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Does Cultural Robotics Need Culture? Conceptual Fragmentation and the Problems of Merging Culture with Robot Design

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Abstract

Increasingly, roboticists have to pay attention to cultural norms and expectations. But roboticists have generally worked with a relatively narrow understanding of culture, based on nationality. This contrasts with the rich and diverse understandings of culture from disciplines as diverse as sociology, philosophy, and anthropology. Here we draw on the philosophy of science literature on scientific terminology to argue that culture is a *conceptually fragmented* concept: the concept has no unified definition, and alternative definitions of culture are useful for different areas within robotics. We argue that this has important implications for robotics. We consider two possible reactions to this situation. One claims that, despite the lack of a unified definition, the concept of culture still fulfils useful roles within robotics, and ought to be preserved. The other argues that the problems with the concept are so great that the concept ought to be eliminated from discussions in robotics. We argue in favour of the former option.

Keywords Cultural robotics · Theories of culture · Social robotics · Conceptual fragmentation

1 Introduction

Cultural robotics is centrally concerned with the design of robots for civil applications. As human–robot interaction (HRI) becomes increasingly commonplace in our everyday lives, an urgent issue is the link between robotics and culture. One issue is that cultural assumptions and judgements are often incorporated into the robotics design process. A further issue concerns how different cultural norms and expectations should be incorporated into a robot's behaviour toward laypersons in scenarios such as care homes, shopping malls, restaurants, and other domestic and medical contexts. For many projects in robotics, our understanding of culture permeates every step of design and implementation, including research, development, and use (cf [85] and [86].

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The concept of culture is central to many applications within robotics. As a result, roboticists face the challenge of defining the concept. Roboticists have tended to work with a relatively narrow definition of culture, which generally equates it with nationality. This contrasts with the many approaches to culture in the humanities and social sciences. Our aim in this paper is not to criticise robotics for its relatively narrow focus, but to show that many of the different approaches to culture from the humanities and social sciences will be useful for robotics. Our aim is to argue that the concept of culture is *conceptually fragmented*. Specifically, we argue that culture can be understood in many different ways, and which definitions are useful for a particular application within robotics depends on the context of application within robotics. We will argue for this, and then draw out some of the implications of this result for the interdisciplinary field of robotics.

Section 2 outlines some of the historical background of cultural robotics, to situate our discussion of culture within the current context of robotics research. We then explain some of the reasons to focus on the concept of culture specifically (Sect. 3). We then introduce the relatively narrow way that culture has typically been understood in robotics, and discuss some of its problematic aspects (Sect. 4). We contrast this with the discussion of culture in the humanities and social

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sciences, by surveying some of the available definitions of culture that these disciplines provide (Sect. 5). We will draw on the framework of Baldwin et al. [8] to group these definitions into 'themes', which are groups of definitions that share common elements. Some of these themes emphasise particular patterns of behaviour, others focus on particular products, and yet more think of culture as an ongoing process of mutual meaning-making. Thus, the different approaches to culture do not just differ in a few minor details, but on the fundamental features that are most important for understanding culture. We outline Baldwin et al.'s approach in order to give a sense of the state of current definitions of culture available in the humanities and social sciences. Section 6 will bring some novel resources from the philosophy of science to bear on understanding culture in robotics. We target recent work on conceptual fragmentation [5, 99]. We specify what it means for a scientific concept to be fragmented, and explain its relevance for science. Section 7 argues that culture in robotics fulfils the requirements to be conceptually fragmented. Specifically, we argue that there are many different definitions of culture, drawn from interdisciplinary discussions across the sciences and humanities, which are useful for different contexts in robotics. Having established the conceptual fragmentation of culture, we consider two potential reactions to the situation in Sect. 8: eliminativism (the view that the concept ought to be abandoned from robotics) and preservationism (the view that it should be preserved, despite being fragmented). We argue in favour of preservationism. Section 9 considers the upshots of our arguments for the interdisciplinary field of robotics.

2 Robotics and Cultural Robotics: A Brief Overview

In this section, we provide a brief overview of how cultural robotics arose as a distinct field from the discipline of robotics, in order to situate our discussion within context, and to clarify the target of our discussion. Here, we briefly describe social robotics as a subfield within HRI, and then explain cultural robotics as a subfield of social robotics (though as we note, the distinction between social and cultural robotics is somewhat blurry).

Robotics currently encompasses a large number of subfields, which have branched out from what was once considered good old fashioned robotics (e.g. robots working on a production line in a factory). One such subfield is HRI. In the early days of HRI, research mainly focused on the physical aspect of an interaction, e.g., what should be the kinematics and dynamics constraints of a robot's arm that can hand out a bottle of water to a human's hand (e.g., [3])? Research on this kind of interaction largely left its social implications unaddressed. Over time, AI approaches enabled robots to become more flexible such that they could operate in unstructured dynamic environments. As a result, roboticists began to pay attention to the *social* aspects of HRI. For instance, it became common to measure the experience of human users in an experiment that involved a human–robot handover (see the survey on robotic handovers by Ortenzi et al. [77]).

As robots became used in increasingly social settings, this gave rise to the field of social robotics. Social robotics as a field is an interdisciplinary area intersecting with social sciences, philosophy, social cognition, linguistics, anthropology, sociology, etc. The proliferation of books exploring the intersection of society, ethics, and emotions with robotics testifies to the increased attention on the social aspects of robotics, e.g., Korn [60], Werthner et al. [105], Braunschweig and Ghallab [20], and Hakli and Seibt [45]. As a result of this surge of interest in the social aspects of robotics, we see applications of social robots to many different domains of life. To name only a few examples, these include assistance robots in shopping malls (e.g., [72]), robot-assisted interventions for social anxiety [81] and Post-Traumatic Stress Disorder [61], and robots being deployed in a care home [17].

Cultural robotics is commonly regarded as a subset of social robotics or the broader field of HRI. Koh et al. [59] provides a short background to cultural robotics with the earliest example of a robot used in a cultural application in 1964. Though cultural robotics could be regarded as a subfield of social robotics, the boundaries between cultural and social robotics are somewhat blurry. As an example of this blurriness, the terms 'social' and 'cultural' tend to be used interchangeably in this field. This is especially true in discussions of non-verbal communication, such as facial expressions, hand gestures, bowing, gazing, eye contact, touching, proxemics (the use of space), and personal space (e.g., [22, 89, 102, 111]).

In this paper we are especially interested in the nuanced and complex ways that culture should be understood in robotics. So, in our survey of cultural robotics, we should mention the appearance of important work by Selma Šabanović's (e.g. [85]). She identified and challenged the assumption that society should play a passive role in the design of technology/robots. By contrast, Šabanović argued for a bi-directional shaping relationship between robotics and society, emphasising the reciprocal influence and interaction between the two [85]. This proposal was an important development for cultural robotics, as it paved the way for co-design approaches in cultural and social robotics. For example, building upon this paradigm shift, Samani et al. [87] examined the process of cultural formation between robots and humans, considering the cultural values of robotics developers, the diversity of cultural communities, and the learning capabilities of robots (see also [82]). This contrasts with some earlier discussion in social robotics, where preferences across different countries played a significant role in determining design elements such as size, capability, and intelligence in social robots (e.g., [13, 74, 91]).

