Design Science

Collective intentionality and the social status of artifactual kinds

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Abstract

There is a well-developed view of artifacts according to which their nature depends on the intentions of their authors or creators. However, in the modern world of artifact design and creation, typically not one but many agents are involved in the process of making an artifact. In this paper, I show how the intentional view can be maintained even for 'collective' artifacts having multiple authors. My approach is to combine some basic concepts that have been proposed in the study of collective intentionality with a suitable model of artifact creation that takes account of the multiple agents and processes that arise in design, engineering and manufacturing a new or existing product. In this way, we can explain how an artifactual kind can be understood via a form of *collective* intentionality. For the design sciences, notions such as we-intentionality and group agency can help to model different types of cooperation and, in particular, to reconcile individualism with strong forms of collectivity at a group level.

Key words: collective intentionality, artifacts, social ontology, philosophy of design and engineering

1. Introduction

1.1. Artifacts and sociality

The study of artifacts, their creation, their nature and their ontological status is of growing interest in many fields of inquiry. The process of artifact creation is not only central to design science but is a flourishing topic in disciplines like anthropology, social psychology and philosophy. Within philosophy, for example, metaphysics investigates the very nature of artifactual kinds and studies their criteria of identity and individuation. Another philosophical direction is one that takes into account that many man-made objects have a purpose or a technical function, and so the study of technical functions and the corresponding uses of artifacts is of concern, notably in the philosophies of design and engineering. Furthermore, since many artifacts are mass-produced and commercialised, they form part of our economic systems. This yields a third perspective: the manner in which artifacts are created and evolve over time is a topic in economics as well as in studies of technology and innovation.[1]

[1] Artworks are also artifacts, and the philosophy of art is also concerned with ontological issues of the kind that arise in metaphysics. This yields a fourth perspective that is closely related to the first. It also throws up links between art and technology, two fields that are traditionally kept at arm's length.

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In this paper, I will consider these three perspectives on artifacts in more detail and discuss some very basic questions of ontology and meaning. More specifically, I wish to focus on some aspects of artifacts and *sociality*. The idea that social contexts are important for understanding artifacts and their development is certainly not a new one. In technology studies there has been since the 1980s a prominent sociological approach that aims to analyse the social construction of technology (Bijker, Hughes & Pinch 1987). One feature of this approach is the idea that technical artifacts develop in response to problems and issues faced by social groups that are in some way involved with the artifact.[2]

> In deciding which problems are relevant [for the artifact], the social groups concerned with the artifact and the meanings that those groups give to the artifact play a crucial role: a problem is defined as such only when there is a social group for which it constitutes a 'problem.' (Pinch & Bijker 1987, p. 30)

In the social constructivist approach, therefore, certain *collectives* figure prominently in understanding artifacts and the meaning of artifactual terms. More recently, some followers of this approach even talk of a 'collectivist' account of technological ontology (Schyfter 2009).

> As entities embedded within social and cultural systems, artifacts must be addressed using an analytic framework that incorporates a strong component of collective artifact sociality, rather than simply individual intentionality. (Schyfter 2009, p. 18)

Here Pablo Schyfter is emphasising two concepts that will feature strongly in my discussion: that of sociality and that of intentionality. The latter concept, for Schyfter, arises through what he calls *formative intentional actions*.[3] These are actions that are socially situated and form part of the norms of use for a given artifact, as in the action of a waiter opening a wine bottle in a restaurant that may show the meaning of the term 'waiter's corkscrew'.[4] The idea of intentionality related to norms of use in a social context is important and we will return to it later on. However, initially I would like to deal with another aspect, also connected with use, but more closely linked to design: the intentionality involved in the creation or making of artifacts, by designers, producers and other stakeholders.

Although he brings together the notions of sociality, collectivity and intentionality, Schyfter does not develop them further with reference to recent work in the philosophy of sociality and the area of collective intentionality. While the idea of social groups and group agency is a very old one, there is a recent surge of interest in the philosophy of sociality, starting around the same time as (but independently from) the social constructivist view of technology in the 1980s (Tuomela 1984; Gilbert 1989). This has led to a lively branch of inquiry nowadays known as *social ontology*. It deals with some of the very basic notions underlying social interaction and social science, such as group agency, cooperation, collectivity, group beliefs and intentions, social norms, and so on.

[2] In today's jargon *user groups* might be prime examples.

[3] Borrowing some ideas from Collins & Kusch (1998).

[4] Writers concerned with the *functions* of technical artifacts have also emphasised the idea that function ascriptions need to be socially recognised (Hansson 2006).

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A central concern in this work is to explain how collective notions like group agency, group belief or group intentions are distinct from but emerge out of the attitudes held by individual agents in a collective.[5]

While scholars in technology studies, including social constructivists, have looked at the impact of social groups on artifacts and technology development in particular cases, to my knowledge they have not examined in a design and development context fundamental questions about group agency and the emergence of group attitudes like beliefs and intentions and how these may bear on the design process. This is the path I would like to explore further here and in doing so examine and defend the following ideas. The first is that artifacts are intentional objects or objects having a dual structure, both physical and intentional. The second claim is that the nature of new artifact types is constituted by the intentions of the creators and makers of these artifacts. However, there are two important provisos to this claim. One is that this idea of artifact determination cannot be reduced to the individual intentions of artifact creators but has an irreducibly social aspect. To emphasise this we will say that it is based on a *collective* or *we-intentionality*. The second caveat is that once a new artifact type has been introduced its users also form part of this we-intentionality and co-determine the nature of the artifact. Considered in terms of the meaning of artifactual concepts: while we can make a formal difference at an individual level between assignments and attributions of meaning, ultimately collective attributions of meaning become stipulative and hence constitutive.

1.2. Artifacts and intentionality

Writing in the latter part of the 19th Century, the philosopher and Jesuit priest, Franz Brentano, championed the idea that there is a realm of intentional phenomena not reducible in kind to the physical realm.[6] In the 20th Century, Roman Ingarden was a prominent exponent of the idea that human, cultural objects are intentional. Ingarden was a student of two of Brentano's most illustrious pupils, Kazimierz Twardowski and Edmund Husserl. As illustrative examples, Ingarden took the cases of flags and churches that require social or institutional acts to give them meaning. He also stressed the dual, physical and intentional, nature of certain forms of art. For example, he referred to the two-layered structure of architectural works, as intentional artworks on the one hand and as 'real' buildings of bricks and mortar, on the other.[7] Much later on John Searle developed the idea of social acts conferring meaning as a central feature of his theory of social institutions (Searle 1995).

This idea has been extended to artifacts more generally. What we might term the *intentionalist* view of artifacts holds that the nature of an artifact or artifactual kind depends on the intentions of its author or creator. One version of this view has been developed in particular by Risto Hilpinen who has formulated a *dependence*

[5] The interdisciplinary COLLINT series of international conferences on Collective Intentionality began in 1999 and reached its 9th edition in 2014. Regular conferences on Social Ontology organised by the European Network on Social Ontology (ENSO) have been held since 2011 and an International Social Ontology Society (ISOS) was formed in 2012 as well as the *Journal of Social Ontology*. Besides mixing disciplines, this community also brings together different philosophical traditions: alongside analytical philosophy, the phenomenological tradition is well-represented.

