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New frontiers for Crowdsourcing: the Extended Mind

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Abstract

We introduce the concept of extended mind crowdsourcing (EMC) which capitalises on the way in which humans naturally extend their cognition into the environment, using external objects such as smartphones and applications to augment their mental capacity. This phenomenon means that human computation is embedded in data and devices, representing a new way through which human cognition can be accessed for collective discoveries. We relate EMC to existing sociological and psychological concepts and argue that it lies at the intersection of human computation, social computing and crowdsourcing.

EMC is a way in which new problems and discoveries can be tackled, for example as necessitated by "wicked" problems, ethnography and culture. We relate EMC to diverse disciplines and point to ways in which the concept may develop in future. We exemplify EMC by presenting a case study where participation in location-based social networks is used to discover the correlation between mobility and human personality traits. This has involved participation from 43 countries and resulted in analysis of over half a million check-ins at street-level locations.

1 Introduction

Crowdsourcing has emerged as an important and effective component for task-led problem solving, generally defined as enlisting a crowd of humans to help solve a problem defined by the system owners [1]. Traditionally this has involved an agent applying human computation to the problem or sub-problem, with tasks distributed and responses mediated through a computer interface. These tasks often occur for a short duration and have an explicit end-point. This is now a relatively well-established form of collective intelligence, that has emerged through a number of successful commericial platforms and become a viable way to conduct survey-based research [2].

As technology is developing, new opportunities and applications for crowdsourcing are emerging. In particular discovery of collective human behaviour and inherent culture is becoming possible. Recent examples include the characterisation of international eating habits [3], the grand vision of the FuturICT initiative [4] and discovery of correlations between personality and decisions in the places that we visit [5]. These developments are occurring hand-in-hand with the progression of technologies capable of capturing more and more of our individual activity and cognition. Collectively these represent sources of rich but complex data.

In this paper we argue that crowdsourcing is beginning to expand from task focussed "job orientation" to provide a means of discovery concerning societal behaviour and culture. We postulate that this additional form of crowdsourcing is capable of capitalising on the way in which humans extend their cognition by integrating patterns of the mind with objects in the external environment. This is described by the so called "extended mind hypothesis" [6] where thinking extends beyond a private and internal space to use objects in the environment. A simple example of this includes actively engaging with a note book to record a memory. Subsequently the mind leans on this recollection and points to the note book where the memory is located. The use of smartphones, apps and social media now exemplify this theory in a digital form, where individuals that exploit technology become *prosumers* (e.g., [7]), simultaneously being both consumers and producers of social and environmental signals that augment the mind.

To capture this new development we formalise the notion of *extended mind crowdsourcing* (EMC) and demonstrate an example of this in detail. We contrast

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and characterise EMC using a framework for human computation systems [8] and argue that EMC falls at the intersection of crowdsourcing with human computation and social computing, while being closely linked to participatory computing. Furthermore, we argue that this form of crowdsourcing opens up prospects for enhanced *discovery*, for example as a new way to challenge wicked problems [9] in social, cultural and organisational areas.

2 Crowdsourcing, Participation and Cognition

The notion of crowdsourcing in the literature dates back to 2006 where it was introduced in the context of a tool for problem solving by Howe [10] in a Wired magazine article. This was informally described as *"taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people in the form of an open call"*. The original motivation behind crowdsourcing was commercial, driven by the concept of *outsourcing*, as a tool to undertake tasks for an organisation in a new manner. The utility that crowdsourcing offers has spread to other problem solving domains, including research and quality assessment.

A more formal definition of crowdsourcing is proposed in [2] as *"the paid recruitment of an online independent global workforce for the objective of working on a specifically defined task or set of tasks"*. This is a contract driven perspective, such as for use of crowdsourcing in survey based research, where worker recruitment is self-selecting subject to prerequisites defined by the task. However in [1] a more general definition is given as *"enlisting a crowd of humans to help solve a problem defined by the system owners"*. This definition reinforces that payment need not be financial and the underlying issue is establishing a means to recruit and retain users which for example, can be for social, competitive or altruistic reasons. Further fundamental issues highlighted in [1] include what the participants are specified to do, how to combine their inputs and how to evaluate them. In [11] the diversity of crowdsourcing definitions is consolidated, resulting in the need for i) a clearly defined crowd, ii) a task with a clear goal, iii) clear recompense received by the crowd, iv) a clear owner of the crowdsource task; v) clearly defined compensation for the participant; vi) an online assigned process of participative type; vii) an open call of variable extent; viii) use of the Internet.