It will be helpful to give three examples of areas where the concept of culture has received central focus in robotics. This is important, as it helps to situate the topic of our paper in a broader context. The first example occurs in 2018, when there was a special session on cultural robotics in one of the flagship conferences in robotics, IROS (International Conference on Intelligent Robots and Systems).[1] A second example of the rise of discussion of culture in robotics is the development of culturally competent robotics in the CARESSES project [22, 56]. CARESSES (Culturally-Aware Robots and Environmental Sensor Systems for Elderly Support)[2] is an international, multidisciplinary project aimed at designing socially assistive robots that can adapt to the cultural backgrounds of the individuals they assist. As a final example, in the 2020 edition of the Robophilosophy conference,[3] 'culturally sustainable social robotics' was the central theme.

The focus on culture as an object of study in the interaction between humans and robots has now reached a level where Lim et al. [64] were able to conduct a survey using more than 50 papers (see also [88]). In these ways, culture has firmly become an object of attention in its own right when it comes to research in HRI and social robotics. It is this trend that has come to be known as cultural robotics. This is the trend that the present paper is concerned with.

3 Our Focus on Culture

Our choice of culture as the focus of this paper is not only driven by the increased interest in the concept within robotics. There are several other reasons that justify our focus. First, the way that roboticists use the concept of culture has important, societal-level consequences. This is most obvious when we consider the concept's use in designing care robots for elderly and vulnerable members of society. As we will show below, deciding whether, and in what ways, robots should treat such individuals with cultural sensitivity has a large impact on the personal welfare of the people cared for, and it reflects on the way that society views the elderly and vulnerable. The practical importance of culture in robotics justifies our focus on it.

Furthermore, we choose to concentrate on culture because the concept has a long history of study in the humanities and social sciences, which we draw on to understand the unique ways that the concept is deployed when it is applied to robotics. Though most of this discussion has not concentrated on robotics specifically, it provides a powerful toolkit for understanding culture in cultural robotics.

4 The Narrow Definition of Culture in Cultural Robotics

In this section, we outline some of the dominant ways of understanding culture within robotics, and some of the problematic aspects of this approach. This will explain the main problem that this paper takes as its starting point.

The vast majority of studies introducing cultural factors into robotics assume a concept of culture that equates it with *national* culture, or nationality, and subsequently treats this as the only viable definition of the concept for the field (e.g., [7, 15, 54, 62, 63, 83, 84, 92]). Culture as nationality has been employed in robotics for two purposes. One, culture as nationality simplifies the task of using culture-specific knowledge to produce robot behaviours in various human–robot interactions. For example, it allows roboticists to ask relatively simple questions concerning how an assistive robot should cater competently to the various breakfast habits of Italian, German and Japanese elderly users [22]. The second reason for the equation of culture with nationality is to simplify the task of making robots more acceptable, trustable, and likeable in the eyes of the users [6, 74]. For instance, Chinese people are more likely to accept recommendations from a robot that communicates implicitly as opposed to Americans, who mostly heed explicit advice from a robot [104]. This is an example of a research programme equating culture with nationality, and using this equation to ascertain the extent to which the robot is thereby accepted by users. In general, the national culture interpretation is so dominant in cultural robotics, that a survey analysing the intersection of culture and robotics could easily find 50 recent studies all considering "culture as national culture—values, norms, and practices that are undertaken by a country" [64].

Here is where another important element of robotics' approach to culture as nationality enters, which is the *cultural dimension* proposed by Hofstede [44].[4] The cultural dimension was initially developed for business management. It aims to guide practices in international business, where interactions with people from diverse cultures are commonplace. It emerged as a response to the increasing demand for effective cross-cultural communication and the lack of a comprehensive cultural guide. Hofstede introduced six key dimensions based on which we can quantify the cultural code: power distance, uncertainty avoidance, individualism-collectivism, masculinity-femininity, and short vs. long-term orientation. This framework is attractive to roboticists, as

[1] https://www.iros2018.org/special-sessions

[2] http://caressesrobot.org/en/

[3] https://cas.au.dk/en/robophilosophy/conferences/rp2020

[4] See also the 'cross cultural theory of communication' advocated by Hall [46–48].

it apparently provides a relatively straightforward way to quantify different elements of a culture, which can then be implemented in robot design (e.g. [21, 63, 78]. We might think of the equation of culture with nationality as the first step, and the subsequent quantifying of that nationality in terms of Hofstede's cultural dimension as the second step, which makes the problem of designing culturally sensitive robots more tractable.

In this way, there are two elements to the dominant approach to culture in robotics which we would like to emphasise. One is the equation of culture with nationality. Another is the specific use of Hofstede's cultural dimension as one prominent instance of this equation. Both of these elements come with problematic consequences. The Hofstede framework has faced criticism for promoting stereotypes and assuming national uniformity [14, 52]. Scholars argue that this framework oversimplifies complex cultural dynamics by relying on national averages and disregarding individual variations within cultures [67]. Similar criticisms have been levelled by roboticists against the equation of culture with nationality. For example, conceiving of an entire culture in terms of nationality excludes people who do not fit neatly into a general view of a 'nation's culture', such as subcultures, refugees, immigrants, religious minorities, or people who don't conform to standard ideas of how people from that nation behave [76].

There are also *practical* problems concerning how roboticists decide on what constitutes the national culture. Sayago [88] points out that an understanding of culture can be affected by the socioeconomic status of participants in experimental studies. Most participants are students, and the locations are university campuses (e.g., [12, 24, 104]). The results are supposed to be an indication of a certain national culture, and the information will then be used in the design of robots for that specific culture. However, clearly there is a worry of unrepresentative samples, leading to crude overgeneralization about the culture in question.

Of course, this narrow approach (equating culture with nationality) is not completely ubiquitous within robotics. A minority of research in cultural robotics differs from this dominant view. Šabanović et al. [86], Ornelas et al. [76] and Winfield [106] are among this minority that interprets culture as developing through interactions between social actors, including artificial actors. The common denominator of these studies is that culture is dynamic and situated in the environment,it is shaped via repeated interactions and co-developed. For instance, Rehm et al. [82] used an ethnography-based approach within the Danish care system, which provides authentic personalised robotic service to a particular context. Though these studies constitute an important counter to the dominant approach, this paper takes as its starting point the dominant approach to culture in robotics, which equates it with nationality. This is the problem that serves as our starting point.

5 The Many Definitions of Culture in the Humanities and Social Sciences

We have briefly surveyed the way that culture is understood in robotics, pointing out that it is both narrow, and problematic. Here, we outline the much broader approach to culture within the social sciences and humanities, in order to demonstrate the contrast between the two. This section also serves to introduce some of the approaches to culture that will be important in the rest of the paper.

Culture predominantly pertains to the intellectual, spiritual, and aesthetic growth of individuals, including art or literature [16, 29]. Whilst the understanding of culture within robotics is relatively homogeneous, within the social sciences and humanities, there is disagreement about the meaning of culture even within a single discipline [109]. The debate surrounding the usage of the term implies that culture is an empty vessel, waiting for individuals, both academics and everyday communicators, to imbue it with meaning [8].

Here we only aim to give a sense of the many different interpretations and approaches to culture within the humanities. To do this, we will draw on the taxonomy of Baldwin et al. [8]. We draw on this source because it encompasses a wide range of different definitions of culture, and helpfully systematises them. The framework is constructed from various disciplines and has been used in other studies for exploring the landscape of interpretation of culture (e.g., [32, 68]). We should note that Baldwin et al. is a useful resource for the breadth of approaches to culture in the humanities and social sciences, but we in no way claim that it is the only such resource, or that it should be the 'standard' reference for discussions of culture in robotics.

