Interaction Analysis and Cognitive Infocommunications

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Abstract— **Cognitive infocommunications encompasses both scientific and engineering oriented approaches to examining extensions of human cognitive capabilities that may be assimilated within the concept of humanity. Necessary (but not sufficient) conditions for the success of any candidate technology include solving problems within private and public spheres of existence, in thought and communication. Exemplar cognitive infocommunication technologies that have been assimilated in to the concept of humanitiy are examined: emotion, gesture, language. Implications for research programmes conducted within the cognitive infocommunications discipline are outlined.**

Index Terms—**interaction, language, reasoning gesture, behaviour, coginfocom, philosophy of cognitive infocommunications.**

I. INTRODUCTION

COGNITIVE INFOCOMMUNICATIONS (coginfocom) has been evolving, conscious of itself as a distinct area of research scrutiny since 2010 [1], if not earlier. Development of the discipline may be tracked through a successful eponymous series of annual academic conferences. To label the subject as a "discipline" is to suggest that substantial unspoken consensus about its nature exists among those who contribute to the field. A discipline is identifiable in the boundaries between it and cognate disciplines, in the primary problems addressed, in how those problems overlap and in how those problems are composed from constituent questions. A purpose of this work is to test that consensus by putting forward specific positions regarding the boundaries and composition of the field.

We think it a basic assumption of coginfocom that humans are prolific at extending their capabilities and assimilating those extensions into what is understood to define humanity. Clothing provides a ready example of a technology that has extended human capabilities and been assimilated into the concept of humanity: clothing offers an infinitely re-configurable means of adornment and self expression; clothing also extends the potential that humans have for survival across a greater span of climate variations than is feasible without clothing. The possibility of adapting to climate variation is an individual level advantage – an adaptation that operates in the private sphere of existence, while the expressive capacity of clothing is available to public view. Within this public sphere, clothing creates new possibilities for signalling group membership and status, among other things. Tattoos also provide a means of expression (although not an infinitely re-configurable one), a public function, but few private advantages follow having one or more tattoos, beyond the potential for self-satisfaction through possession. In ordinary circumstances, people expect other people to have clothing, but do not have an expectation that other people will have tattoos. Clothing has been assimilated into the concept of humanity, but tattoos have not. Clothing is an example of a successful coginfocom technology, but tattoos are not. Not being a successful coginfocom technology means not that the technology is counter-productive,[1] but rather that it is not assimilated into the concept of humanity. Between clothing and tattoos, only clothing solves problems in both private and public spheres of existence.

In focusing on extensions of human capabilities enabled by new technologies, coginfocom attends to both the private and public dimensions of existence. The deployment of language as a system that supports both thinking and communicating is another example of humans achieving innovations and subsequently including the innovation in the concept of humanity. It is a defining property of coginfocom technologies that they enable advantages in both the private (as in thought) and public (as in communication) spheres of human behaviour.

A substantial focus in the coginfocom literature is on more recent technological advances as candidates for being understood as part of humanity: calculators and telephony have been discussed, for example. Calculators and associated technologies are addressed by those who focus on mathability [2]. For many coginfocom technologies, the relevant innovations are nearly universal in availability, if not in adoption. Vision-corrective eye-wear, money and clocks are in this category. At the inception of a new technology, it cannot have had a chance to prove its worth in public and private spheres, and when inspecting new technologies it is natural that many will not have been around long enough to become incorporated into the concept of humanity. Interest in these new technologies within coginfocom partly associates with the proof that they are possible and demonstration that they have efficacy. Sometimes they are developed with particular problems in the public or private sphere in mind, but generally, researchers relish the fact that something developed will be accompanied by affordances that serve unforeseen uses, and therefore solve unexpected problems. So, some will at times focus on technology development and some will focus at times on assessing the likelihood that the solutions provided by

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[1]It does not necessarily create harm to obtain a tattoo.

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technologies in the public and private spheres will fill niches that may lead to their assimilation.

The fact that a technology successfully fills a niche does not entail that the technology will be assimilated. Some promising candidates may be abandoned and some may be overtaken by more general innovations. Examples abound. Photographic slide projectors were popular for decades, have seemingly been abandoned without a replacement taking over their function. People continue to photograph scenes, probably photographing more now than during the age of slide projection, but the spectacle of slide shows appears to no longer be celebrated – co-located sharing of enlarged images is no longer a social fixture. In contrast, wristwatches used to be fairly ubiquitous as personal time-pieces, but time-tracking seems to have been generalized as one of many functions of multi-purpose mobile devices that people keep about their person. Similarly, the technology for replaying recorded music frequently undergoes transformation, but the function of replaying music is one that many maintain in whatever technology of the day enables this.

Many of the extensions to cognitive capabilities that people embrace spawn academic disciplines, sub-disciplines, and inter-disciplines in which researchers attempt to identify and make sense of the fundamental principles of the extensions and how they affect individual and social activities. Some coginfocom researchers seek to develop technologies that are candidates for general adoption. Some study the principles that determine widespread adoption or abandonment of new technologies. Some seek to understand how humans behave with existing technologies.[2] Here, "how humans behave" relates to transitions among psychological and physical states experienced by individuals and groups, with impacts on emotion, reasoning and interaction. Studying how humans behave with technologies that already exist can lead to identification of problems that may be solved with new technologies, but new technologies for their own sake (or for the sake of the profits that may derive from them) are not the target of all research engaged within coginfocom. Indeed, some seek understanding of how extant technologies are used and adapted, and grasp of the principles that differentiate between technologies that will become widely adopted, to the point of assimilation, and those that acquire only limited traction or no traction at all. For such researchers, grasping parameters of human thought and behaviour is essential to their progress. Open questions and challenges across these areas have been catalogued (e.g. [3]).