Due to reliance on extensive human participation, crowdsourcing has close relationships with other areas of computation [8], particularly as a sub-set of collective intelligence [12] and with overlap to both social computing [13] and human computation [14]. Across these different forms of computational systems there is a dependency on humans to impart some form of explicit reasoning, judgment or analysis that is reconciled to create an overall finding that could not be deduced from a single agent in isolation. This leaves scope for many different approaches and characterisations and has led to the development of classification systems, such as proposed in [8] which concern participant motivation, quality control, aggregation, human skill, process order and task request cardinality. Key components of crowdsourcing are shown in Figure 1. Here we see the independent flows of human-computer interaction, with individuals broadly shaping their views from their interaction with the world and society.

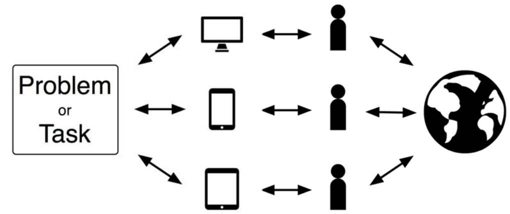

Figure 1. Overview of components and process for crowdsourcing.

2.1 Participatory Computing

Closely related to crowdsourcing is the concept of *participatory computing*, an umbrella term expressing the idea that data and resources can be contributed by devices and software for collective purposes [4]. The data in these scenarios are often distributed and difficult to capture by conventional means. The focus of participatory computing is largely technical and data driven, often concerning the volume, variety and velocity of data. This often leads to the use of analysis techniques from complexity science [15]. The origin of participatory computing can be tracked back in this direction to Burke et al [16] which introduced the concept of *participatory sensing*, where through sensors embedded in mobile devices, data could be collected from accompanying human activity in the physical world, particularly the urban environment. This has gained significant traction in the academic community, particularly concerning the computing and engineering literature, where significant challenges have rested on soft-, middle- and hard-ware design issues such as those surveyed in [17]. These involve a wide variety of applications including road surface monitoring [18] and traffic conditions [19]. Popular smartphone applications in this area are surveyed in [20].

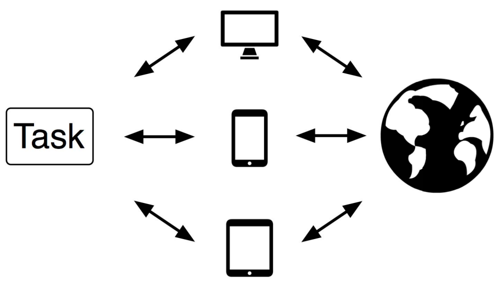

Figure 2. Overview of components and process for participatory computing.

In Figure 2 we show a simple schema that expresses the role of devices in accomplishing tasks. The devices are embedded in the world environment, which may include people or objects. In contrast to Figure 1 the role of the human in providing computational input is diminished and the focus is on pipelining data for a specific task. Throughout much of the literature, participation is viewed from a meta-scale perspective and the role of the human is restricted to an abstract agent that creates or ports data. There is limited characterisation of the relationship between the individual and the technology beyond functional requirements for data acquisition. However this relationship is important because it governs the opportunity the device has for capturing implicit and explicit data concerning the individual user, social interactions and the wider environment.

2.2 Cognition and the Extended Mind

From a cognitive perspective there has been a substantial interest to support the view that cognitive processes are *"deeply rooted in the body's interactions with the world"* [21]. While some aspects of this are debated by the cognitive community, there is some general support for devolvement of cognitive load to environmental objects [21], which through technology gives a way to access the results of cognition. A key argument made by Clark and Chalmers in 1998 [6] concerning the *extended mind* explains why human acceptance and exploitation of supporting technological "objects" such as the smartphone is so natural. Spanning cognition and philosophy, the extended mind hypothesis postulates that humans begin to engage objects in the environment to support their cognition, effectively outsourcing cognitive capabilities where possible. This concept is referred to as *active externalism* and is built on the idea that the human mind and its boundaries are not clear cut - the human's environment and objectives within it effectively become part of human cognition.