Baldwin et al. group definitions into 'themes'. A theme is like a very general approach into which many different definitions may fall. The themes proposed by Baldwin et al. [8] are as follows: structure/pattern, functions, process, product, refinement, group membership, and power/ideology. The easiest way to understand these is with examples. The structure/pattern theme looks at culture in terms of a system of ideas, behaviour, symbols, or any combination of these. For instance, in this theme, culture can be seen as a cognitive structure inside the minds of the individuals in a community of people [73], or a "whole way of life" such as stereotyped patterns [51] which are handed from one generation to the next through the means of language and imitation [11]. Many anthropologists hold this view of culture. As a case in point, Goodenough [37] defined culture as "standards for deciding what is … what can be … what one feels about it … what to do about it, and … how to go about doing it". A different group of authors within this theme has highlighted cultures as symbol systems, encompassing language and discourse. This perspective has its roots in sociological work. For example, Talcott Parsons [79] provided a succinct definition of culture as "a commonly shared system of symbols, the meanings of which are understood on both sides with an approximation to agreement" (p. 21). Dell Hymes [49] proposed the concept of culture as a "speech community," where a group shares knowledge of rules for communication and interpretation (p. 51).

The function-based theme sees CULTURE as a tool for achieving some end, such as providing people with a shared sense of identity/belonging, or of difference from other groups (e.g., [34, 71]). Structural definitions focus on CULTURE as the logic, while the functional definition focuses on the purpose of culture in providing that logic [94]. For instance, according to Michael Agar [2], culture "solves a problem" and defines the logic of communication for its members.

Another theme is culture as a process, which focuses on the ongoing social construction of culture. In this theme, culture is framed as the process of sense-making ([96], p. 2), producing group meaning [10, 90, 93], or that of relating to others [18]. For the process theme, culture is created in an ongoing way by the participation of different members of the group. For instance, "[culture as] engaging in an ongoing process to define and redefine themselves (ideologically in order to preserve and reestablish their historical memory, sense of belonging, and their relationship to the defining homeland" [28], p. 340, [36]).

Culture is understood as an artefact for the product theme, for instance, art, architecture or books. This definition primarily emphasises artefacts rather than the process itself. These definitions revolve around "extrinsic factors, including clothing, food, and technology" ([9] p. 249), and can be referred to as "material culture" [19, 25, 26], for example, "a pull-open beer can or a radio telescope". In this theme, the content that the artefact represents is the result of the accumulated knowledge or activity of a culture [31]. Note that such products need not be concrete items, they could be a production of a certain play, or a particularly important rugby match.

The refinement theme understands culture as a sense of individual or group cultivation of higher intellect or morality. In this theme, culture can be interpreted as any human effort to distinguish humans from other species, which can encapsulate some other previous definitions as well ([42], p. 270). The group-membership theme understands culture in terms of a place or group of people, or belonging to such a place or group, e.g., country or identity [107]. Many of the definitions explored so far incorporate the concept of a group within their framework. Consequently, this theme has significant overlap with other themes discussed. This understanding often associates culture with the political boundaries of nations [38].

Finally, definitions based on power or ideology move the focus from what culture is or how it arises to questions of whom it serves. Definitions within this theme understand culture in terms of the dominant politics and ideology of the group [4]. Among critical definitions of culture, two main subthemes can be identified: political dominance and fragmentation. Many authors describe culture as a manifestation of political dominance, often from a critical perspective rooted in Marxist or neo-Marxist critique of society [1, 27]. These definitions highlight the presence of power-based interests that shape how a group perceives and constructs its culture. This includes the tendency to view one's own culture as superior, as well as the forces within a society that seek to define the norms, definitions, and ideologies that guide culture. In this view, culture is not merely a pattern or an ongoing process of meaning-making, but something that serves the interests of those in power. The second subset of ideological definitions of CULTURE pertains to culture as fragmentation, also known as postmodern definitions. According to Clifford [23], "power relations exist within changing and contestable relationships, leading to the absence of any essential or eternal status for art and culture". This highlights another critical perspective of culture: its fragmented nature. Postmodern writers challenge single definitions of culture, arguing that they inherently exclude alternative constructions of culture. They advocate for a reflexive approach that questions how academics construct the term 'culture'. Clifford emphasizes that 'culture', as well as our understanding of it, is historically produced and subject to active contestation (see also [33, 41]).

We have surveyed the themes into which the different definitions of culture within Baldwin et al.'s framework fit. It is important to be clear that each of these definitions are intended as a means of approaching culture, or as a useful lens through which to approach cultures. Each one comes with its own advantages and drawbacks, but no one of them should be taken as 'the correct' definition. Rather, each one is useful for specific purposes that the others may not be.

Above, we mentioned that we have employed Baldwin et al.'s framework because it provides a particularly thorough survey of the sheer range of ways of approaching culture, which contrasts with the relatively narrow approach in robotics. There is a second reason why Baldwin et al.'s taxonomy is useful when thinking about cultural robotics, which is as follows. Each 'theme' into which various definitions are grouped highlights certain important properties of culture, at the expense of others. For example, the process theme highlights the way that cultures evolve and change over time. The product theme highlights the items that a culture produces, and so on. Different themes place different emphases on different properties of culture. Given the sheer range of applications in cultural robotics, there are some contexts where some properties will be more important than others (we will argue for this claim below). Baldwin et al.'s framework provides a range of definitions of culture, and so provides the roboticist with a toolkit of different approaches, which can be deployed flexibly depending on which properties of culture are especially important to the context of application. This is an important virtue of the framework of Baldwin et al. for roboticists.

There is a stark contrast between the narrow approach to culture within robotics and the broad set of approaches in the social sciences and humanities that we have summarised. For example, the cultural dimension work of Hofstede, which involves identifying six core dimensions along which cultures can be categorised, would be just one relatively small approach to culture. Indeed, the dominant approach to culture in robotics could be construed as just one definition within the structure/pattern theme listed by Baldwin et al.

6 Conceptual Fragmentation in Science

The central starting point of this paper is the contrast between the narrow understanding of culture in robotics, and the broad and nuanced range of approaches to it in the social sciences and humanities. A question at this point is: how (if at all) are the many different definitions of culture relevant to robotics? We will address this question by arguing for a particular picture of the interaction between these definitions and robotics. We argue that culture is conceptually fragmented: it is subject to many different definitions, which differ in their usefulness depending on the context of application in robotics. This section will outline some of the philosophy of science work that we draw on to analyse culture in robotics, as a scientific concept. This is the 'conceptual fragmentation' framework. In Sect. 7, we will argue that culture is conceptually fragmented in robotics: there are many available definitions of the term, which are useful for different areas of robotics.

Much philosophy of science has focused on the ways in which concepts can help and hinder scientific research programmes. An essential component of scientific progress is conceptual development. Scientists need to select the most useful concepts for describing their subject matter, and concepts need to be defined in the way that makes them scientifically useful. The conceptual fragmentation framework originates in the philosophy of science, and aims to understand conceptual development, and provide criteria through which we can judge the scientific usefulness of a concept [99].