[6] Especially in Brentano (1874).

[7] See in particular Ingarden (1961).

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condition requiring that the existence and some of the properties of an artifact depend on an author's intention to make an object of a certain kind.

> An object *o* is an artifact authored by *A* only if some properties of *o* depend on the content of *A*'s intentions. (Hilpinen 1993, p. 159)

(see also Hilpinen (2011) for a more recent discussion). There is also a related *success condition*:

> If an object *o* is an artifact authored by *A*, there is a sortal description *K* such that the existence of *o* depends on *A*'s intention to produce an object of kind *K*. (Hilpinen 1993, p. 159)[8]

Stronger or weaker forms of the intentionalist view are obtained by regarding the dependence condition as applying to few, many or all of the principal features of an artifact. For example a strong intentionalist view of artifacts has been propounded by Amie Thomasson who argues that the metaphysical natures of artifactual kinds are constituted by the concepts and intentions of their authors, (see especially Thomasson (2003, 2007)).

Thomasson rejects a common view that artifactual kinds are individuated by means of their *function*. Her suggestion is that the creator's intentions form the most relevant guide to the extension of an artifact type and so artifacts must be the intended products of human activities. This is not to say that functions cannot be among the features that the author of an artifact intends it to have. Rather, there are artifacts such as artworks that need not always be associated with an intended function, while some artifacts that do possess functional properties need not be fully determined by those properties (they may be neither necessary nor sufficient for that purpose).[9,10]

A consequence of Thomasson's view is that, since intentions are constitutive of meaning, makers (in a very general sense of maker) cannot be completely wrong about the nature of the artifacts they produce. As with social concepts, beliefs about artifacts may partly be constitutive of their meaning.

Thomasson defends her view by considering a simplified account of a single, individual artisan intentionally creating a prototype artifact of a new kind. Since the object is of a new type, there is no question of her aiming to copy an existing design or conform to a previously available specification of some product, to which she could succeed or fail. Instead, the features that are relevant to the new kind *K* are those features intentionally given by her. She must have a substantive idea of what kind of object a *K* must be, along with the intention to produce

[8] For Hilpinen the content of the intention is not the artifact itself but a description – here called 'sortal description' – characterising what type of object is supposed to be created. Notice that since authorship is part of the concept of artifact, in these references to an author *A* there is no loss of generality.

[9] Working prototypes may share all the essential features of a commercial product yet not be designed for public consumption. For example at automobile shows like Frankfurt's IAA it has become customary for manufacturers to display concept cars. These may be fully working motor vehicles but nevertheless not designed for public use on the road or track, more often their 'function' is to showcase certain stylistic or technical features such as lightness, aerodynamic form, innovative materials, fuel economy, and so on. In this case while clearly belonging to the category of motor car they are not functioning in the same way as the other vehicles on display.

[10] Functional views of the nature of artifacts can be found in Millikan (1999) and McLaughlin (2001). Vega-Encabo & Lawler (2014) offer a recent critique and comparison of functional versus intentionalist accounts of the creation of new artifactual kinds.

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that kind of object. By creating a new artifact and delineating a new kind she has stipulated the features that are relevant for and constitutive of that kind.

As Thomasson remarks, there is an element of 'self-referentiality' in artifactual concepts. It follows that there is not only a natural comparison but also a contrast with Searle's view of institutional concepts in Searle (1995).

> Whereas for a certain sort of thing to be money, it is necessary (and sufficient) that it be the sort of thing that is collectively regarded as money, for an individual object to be a chair, it must itself have been intended to be a chair. (Thomasson 2007, p. 58)

In recent years, the dual nature of *technical* artifacts has been highlighted and studied by a number of scholars working on the philosophical foundations of design, engineering and technology. From 2000, a research programme entitled *The Dual Nature of Technical Artefacts* ran for several years coordinated by the Delft University of Technology in The Netherlands. According to its manifesto, this programme aims to develop a coherent conceptualisation of technical artifacts

> taking into account their dual nature as (i) designed physical structures which realize (ii) intentionality-bearing functions. [11]

A key aspect of the programme was to investigate the nature of (i) and (ii) and especially their interrelations; this was realised through a substantial output of research papers and books.[12] We will shortly examine one of these works in more detail.

1.3. Aims and approach

In the modern world of artifact design, creation and manufacturing, typically many agents will be involved in the process of creating an artifact or indeed designing and making a new artifactual kind. Both Hilpinen and Thomasson accept that there may be a plurality of agents involved. In such cases, Hilpinen (1993) refers to a 'collective author' and the item created as a 'collective artifact'. The question then arises: what becomes of the intentionalist view? Does it become indefensible once individual intentionality is no longer relevant? Recently, Thomasson (2014) has acknowledged the need to go beyond individual intentionality in understanding artifactual kinds. But while she admits that an account involving collective intentionality might have plausibility, she is unsure whether any of the well-known accounts of collective intentionality debated by philosophers would be appropriate for the task.

There seems to be a hidden challenge here: to develop a suitable account of artifactual kinds based on a concept of collective intentionality. This will be my aim in this essay which will argue that the intentionalist view is still defensible providing individual intentionality is replaced by a suitable form of *collective* or *we-intentionality*. Collective intentionality has become a pivotal concept in studies of social intelligence. The concept of we-intention was already introduced and analysed in the works of Wilfred Sellars (e.g., in Sellars (1968)). Later a

[11] See Kroes & Meijers (2002).

[12] On the nature of technical functions and their ascriptions, see Houkes *et al.* (2002), Kroes (2010*a*) and Kroes (2010*b*).

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systematic account of we-intentions was given by Tuomela (1984) and developed into a central concept in his theory of social action.[13] More recently, John Searle has made we-intentionality a vital component in his account of social reality (Searle 2010).

The path to collective intentionality is inviting, but to pursue this goal we will need a more sophisticated model of artifact creation: the single-agent, 'artisan' model is not cut out to explain how collective intentionality could underlie the nature of an artifactual kind. A suitable alternative model has been proposed by two authors contributing to the 'Dual Nature' research programme just mentioned: Wybo Houkes and Pieter Vermaas.[14] My arguments for a collective intentionalist view of artifacts will contain four main steps. First, we will examine in more detail the Houkes & Vermaas (2009) model of artifact creation. A crucial feature is that it provides first and foremost an action-theoretic rather than a functional account of artifacts. Secondly, we will review some of the core ideas of collective intentionality and in particular take a closer look at Raimo Tuomela's analysis of cooperation in the we-mode and show how it can be applied to the Houkes and Vermaas model. Thirdly, we will examine briefly the notion of group belief. This is important for understanding how different actors involved in designing and making artifacts, while possibly entertaining, as individuals, different ideas (and beliefs) about the nature of the object being created, may nevertheless establish as a group a coherent, collective view. Fourth, we need to extend the idea of intentionality to include the broader collective of artifact *users*.