Clark and Chalmers describe this as *"the general tendency of human reasoners to lean heavily on environmental support"*, bringing the spotlight on physical instruments (pens, notepads, slides rules etc) and also how we may arrange things such as Scrabble® pieces to prompt thoughts. While simplistic, they exemplify devolution and delegation leading to coupled systems, where cognition becomes a consequence of the way in which the pieces have become arranged, complementary to internal cognitive processes.

When technology is brought into consideration, one might argue that the concept of *active externalism* has come of age. Examples such as the smartphone, social networks and their apps are relevant to this paper. Outsourcing of memory based tasks, knowledge acquisition and interaction with the environment are now routinely devolved from the human to the smartphone on an everyday basis. In the other direction, Clark and Chalmers argue that technology becomes incorporated into our minds by taking over functions such as memory, planning, spatial navigation and decision making. Portability is important in engaging with the extended mind hypothesis because the smartphone is acting in the environment as a cognitive component which travels with its owner for the majority of the time. It has awareness of its location and is exposed to signals and stimuli that capture the consequences of human cognition and behaviour.

3 Extended Mind Crowdsourcing

We argue that following mass technological adoption and increasing technological capability, embodied cognition is now an important driver for crowdsourcing. To develop this concept in a general form we make the following definition.

Definition 1 *Extended mind crowdsourcing (EMC) engages data from devices and objects used for active externalism, by a social group of participants, to obtain implicit and explicit human computation for collective discovery.*

The idea of extended mind crowdsourcing is shown diagrammatically in Figure 3. The human mind, and behavioural results of cognition, are being captured by devices and our interaction with objects such as social media, sensors, computers and smartphones. These data are captured and sampled electronically which gives us a new basis for investigation and are not necessarily the result of a pre-defined task or issue. Many *wicked problems* [9] in society are relevant to this category as they are not well-defined, highly dynamic and hugely complex. This makes them difficult to investigate and understand, leading to the challenge of rational solutions [22]. Conceptually EMC can be thought of as discovering and aggregating many individual extended minds, providing insights into a collective mind of society. Note that an individual extended mind may clearly represent an individual human, but it may also represent a group, such as a network or a collective. Deliberately we define computation in terms of a tool for discovery, so that wide ranging forms of aggregation and analysis are possible, for example from correlation and prediction through to reasoning.

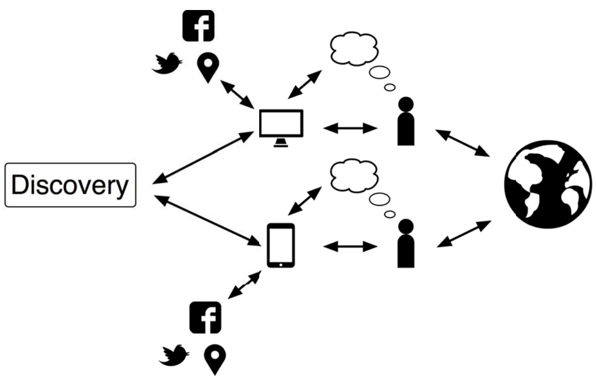

Figure 3. Overview of components and process for extended mind crowdsourcing.

3.1 Characteristics of EMC

The important work of Quinn et al [8] classifies various informal concepts concerning human computation, crowdsourcing and social computing. Adopting their schema, Figure 4 identifies extended mind crowdsourcing as the intersection of these concepts.

Regarding *social computing*, EMC is embedded in this area because the extended mind hypothesis is facilitated by technology that mediates natural human behaviour such as interaction with friends and conversation. [8] notes that this is a key distinguishing feature of social computing and as such there is strong alignment with this concept. The distinction with social computing is that EMC has the intention of performing a computation, specifically for discovery, whereas this is not usually the direct purpose of social computing.