Sometimes, the definitions of concepts are deficient in some way, and new definitions need to be offered. This is *conceptual alteration.* As an example of conceptual alteration, the concept acid in chemistry has had a long history. An acid was originally defined in terms of its superficial properties, such as being sour-tasting, corrosive, and its ability to redden plant dyes. Over time this definition had to be refined, and the dominant approach now defines an acid as an electron pair acceptor. That is, anything with an incompletely filled outer electron shell [97]. Clearly, this conceptual alteration represents scientific progress. The new definition is more useful for contemporary chemistry than the old one.

Sometimes, progress requires a more radical solution. Rather than offering a new definition of an existing concept, sometimes we need to abandon a concept entirely. This is *conceptual eliminativism*. In cases of eliminativism, the concept needs to be dropped from science entirely, meaning that scientific theories, explanations, and predictions no longer use the concept. Three examples are phlogiston in chemistry, aether in astronomy and miasma in medicine.[5] These concepts derived from theories about fire, planetary motion, and disease respectively. However, the theories that the concepts were embedded within were so inaccurate, that it was a step toward clarity to simply drop the concepts from science altogether, rather than attempt to redefine or alter them to be consistent with new results. Here it would only cause confusion to attempt to keep the deficient concepts.

So far, we have mentioned conceptual *alteration* and conceptual *eliminativism*. What is conceptual *fragmentation*? The conceptual fragmentation framework aims to isolate an important class of scientific concepts that raise specific issues concerning conceptual usefulness in scientific practice. One of the most common and important motivations for conceptual change in science is the discovery that an important scientific concept, once thought to have a unitary meaning, actually turns out to have a range of alternative definitions. This is very commonplace in science. A paradigm case is species in biology. Zachos [110] lists 32 alternative definitions of species, which differ radically from one another, and are useful in very different contexts in biological science.

There is more to conceptual fragmentation than there just being more than one proposed definition for a certain concept. For a concept to be conceptually fragmented, two criteria must be met:

1. There is a range of alternative definitions of the target concept.

[5] Phlogiston is a now defunct concept that was used to explain the combustibility of air. In this theory, what we now know to be carbon dioxide was known as 'dephlogistonated air'. Aether was a hypothetical element that planets were believed to move through. Miasma was a concept from a scientific theory of disease (superceded by germ theory). The details of these scientific cases are complex, but they are not crucial here, so we can avoid these complications. The important point for this paper is just that sometimes supposedly important scientific concepts need to be eliminated from science to enable scientific progress.

2. There are at least two theoretical contexts within a scientific discipline, such that one definition is more useful for one of them, and another definition is useful for another.

To illustrate (1–2), we will use a very simple example: the concept hardness in materials science [108]. One meaning of hardness applies to metals, and it measures the *dentability* of a metal. I.e. the shallower the dent that a known amount of pressure leaves on a metal, the harder the metal. However, in other contexts, such as measuring the hardness of rubber, this definition is clearly inappropriate, since when we attempt to dent rubber, it will typically bounce back into place, eliminating the dent and therefore incorrectly giving us the result that rubber is harder than metal. As a result, hardness has a different definition when applied to rubbers, and is measured using a durometer. This instrument does not measure dentability, but another property of the material, known as Young's modulus of plasticity [43, 98]. There are many interesting issues to do with hardness, but the important point for this paper is why it qualifies as conceptually fragmented. Specifically, there are at least two different definitions of hardness (thus fulfilling criterion (1) above). Furthermore, these alternative definitions are useful for different scientific contexts (e.g. metals and rubbers), so they fulfil criterion (2). Hardness is conceptually fragmented.

In order to fulfil criterion (2), two different definitions of a concept must be useful for at least two different purposes within a scientific research programme. For this reason, conceptual fragmentation is always relative to a particular scientific context. Whether a concept is fragmented depends not just on the concept itself, but on the way that the concept features in scientific research. So, it is possible for the same concept to not be fragmented in one scientific context, and to be fragmented in another.

The usefulness of different concepts in different contexts (criterion (2)) is not 'absolute'. The conceptual fragmentation framework doesn't claim that, for each context in science, there is one and only one definition of a particular term that is useful in that context. Rather, the claim is that each definition of the term will be useful for different purposes within science. An important part of science is to select the correct definition for each purpose. In some contexts, some purposes will be more important than those purposes are in other contexts. In such a case, it's important that the correct definition is selected that suits that particular purpose. This is entirely consistent with the idea that some contexts may have more than one purpose, and so require more than one definition. This will become important in the next section, when we apply the conceptual fragmentation framework to culture in robotics.

We might reasonably ask why it matters if a concept is fragmented, and therefore why it matters whether culture is fragmented in robotics. There are two reasons. First, conceptual fragmentation provides an insight into how a concept functions in scientific research by highlighting the subtle ways that its meaning changes across contexts. This suggests that the framework will be helpful in understanding how culture should be understood in robotics. Secondly, fragmentation is often a precursor to eliminativism in a science [99]. The fact that a concept is ambiguous between various alternative meanings raises the possibility that retaining the concept would lead to ambiguity, confusion and cross-purpose talking in the discipline itself, with all the impediment to scientific progress that come along with those issues. In the next section, we argue that culture is indeed conceptually fragmented. In Sect. 8, we will turn to the implications of this for the future of the concept in robotics.

7 Conceptual Fragmentation: Upshots for Robot Design and Robot Domain

We have outlined the conceptual fragmentation framework from the philosophy of science. Above, we raised the question of how (if at all) the many different definitions of the culture in the social sciences and humanities are relevant to the notion of culture in robotics. In this section, we argue for a specific view on the relationship between the many definitions of culture in the social sciences and humanities and robotics, which is conceptual fragmentation. We argue that several definitions of culture are relevant to robotics, which differ in their usefulness depending on context.

To demonstrate that culture is conceptually fragmented, we need to show that it fulfils both criteria (1) and (2). It is uncontroversial that it fulfils criterion (1). The survey in Sect. 5 demonstrates this clearly. In this section, we will argue that the concept fulfils criterion (2) by providing some examples of cases where alternative definitions are useful for distinct purposes in cultural robotics. This task is complicated by the fact that at present, there is no systematic analysis linking cultural theories to robotics methods and domains [65]. In the absence of such analysis, we will draw on several of the themes from the Baldwin et al. framework we discussed in Sect. 5, and examine the relevance of the different themes to different contexts in robotics.

Recall from Sect. 4 that Baldwin et al. surveyed over 300 definitions of culture, from across the humanities and sciences, and grouped them into 'themes'. In this section, we choose three cultural themes from Sect. 4, which display especially clearly the way in which different cultural themes vary in how important they are for different contexts in robotics. This will show that the concept culture fulfils criterion (2), and is conceptually fragmented.

The conceptual fragmentation framework as applied to culture in robotics is as follows. Different definitions of culture highlight different properties. For example, product definitions highlight certain products as being definitive of a culture. Conversely, process definitions highlight the way that social interaction grows and develops over time in a reciprocal way. In context X, it might be especially helpful to focus on the *products* of a culture. Conversely, in context Y, it might be really important to focus on the way that cultural norms *grow and develop* over time. In such a case, the product definition might be more useful for context X, and the process definition might be useful for context Y. As we noted above, this doesn't imply that *no other* ways of approaching culture are useful for context X and context Y. It is just that the properties that different definitions highlight will differ in how important they are in different applications in robotics. This is the way in which criterion (2) is true for the concept of culture in cultural robotics.