A goal of the present paper is to contribute our views on what it takes for new technologies to become assimilated into the concept of humanity. We analyze this question this with reference to the thread of cogninfocom that addresses linguistic and behavioural interaction analysis. There is temptation to think that the answer is trivial: successful coginfocom technologies (clothes, language, money, medicine, and so on) are *good*. However, this response is inadequate. Firstly, what constitutes "good" has remained unresolved since Plato recorded Socrates' asking of that question, if not before. Secondly, no instance of successful coginfocom technology is inherently good. One might argue that each example of a successful coginfocom technology is more appropriately considered an infection that has taken hold in humanity and which could cause extensive harm if allowed out of balance, just as bacteria of the gut support healthy living for the bacteria and the host when in the right balance, but can lead to fatality when out of balance. We think that each successful coginfocm technology solves a problem that is at hand or imminent,[3] that the problems evolve, and that the use of the solutions habituate. Having a capacity to solve a problem is a selective advantage over lacking that capacity, and such capacities may be culturally propagated as part of habituation.[4] Solutions are available for adaptation to other purposes: mobile phones were not invented to replace wrist-watches. The semantic field evoked by "infection" is apt in that the innovations that are good enough to be assimilated do so through "contagion" – they "go viral". The coginfocom technologies that assimilate are those which successfully solve problems in both private and public spheres of human existence.

The structure of our argument is as follows.[5] First we analyze thought, emotion, language and gesture as ancient coginfocom technologies that are indisputably assimilated into the concept of humanity. One longstanding thread of coginfocom research, as manifest in tracks in the annual conference series on linguistic and behavioural interaction analysis, have thought, emotion, language and gesture as the primary focus from the perspectives highlighted above (how people use them, how they may be supported, and so on). We note private and public advantages created by each.[6] We discuss thinking as a proxy for the private sphere of human behaviour and communicating as a proxy for the public sphere. We intend that more recent coginfocom technologies should be scrutinized similarly. We also highlight the ethical issues that surround the potential for new technologies that enhance human cognitive capabilities. We conclude with more questions than answers.

II. THOUGHT

Artificial intelligence research has recently given significant attention to neural network models used in learning input-output mappings implicit in enormous data-sets. For many natural language applications, systems based on such models achieve better results than current alternatives. Even as they behave well in response to stimuli on which they are not trained, there is no tendency to describe them as "thinking", in spite of a long tradition of analyzing thought as reducible to configurations of neurons and their electro-chemical behaviours. Many presume that in addition to monitoring input-output relations,"thought" involves at least the willful selection of input-output relations to monitor. Thought appears to have a useful function in guiding the macro-level time course of electro-chemical behaviours among connected neurons, and

[2]Naturally, these categories of researchers overlap.

[3]Some innovations emerge, solving problems people did not know existed.

[4]Thus, aspects of the development and assimilation of coginfocom technologies invoke genetics and epigenetics.

[5]This paper expands on work presented at a recent coginfocom meeting [4]. Although that paper mentioned issues of ethics, the full section on ethics here (§VII) was not included in that work.

[6]For some, either the public and private nature is less obvious than the other.

this seemingly solves the problem of otherwise arbitrarily structured consciousness, as is experienced during dreams.

Self-control of consciousness, a species of free will, is separable from humanity. One who seems to be guided by an entirely predictable stimulus-response mechanism will still be regarded as human. In some jurisdictions, a human lacking in self-control of consciousness is accorded societal protections, not categorized as "not human". A capacity for self-control of consciousness enables the perception of free will. It mitigates problems endemic to functioning in the "blooming, buzzing confusion" that would otherwise constitute experience. However, the fact that many choose to cede control of consciousness by means of chemicals, music, etc., is evidence that self-control of consciousness is not a universal good.

III. EMOTION

Neither is emotion necessary to humanity. However, perhaps more strongly than the case of lacking thought, lacking emotion can lead to an individual being labelled "inhuman", but not "not human". The desire to have or not have particular emotions may motivate choice in thought and behaviour. Arguably, shared aspects of embodiment entail that humans potentially experience the same inventory of emotions, even if triggers differ. Perhaps this requires relativization to co-located embodiment, such as when culture and milieu are shared, since, for instance, disgust triggers are not universal, while physical components of disgust response (the oral-nasal reflexes that accompany nausea) evidently are. Desire to experience (or not) a particular emotion motivates self-direction of consciousness upon how to obtain (or avoid) it.

Having an emotion can disrupt aspects of thinking. Reasoning is rational when it is guided by commitment to logically valid arguments and sensitivity to the differences between validity and probability. Emotions have the strength to obscure one's estimation of likelihoods. On the other hand, an emotion-based bias may provide the basis for decision where there is an information deficit, but where decision is essential. In those cases, emotions make decision possible. That emotion-led decision is sometimes useful does not make it logically valid – benefits of using emotions as a guide to making decision do not include situations in which the resulting decisions conflict with valid arguments or with more informative sources of probability estimates. Applying emotion-led decision making beyond its circumscribed area of benefit can be disruptive.

This discussion has emphasized the value and risks of emotions to human thinking. Decision making technology intended to be sensitive to human emotions also risks bias.[7] In emotion classification, it is standard for error analysis to reveal predispositions in classification that can be traced to imbalances in the data [5]. The urgency of this is evident in the analysis of emotion expressed in children's faces [6]: datasets that form the basis of learning sample surprise overwhelmingly more than fear, but the two emotions have common elements. One can easily imagine a children's call-line facility that could depend on accurate emotion classification if it were possible to fully overcome such bias.