There is no unique definition of *human computation*, but from considering a range of literature in this area, Quinn et al [8] conclude that human computation constitutes problems that: i) fit with the general paradigm of computation, and as such might be someday solvable by computers; ii) have human participation directed by the computational system or process. Because i) and ii) have been deduced from task focussed approaches to human computation, we find that EMC challenges these requirements in different ways. With regard to i) EMC maps into this space through human computation being extended into devices and objects, the consequences of which are embedded in data. This represents an interface between human and machine computation, but this does not represent something that is intended to replace human computation. With regard to ii), EMC contrasts with the idea of human participation being directed by the computational system or process. In EMC the individual chooses the extent to which she is directed by systems, for example choosing whether or not to engage with objects or devices.

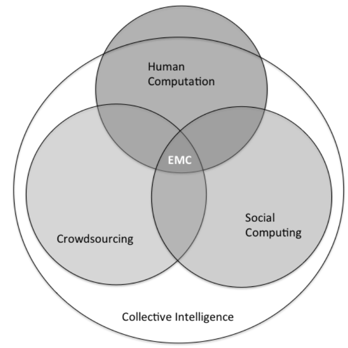

Figure 4. The relationship between Extended Mind Crowdsourcing and key concepts.

Finally in terms of crowdsourcing, EMC focusses on aggregation and analysis of data that arises as a consequence of use of devices to support cognition. This is a shift from the traditional idea of crowdsourcing that was introduced in Section 2 as tasks to engage human computation.

3.2 EMC and Distributed Cognition

The EMC definition captures the way in which the human undertakes and responds to daily activity. In this sense it supports observation of human life and our interpretation and response to the environment. From a cognitive perspective (e.g., [23]), the concept is very close to that of culture as a *"human cognitive process that takes place both inside and outside the minds of people"*. Further in this direction, EMC represents a type of distributed cognition, as formalised in [24].

This model widely encompasses cognitive events beyond the physical being of a human and it has two underlying principles: i) expanded boundaries of the "unit of analysis" for cognition and ii) an assumption that a diverse range of mechanisms are involved in cognitive processes.

EMC effectively samples the results of distributed cognition "in-the-wild" [23] and when observing human activity in this context [25], three forms of cognitive process occur: i) across social groups; ii) between internal and external structures and iii) over time. EMC has the scope to directly sample the results of distributed cognitive processes through a wide variety of electronic devices and technologies. In particular: social media, social networks and electronic communication encompass cognitive processes across social groups; interaction with smartphones, software and pervasive devices for active externalism crosses boundaries between internal and external structures; the use of hardware, software and services for memories reflects cognitive processes on a temporal basis.

The model of distributed cognition also draws attention to the interplay between individuals and groups in terms of cognition and behaviour, presenting how 'society of mind' and the 'mind in society' standpoints both function [25]. EMC can contribute to both these schools of thought. This is dependent on the form of active externalism, and whether it reflects cognitive process that are driven by the individual or a group. However in practice for EMC, a delineation between these types of cognitive process may be hard to establish, because individual agents are socially intertwined and embedded in a complex society and digital worlds. This does not pose a significant problem, because it is precisely this combination of individual and group-based cognitive processes that lead to new insights. Hutchins [25] points out that *"by simultaneously considering the society of mind and mind of society, the distributed cognition approach provides a new place to look for the origins of complexity"*.

3.3 Further Observations

Extended mind crowdsourcing supports 'in-the-wild' activity and in doing so, enables observation of problems that may not necessarily be *a-priori* defined nor anticipated. This means that it is widely applicable to many disciplines and open issues, including those characterised as wicked problems [9]. By definition wicked problems may be insoluble but it is possible that the exposure of distributed cognition, through EMC, can offer insights to understand *"the origins of complexity"* [25]. For example, discoveries may emerge as a consequence of unforeseen external stimuli, such as an event in the environment that provokes a response, or a change in extended cognition from humans. To date observations of this nature have largely been seen on a local scale such as through dialogue analysis (e.g., [26]) and EMC provides a new basis to expand this further. This leads to many potential social insights, including *cognition, decision making, behaviour, groups, organizations, societies, and the world system*, which underpin the emerging area of computational social science [27]. EMC also includes potential discoveries related to qualitative and societal concepts such as culture and emotion. For example recent discoveries have found evidence on how different societies approach eating and drinking [3] and how societies engage with empathy [28].