Once these main ideas are in place, I will discuss an approach to technical innovation that deals not only with the design and production processes that follow the concept and product generation phases, but also tries to comprehend the disruptive phase that precedes the conceptualisation and design of new products. This approach will also prove useful for our final exercise: to examine in a very preliminary fashion some issues where concepts from collective intentionality may bear on practical aspects of the design process.

1.4. Design science and philosophy

Philosophical studies often seem far removed from practical, real-world considerations. However, if philosophers can provide concepts and ideas that help us understand the nature of artifacts and artifactual kinds, these ideas should certainly have ramifications for those involved in designing and creating artifacts. So, even when focused primarily on conceptual and foundational issues, we can try to extract some features that might be relevant for design methodology.

What might be the role of philosophy and what kind of contribution can it make? In our case we are dealing with two different, though related branches of philosophy. The first is the analytical philosophy of technology and design. In particular, here we will deal with a semiformal reconstruction of some core features of the design and production of artifacts. It is a model of artifact creation centred on the actions and intentions of the different agents involved, from product-designers to manufacturers and end users. Although inevitably idealised in many ways, the model comes much closer to modern engineering practice than the simplified 'artisanal' account mentioned earlier. Models of

[13] See e.g., by Tuomela & Miller (1985).

[14] See especially (Houkes & Vermaas 2004, 2009).

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this kind are useful, not only for the metaphysical analysis of artifacts. In the philosophy of science, there are many formal and semiformal models that try to help us understand the structure and growth of scientific knowledge. Much (though not all) of this knowledge is embodied in descriptive (scientific) *theories* and there is a wealth of formal languages and mathematical tools that can be brought to bear on reconstructing and analysing this knowledge. Studies of technology and technical innovation have to deal not just with descriptive (technological) knowledge, but more especially with skills, processes, goals and actions, embedded in social contexts. Concepts and languages for describing these features are less well developed than in the case of, say, the natural sciences. The model of Houkes and Vermaas plays for technology a role analogous to that played by many formal models in the philosophy of science. It is a valuable starting point for analysing different aspects of the design and production process.

Why then do we need to go beyond this engineering model? While the model considers interactions between the different actors involved in artifact design and production, it treats beliefs, intentions and actions only at an individual level. Among the relevant groups of actors only the end users are treated as a plurality; other agent types are imagined to be single agents even though it is clear that in practice there will normally be *teams* of designers, a *plurality* of makers, and so on. The model does not seek to represent the relevant agents as a collective, nor treat them as group agents that may possess group beliefs and shared intentions. In short, while each of the main design and make stages of artifact production is carefully characterised in the action-theoretic model, we are missing an appreciation of how cooperation between actors (of the same or different agent types) may lead to (and rely upon) group or collective beliefs and goals.

My view is that adding these missing elements to the engineering model will strengthen it and increase its explanatory potential. As we noted earlier, the area of *social ontology* deals with the relevant notions of group agency, group beliefs and we-intentionality and provides the concepts we need. It may also suggest some departures from everyday language. In everyday speech, *collectivism* is often contrasted with *individualism*. 'Collectivism' seems to suggest conformity or a lack of independence, while 'individualism' suggests the opposite. However, in philosophical studies a more nuanced position is often taken. According to this view, groups may display a strong form of collectivism in terms of their overall goals and their forms of internal cooperation, while at an individual level group members may entertain different opinions and beliefs. Despite these differences, group beliefs and commitments may emerge and be adhered to (by the group, acting as a group).

Concepts related to group agency are therefore important for several reasons. For one thing, these notions play an explanatory role in social sciences, aiming to produce more effective theories than reductionist theories that are based on individual judgements, preferences, and so forth. Second, group concepts may help to provide a typology of different forms of cooperation, and these in turn may be relevant for the understanding of design processes and collective artifacts. Moreover, these notions bear on practice as well as theory. There are examples from real-world design and manufacturing, even in mature industries, where collectivism and individualism co-exist and play equal roles in best practice.

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Concepts like group agency and group attitudes can help to explain how this co-existence can come about and be successfully managed.[15]

2. An 'engineering' model of artifact creation

Houkes & Vermaas (2004, 2009) have developed an elaborate account of artifacts that is intended to reflect engineering practice. It involves a detailed model of agents' actions, beliefs and intentions in terms of action plans relevant for artifact design and production. Like Thomasson, they reject the idea that artifacts should be understood primarily in terms of their functions and they aim to replace the function-oriented philosophy of artifacts with an account based on intentional actions.[16]

There are several reasons to take an interest in the account provided by Houkes and Vermaas. It aims to reflect modern engineering practice by distinguishing between design, use and manufacture, as well as between the different actors involved in these processes. In particular, their account includes a use plan, a design plan, as well as plans for product-designing, making and manufacturing. Each of these involves the intentions, goals and beliefs of the specific actors involved. Not only is this a genuinely multiagent view that aims to reflect engineering practice, but also, since it is action-theoretic, it can be embedded in more general theories of social action.

Nevertheless, all is not smooth sailing: there is a major obstacle to overcome in applying this model in the present context. Houkes and Vermaas themselves reject the intentionalist stance and claim that their model is incompatible with views such as those of Thomasson. While they accept the idea 'that artifacts are intentionally produced by humans', Houkes & Vermaas (2009, p. 410), with explicit reference to Thomasson they question the idea that artifactual kinds can be identified on the basis of makers' intentions. They also reject her suggestion that makers can in general be said to have substantively correct ideas about properties relevant to an artifactual kind. As they say of their own model:

> It does not afford a clear relation between the intentions of any of the agents involved in producing the artifact and membership of an artifact kind. (Houkes & Vermaas 2009, p. 404)

The main thesis that Houkes and Vermaas attack and Thomasson defends is therefore the claim:

> (A) Artifacts are the intended products of largely successful intentions to create something of that kind.

While for Houkes and Vermaas the ascription of technical functions to artifacts plays a role in their model of artifact design and production, functions do not provide the 'essences' of artifacts. Rather, their theory of function ascription is action oriented and highlights the capacities of artifacts relative to a plan, e.g., a

[15] The example of Honda Motor Company will be discussed below.

[16] See especially Houkes & Vermaas (2004). In keeping with the aims of the *Dual Nature* research programme, Houkes and Vermaas do investigate technical functions, but from this action-theoretic viewpoint.

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use plan. It is therefore a relative and context-dependent notion based on artifact actions.[17]

In their 'engineering' model of artifact creation, Houkes and Vermaas consider four agent types: *user*, *designer*, *maker* and *manufacturer*. A key element in the model is a *use plan*, understood as a series of goal-directed actions. Use is then characterised as the carrying out (by the user) of the actions that make up the use plan. The designer's role on the other hand helps users to realise their goals by constructing and communicating use plans.