Benefits can follow from it being known what emotions one is experiencing. This is true within all sorts of relationships: couples, parents and children, siblings, within communities, between communities. The types of emotions that people discuss corresponds to the sort of relationships they share. Identification of which emotions are shared and which are not shared determines political and romantic discourse, alike.

It is a marvel of professional actors that they are able to convey emotions that they may not be experiencing. In general, humans "wear their heart upon their sleeves".[8] Frequently, when people try to hide their emotions communications on which the emotions have a bearing break down. Since intense emotions more or less declare themselves, and are merely decorated by any language used to express them, mismatch between the decorating language and visible emotions then becomes evident deception, and episodes of deception often undermine successful communication. Many people report that language is insufficiently expressive to represent their emotions accurately and completely [7], and in these cases they may prefer that the intensity of their emotions reveal the emotions directly in communication situations.

IV. LANGUAGE

Language is a representation system humans use for thought and communication, but is not the sole medium for either.

The primary function of natural languages appears to be thinking. People have more thoughts than they communicate, and they think the thoughts that they communicate before they utter them. Human languages provide powerfully expressive features in support of nuanced thought, and among them are those idealized in logical connectives, such as "if" and "not". People are also capable of non-linguistic thought, including visualization of non-existing possibilities and potential futures of those possibilities. A succinct way to describe a potential development of a non-existing possibility is as a "possible narrative": the word "narrative" denotes the linguistic representation of the happening of possibilities. Human languages support representation of negation that is not supported by visual reasoning about positive possibilities. Conditionals similarly enable representation of hypothetical or counter-factual situations.[9] In addition to enabling the distinction between content that is not visualized and content that is not available to be visualized, between what is not known to be true and what is known to be false, natural language enables the representation of absolute impossibilities and paradoxes: for example, "this sentence is false". Representation is pre-requisite to reasoning.

Because people think in language, human language is also useful in communication, even though it is an imperfect code. People generally know what they mean by what they say, but often misunderstand what others mean when using the same sentences. People do not use even formulaic expressions in the same manner as each other, and people frequently embark

[7]We thank an anonymous reviewer for emphasizing the relevance of the problem of bias in machine learning approaches to AI.

[8]We apologize to Shakespeare; cf. *Othello*, Act 1, Scene 1.

[9]Indeed, it is a move in formal logic to define negation using implication and impossibilities: where $\perp$ denotes logical inconsistency, $p \rightarrow \perp \equiv \neg p$.

on linguistic innovations, such as metaphor. Until telepathy is solved, humans have no way of knowing whether they have trully understood each other. At best, people act as if mutual understanding is achieved when there is no available evidence of misunderstanding (cf. [8], [9], [10]). In the meantime, people use natural languages in communication as if they are successful, and when disagreements arise, sometimes to attempt to verify whether they are using language in different ways or instead have different viewpoints.

V. GESTURE

Gestures are bodily movements that accompany language, therefore gesture has a role in thought as well as in communication. We think the role of gesture in thought is more direct than in communication. Here we do not address bodily movements that constitute language, as in sign language. We think of sign language as language, and therefore with all of the limits and affordances described above (§IV).

People gesture in solitude. People are idiosyncratic in their gesturing. We think these two facts are self-evident, and sufficient to prove the claim that the purpose of gestures is not the communication of content. Rather, people gesture in a manner that helps focus their thoughts and represent their thoughts in language. It has been observed that sometimes people "hold" gestures during utterance and thought repair [11]; this is evidence that gesture contributes to thought formulation.

Some gestures are conventionalized beyond idiolects, and many deictic gestures are in this category. Other gestures are created for the nonce. For example, iconic representations are more or less apt because of shared embodiment and shared perception of what is salient in a scene and how a bodily shape matches what is salient. Unconventional deictic gestures also exist and also exploit salience: if something is noteworthy in a situation, moving one's chin in an unusual way and in the direction of the noteworthiness can be successfully understood as pointing toward the salient elements. This, too, requires prior thought, the intention to point.

Gestures are often used to set up and refine representational spaces for illustrating narratives. This supports speakers infinitely more than listeners. A gesture may have clear meaning for a speaker, but are mostly such that no observer could hope to successfully decode the content of a discourse by watching without understanding the accompanying linguistic content.

However, gestures more successfuly serve communication with regard to psychological attitudes of speakers. Attending to gesture will give a witness a reasonable set of cues about the emotions that the speaker has. Possibly this is why mainstream news broadcasters deploy seemingly stylized but simultaneously bizarre gestures while conveying reports on television. This may be a means of obstructing the revelation of their actual emotions towards the content they report.

VI. LINGUISTIC AND BEHAVIOURAL INTERACTION ANALYSIS

Emotion, thought, language, and gesture are successful coginfocom technologies. We attempt to discover basic facts about these technologies, how people adapt them and how their use interacts. Understanding linguistic and behavioural interactions is important to anticipating new technologies that may arise and extend human cognitive capabilities further. It seems that a pre-requisite for adoption of coginfocom innovations is that they have both private and public functionality, in the same manner that thought is a primarily private function and communication is a primarily public function: the successful proliferation of smart-phones may be attributed to the fact that they have assimilated functions of personal digital assistants and synchronous and asynchronous communication with individuals and groups. The problem solved by the innovation may not be the same in the private sphere and the public sphere, but the duality in spheres of use reinforces habituation.