The relevance of networked individualism [29] to EMC is worth noting. Networked individualism decouples the spatial proximity of a human agent from social interactions, which can occur through computer supported communication and social media. This concept emphasises person-to-person connectivity and agility of human switching between different social networks and ties. This is consistent with the idea of the technology supported extended mind.

EMC also has links to Cultural-Historical Activity Theory [30, 31] (CHAT), proposed as a way to avoid *'atomistic and functional modes of analysis"* [31]. This shares with EMC the idea that cognition is not isolated from the world, and that the individual characteristics of the human are highly influential. Vygotsky [31] identifies this in the context of educational psychology, and as pointed out in [30], states: *"the thought process appear as ... segregated from the fullness of life, from the personal need and interests, the inclinations and impulses of the thinker"*.

Vygotsky was clearly identifying with the reality of cognition 'in-the-wild', and in today's world this involves technology as an object to extend cognition. Kuutti [32] has offered Activity Theory as a potential framework for human computer interaction, arguing that greater emphasis on human actors and contextualisation are issues that can be improved by its adoption. Using this framework, EMC offers: new opportunity to include human action as a unit of analysis; a new basis for retaining and accessing historic activities; and new forms of artifact and mediation through digital media.

4 An EMC Exemplar

To explain EMC further, we introduce a case-study exploring human behaviour through EMC. A fundamental but often overlooked issue in society is *human mobility*, specifically relating to the places we visit and why. Although mobility is not classed as a "problem" in the sense of it being unwanted, the consequences of mobility on society, both positive and negative, are substantial. Equally, the influences upon human mobility from society are complex and diverse. For example, environmental consequences of mobility are significant yet mobility is widely seen as a positive indicator of economic health. For the individual, mobility has well-being implications as well as an economic cost. Mobility is also a fundamental feature of urban planning, smart cities and quality of life. From a business perspective, mobility expresses consumer preferences and individual choice, with influences from marketing, the media and cultural norms. From cognitive perspective these can be viewed both as societal (group) influences and factors that reflect the disposition of the individual. From such complexity it is fair to say that human mobility exhibits many characteristics of wicked problems [22].

Despite sophisticated technologies emerging (see Section 4.2) we have a relatively limited insight into the drivers and influences on human mobility. EMC offers an alternative way to approach this. The particular aspect that we address through EMC concerns individual differences between humans, and how this affects the visited places we choose to share knowledge of. As far as we can establish, it is the only known study that addresses individual participant differences (human disposition through personality) in the analyses. This gives insight to where some of the complexity lies through access to the extended mind.

4.1 Location-based Social Networks

We use location-based social networks (LBSNs) as the extended mind in this scenario. LBSNs operate on location-aware smartphone platforms with users triggering a record of their presence at a location via a smartphone application. This action is referred to as a 'check-in' at a venue. Check-ins are shared in near-real time using a dedicated social network. In LBSNs the geographical location of a user is normally represented at street level, for example a shop, park, or building. Extensible taxonomies of check-ins have grown from massive user participation and have become widespread for urban areas in the developed world. Examples of LBSN include Facebook, Foursquare and Google+. These networks represent a new form of active externalism which are exploited to record, judge and share places that people visit. Consequently they offer a new opportunity for EMC and this has been the motivation for investigating personality through Foursquare activity.

4.2 Mobility Behaviour

Human mobility behaviour is currently best understood at the meta-level, using social network structures (e.g., [33]) or statistical physics to capture patterns that exist (e.g., [34]) and the underlying characteristics of these [35]. Only recently have social media check-ins been used in this type of investigation (e.g., [36]), with previous studies reliant on tracking cell phone connections. While these findings have given profound insights into human self-organisation as a species (e.g., [37]), individual level human behaviours at street level may have significant differences. For example, humans choose to shop at different locations, visit different areas and may choose to be active at different times. How these mobility differences manifest themselves in relation to individual human differences is not understood and this is an important 'next step' in discovering more about human behaviour and society.

4.3 Capturing Individual Differences

Individual differences in human behaviour relate to how we generally approach the world and situations within it. This is the overall argument originally made by trait theorists (e.g., [38]) which has gained considerable interest in psychology. Assuming that traits are influential, there is reason to believe that they may influence the decisions people make about their own mobility and the types of place that they choose to visit. Traits are often described informally as one's *personality*, and interesting correlations have been found between personality and a diverse range of everyday choices. Recently personality has been correlated with online social behaviours concerning Facebook (e.g., [39]) and Twitter (e.g., [40]) as well as general Internet usage [41].