To characterise a class of artifacts, three stages of *product-designing*, *making* and *manufacturing* are described in more detail. Behind product-design is the idea that the designer describes a new item that contributes to the realisation of a use plan by prospective users of the artifact: as they put it, the designer 'd intends to contribute to producing items x_i, x_j, etc. that do not yet exist by *product-designing* them.'

In simplified form, the product-design stage is described as follows (Houkes & Vermaas 2009, p. 410):

(i) designer d believes that an item x with (physiochemical) capacity φ does not exist.
(ii) d contributes to realising a goal g_{dx} by describing item x (with capacity φ).
(iii) d believes that a composite of components $c_1, \ldots, c_i, \ldots$ with capacities $\varphi_1, \ldots, \varphi_i, \ldots$ achieves the desired capacity φ.
(iv) d believes that the various design tasks g_{dci} are simultaneously fulfilled.
(v) d intends to communicate a description of x (to appropriate agents).

To the extent that some of the components c_i may also need to be product-designed, the first four steps may be iterated for each such c_i. This feature is built into the full description of the model.

The process of *making* a new artifactual kind is also characterised as a goal-directed series of actions. In Houkes & Vermaas (2009), this is described as follows:

(i) maker m wants to bring about the existence of item x as described by agent a who, with that item x, wants to bring about the goal state g_a.
(ii) m chooses or constructs a suitable make plan mp.
(iii) m intends to carry out mp (and acts accordingly).

Again, I am simplifying here by omitting some steps at which the maker verifies whether the plan mp has succeeded. This part of the model distinguishes the making of x from the agent a who with x wants to bring about the goal state g_a. For example, as Houkes and Vermaas note, agent a may be the product-designer, while m could be a different engineer involved in the production process.

A third type of agent is the manufacturer who supports all the processes involve in product creation and delivery. In the model, it is supposed that the manufacturer designs the make plans that makers use:

(i) manufacturer mf wants to contribute to maker's goal of bringing about item x as described by agent a.
(ii) mf constructs a suitable make plan mp involving items $y_1, y_2, \ldots$.

[17] See especially Houkes & Vermaas (2004). They also discuss technical functions in Vermaas & Houkes (2006).

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(iii) mf contributes to producing $y_1, y_2, \ldots$.
(iv) mf intends to communicate mp to users.

Once again, this is only a core part of the model. In the full version (Houkes & Vermaas 2009), consider also processes whereby manufacturers verify and adjust their make plans in order to arrive at a successful version of the item x.

2.1. Summarising the basic features of the model

If we restrict attention to successful artifact creation, then what we have described here represents the core features of the Houkes and Vermaas model. Let us summarise its main features. This is a multiagent account comprising several agent types with specific roles. There is an overarching goal, to design, produce and use an item x of an artifactual kind, say K, according to certain plans. To reach this goal there are various subgoals, each with corresponding plans. These may involve designing and producing the required subcomponents of $x, c_1, \ldots, c_i, \ldots$ assembled according to suitable make plans. The model involves agent beliefs, about capacities, properties and plans, as well as intentions, to act and carry out plans. There is also agent *communication* involved, since for example designers communicate plans to makers, manufacturers communicate plans to users, and so forth. We now need to examine whether and how these features may support an intentionalist understanding of artifacts.

3. A role for collective intentionality

Can we reconcile the view that artifacts are determined by a collective form of intentionality with the model of artifact creation proposed by Houkes and Vermaas? They themselves are sceptical about this. They take it to be a key feature (and improvement) that their model distinguishes between plan-designers, product-designers, makers and manufacturers. However, even when these agents act deliberately and their 'intentions are related to the characteristics of the produced item' (Houkes & Vermaas 2009, p. 415), it is claimed that they may have 'incomplete or conflicting notions of what is required to create a successful object of the kind.' Their reluctance to accept that artifact kinds are collectively determined by all the agents involved in the design and production process seems to rest on the doubt that such kinds could ever be said to be collectively determined (by a group or team) when members of the group display conflicting conceptions and intentions. This seems to be a primary reason for their rejection of thesis (A).[18]

Rather than constituting an argument against collective intentionality, it seems to me that individual differences in the conceptions held by the key agents in the design and production process may yield an argument in favour of introducing collective intentionality into the Houkes and Vermaas model.

3.1. Collective intentionality and cooperation in the we-mode

Collective intentionality and related concepts have been studied by scholars from different disciplines over a number of years, with increasing vitality since the

[18] For argument's sake, I will assume that team members might individually have different conceptions about the nature of the kind. In the above quotation, it seems that Houkes and Vermaas's claim is a weaker one, that there may be a conflict not over the kind itself but over the means needed to create it.

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early 1990s. Besides John Searle and Raimo Tuomela mentioned earlier, influential writers include Margaret Gilbert and Michael Bratman.[19] The central concept within Gilbert's theory is that of *joint commitment*, while Bratman has focused especially on understanding *shared intentions*. While these concepts are formally distinct and display different social and normative features, as Smith (2015) argues, they have many similarities and commonalities.[20]

Like several other scholars, Bratman aims to explicate simple forms of human sociality (he calls it modest sociality) and he does so by analysing shared intentions and joint activities. Typical examples could be singing a duet together, painting a house together, or going to a football match together. His approach is based on a planning theory of intention and agency. For Bratman, shared intentions are based on joint activities and in his words involve:

> (i) intentions on the part of each [actor] in favor of the joint activity,
> (ii) intentions on the part of each in favor of the joint activity by way of the intentions of each in (i) and by way of relevant mutual responsiveness in subintention and action,
> (iii) intentions on the part of each in favor of the joint activity by way of meshing subplans of the intentions of each in (i),
> (iv) beliefs of each that, if the intentions of each in (i) persist, the participants will perform the joint activity by way of those intentions and relevant mutual responsiveness in subintention and action,
> (v) beliefs of each that the intentions of each in (i) are persistence interdependent,
> (vi) the intentions of each in (i) are persistence interdependent, and
> (vii) common knowledge of (i)–(vii). (Bratman 2014, pp. 85–86.)

Here, the idea of persistence interdependence of an intention is that each agent continues to intend so long as the other does so and there is mutual knowledge of this. I do not wish to dig deeper into the details of Bratman's theory of shared agency. I mention it since it is a well-received view in the area of social ontology and because even this very brief summary suggests obvious connections we can make to the artifact creation model. Both involve plans, intentions, actions and activities in an essential way and it seems clear that in the Houkes and Vermaas model, some of these activities as well as the intentions in their favour must be jointly shared by the relevant actors. In both cases, there are also subplans and there is appropriate communication between actors (explicit in the Houkes and Vermaas model and implicit in Bratman's summary just quoted).

While Bratman, like Gilbert and others, provides valuable insights, the theory of joint action and shared intention described in Bratman (2014) restricts attention to shared actions within stable groups where there are no asymmetrical authority relations. Strictly speaking, his theory could be applied to the actors and processes involved in artifact design and production only if there is a flat, nonhierarchical organisational structure. Since this is not normally the case, for our purposes it will be convenient to look closer at an alternative approach

[19] Especially (Gilbert 1989) and the essays collected in Bratman (1999).
[20] For their most recent formulations, see Gilbert (2013) and Bratman (2014).