7.1 Culture as a Structure/Pattern

The theme of culture as a structure/pattern, has received significant attention from roboticists, especially when this theme is interpreted through Hofstede's framework, which we discussed in Sect. 4 (e.g. [63, 78, 103]). For example, Eresha et al. [30] use this to recommend that a robot would be programmed to stand closer to an 'Arab' person than a German in a human–robot interaction scenario.[6] Such a scenario might be, for example, a robot giving directions to a human in a shopping mall. The reasoning behind such programing is that due to the scores on Hofstede's Individualism dimension, Germany is considered to be an individualistic culture, while the Middle-Eastern world is considered to be collectivistic, and the Individualism dimension is strongly related to interpersonal distance behaviour. Here we see a direct link between a specific understanding of culture (the notion of culture as a structure/pattern for behaviour) and a concrete upshot for robotics design and implementation (the distance at which a robot should stand from humans of different nationalities). Though we have reservations (outlined above) about the use of Hofstede's framework, this represents a context where a particular approach to culture (the structure/pattern approach) is especially useful.

Here is another potential example of a context in robotics where the structure/pattern approach may be useful (though it comes with a note of caution that we provide in due course). In service robots to be used in restaurants, a robot may rely on cultural generalisations about the food consumption preferences of diners based on the cultural practices of their country. For example, English, Japanese and Italian diners all differ in their preferences of eating methods, the order in which courses are to arrive, how likely they are to share certain foods, etc. Our note of caution is that we must always be cautious in using generalisations about culture to guide a robot's behaviour, for the reasons we mentioned in Sect. 4.

7.2 Culture as Process

The previous examples show a context in robotics where patterns of behaviour may be a useful way of thinking about culture. However, this way of thinking of culture has important limitations. In being relatively rigid, it does not highlight the ways that a culture can change and adapt over time. These dynamic properties of culture are properties that are especially important to take into account in the design and implementation of robots for other contexts. The examples given above (giving directions to customers in a shopping mall, and serving food at a restaurant), are cases where the interaction with humans are very brief and superficial, so there is less of an emphasis on the robot's relationship with the humans growing in a dynamic and flexible way over time. Contrast this with a robot working on an assembly line, which is expected to work especially closely with human co-workers over an extended period of time, such as several years (e.g. [70]). Here, we will need to equip the robot with the capability to interact and adapt over time to the specific habits of human co-workers. For instance, the robot should be able to recognise the object in the hand of a human coworker and reason about when to receive the object from them so that their mutual activities fulfil the assembly tasks. This long-term collaboration will inevitably involve changes in the relationship between human and robot over time. In the process of collaboration, the human co-worker may adapt their behaviour according to the robot's physical constraints, e.g., putting certain pieces close to the robot's left arm as the robot's right arm is programmed to manipulate a specific tool, as opposed to previously handling the piece themselves.

In this context, one core aim of robot design is to foster a culture of collaboration between human and robot. In this setting, the process theme is especially helpful, as robots must be active participants in creating culture, and must react dynamically and flexibly over time. Here the notion of a culture is not so much a coded pattern of behaviours as it is something that steadily emerges through the process of interactions between robots and humans. For this context, a process conception should be preferred to a structure/pattern approach.

This is not to say that the process theme is the *only* definition of culture that is relevant when designing and implementing a work-place robot of this kind. There may

[6] We use the word 'Arab' with genuine reluctance. We choose to use it to reflect the terminology of Eresha et al. [30], though we do so whilst noting the problematic aspects of the term. For example, we question the decision to treat 'Arab' (an antiquated and potentially offensive term for a large number of people of varying nationalities) in the same way as 'German' (a non-offensive term for members of one nationality). However, with this reluctance noted, we use it here to mirror the use of the word by the authors of the previously mentioned article.

be strict and relatively rigid cultural norms *as well*, which can be helpfully conceptualised through thinking of culture as a structure/pattern. In such a case, it may be that both definitions are important for this context. We only claim that different properties of culture will differ in their importance across contexts, and thereby that different definitions of culture that highlight these different properties will also differ in their importance.

7.3 Culture as Product

We have examined the case of robots giving directions to humans in a shopping mall, restaurant waiter robots, and a robot in a factory. Consider now deploying a robot in a public square for the purpose of entertainment, e.g., a dancing robot displaying music [95]. In this scenario, the type of robot (e.g., humanoid or not) and movements, colour, music harmony and the knowledge of popular art are important areas to explore for enabling public engagement with this cultured robot. As a result, a very important way to understand culture in this context may be the product theme. According to Baldwin et al ([8], p.44), this theme understands culture in terms of the artefacts that arise from meaningful and co-ordinated activities engaged by members of the culture. Examples include coordinated behaviours used to create some concrete item such as a satellite, a cigar, or a football. In our robot example, the coordinated behaviours would be the dances by the robots for the purpose of creating the product of public entertainment.

Note that, within the world of entertainment robotics, there may be some contexts where other cultural themes are important. For example, suppose a robot was deployed to participate in a collaborative improvisational theatre performance in a public square. Similar to the assembly task, the robot culture will be shaped by the process of interactions between robots and humans, hence the process theme is important here. In this case, it will probably be that the product theme and the process theme are both important for different aspects of the implementation.

All of these examples provide an answer to the question of how different definitions of culture from the social sciences and humanities are relevant to robotics. Specifically, culture is *conceptually fragmented* in robotics. Alternative definitions of culture from the social sciences and humanities highlight certain properties of culture, which differ in their importance across different contexts in robotics. Culture as structure/pattern is important for some assistance robots (in shopping malls and restaurants). Culture as process is especially important for certain kinds of workplace robots. Culture as product is especially useful for certain kinds of entertainment robots. Therefore, culture fulfils criterion (2). We conclude that culture is conceptually fragmented in robotics.

8 The Future of Culture: Eliminativism or Preservationism?

We have argued that culture is conceptually fragmented in robotics. Advocates of conceptual fragmentation often argue that conceptually fragmented concepts should be *eliminated* from the scientific discipline(s) in which they are fragmented [99]. The conceptual fragmentation framework raises important questions about the usefulness of the concept for robotics. We explore these questions in the present section.

We can define *eliminativism* as the view that the concept of culture should be eliminated from robotics, and replaced with more fine-grained, precise concepts. According to eliminativism, each of these fine-grained concepts would capture some specific definition of culture, such as those we encountered above. Eliminativists about culture will claim that the concept is likely to cause theoretical problems, which will be resolved if the concept is abandoned from robotics. The challenge for the eliminativists is to identify the theoretical problems that justify elimination of culture. Likewise, we can define *preservationism* as the view that culture should be retained within robotics, despite the fact that it has conceptually fragmented. Preservationists will claim that, even though culture is conceptually fragmented, it is still useful for robotics, and should be retained and used in the discipline. The challenge for preservationists is to explain what role culture plays, which justifies preservation.

In subSect. 8.1, we outline the arguments in favour of eliminativism. We show that they are not convincing, and outline some serious challenges that eliminativism faces. SubSect. 8.2 articulates preservationism, and gives an argument in favour of it. We conclude in favour of preservationism.