Reasoning along the lines we suggest here might influence one's thinking about nascent coginfocom technology. Consider dialogue systems. Dialogue systems have been proposed and explored (including by us) for individuals in managing health and well-being. Dialogue systems primarily target private use. Increasingly, online "bots" are used for public communication. Frequently, they have dubious ethical value as they attempt to fool people into thinking that they are not bots, but people, and to spread disinformation widely. Dialogue systems appear to have clear private value but questionable public value. Thus, one might reasonably project that dialogue system technology will not be assimilated by humanity. If public value can be established for dialogue systems, then a lasting future for dialogue systems might be projected. Establishing a means within dialogue systems for them to reveal their nature as artificial dialogue systems, regardless of who deploys them, may be one of the possible paths to deserve and gain trustworthiness – deserved trustworthiness may open clear public value to dialogue systems, and thence a possibility of assimilation.

Fidget spinners offer a solution to the problem of consuming nervous energy. This is a private function. They also had a public function shared with many other fads: namely, using one in public made one visible as someone who had access to a fidget spinner. Being a person who visibly has X is, in general, a limited public function, communicating little else beyond that. For most X, public interest in having X is determined by how easy it is to have X and how long an X lasts. As more people have X, more people want X, up to a point, and then it is no longer differentiating to have X, and therefore possessing X ceases to convey information. One can then expect interest in X to wane. In the case of fidget spinners, if they are re-released in a manner that not just consumes energy but also harvests energy, in support of activities in both private and public spheres, then one might imagine them assimilating.

Much research into coginfocom technologies validates those technologies in either private or public spheres. Naturally, this includes bench-marking the technologies with respect to prior art without directly seeking validation in private or public spheres, given that prior art may have had independent validation along those lines. For example, the role of many natural language technologies is clear within larger systems, therefore it makes sense to seek improvements on fundamental components like part of speech tagging or parsing. Similarly, it makes sense to explore fundamental properties of the public and private spheres themselves, in order to understand where

problems in those areas exist. Given that these spheres are private and public with respect to humanity, and given the premise that cogninfocom is about extending the capabilities of humans, it follows that fundamental knowledge about humans behaving in public and private spheres is always a moving target, as new technologies are assimilated. Thus, within coginfocom, one expects to see research that seems to explore technology "for its own sake" and humanity "for its own sake", but which actually, if indirectly, contributes information about the viability of extending capabilities of both.

The discussion so far indicates that for coginfocom technologies to be assimilated as part of humanity, it is a necessary condition that they contribute solutions to problems in the private and public spheres. However, these are not sufficient conditions. A coginfocom technology may well provide useful solutions, while a "lesser" technology out-competes it. As an example, one might reflect again on the role of music. All but a few forms of music were proscribed from *The Republic*, because of the capacity of music to "excite the passions", thus diminishing control over the populace. It appears to be an implicit hypothesis that musical experiences impinge on mental states, and this hypothesis has empirical support [12]. Arguably, if the goal of communication were the revealing and sharing of mental states, one might develop music-based communication technology and anticipate a system that is more effective as a solution than natural language.[10] Crucially, natural language affords the possibility of hiding mental states, through the potential it creates for ambiguity, vagueness, misrepresentation, partial truths and outright lies. On this line, the communicative value of language in the public sphere is precisely in its support of mis-communication. Music might provide a means of supporting thought and communication which is superior to that of natural languages, but natural languages have been more completely assimilated by humanity.

While for a coginfocom solution to become part of humanity it is necessary for it to make contributions to both the private and public spheres, the nature of the contributions may be distinct in each sphere, and further, it is open for the efficacy to be greater in one than the other. It is also open for other considerations to impinge where competing technologies address overlapping problems. While some considerations such as determine the success of fads, as discussed above, may apply, it seems that in general, the "easier" solution wins. Ease may be judged in relation to computational efficiency/cognitive complexity or physical effort. To see that this is a non-trivial empirical hypothesis, it should be contrasted with an alternative criterion, for example, that, in general, the most "beautiful" solution wins. One might argue, again with reference to natural languages, that they are all of approximately equivalent computational complexity (context free or at most mildly context sensitive, and therefore at worst, polynomial-time in the length of the sentence to judge grammaticality) and therefore there is no choice to be made with reference to ease of use, even if there were universal perceptions that some particular language is more beautiful than the rest. Therefore, it makes sense that people, in general, continue to use their native language(s) unless circumstances place them in situations where other languages are useful to them. Others might make reference to smart telephones for an alternative argument that beauty presents criteria at least as powerful as "ease", particularly those who find the explanation of the market success of Apple Corporation's iPhones to be their beauty (and not the issues of exclusivity related to their monetary expense, as with other possible instantiations of X, as discussed above).[11]

As coginfocom technologies are assimilated, they create new problems and offer new affordances for adaptation. They interact with other aspects of humanity and open new questions about human behavior in isolation and within interactions.

VII. ETHICS

The prospect of assimilation of technologies that enhance human cognitive capabilities is accompanied by the necessity to explore the ethical ramifications of these technologies [14]. The necessity of attention to the risks associated with such enhancements is embedded in Judeo-Christian creation myth: the extension of cognitive capabilities enabled by eating from the Tree of Knowledge results in being cast out of Eden.

Researchers in medicine study the possibility of pharmaceutical products that can enhance cognitive capabilities [15]. Naturally, this is accompanied by scrutiny of ethical issues raised by such drugs [16]. Some have studied attitudes towards drugs and noted a tendency to be critical of the use of cognitive enhancing drugs where they provide unfair advantages, just as performance enhancing drugs are thought of as "cheating" in athletics [17]. Other researchers provide considered argument that drugs associated with cognitive enhancement should not be deemed unfair *a priori* [18]. The coginfocom discipline has a tendency to focus on coginfocom technologies as those involving computers and robotics, and that is why the focus here on, for example, language, as a coginfocom technology is somewhat jarring, even though computing is often discussed using the label "information and communication technologies".[12] This focus may account for the relative lack of attention to the relationship with medical research on cognitive enhancement. Nonetheless, issues of ethics are shared. However, this does not make it easier to identify the most appropriate ethical framework in which to analyze the issues. Medical ethics is dominated by utilitarian reasoning. Information ethics is a relatively newer approach and sometimes leads to distinctive conclusions [19] – we are not ourselves expert in information ethics but suspect that the framework would endorse developing the cognitive enhancements that coginfocom aspires to while studying their use and supporting regulation of their deployment.