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to collective intentionality, for example, that taken by Raimo Tuomela (I'll use especially Tuomela (2007)).

In Tuomela's account, the core concepts of collective intentionality are joint intentions and social actions, group attitudes and cooperation. Fundamental to this is his important distinction between the *I-mode* and the *we-mode* in forming intentions and in cooperating to achieve goals. It is the sharing of goals and cooperation in the we-mode that helps distinguish a form of collective intentionality that is not reducible to individual intentions as represented in the I-mode. Very roughly put, the difference is that in the I-mode an agent, even if acting within a group or collective, is acting in her own interests, while in the we-mode agents are acting in the interests of the group as a whole and are committed to certain group goals or intentions.

The Houkes and Vermaas model of artifacts incorporates action, agency and a plurality of agents, and so is precisely of the right kind for analysing within Tuomela's framework under the we-mode of intention and cooperation. As we have seen it is a multiagent model of cooperation and there are explicit and common goals, communication between agents and even shared plans to achieve goals.

Here is Tuomela's formal account of cooperation in the we-mode, given for the simplified case of two agents, A_1 and A_2 (the embedded condition (AT^*) will be explained below):

> A_1 and A_2 *(successfully) cooperate with each other in the we-mode* in bringing about a goal G if and only if
>
> (1) G is a collective goal type, namely an 'achievement-whole' the achievement of which can be divided – either *ex ante actu* or *ex post actu* – into A_1's and A_2's parts;
> (2) A_1 and A_2 jointly intend to achieve G by acting jointly in the sense of (AT^*), and they achieve G jointly in accordance with and partly because of this joint intention of their to achieve G together. (Tuomela 2007, p. 165.)

This is Tuomela's 'conceptually minimal' notion of a we-mode cooperation. It is further embellished to a 'weakly rational' form of cooperation by requiring, in addition, that A_1 and A_2 rationally believe (1) and (2), and that (2) holds in part because of this shared belief.

To understand this account of cooperation, we need to clarify an underlying property of *joint action* on which it depends. This relies on the further condition (AT^*) explained by Tuomela as follows. X is jointly performed (by two agents 'you' and 'I') if

> (1) X is a collective action type, that is, an 'achievement-whole' divisible – either *ex ante actu* or *ex post actu* – into your and my parts;
> (2) we jointly intended to perform X jointly;
> (3) we performed X jointly in accordance with and partly because of our joint intention to perform X (or some 'closely related' action) jointly;
> (4) you and I mutually believed – or at least shared the belief – that 1, 2, and 3;
> (5) 2 in part because of 4. (Tuomela 2007, p. 112.)

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In short, that agents acted jointly in the sense of (AT^*) means that there was a joint intention to perform the action of a certain type X and that the performance of X was in accordance with a joint intention to perform X. Moreover, there is mutual belief about this among the agents concerned.

Without going into all the subtleties of joint actions and collective goals as analysed by Tuomela (2007), we can nevertheless make the following suggestions. First, suppose that a collective goal type G is the goal to produce an item x of an artifact type K and let us suppose that this goal succeeds and x is produced. The agents involved in the cooperation to achieve G may include the product-designers, makers and manufacturers, each with roles as described in the account of Houkes and Vermaas. They design, communicate and carry out plans. These agents cooperate in the we-mode since they jointly intend to achieve G by acting jointly in the sense of Tuomela's joint action account; each agent a_i performing according to its appropriate role type. This cooperation involves the mutual belief that they so intend. The various subgoals, say $g_1, \ldots g_i, \ldots$ involving components $c_1, \ldots c_i, \ldots$ are similarly achieved via joint actions and cooperation in the we-mode.

Both models refer to what is eventually a successful form of cooperation, since ultimately an artifact of type K is produced. Having G as a collective goal type means in this case that there is a shared commitment to produce an artifact of type K and that the agents involved are thus acting as a group. By saying that 'the production of an artifact of type K' is a shared goal, and referring to 'K' in this statement, we are not begging the question about collective intentionality. We are supposing that an artifact is successfully produced, that this did not come about by accident, but by design, and that a group effort was involved in this. As we saw, the Houkes and Vermaas model refers to 'an item x' in several different places. So in the main goal (and its subgoals) it is clear that the same item x is being described in each case.[21]

The Houkes and Vermaas model clearly conforms to the first part of the we-mode cooperation model since it divides the achievement of the goal into the different agents' parts and moreover there is even a sharing of subgoals. We have just seen this in the examples of the maker's and manufacturer's intentions described earlier. Another example arises in the description of design plans found in Houkes & Vermaas (2009) that we did not examine in detail. For example, in clause D1 of their design plan one finds the following condition:

> The designer d wants to contribute to a user's goal of bringing about a state g_u. (Houkes & Vermaas 2009, p. 406)

So here, g_u forms part of a use plan and is a goal shared by both agents.[22]

What is the nature of the collective intentionality surrounding the artifactual kind K? The key to understanding this is to see that it rests on shared intentions to carry out joint plans according to an agreed assignment of roles. It does not rest on the assumption that agents have mutual beliefs about K or perhaps shared mental

[21] It seems clear, then, that within the Houkes and Vermaas model we can legitimately maintain that there is a common goal G even if there are differences of opinion about K (or item x) within the team of producers. But if necessary we could replace the expression 'artifact of type K' by an expression such as 'an artifact of the type later marketed under the label 'K' ' or some equivalent formulation.

[22] Again, depending on the complexities of the example, presumably g_u could be the overall goal G or merely one of several subgoals.

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models of item x. This is a very fundamental point. Tuomela's cooperation model and the action performance submodel do not specifically refer to other attitudes like first-order beliefs about K. The mutual beliefs in the we-mode cooperation model are higher-level beliefs about group cooperation, action types etc., not lower-level beliefs about the nature of K. They refer to the fact that agents assume that other agents are acting in a cooperative manner and indeed this seems to be a clear feature of the Houkes and Vermaas model. In our case, they do not need to share (first-order) beliefs about K. This point is crucial for understanding (and obviating) Houkes and Vermaas's objections to the intentionalist view of artifacts.