8.1 Eliminativism

In this subsection, we first explain and clarify eliminativism, then outline two arguments that might be given in favour of it. We call these the argument concerning confusion and cross-purpose talking, and the argument concerning the equation of culture with nationality. We then argue that these arguments are unsuccessful. We then consider a more general problem for eliminativism, which is that there are good reasons to think that eliminativism is a more plausible option for concepts in *natural* science, rather than social sciences or the humanities.

The eliminativist claims that the concept culture should simply be replaced by more precise concepts that reflect specific themes. The concepts that would replace it will mirror the various different cultural themes, e.g. structure/pattern, process, product, and so on. Having eliminated culture and replaced it with these more precise concepts, the appropriate concept can be selected for the specific theoretical task that the roboticist has. The eliminativist will claim that this will introduce precision and specificity into the field.

Though we do not advocate eliminativism, we do note that it is not as extreme as it initially looks. In science generally, eliminativism is a normal part of scientific progress. Science continually abandons suboptimal concepts, and replaces them with ones that are more scientifically useful. Abandoning the concept phlogiston was an important forward step for theories of combustion. Similarly, eliminating aether and miasma were positive moves for astronomy and medicine, respectively. Eliminativism about certain scientific concepts is a normal part of scientific progress. Similarly, eliminativism only applies to the scientific discipline in which the concept is fragmented (in this case, robotics). The argument therefore does not apply to uses of the concept culture in the disciplines that we drew upon earlier, such as sociology and philosophy, or vernacular language. We need not worry that eliminativism will prevent us from ever discussing culture again. The argument only applies to *robotics.*

An obvious question for the eliminativist is: what will the field of ‘cultural robotics’ be called, if we eliminate the concept of culture? One option is to simply make do with the term ‘social robotics’, since (as we argued above) the boundary between the two fields is somewhat blurry anyway. Within this field, it would make sense to sub-divide the field into precise areas. For example, we might use labels like ‘care-home robotics’, ‘entertainment robotics’, ‘service robotics’, and so on.

It is important to safeguard against a natural misinterpretation of eliminativism. It might appear to embrace an overly reductionist interpretation of robotics, as being nothing more than a branch of engineering and computer science. However, by suggesting that we purge culture from robotics, eliminativism does not claim that robotics should proceed without the input from more humanities-focussed disciplines that have traditionally discussed the concept of culture, such as philosophy, anthropology, cultural studies, and sociology. This view would see robotics as isolated from its neighbouring disciplines. However, this is not an implication of eliminativism. The eliminativist can recognise that robotics cannot proceed without being thoroughly interdisciplinary. The goal is not to deny the importance of the contribution from the social sciences and the humanities, but rather to argue that avoiding the concept will make the discussion more productive.

Though we ultimately reject eliminativism (see below) we hope that these clarifications have shown that it is not as extreme as it initially looks. With the view clarified, we now turn to criticising it. We consider two arguments in favour of the view, and argue that they are unsuccessful, and then consider a more general problem for eliminativism. The first argument in favour of eliminativism is called the argument concerning confusion and cross-purpose talking. This argument claims that, if a concept like culture has many alternative definitions, each of which is useful in different theoretical contexts, then by retaining the original concept, we risk practitioners assuming that they are talking about the same thing, when in fact they are not. For this reason (claims this argument for eliminativism) continuing to use the concept culture is likely to cause confusion, lack of precision, and cross-purpose talking in the field. This is the kind of argument that eliminativists typically embrace [99]. According to the eliminativist proposal, eliminating culture would reduce the potential for these kinds of confusions.

The second argument in favour of eliminativism is called the argument concerning the equation of culture with nationality. The second argument for eliminativism points out that eliminating the concept would remove the problematic equation of culture with nationality in robotics. As we discussed above, the majority of the work on the intersection of robotics and culture focuses on nationality. This confounding between nationality and culture, however, is very problematic. In Sect. 4, we noted that it potentially perpetuates stereotypes, existing power structures, encourages assimilation, and thereby marginalises refugees, immigrants, minorities and subcultures [76, 88]. The second argument for eliminativism goes as follows. If we accept that this confounding between nationality and culture is deeply ethically problematic, and given its prevalence in the current research, eliminating the concept of culture should be embraced because it is a way to avoid this conflation.

We have outlined two arguments that could be given in favour of eliminativism, the argument concerning confusion and cross-purpose talking and the argument concerning the equation of culture with nationality. However, both arguments face serious challenges, which we now outline. Start with the argument concerning confusion and cross-purpose talking. One problem with this argument is that the discussion of culture in robotics is a relatively recent addition to the field. Given that the field of cultural robotics is so young, we should not jump to judgements about how much confusion and cross-purpose talking the use of culture is likely to cause, and its wider contribution and impact. The field simply has not had time to develop productive and useful nuanced views on the many meanings of culture, much less to integrate them with every stage of the design and implementation process. For this reason, elimination is currently premature. This is problematic for the first argument in favour of eliminativism, since that argument rests on the concept making a particular negative impact in the field. A more reasonable reaction is simply to wait and see whether the concept leads to confusion and cross-purpose talking, and whether more nuanced and careful understandings of culture can be developed for robotics. We conclude that the first argument in favour of eliminativism is unsuccessful.

The second argument in favour of eliminativism is the argument concerning the problematic equation of culture with nationality. This argument is also unsuccessful. The core issue is that it assumes that eliminativism is the *only* solution to this kind of problematic equation of culture with nationality. But there are other solutions available. An increased appreciation of the problematic consequences of equating nationality with culture, and increased appreciation of the different meanings of culture in robotics would also serve to counteract the problematic consequences of equating culture and nationality. Indeed, a critic of eliminativism might suggest that merely abandoning the concept of culture is a suboptimal way of tackling the problematic equation of culture with nationality, because it does not involve confronting the problematic issues in a straightforward manner. Thus, the second argument for eliminativism is also unconvincing.

Here is a more general issue facing eliminativism about culture in robotics. Note that the primary examples of concepts that have been eliminated come from the natural sciences (e.g. miasma, phlogiston, etc.). Indeed, work on conceptual fragmentation that emphasises eliminativism has typically focussed on the natural sciences (e.g. [99]). Concepts from the social sciences, by contrast to the concepts of natural science, are more likely to be imbued with people's ideas and values. Concepts such as 'culture', which are subject to high levels of interpretation by people, inevitably evolve over time in reaction to people's own values and behaviours [40, 55]. This inherently makes the concept multifaceted, in a way that requires many different perspectives for it to be a viable object of study. The result we would expect is that the concept is associated with many different meanings across different authors, disciplines, and roboticists. For these reasons, for concepts in the social sciences, it may be that conceptual fragmentation is the norm, rather than a problematic exception. If we accept this fact, it presents a difficulty for the eliminativist. The eliminativist identifies the multifaceted and evolving nature of culture (and its subsequent conceptual fragmentation) as a reason to eliminate the concept, but (more so than with the concepts of natural science) this may simply be a feature of the way that many concepts in the social sciences work. Because these features are so normal for concepts in social sciences, eliminativism may be an inappropriately strong reaction to the current case.

We have argued that eliminativism is not as extreme as it first appears. Nonetheless, we have examined two arguments in favour of it and shown that they are unsuccessful. We have also considered a more general objection to eliminativism. We conclude by setting eliminativism aside.