These issues are larger than those addressed by coginfocom researchers in their daily practice. Daily practice for any research involving human participants includes putting it prior

[10] Prosody in natural language may be an example of an adaptation of this technology.

[11] The iPhone is interesting in another respect, as it is an example of a technology for which the perception of need followed its availability (cf. fn. 3), rather than the device filling an obvious need gap. Coginfocom technologies also arise in the other direction, through careful analysis of the user [13].

[12] A Turing machine is equivalent in tangiblity to a language.

independent scrutiny for research ethics evaluation. We think that research ethics committees that evaluate the work of coginfocom researchers dwell on the risks to participants being and their privacy but not the wider issues associated with the acceptability of cognitive enhancements. Indeed, these issues are so wide that they cannot be treated or solved completely within any of those committees, nor here, either. Our tentative conclusion is what we claim above to be consistent with the information ethics perspective: it makes sense to develop new possibilities for cognitive enhancements at the same time as studying how extant ones are used and assimilated and while supporting informed regulation of their deployment. Additionally, we think that regulation of deployment should not absolve potential users of responsibility. It is a persistent risk associated with technology that users may yield responsibility to the technology – whether that means having it make decisions for them or allowing prior abilities to atrophy with dependence on the technologies.[13] For example, from the perspective of cognitive capacity to manage social networks [21], both language and online social media constitute coginfocom technologies. Correlations have been shown between excessive online social media use and psychiatric disorders [22], and evidence of causal links between excessive social media use and efficiency has been produced [23]. Healthy use of cognition enhancing technologies entails being able to moderate that use.

VIII. Related work

We feel that the theory of successful coginfocom technology that we have proposed is consistent with research within coginfocom as well as work within its constituent and cognate disciplines. Our presentation of coginfocom is compatible with definitions provided elsewhere [24], [25], [26] and with prior syntheses of coginfocom research [27], [28]. Recent analysis of prerequisites to future advances in human-computer interaction has presented the view that comprehending, respecting and overcoming human limits are integral to success [29], and interface "efficiency" is identified as a criterion associated with success. It is important to contemplate success criteria.

In the same way that we have discussed emotion, gesture, language and thought as examples of coginfocom technology, other researchers have explored other systems of representation that humans have adopted in support of reasoning; for example, maps are adopted as aids to spatial reasoning [30], [31]. Intersections of topic areas are also addressed in the coginfocom literature. For instance, language use in situations that demand communication of spatial directions has been studied [32], [33], [34]. Some coginfocom researchers have studied linguistic representation of reasoning [35]. The dynamics of human use of gesture during dialogue is a core topic in coginfocom [36], [37], [38], [39], [40], [41], as is emotion [42], the linguistic expression of emotion [43], emotion voicing [44], [45], [46], emotion depiction [47], [48], influence of emotion on reasoning [49], and the synthesis of modalities of expression [50], [51], [52], [53], [54], [55], [56].

[13]This is a counterpart to ethical responsibilities of participants in research studies – typically, the focus is on the ethical responsibilities of the researchers, but participants have responsibilities, as well [20].

At present, most researchers who study topics of relevance to coginfocom were originally trained in one or more of the disciplines that contribute to coginfocom, and continue to provide advances within those disciplines. In advancing the constituent disciplines, they are, by definition, advancing coginfocom. Take linguistics as an example of a constituent discipline. Pursuing linguistics from a coginfocom perspective adds something that is not typically explicit within traditional study of linguistics, through scrutiny of alternative (and additional) technologies that humans may adopt.[14] This is true of each constituent discipline. Coginfocom adds to the constituent disciplines, *inter alia*, focus on each discipline's content as a technology that has been adopted by humans in the past or which might be adopted in the future, whose dynamics in isolation and interaction with other dimensions of humanity requires examination. One could argue that an expansive view of cognitive science or artificial intelligence or, in fact, of any of the contributing disciplines would encompass coginfocom, and we think this argument is correct. If any of the contributing disciplines is expanded in scope to include the perspective that the discipline's content involves a technology that has been assimilated into humanity but which is not essential to humanity it would then be equivalent to a coginfocom perspective on that discipline. We have articulated here theory of successful coginfocom technology, regardless of contributing discipline: for it to be assimilated, it must provide advantages in both the private and public spheres of human existence.

IX. Conclusion

We have explored a theory that viable coginfocom developments are those that operate both in the private and public spheres, enhancing human capabilities for thought and interaction. Coginfocom research may attempt to increase understanding of the interaction of these spheres or properties of the spheres in relative isolation. Research that extends and validates cognition enhancing technologies or that attempts to understand the nature of human cognition or communication, even if in isolation from direct questions of contribution to private and public spheres, still contributes to coginfocom. We think that it is not necessary for each contribution to be contextualized with reference to the totality of coginfocom. The relations may not even be evident at idea inception nor after their validation. It is of primary importance that each contribution advance knowledge with rigorous scholarship. As each makes public the knowledge acquired in private, others may "connect the dots" as inspired by their own insights.

It is indicative of a standard developmental stage of a discipline for it to be open to the exploration of its philosophical principles, at the very least examining whether it creates new ethical dilemmas. The nature of such explorations is that they are never complete. We hope that as coginfocom researchers, we can engage our peers in continuing the discussion.