The classical, textbook account of teamwork in design appears to support our picture of we-mode cooperation. Here is a typical statement, taken from David Ullman's standard text on the mechanical design process:

> Modern design problems require a design team – a small number of people with complementary skills who are committed to a common purpose, common performance goals, and a common approach for which they hold themselves mutually accountable. (Ullman 2010, p. 67)

On the other hand, when Houkes and Vermaas consider the question whether product-designers, manufacturers and makers might *collectively* determine artifact kinds, they raise a strong doubt by noting that the actors involved may disagree on certain matters:

> . . . the literature on engineering teamwork shows that conflicting conceptions and intentions among participants often survive intensive teamwork. (Houkes & Vermaas 2009, p. 417)

Indeed, we might say that without disagreements most innovation would be stymied. In a corporate climate of 'yes-men', there would be no room for innovative ideas challenging current thinking to emerge bottom-up. This would be the antithesis of the approach of corporations such as Honda Motor Company that makes use of a type of meeting, known as *waigaya*, that aims to improve any aspect of the design and manufacturing (or sales and marketing) processes through a thorough and possibly lengthy discussion among different actors. In *waigaya*, few or many employees from different departments and responsibilities meet to discuss a given issue or problem. Such meetings may be held regularly for days or even years until an agreed proposal or solution is found. In keeping with the 'flat' hierarchical structure at Honda, participants in a *waigaya* carry equal weight in their opinions. Ideas generated and results of the discussions become corporate property, and at the end of *waigaya* a set of corporate decisions and plans for enacting are generated.

According to Jeffrey Rothfeder (see Rothfeder (2014, Ch. 3)), *waigaya* proceeds according to four basic rules:

(1) Everybody is equal in *waigaya* – there are no bad ideas except those that are not aired.
(2) All ideas must be disputed and rejected until they are either proven valid or vanquished.
(3) When a person shares an idea, he or she doesn't own it anymore – it belongs to Honda and the group can do with it what it will.

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(4) At the end of *waigaya*, decisions and responsibilities are generated – a precise list of who is to do what next and by when. (Rothfeder 2014, pp. 69–70.)

What the example of *waigaya* illustrates is how from differing conceptions an agreed plan may emerge – by whatever discussion process that happened to take place – that the team then has to adhere to. It is instructive to note that ideas, once aired, are no longer 'owned' by the person who raised them. Let us now explore this idea a little further.

4. Group agency and group beliefs

I mentioned earlier that we would still need a third step on the way to justifying our collective intentionalist view of artifactual kinds. The reason is that while in Toumela's model the shared beliefs are in the form of assumptions about other agents' intentions to perform jointly, in the account of Houkes and Vermaas some first-order beliefs – about the kind K or the object x being made – do explicitly arise, e.g., at the design and make stages, and these beliefs are communicated between agents. For instance they may be beliefs about x and its properties, or about components of x, or the correctness of their make plans, and so on. Since any of these beliefs might be disputed by members of the design team or by other stakeholders at different stages of the design and production process, we need to accommodate such potential differences of opinion within our picture of we-intentionality.

Let us turn first to the idea of group agency. The notion of group agency has its roots in antiquity and has been studied by philosophers, sociologists, legal theorists and psychologists since the 19th Century. Different theories of group agency have been popular at different times. At opposing extremes there is the emergentist tradition from legal and social theory that flourished in the 19th Century versus the view of methodological individualism that gained many adherents in economics and analytical philosophy from the mid-20th Century onwards.[23] The strong emergentist tradition is usually associated with the German legal and social historian Otto von Gierke and asserts the reality of social groups and group agents as entities having a life and mind of their own (von Gierke 1950). This may be contrasted with the strongly reductionist view, popular in neoclassical economics and game theory, according to which social phenomena in general and group behaviour in particular can be fully understood in terms of individual agents. There are many intermediate views of group agency. Recently we have witnessed a strong social turn in many disciplines, from philosophy to computer science, in which group agency and group attitudes are treated as fully legitimate objects of study with explanatory power in the social sciences, but without necessarily adopting the 'animationist' view of earlier times.[24] Aside from philosophical work in the area of social ontology, there are notable contributions

[23] Here I follow the terminology from List & Pettit (2011) who also provide a discussion and comparison of the main schools of thought.

[24] Nevertheless today there is a growing body of work on different forms of extended and distributed *cognition*; see Miłkowski (2013). Among intermediate positions on group agency, List and Pettit claim to support a form of methodological individualism, but without reductionism (List & Pettit 2011). On the other hand Tuomela's position is emergentist but without animationist or supra-individualist elements (Tuomela 2013).

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from social choice theory and political science (List & Pettit 2011), from game theory and economics (Bacharach 2006; Gold & Sugden 2007; Sugden 2015), and from social psychology (Colman, Pulford, & Lawrence 2014). A strong element of these studies is the aim to understand both in theory and in practice how agents belonging to a group or team may form judgements and reason about them by putting the interests of the group above their own individual preferences.

Just as there are different types of group and group agency, so the study of group agents takes different forms. Tuomela, for example, is mainly concerned with the we-mode form of group participation. In these situations we may assume that group beliefs and intentions are reached by mutual agreement and consensus. By contrast (List & Pettit 2011) are primarily interested in groups where members' involvement is of the I-mode sort. [25] In this case group members reach opinions in their own interests, and group beliefs and intentions are supposed to be obtained via some process of judgement aggregation, based on voting or otherwise. List & Pettit (2011) discuss different types of criteria to ensure the rationality of the resulting group beliefs. Therefore, while the approaches of Bratman, Gilbert and Tuomela are mainly descriptive in kind, the focus of List & Pettit (2011) is primarily prescriptive.[26] Which kind of group agency would apply in modern corporations? That again depends on the context as well as the corporation involved. Where committee or boardroom decisions are reached by some form of voting or other aggregation procedure, different personal opinions might be expressed by members, without the need for full consensus. On the other hand, as the example of *waigaya* illustrates there are clearly forms of teamwork present even in large corporations where consensus and group decisions emerge not by some aggregation of individual views but by painstaking discussion and debate.

A key point to grasp is that even on these differing accounts of group beliefs, in both cases it is a well established view that such beliefs are not necessarily held individually by every member of a given collective, or even by a majority of members.[27] In the Houkes and Vermaas model we need not assume that the beliefs and conceptions communicated between the relevant agents are shared by all actors individually. They can be either individual beliefs that are communicated between actors or (in the important cases) *group* beliefs when they are taken up by a team as a whole. In Tuomela's own approach, for example, group beliefs are understood to involve an intentional joint acceptance and commitment on the part of certain group members, but they need not be mutually held by all of the agents in the group. And this is very likely to be the case within a corporation and its operative teams.[28]

Therefore, in the case where the plans for cooperating and achieving the goal type rely necessarily on specific beliefs (about the nature of an artifactual kind K) i.e., on conceptions of K, it is sufficient if these are group beliefs, the important

[25] To apply Tuomela's terminology. Tuomela nowadays also uses the concept of *pro-group I-mode* which would be appropriate here.

[26] We may note however that Bratman and Gilbert in particular do discuss norms and commitments associated with shared intentions. Given the differences mentioned, group agency in the sense of Bratman and Tuomela applies well to many forms of team work and collaboration, while the ideas developed in List & Pettit (2011) apply more especially to groups where certain kinds of decision-making are involved, such as in committees, or cases where different expert opinions need to be averaged.

[27] Unlike in the case of *common* and *shared* beliefs.

[28] For Tuomela's account see for instance Tuomela (1992) and Tuomela (2007). For a recent discussion of different approaches to group belief and a formal analysis of this notion, see Gaudou *et al.* (2015).