8.2 Preservationism

Preservationism argues that the concept culture should be retained in robotics, rather than being replaced with more fine-grained concepts. Above, we rejected eliminativism. However, above, we have only presented difficulties for eliminativism. We have not shown that preservationism is itself an attractive view. That is the purpose of the present subsection. Here we will consider two arguments in favour of preservationism, which we call the argument concerning unrealism, and the argument concerning scientific roles. Whilst both of these arguments face challenges, we will show that there is a promising version of the second argument, which we outline at the end of this subsection. We conclude in favour of preservationism.

The first argument in favour of preserving the term is very straightforward: it is that it is unrealistic to expect practitioners to abandon the concept of culture from discussions in robotics. Stakeholders use the concept a lot, and it's very unlikely that they will change. This is the argument for preservationism concerning unrealism. This argument is not very convincing, for two reasons. First, it is relatively shortsighted to think that the concept cannot be removed. As we have shown in Sect. 6, the history of science is full of examples of apparently important concepts later being abandoned. There's no good reason to think that culture in robotics should be an exception. Second, even setting this point aside, the purpose of the eliminativist argument is to show that culture *should* be eliminated from cultural robotics, not necessarily that it *will* be eliminated. That is, eliminativists claim it would be scientifically beneficial to eliminate the concept, whether or not this is something that scientists will actually do. This argument would still stand even if it is unlikely that culture actually will be eliminated from cultural robotics. We conclude that the argument from unrealism is not a good argument in favour of preservationism.

A much stronger argument in favour of preservationism is the argument concerning scientific roles. This argument aims to identify a scientifically useful and important role (or roles) that the concept of culture plays in robotics, which we would lose if we were to eliminate the concept. Because the concept fulfils this role (or these roles), the argument goes, we should preserve the concept. To clarify the focus of this argument, this argument does not only claim that individual definitions (or themes) are useful in robotics. That is true, but that does not constitute a good argument for preservationism, because preservationism concerns the overarching concept of culture as a whole, rather than the individual definitions or themes we considered above. By 'the overarching concept of culture' we mean simply the concept of culture, rather than any particular specification or definition of that concept. For this reason, this argument for preservationism requires us to find a theoretical use for the overarching concept of culture itself, not just some of its possible definitions.

Our view is that one version of the argument concerning scientific roles in favour of preservationism is very promising, but some work needs to be done to identify which role(s) the argument should rely on. Identifying useful roles for the concept culture is more challenging than it initially looks. The introduction of culture to robotics is relatively recent, and someone sceptical of preservationism may suggest that the positive contribution it makes to the field is somewhat unclear. To see this, consider how cultural robotics grew out of social robotics (a process we described in Sect. 2). The field of social robotics is considered the foundation of cultural robotics [59]. Social robotics studies human–robot interactions in social contexts including the appearance and behaviour of socially interactive robots. What constitutes a social context can be broad and often debatable [53]. This is because many researchers believe that robots are not strictly social and also, we cannot have social robots without a clear understanding of conscience [80]. Someone sceptical of preserving the concept of culture will suggest that it is not clear what additional benefit the concept of culture has added to robotics, *in addition to the conceptual resources already available to social robotics*. Such a sceptic may claim that any research we might like to subsume under the umbrella of cultural robotics can just come under the heading of social robotics.

Of course, if the concept of culture does not make any important contribution beyond the resources that social robotics already offers, then there is very little to justify preserving the term. So, in order for the argument concerning scientific roles in support of preservationism to be a good one, the preservationist will need to answer the following question: what does the concept culture add, scientifically speaking, which social robotics did not already have use of? To assess this claim, let us analyse a few typical topics in social robotics according to the International Journal of Social Robotics.[7] Here we will briefly consider several contexts within robotics (assistive robotics, interactive robotics and robot navigation). We will argue that culture does *not* make a clear contribution in addition to the resources offered by social robotics. Therefore, it is not a useful way for the preservationist to justify preservation of culture in robotics. Then we will consider a context which is more promising for the preservationist argument concerning scientific roles, which is a multidisciplinary context. We ultimately argue that the multidisciplinary context is a good reason to preserve the concept. We therefore conclude in favour of preservationism.

8.2.1 Assistive Robotics

One important topic in social robotics is assistive robotics. Cultural robotics has been commonly applied in many use cases of assistive robotics according to Lim et al. [64]. In fact, robots assisting the elderly in shopping malls (e.g., [50]) or in care homes (e.g., [22]) are popular motivating examples of cultural robotics. The reason behind this motivation is that robots should adapt to the culture of elderly people to be trustable and acceptable in their eyes. In this case, the mention of culture does not add to the research or the quality of the service that the assistive robot provides, rather it is a proxy word for including structure/pattern into the robot's program. In this area, the use of the concept culture does not provide a clear benefit to the research programme, above and beyond the resources that social robotics and other concepts provide.

8.2.2 Interactive Robotics

Interactive robotic arts are another area of concern to social robotics, e.g., interactive robotic painters [35, 39] or a robot magician [69]. It is easy to see that this topic is also within the interest of cultural robotics. What is not clear is how including culture would add any specific methods or design choice to the field, unless we subscribe to a more precise concept of culture as a product or process. But if those concepts are sufficient to do the work in interactive robotics, then the contribution of the overarching concept of culture itself is somewhat unclear. So, this is not a promising way to justify preservationism.

8.2.3 Robot Navigation

According to the International Journal of Social Robotics website, another topic within the scope of social robotics is socially-aware robot navigation, task and motion planning (e.g., a recent survey by [66]). This topic is relevant for most robotics applications as it concerns making robots autonomously move, and reason about the fulfilment of their tasks, e.g., robot guiding a museum tour (e.g., [100]) or giving assistance in an airport (e.g., [101]). The same argument above applies here. Using the concept of culture would not alter the automated planning techniques that, for instance, are employed in a robot co-worker scenario. It is difficult to envisage how culture as an overarching concept would enhance the methods developed within social robotics in the way that a more precise concept could not.

Here we will summarise the dialectical point we have reached. We are discussing the argument concerning scientific roles, which is an argument for preserving the concept of culture in robotics. The argument concerning scientific roles says that we should preserve the concept of culture in robotics because the concept fulfils important role(s) for robotics. However, this suggestion faces a challenge, which is that someone may claim that culture does not add any resources to the ones already in use in social robotics. We then considered three areas of cultural robotics (assistive robotics, interactive robotics and robot navigation) and argued that in these contexts, the contribution that culture makes is unclear. For this

[7] https://www.springer.com/journal/12369/aims-and-scope

reason, these are not promising ways for the preservationist to develop the argument concerning scientific roles. The general issue with these cases (assistive robotics, interactive robotics and robot navigation) is that many of the relevant concepts are already present in social robotics, and the addition of the concept of culture did not make a substantive addition to the field. Now, we will turn to a much more promising approach for the preservationist.