While not without significant ongoing debate [42], the five-factor Personality characterisation [43] has become very popular. This addresses *Openness, Conscientiousness, Agreeableness, Extraversion* and *Neuroticism.* Trait strength can be determined by questionnaire [44] which requires direct input from the participant. The individual traits are characterised as follows:

Openness encompasses traits such as originality, curiosity, spontaneity and imagination. Discovery, creativity and a desire to increase the breadth and depth of ideas, views and experiences are associated with this trait.

Conscientiousness describes general diligence, persistence, organisation and resourcefulness. A high score in Conscientiousness can indicate a focused and directed approach to behaviour, with a keenness to close tasks properly.

Extraversion concerns outgoingness, assertiveness and sociability. Extraverts tend to be natural at interacting with others and comfortable with large groups of people and social environments.

Agreeableness refers to a trusting, cooperative and giving nature. A high agreeableness level indicates potential altruism and an ability to collaborate with others.

Neuroticism relates to emotional consistency and stability, covering impulsiveness and a disposition for negative expression. Highly neurotic individuals are disposed to experiencing stress and may be prone to moodiness.

Each of these dimensions are represented on a numeric scale which is easily computable and comparable. This makes the five factor model highly convenient for computational purposes.

4.4 The Foursquare Personality Case Study

This example of EMC has been undertaken using Foursquare, a popular LBSN. This LBSN provides functionality to gain insight into human activity at the street level. Using a viral web campaign, volunteers were recruited from users of Foursquare. Participants engaged by undertaking an online questionnaire that involved 44 questions from which personality could be assessed [44]. Participation involved users securely accessing their account through an API provided by Foursquare which was embedded in the online interface while respecting terms and conditions of usage.

In response to a Foursquare user logging in with their credentials, access to the individual's Foursquare activity was granted. The individual's check-in history was accessed for subsequent analysis while the individual undertook the personality questionnaire. This occurred with transparency and in reward, the participant received a summary of their personality profile in the five dimensions, together with an interactive map of all Foursquare venues they had visited showing their personality as compared to average personality recorded at those locations. A picture of the interface is shown in Figure 5.

The case study recruited 183 participants who collectively provided 542,958 check-ins at 119,746 venues. Participants logged check-ins for 43 different countries, with the UK and USA being the most popular country followed by France, the Netherlands and Brazil. Crowdsourcing of these check-in and personality data allowed us to examine underlying characteristics relating personality and the check-in behaviour.

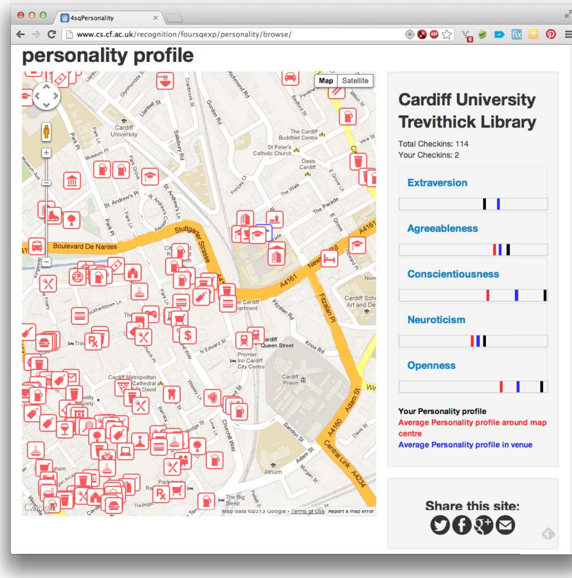

Figure 5. Foursquare user personality interface, showing the user's personality profile as compared to the aggregated profiles of other visitors at a chosen venue.