[14]This does not mean that linguistics who have probably never read a paper published under the aegis of coginfocom do not also contemplate alternatives to natural language. Considering alternatives is, in fact, attested in linguistic theory (e.g. [57, Chr 2 (pp. 8-33), "The Peculiarities of Language"], but this is not the main activity of linguistic theory.

REFERENCES

[1] P. Baranyi and A. Csapo, "Cognitive infocommunications: Coginfocom," in *2010 11th International Symposium on Computational Intelligence and Informatics (CINTI)*, 2010. pp. 141–146. DOI: 10.1109/CINTI.2010.5672257

[2] P. Baranyi and A. Gilányi, "Mathability: Emulating and enhancing human mathematical capabilities," in *IEEE 4th International Conference on Cognitive Infocommunications (CogInfoCom)*, 2013. pp. 555–558. DOI: 10.1109/CogInfoCom.2013.6719309

[3] A. Esposito, A. M. Esposito, and C. Vogel, "Needs and challenges in human computer interaction for processing social emotional information," *Pattern Recognition Letters*, vol. 66, pp. 41–51, 2015. DOI: http://dx.doi.org/10.1016/j.patrec.2015.02.013

[4] C. Vogel and A. Esposito, "Linguistic and behaviour interaction analysis within cognitive infocommunications," in *Proceedings of the 10th IEEE International Conference on Cognitive Infocommunications*, 2019, pp. 47–52.

[5] D. Galanis, S. Karabetsos, M. Koutsombogera, H. Papageorgiou, A. Esposito, and M.-T. Riviello, "Classification of emotional speech units in call centre interactions," in *4th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, pp. 403–406., 2013. DOI: 10.1109/CogInfo-Com.2013.6719279

[6] A. Howard, C. Zhang, and E. Horvitz, "Addressing bias in machine learning algorithms: A pilot study on emotion recognition for intelligent systems," in *2017 IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO)*, pp. 1–7., 2017. DOI: 10.1109/ARSO.2017.8025197

[7] M. O'Neill, "'Wholly Incommunicable by Words': Romantic expressions of the inexpressible," *The Wordsworth Circle,* vol. 31, no. 1, pp. 13–20, 2000. DOI: 10.1086/TWC24044189

[8] T. J. Taylor, Mutual Misunderstanding: *Scepticism and the Theorizing of Language and Interpretation*. Duke University Press, 1992. DOI: 10.1215/9780822383000

[9] P. Healey, "Communication as a special case of misunderstanding: Semantic coordination in dialogue," Ph.D. dissertation, Centre for Cognitive Science, University of Edinburgh, 1995. [Online]. Available: https://era.ed.ac.uk/handle/1842/20559

[10] C. Vogel, "Attribution of mutual understanding," *Journal of Law & Policy*, vol. 21, no. 2, pp. 377–420, 2013. [Online]. Available: https://brooklynworks.brooklaw.edu/jlp/vol21/iss2/6

[11] D. MacNeill, "Growth points cross linguistically," in Language and Conceptualization, ser. Language, Culture & Cognition, J. Nuyts and E. Pederson, Eds. Cambridge University Press, 1997, pp. 190–212. DOI: 10.1017/cbo9781139086677.008

[12] R. E. Milliman, "Using background music to affect the behavior of supermarket shoppers," *Journal of Marketing*, vol. 46, no. 3, pp. 86–91, 1982. DOI: 10.2307/1251706

[13] B. Szabó and K. Hercegfi, "Research questions on integrating user experience approaches into software development processes," in *2017 8th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, pp. 243–246., 2017. DOI: 10.1109/CogInfoCom.2017.8268250

[14] N. Bostrom and A. Sandberg, "Cognitive enhancement: Methods, ethics, regulatory challenges," *Science and Engineering Ethics*, vol. 15, no. 3, pp. 311–341, 2009. DOI: 10.1007/s11948-009-9142-5

[15] R. W. Buchanan, R. S. E. Keef, D. Umbricht, M. F. Green, T. Laughren, and S. R. Marder, "The FDA-NIMH-MATRICS guidelines for clinical trial design of cognitive-enhancing drugs: What do we know 5 years later?" *Schizophrenia Bulletin*, vol. 37, no. 6, pp. 1209–1217, 2011. DOI: 10.1093/schbul/sbq038

[16] V. Cakic, "Smart drugs for cognitive enhancement: Ethical and pragmatic considerations for the era of cosmetic neurology," *Journal of Medical Ethics*, vol. 35, no. 10, pp. 611–615, 2009. DOI: 10.1136/jme.2009.030882

[17] C. Scheske and S. Schnall, "The ethics of "smart drugs": Moral judgments about healthy people's use of cognitive-enhancing drugs," *Basic and Applied Social Psychology*, vol. 34, no. 6, pp. 508–515, 2012. DOI: 10.1080/01973533.2012.711692

[18] H. Greely, B. Sahakian, J. Harris, R. C. Kessler, M. Gazzaniga, P. Campbell, and M. J. Farah, "Towards responsible use of cognitiveenhancing drubs by the healthy," *Nature*, vol. 456, no. 7223, pp. 702–705, 2008. DOI: 10.1038/456702a

[19] L. Floridi, "Information ethics: On the philosophical foundation of computer ethics," *Ethics and Information Technology*, vol. 1, pp. 37–56, 1999. DOI: 10.1023/a:1010018611096

[20] M. Koutsombogera and C. Vogel, "Ethical responsibilities of researchers and participants in the development of multimodal interaction corpora," in *8th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, P. Baranyi, A. Esposito, P. Földesi, and T. Mihálydeák, Eds., 2017. pp. 277–282. DOI: 10.1109/coginfocom.2017.8268256

[21] R. Dunbar, *Grooming, Gossip, and the Evolution of Language*. Harvard University Press, 1998.