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feature being that they are not necessarily held by each agent individually (though they may be communicated and acted upon). Another point to observe is that not all agents involved in a production process need be cooperating in the we-mode. While in modern forms of production, technicians and assembly-line workers are usually highly 'integrated' into the production process and aware of their role in the manufacturing the final product, we can allow for the case of an assembly-line worker who acts only in the I-mode in Tuomela's sense. We can leave room for this while holding that those agents who are essentially responsible for the final outcome are cooperating in the we-mode.

As quoted earlier, Houkes and Vermaas suggest that conflicting conceptions and even intentions among participants 'often survive intensive teamwork.' If true, we would have to analyse whether these are disagreements at an individual level that need not affect group judgements and policies or whether they are so far-reaching as to threaten the integrity of group decisions and actions. What we can observe here is that the engineering model we have been discussing presupposes that an artifact is successfully produced.[29] And this suggests that at the group level of cooperation and action the we-mode form is stronger. In particular, the I-mode form of cooperation does not seem to explain how a new artifact type could successfully be produced. In the I-mode, while cooperation between agents is possible, typically joint goals, collective actions and group attitudes are missing. This scarcely seems adequate to explain how the outcomes of modern design and production processes can be so effective.

It might seem at first counterintuitive to claim that the nature of an artifactual kind K depends on a form of collective intentionality, while the actors involved may hold differing *conceptions* of K. This might indeed appear strange if one is thinking that the 'essence' of K is collectively determined by some mutual idea, a shared mental model or perhaps an agreed list of technical functions and defining properties. But this is not the case under the multiagent, action-theoretic model of artifact creation. In this model the 'nature' of K depends on the plans that the agents enact under (I claim) a we-intentional form of cooperation. Those beliefs that support different phases of artifact creation, inasmuch as they are beliefs about the nature of K, should be regarded as group beliefs to which core members of the team are committed *as a group* in order to pursue the overarching goal. If this is correct, then production of an artifact in the manner envisaged by Houkes and Vermaas can illustrate an elaborate form of cooperation in the we-mode, with common goals and group commitments, and therefore exhibit exemplary features of collective intentionality. If those essentially involved in the design and production process act as a team, then their group commitments, attitudes and goals are what help to ensure the successful outcome. Moreover, the notion of we-mode and the appeal to collective intentionality and group attitudes helps to explain how a coherent artifactual type K may be successfully established even if different beliefs and conceptions about K are held by individual team members.

5. Users

In moving from individual to collective intentionality up to now we have focused more on the roles of the professional actors (designers, engineers, manufacturers, . . .). However end users are also very much present in the model proposed

[29] And if it is a new artifactual kind presumably that it is successfully introduced to market.

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by Houkes and Vermaas. As we saw, use plans are a central feature of this model. Houkes & Vermaas (2004) make it clear that these are not only created by designers, but also by ordinary end users. They distinguish between standard use that accords with a traditional or designed plan, and non-standard use that follows a different plan, devised by the user or by other users. In the latter case the actors involved may be redesigners or innovative users who have produced new plans for a pre-existing artifact.

Contemporary approaches to design and technical innovation tend to lay a greater emphasis on the consumer and end user. This is evident in the paradigm of *human-centred* design that has now become well established. Among the key principles of human-centred design (as defined in an ISO (2010) standard document) is the involvement of users throughout design and development, that the evaluation of design is user-centred, that this is an iterative process and there is consideration of the whole user experience. This leads naturally to the idea of the consumer as co-designer. Some recent economic studies of innovation have drawn attention to the concept of the consumer-innovator and the considerable extent to which this is already featuring in developed economies (von Hippel 2005; von Hippel, Ogawa & de Jong 2011). In this case, it is not merely that the consumer forms part of design evaluation, it is that the (non-professional) consumer is actually inventing and designing new items some of which are taken up as new commercial products. Von Hippel emphasises not only the large number of user-innovators but also the increasing availability of tools, platforms and support for co-design and development. A classical example is the open software movement, but there are also many other examples, from manufacturing as well as from service industries.[30]

Some writers go as far to suggest that co-design, and what is coming to be known as *co-creation*, are radically changing the role of the designer and form part of a general transition towards a non-consumerist society. Sanders & Stappers (2008) develop this view at length and suggest that it is bringing about a change in focus from the designing of *products* to the designing for *purposes* such as for emotion, experiencing, sustainability, and so forth. On their account, while there is a (changing) role for the professional designer, the traditional distinctions between designer, research and consumer need to be reconfigured.

Whatever view one takes of the design process, it seems clear that the nature of an artifactual kind is to some degree co-determined by its end uses and thus by its end users. This much is now conceded by Amie Thomasson. Having previously insisted on individual intentions as kind-determining, she has recently stated.

> I have begun to think [. . .] that there is an important and revealing sense in which members of public artifact kinds *do* depend on intentional states beyond those of their makers. The need for individual intentions alone does not seem to fully capture what it is to be a member of one of our standard,

[30] Another good example is provided by the phenomenon of Apps, launched by Apple Inc. in 2008. Here is a paradigmatic case where users and consumers can invent and even develop and sell new artifacts precisely due to the fact that a large corporation has provided the technical and commercial framework (devices, operating systems, contractual schemes) to support this. Moreover, in this way the corporation in turn lets innovative users drive the technological development of the products (devices, software) that support these artifacts by showing what new kinds of functionalities the original devices may have now and in the future.

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> extant artifact kinds: what it is to be a table, a teapot, or a salad fork. (Thomasson 2014, p. 55)[31]

Thomasson's approach is now to analyse this collective feature of kind determination in terms of public norms, in general they are norms of use to which the artifact is intended to be subject. Though less specific, these norms are reminiscent of the formative intentional actions discussed by Schyfter that we met in the introduction.

With some adjustments in detail I think the model of Houkes and Vermaas can account for aspects of human-centred design and even co-design, where engineering and manufacturing are involved. If so, we may think of end users as part of the design and production process and therefore as part of the group or collective view of the artifactual kind. This represents a very broad (though not all-encompassing) version of collective intentionality.

6. Group attitudes and innovation

Another kind of viewpoint emerges when the dynamics of artifact creation is taken fully into account, as for instance in theories of innovation. While the perspective of the philosophy of design and engineering that we have been considering treats actions, processes and multiple agents, it does not aim to cover all aspects of novelty and innovation. The starting points of the Houkes and Vermaas model are a use plan and a designer's goal to contribute to producing a certain item that in a sense conforms to the use plan. In other words, on this model, even if the item in question is an instance of a new artifactual kind, there is already present a basic concept of what should be produced and what its functionalities should be. Agents involved in the production process come to agree on, or at least act in agreement with, joint plans to achieve common goals. It is obvious that this model does not aim to explain what goes on before use plans and designer goals are fully formed; in other words what actions, beliefs, decisions or processes lead up to the initial design intention.