The results of this study [45] have revealed how check-in behaviour correlates (Spearman correlation) with personality traits concerning Conscientiousness, Openness and Neuroticism. To investigate this at a high level all venues were broadly assessed in terms of their popularity and sociability. The popularity of each of the 119,746 venues was examined by considering the average number of likes provided by all Foursquare users for a given venue. Sociable venues can be described as those that individuals would be expected to visit with friends or associates to engage in activities. Prior to analysis, the Crowdflower[1] crowdsourcing service was commissioned to identify which of the 663 Foursquare venue categories could be described as 'sociable'. Each of the categories was shown to at least five agents and only those categories rated 'sociable' with a Crowdflower confidence level[2] of 80% or above were considered. 479 out of the 663 Foursquare venue categories were found to be sociable, resulting in 46,843

[1] http://www.crowdflower.com

[2] A measure in Crowdflower based on the trust scores of the agents involved.

sociable venues in the dataset.

It was reported in [45] that Conscientiousness positively correlates with the number of venues visited ($r = 0.1522, p < 0.05$), Openness positively correlates with check-ins at both sociable venues ($r = 0.150946, p < 0.05$) and popular venues ($r = 0.15213, p < 0.05$) and Neuroticism negatively correlates with the number of sociable venues visited ($r = -0.171348, p < 0.05$). These findings provided insight into how individuals deal with the cognitive burden of this technology, how individuals seek diversity of experience and highlight characteristics that individuals have when not prioritising participation at sociable venues.

From a crowdsourcing perspective, the Foursquare Personality case study has strong alignment with Definition 1. LBSNs are important because they directly support active externalism: they represent an object through which cognition is supported and extended - the network structure is a vehicle for communication and some users may opt to use the LBSN as a memory through which individuals can recall where and when they have previously checked-in. Furthermore, the notion of a check-in is a conscious cognitive event that indicates a threshold of importance to the individual has been reached and that action has been taken in response. Thus they represent a discrete signal that embeds implicit human cognition and opens up the discovery of new collective traits. These have been combined with explicit participant input that establishes an individual's personality profile. This study has longer term implications for both ethnography and anthropology: extended mind crowdsourcing represents a way in which participants can be observed and differentiated using technology. This opens opportunities to consider more deeply the cultures that exist between individuals and groups.

5 Limitations and Future Research

It is important to note that are considerable limitations and challenges that face EMC. Perhaps most significantly, from a technological perspective, collecting meaningful data that embodies an individual's extended mind is a significant challenge that is only just becoming feasible. However, achieving this while not contravening personal privacy and identity is significant, as is gaining participants. The data collected, particularly if volunteered or of a sensory nature, is likely to suffer from considerable noise and incomplete sampling.

As this is the first paper to tackle the concept of EMC there are many future research challenges to address. The concept is dependent on active externalism and only recently have mass portable devices and objects, such as smartphones, emerged to fulfil this role. Therefore opportunities to determine and extract meaningful signals from data in these devices are in their infancy. Beyond this, aggregation techniques that allow concepts such as the "mind of society" to be explored from many individual extended minds are fundamental. EMC is a potentially a powerful form distributed cognition and techniques to extract how both individual and group decisions are made could provide useful insight into cognitive behaviours, such as cognitive heuristics for groups and cultures, from in-the-wild studies.

Using EMC to gain insights into wicked problems is also an important frontier to tackle. Arguably many of societies biggest challenges are "wicked" and tools and techniques to cast new insights on where and how complexity occurs is very valuable. Finally the sociological implications of EMC are worthy of in-depth consideration.

6 Conclusions

This paper has brought together many different academic fields to explain, understand and motivate the new concept of *extended mind crowdsourcing*. This concept engages human cognition and computation in an implicit manner, by accessing and aggregating the data that occurs from our increasing use of technology to extend cognition into the external environment. We argue that adopting technology for active externalism provides a new way to access human cognition, albeit in a less structured manner than in other forms of human computational systems that are task driven. This makes the concept useful for investigation of particular types of scenario, for example in the discovery of loosely defined problems. This opens up new opportunities to investigate problems from different dimensions and without a-priori expectations of findings. In particular wicked problems may well benefit from this model of investigation.

In developing the concept we have provided linkage to relevant existing psychological and sociological frameworks. To exemplify EMC we have focussed on a scenario where the smartphone is used as a proxy for a subset of its owner's activity. This occurs in the recently emerging location based social networks. By gaining explicit computation from the user and implicit computation from the location-based social network, we have been able to discover significant correlations between three personality traits and human mobility behaviour at the street level.

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