[22] C. S. Andreassen, J. Billieux, M. D. Griffiths, D. J. Kuss, Z. Demetrovics, E. Mazzoni, and S. Ballesen, "The relationship between addictive use of social media and video games and symptoms of psychiatric disorders: A large-scale cross-sectional study," *Psychology of Addictive Behaviors*, vol. 30, no. 2, pp. 252–262, 2016. DOI: 10.1037/adb0000160

[23] S. Brooks, "Does personal social media usage affect efficiency and wellbeing," *Computers in Human Behavior*, vol. 46, pp. 26–37, 2015. DOI: 10.1016/j.chb.2014.12.053

[24] P. Baranyi and A. Csapo, "Definition and synergies of cognitive infocommunications," *Acta Polytechnica Hungarica*, vol. 9, no. 1, pp. 67–83, 2012. [Online]. Available: http://acta.uni-obuda.hu//Baranyi_Csapo_33.pdf

[25] A. Csapo and P. Baranyi, "Coginfocom channels and related definitions revisited," in *IEEE 10th Jubilee International Symposium on Intelligent Systems and Informatics (SISY)*, 2012. pp. 73–78. DOI: 10.1109/sisy.2012.6339489

[26] P. Baranyi, A. Csapo, and G. Sallai, *Cognitive Infocommunications (CogInfoCom)*. Springer, 2015. ISBN 978-3-319-19607-7 DOI: 10.1007/978-3-319-19608-4.

[27] G. Sallai, "The cradle of cognitive infocommunications," *Acta Polytechnica Hungarica,* vol. 9, no. 1, pp. 171–181, 2012. [Online]. Available: http://acta.uni-obuda.hu//Sallai_33.pdf

[28] P. Baranyi, A. Csapo, and P. Varlaki, "An overview of research trends in CogInfoCom," in *IEEE 18th International Conference on Intelligent Engineering Systems*, ser. INES, 2014. pp. 181–186. DOI: 10.1109/ines.2014.6909365

[29] Á. Török, "From human-computer interaction to cognitive infocommunications: a cognitive science perspective," in *7th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, P. Baranyi et al., Eds., pp. 433–438., 2016. DOI: 10.1109/coginfocom.2016.7804588

[30] Á. Török, Z. G. Török, and B. Tölgyesi, "Cluttered centres: Interaction between eccentricity and clutter in attracting visual attention of readers of a 16th century map," in *8th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, P. Baranyi, A. Esposito, P. Földesi, and T. Mihálydeák, Eds., 2017. pp. 433–437. DOI: 10.1109/coginfocom.2017.8268285

[31] Á. Török and Z. G. Török, "Looking at the map – or navigating in a virtual city: Interaction of visuospatial display and spatial strategies in vr," in *9th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, P. Baranyi et al., Eds., 2018. pp. 327–333. DOI: 10.1109/coginfocom.2018.8639898

[32] J. Reverdy and C. Vogel, "Measuring synchrony in task-based dialogues," in *Proceedings of the 18th Annual Conference of the International Speech Communication Association (INTERSPEECH2017)*, 2017. pp. 1701–1705. DOI: 10.21437/interspeech.2017-1604

[33] C. Vogel, M. Ribeiro Lopes, and A. Esposito, "Gender differences in the language of the map task dialogues," in *8th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, P. Baranyi, A. Esposito, P. Földesi, and T. Mihálydeák, Eds., 2017. pp. 151–156. DOI: 10.1109/coginfocom.2017.8268233

[34] J. Reverdy, H. Akira, and C. Vogel, "Alignment in a multimodal interlingual computer-mediated map task corpus," in *Proceedings of the Eleventh International Conference on Language Resources and Evaluation (LREC 2018)*, H. Koiso and P. Paggio, Eds. Paris, France: European Language Resources Association (ELRA), 2018. ISBN 979-10-95546-16-0 pp. 55–59. [Online]. Available: http://lrec-conf.org/workshops/lrec2018/W20/pdf/14_W20.pdf

[35] I. Poggi, F. D'Errico, and L. Vincze, "Uncertain words, uncertain texts. perception and effects of uncertainty in biomedical communication," *Acta Polytechnia Hungarica*, vol. 16, no. 2, pp. 13–34, 2019. [Online]. Available: http://acta.uni-obuda.hu//Poggi_DErrico_Vincze_89.pdf

[36] A. Kendon, Gesture: *Visible Action as Utteranc*e. Cambridge University Press, 2004. DOI: 10.1017/cbo9780511807572

[37] A. Esposito and M. Marinaro, "What pauses can tell us about speech and gesture partnership," in *The Fundamentals of Verbal and Non-Verbal Communication and the Biometrical Issue*, A. Esposito, E. Keller, M. Marinaro, and M. Bratanic, Eds. Amsterdam: IOS Press, 2007, pp. 45–57. [Online]. Available: http://ebooks.iospress.nl/volumearticle/8732

[38] C. Navarretta, "Alignment of communicative behaviors and familiarity in first encounters," in *2014 5th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 2016. pp. 185–190. DOI: 10.1109/CogInfo-Com.2014.7020443

[39] ——, "Predicting an individual's gestures from the interlocutor's cooccurring gestures and related speech," in *2016 7th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 2016. pp. 233–238. DOI: 10.1109/CogInfoCom.2016.7804554

[40] ——, "Prediction of audience response from spoken sequences, speech pauses and co-speech gestures in humorous discourse by barack obama," in *2017 8th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 2016. pp. 327–332. DOI: 10.1109/CogInfoCom.2017.8268265

[41] M. Koutsombogera, R. Costello, and C. Vogel, "Quantifying dominance in the multisimo corpus," in *9th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, P. Baranyi, A. Esposito, P. Földesi, and T. Mihálydeák, Eds., 2018. pp. 147–152. DOI: 10.1109/coginfocom.2018.8639952

[42] F. Berthelon and P. Sander, "On multimodality in the perception of emotions from materials of the hucomtech corpus," in *2013 5th IEEE International Conference on Cognitive Infocommunications (CogInfo-Com)*, 2013. pp. 59–64. DOI: 10.1109/CogInfoCom.2013.6719313

[43] B. Lewandowska-Tomaszczyk and P. A. Wilson, "Compassion, empathy and sympathy expression features in affective robotics," in *2016 7th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 2016. DOI: 10.1109/CogInfoCom.2016.7804526 pp. 65– 70.