A more promising approach is to point out that cultural robotics is a very multidisciplinary field. For progress to be made, we require input from across the natural sciences, humanities, and social sciences. As work on epistemic cultures has emphasised, these fields employ different norms, practices, standards of evidence, technological tools, division of labour, funding sources, and the modes of inquiry employed by their research communities (see [57] and especially [58], p.364). For this reason, concepts are useful when they identify 'common ground'. In other words, concepts are useful when they identify an area where many disciplines can have worthwhile input. One role for the concept of culture is to identify an area of robotics which encompasses concerns and problems that a variety of disciplines have important input to. According to this view, the concept of culture, rather than having one specific definition, might more fruitfully be thought of as way of demarcating a particular field of study, for which some tools that have been developed by the social sciences and humanities are particularly useful. The concept culture signals one area of robotics where there is a clear need for input from the social sciences and the humanities. In this way, the concept draws together researchers from a variety of disciplines to focus on a common set of problems, where all of the disciplines overlap. Indeed, as well as signalling an area where the social sciences and humanities can have important input, the concept also helps to signal which kinds of theoretical tools and methodologies will be useful for this area of robotics. Specifically, it signals that the important theoretical tools will be those that have been developed by the social sciences and humanities to think about culture in all its complexity.

This argument for preservationism relies on identifying culture as a concept that aids multidisciplinary work, because the concept helps to identify common ground. From this perspective, the fact that culture has been understood in so many different ways is actually an *advantage* of the concept's use within robotics, because it allows for the concept to be used flexibly in different areas of robotics, utilising the approaches of many different disciplines. By contrast with this flexible approach, the eliminativist suggestion involves eliminating the concept and replacing it with a relatively rigid set of alternative definitions of culture. But (claims the preservationist) this rigidity is not appropriate when the field is still figuring out what are the many different ways that thinking about culture might be appropriate in robotics.

In our view, this is the best argument in favour of preservationism. Rather than pointing to one area of robotics (such as interactive robotics, etc.) and suggesting that culture fulfils an important role in that area, this suggestion involves the claim that the overarching concept of culture helps multidisciplinary work in robotics generally, by identifying areas of common ground, and signalling the kinds of approaches that are appropriate. The preservationist then claims that the concept should be preserved because it fulfils this important role.

We have considered the arguments in favour of eliminativism and preservationism. We have argued that the two main arguments for eliminativism face serious challenges, and that there is one argument for preservationism which is promising. We conclude that preservationism is the better option.

9 Implications for Future Research

We have examined the many ways that culture has been understood in cultural robotics, and argued that the concept is conceptually fragmented. We have also examined two potential reactions to the situation: eliminativism and preservationism, and argued in favour of preservationism. These results have important upshots for robotics. As demonstrated above, the conceptual fragmentation framework gives a picture of the ways in which the different definitions of culture in the social sciences and humanities are relevant for robotics. The eliminativism/preservationism debate presents an account of the ways in which the overarching concept of culture itself remains useful for robotics, despite all of the many definitions that have been offered of the term.

There are three implications of these results for future research in social and cultural robotics that we would like to highlight. The first is that conceptual fragmentation draws attention to the subtle and often overlooked ways that *context* can affect how a particular term should be used in robotics. As we have argued in this paper, culture is not a 'static' concept in robotics. Rather, its usefulness shifts and changes depending on where the robot in question is to be deployed, what it is intended to do, how long it is intended to work with the same humans, and many other factors. This is important for practising roboticists. It is commonplace to recognise that that culture is a very complex phenomenon. This is true, of course, but the arguments of this paper demonstrate that part of this complexity arises from different ways of thinking about the phenomenon, *in different contexts*. It is not just that the concept is intrinsically complex (though it is), but also that the complexity stems in part from the fact that it is relevant to many different areas of robotics, each of which place their own demands on the concept. In this way, the examples in Sect. 7 work as examples of how to think about culture across contexts in robotics, which can be imitated by practising roboticists.

The second implication of this paper is especially relevant to the *interdisciplinary* nature of cultural robotics. We have drawn on the 'conceptual fragmentation' framework from the philosophy of science in order to analyse culture in robotics. This demonstrates the fruitfulness of thinking about robotics through the lens of philosophy of science. This paper shows that philosophy of science constitutes an important resource for robotics. More specifically, this paper identifies a specific point for interdisciplinary engagement between the social sciences and humanities, and robotics. This paper started with a stark contrast between the narrow (and problematic) ways that culture is typically understood in robotics, as opposed to the nuanced and sophisticated ways that culture is approached in the humanities and social sciences. The main positive contribution of this paper is that it highlights a way to move beyond the current (narrow and problematic) understanding of culture in robotics, and toward a more sophisticated way to integrate more nuanced approaches to culture with robotics. More specifically, when confronted with an application case in cultural robotics, the challenge is to think about what properties of culture are most relevant to the robot's design and implementation, since this will impact on how we should think about culture, in this context. This is a clear area where the humanities and social sciences are ideally placed to make a contribution. Thinkers in these disciplines have the necessary skills to assess the implications of different ways of thinking of culture, in all their complexities and nuance, because of its long history of study in these fields. Indeed, deciding which aspects of culture require especial emphasis in a particular context will require input from all relevant stakeholders, including those groups that the relevant robot is intended to interact with. This is a clear point of engagement where the skills of the social sciences and humanities are essential, and are crucial for stepping beyond the problematic ways that culture is typically understood in robotics at the moment. However, such a project will always require close collaboration with roboticists as well, in order to ensure that the resultant ways of approaching culture are practical and implementable. For this reason, the process of examining a context in robotics, and thinking about how best to conceptualise culture within that context must be interdisciplinary. The humanities and social sciences are well placed to explore how we should think about culture in a particular context, whilst roboticists are required to ensure that these approaches are practical and implementable in actual robot design. In this way, this paper identifies a clear point of interdisciplinary contact, and shows why the input of various different disciplines is essential, and how this interdisciplinary contact will help us to move past the currently suboptimal ways that culture is studied in robotics.

The third implication is more specific to the technical aspects of robotics per se. We have surveyed the relevance of different ways of thinking about culture in robotics, and demonstrated the ways in which a certain approach to culture can be especially beneficial in a particular context in robotics, because it highlights specific properties that are especially relevant for that context. The second implication of the paper (above) was to reflect on how these approaches might be implemented. The third implication involves identifying technical methods within robotics which can implement the specific properties associated with these particular themes. This will involve examining cutting edge methods, and introducing new ones in the case of inadequacy. For example, suppose we want a robot to recognise cultural cues in humans in a particular context. Interdisciplinary work with social scientists and humanities researchers may lead us to decide that conceiving of culture as a pattern (in a way that goes beyond nationality) is salient for this goal. The analysis of the various themes of culture that this paper provides will constrain the subsequent technical tasks in the following way. In such a case, we need to draw on wider social science research to establish what sort of pattern of behaviours are relevant to this notion of culture. The roboticist's goal would be to find an acceptable reduction[8] of this complex theme into a contextual computational model. This would require asking questions of a technical nature, guided by the overarching cultural theme, as identified by the social sciences and humanities. Such a project would involve identifying which properties are signifiers of that cultural pattern. There would then be a plethora of technical questions, such as *which* of these properties should we programme the robot to recognise? How can we programme the robot with this recognitional ability, given their sensory capability? Which Machine Learning techniques should be used for this task, based on the possibly small number of data obtained in a particular application?

The more general conclusion of this paper is that work in robotics cannot proceed in isolation from the rich tradition of thinking about culture in the social sciences and humanities. As work on cultural robotics progresses, this tradition has the potential to improve and transform the ways that robots interact with humans in our day to day lives.

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[8] When we say 'acceptable' reduction, we do not mean to imply that *all* facets of this cultural theme could be neatly translated into a computational model. Rather, it would involve preserving an acceptable amount of the cultural theme in the robot's programme.

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