remote meeting channel are highly significant for business leaders, especially in the areas of risk reduction, innovative problem solving and cost management. Once this is understood business leaders will consider taking the appropriate action.

Generally Exploration and Production programmes are operating in ever more challenging environments and the requirement for cost effective collaboration technologies and procedures to link sub-contractors and experts is paramount. In delivering a complex engineering project, or alternatively managing risk or managing a crisis response, a common view of the issue at hand is prerequisite for considered decision making. Without these references trouble-shooters will make weak decisions.

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