[44] A. Esposito, "The perceptual and cognitive role of visual and auditory channels in conveying emotional information," *Cognitive Computation*, vol. 1, no. 3, pp. 268–273, 2009. DOI: 10.1007/s12559-009-9017-8

[45] A. Esposito, M. T. Riviello, and N. Bourbakis, "Cultural specific effects on the recognition of basic emotions: A study on italian subjects," in *HCI and Usability for e-Inclusion: 5th Symposium of the Workgroup Human-Computer Interaction and Usability Engineering of the Austrian Computer Society, USAB 2009, Linz, Austria, November 9-10, 2009 Proceedings*, A. Holzinger and K. Miesenberger, Eds. Springer Berlin Heidelberg, 2009, pp. 135–148. DOI: 10.1007/978-3-642-10308-7_9

[46] A. Origlia, V. Galatá, and F. Cutugno, "Introducing context in syllable based emotion tracking," in *2014 5th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 2014. pp. 337–342. DOI: 10.1109/CogInfoCom.2014.7020475

[47] A. Esposito, A. M. Esposito, I. Cirillo, L. Panfilo, F. Scibelli, M. Maldonato, and C. Vogel, "Differences between hearing and deaf subjects in decoding foreign emotional faces," in *8th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, P. Baranyi, A. Esposito, P. Földesi, and T. Mihálydeák, Eds., 2017. pp. 175–180. DOI: 10.1109/coginfocom.2017.8268237

[48] A. Esposito, A. M. Esposito, G. Cordasco, M. Maldonato, C. Vogel, and N. Bourbakis, "Emotional faces of children and adults: What changes in their perception," in *9th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, P. Baranyi, A. Esposito, P. Földesi, and T. Mihálydeák, Eds., 2018. pp. 105–110. DOI: 10.1109/coginfocom.2018.8639963

[49] O. Matarazzo, B. Pizzini, C. Greco, and M. Carpentieri, "Effects of a chance task outcome on the offers in the ultimatum game: The mediation role of emotions," in *7th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, P. Baranyi et al., Eds., 2016. pp. 295–300. DOI: 10.1109/coginfocom.2016.7804564

[50] N. Bourbakis, A. Esposito, and D. Kvaraki, "Extracting and associating meta-features for understanding people's emotional behaviour: Face and speech," *Cognitive Computation*, vol. 3, no. 3, pp. 436–448, 2011 DOI: 10.1007/s12559-010-9072-1

[51] A. Esposito, "The amount of information on emotional states conveyed by the verbal and nonverbal channels: Some perceptual data," in *Progress in Nonlinear Speech Processing*, ser. LNCS 4391, Y. Stylianou, M. Faundez-Zanuy, and A. Esposito, Eds. Springer-Verlag: Berlin, 2007, pp. 249–268. DOI: 10.1007/978-3-540-71505-4_13

[52] R. Volpe, L. Chanquoy, and A. Esposito, "The matrix of meaning: Representing meaning in mind; prolegomena to a theoretical mind," in *Analysis of Verbal and Nonverbal Communication and Enactment: The Processing Issues*, A. Esposito, A. Vinciarelli, K. Vicsi, C. Pelauchaud, and A. Nijholt, Eds. Heidelberg: Springer, 2011, pp. 316–334. DOI: 10.1007/978-3-642-25775-9_30

[53] M. T. Riviello, A. Esposito, and K. Vicsi, "A cross-cultural study on the perception of emotions: How Hungarian subjects evaluate American and Italian emotional expressions," in *Cognitive Behavioural Systems*, A. Esposito, A. M. Esposito, A. Vinciarelli, R. Hoffmann, and V. C. Müller, Eds. Springer, LNCS 7403, 2012, pp. 424–448. DOI: 10.1007/978-3-642-34584-5_38

[54] L. Hunyadi, "On multimodality in the perception of emotions from materials of the hucomtech corpus," in *2015 6th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 2015. pp. 489–492. DOI: 10.1109/CogInfoCom.2015.7390642

[55] S.-E. Fotinea, E. Efthimiou, M. Koutsombogera, A.-L. Dimou, T. Goulas, P. Maragos, and C. Tzafestas, "The mobot human-robot communication model," in *2015 6th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 2015. pp. 201–206. DOI: 10.1109/CogInfo-Com.2015.7390590

[56] A. Esposito and L. C. Jain, "Modeling social signals and contexts in robotic socially believable behaving systems," in *Toward Robotic Socially Believable Behaving Systems Volume II - "Modeling Social Signals"*, A. Esposito and L. C. Jain, Eds. Cham, Switzerland: Springer, 2016, pp. 5–13. DOI: 10.1007/978-3-319-31053-4_2

[57] A. Carstairs-McCarthy, *The Origins of Complex Language: An Inquiry into the Evolutionary Beginnings of Sentences, Syllables and Truth*. Oxford: Oxford University Press, 1999.

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