We have seen that makers' intentions, even in a collective sense, do not fully determine an artifactual kind; there is usually a degree of uncertainty and underdetermination. The economist David Lane refers to this feature as ontological uncertainty and identifies it as a key element in a theory of innovation.[32] For Lane, uncertainty is a broad concept. It includes on the one hand semantic uncertainty about attributions of functionalities to artifacts: a key feature of innovation consists in attributing new functionalities to existing objects or kinds. On the other hand, it also includes (and this is a main component in the ontological case) uncertainties that actors face in their conceptions of the world, in their interactions with other actors and in the manner in which modes of interaction may change in the future. In short, what Lane describes is a complex system with many interacting components whose behaviour cannot be predicted in a deterministic fashion.

According to Lane & Maxfield (2005), a theory of innovation cannot deliver a predictive theory of technological change; but it can provide a conceptual framework in which episodes of innovation and technical change can be analysed

[31] A 'public' artifact for Thomasson (2014) is any member of 'familiar, recognized, public artifactual kinds: things like forks, computers, cars, statues, clothes, and the like.' (p. 46)
[32] See Lane (2010) and especially Lane & Maxfield (2005).

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and understood. This conceptual framework or general ontology includes a number of distinctive features and technical terms. Like many approaches to complex systems, it is based on an organisational view and an analysis of organisational structures, in this case structures such as the so-called agent–artifact space, the generative relationships between agents, as well as commercial markets. A prominent concept in Lane and Maxfield's model is that of narrative and narrative structure. The idea is that agents' actions are embedded in a narrative structure that they themselves use to interpret and explain their own and other agents' actions and to give coherence to their concepts. Understanding episodes of innovation and technical change thus involves understanding the relevant narrative structures and communities of actors as well as unravelling the narratives or stories of the leading protagonists. Naturally, this process itself involves piecing together a story.

Complexity and innovation are also explored in Lane (2010) where, in particular, a dynamic of positive feedback is described. This applies to innovations where there are attributions of new functionalities to artifacts. A key element in this process is that relevant organisational structures are also transformed. The general pattern is described in this way:

(1) New artifact types are designed to achieve some particular attribution of functionality.
(2) Organisational transformations are constructed to proliferate the use of tokens of the new type.
(3) Novel patterns of human interaction emerge around these artifacts in use.
(4) New attributions of functionality are generated – by participants or observers – to describe what the participants in these interactions are obtaining or might obtain from them.
(5) New artifacts are conceived and designed to instantiate the new attributed functionality. (Lane 2010[33].)

At first sight this is a very different picture of artifact creation from the action-theoretic account of cooperating agents provided by Houkes and Vermaas. Where the latter describes joint plans and agreed goals, Lane and his co-authors describe a complex, dynamical system with competing actors, conflicting views and goals, and uncertain outcomes. Innovation in creating or changing artifacts involves changes to the generative relations between agents, and new patterns of interaction are formed in the organisational structures. It is interesting to note that Lane's approach is not tied to modern engineering or high-technology sectors; it also takes into account episodes that are closer to the artisan model of artifact creation. For example, while Lane & Maxfield (2005) provides a case study from modern developments in distributed control technology for buildings, in Lane (2010) the development of printing from the 15th Century is examined.

Nonetheless, there are several features that the two accounts share that are important from my point of view. One is the idea that meaning is determined by use, and in Lane and Maxfield's case it is clear that new functionalities emerge through use and lead to further innovations. Another is the emphasis

[33] Lane calls this process 1–5 exaptive bootstrapping. 'Exaptation' conveys the idea that an artifactual kind may embrace new functionalities and patterns of use. This term is now often used by writers on artifacts. 'Bootstrapping' refers to the fact that phase 5 finishes where 1 begins.

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on actions and processes, the actors involved in them and their interactions. Where the two models differ is their focus on different stages in artifact creation and production. In Lane's pattern of exaptive bootstrapping cited above, we can see that Houkes and Vermaas's model can be applied at stages 1 and 5, while the main thrust of Lane's account is directed at the disruptive stages 2–4. A positive feature of the account is that innovation does not proceed along a preset path or a technological trajectory, there are no technological guideposts or paradigms. Can we also reconcile this feature with the collective intentionality account of artifacts described earlier? As we have seen, making a theory of artifacts and function ascriptions action-theoretic does not prevent it from embracing collective intentionality. The Lane and Maxfield account considers varied forms of agent interaction and cooperation, and also conflicts. Some of the cooperative features may count as being of the we-mode variety, some perhaps as I-mode; while shared narrative structures may suggest weaker forms of agreement between actors. My suggestion is that the model of Houkes and Vermaas can be seen as a way to understand what collective intentionality consists in and how it brings about the creation of an artifact or artifactual kinds. On the other hand, the approach of Lane and Maxfield aims to understand how new agreements come about and collective intentionality may be reconfigured as a result of social and other changes to the system. Each of these aspects plays an important role in a theory of artifacts.

7. Group agency and design

I have argued that we-intentionality is compatible with the multiagent, action-theoretic model of artifact creation and that we should add this feature to the Houkes and Vermaas account. How does this bear on practical aspects of the design process? A number of questions comes to mind. For example, one might ask whether we-mode intentionality may come in degrees. Whether full we-intentionality is always desirable or whether there are cases where it should be avoided. Is it a feature that can be controlled by organisations? In view of Houkes and Vermaas's concern about lingering differences surviving teamwork, we may also inquire as to what kinds of conflicts and disagreements may arise in practice and to what extent they are compatible with we-intentionality. To fully answer such questions, we would need to enter into specific domains of artifact design and production. Here, I make only some general remarks.

First, on Tuomela's account, the we-mode and I-mode are mutually exclusive forms. Apart from borderline cases, agents are either cooperating in the stronger we-mode, or they are not. However, for larger groups, there is evidently a trivial sense in which they could exhibit degrees of we-intentionality depending on whether a greater or lesser proportion of their members are acting in the we-mode. In Tuomela's case, it seems we would only attribute group agency to collectives where the form of cooperation is predominantly we-mode, while for group agency in the sense of List and Pettit an I-mode form of participation would suffice. In this latter sense, it is rather obvious that the type and structure of group agents can be designed and controlled, as List & Pettit (2011) explore in depth. But what about we-intentionality, are there also ways and occasions in which it can be promoted and controlled? To deal with this issue, let us return to David Lane's account and also to the case of Honda Motor Co. that we discussed earlier.

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7.1. Conditions for intentionality?

In the model presented by Houkes and Vermaas, we do not ask how the various forms of communication and cooperation between agents come about; they are simply present and largely taken for granted. To look further into their origins we should step outside this model and look closer at the transition stages leading up to the creation of new artifacts. To this end, let us reconsider David Lane's analysis of innovation that complements the Houkes and Vermaas account. It is worth remarking that this approach to understanding innovation not only aims at describing episodes of change, but it also offers a framework for promoting and controlling innovation; one that has been tried and tested in large-scale, collaborative projects.[34]

At first sight, Lane's approach might not seem to mesh well with the idea of we-intentionality as we have portrayed it so far. Indeed, since parts of this transition phase are clearly disruptive, it breaks with we-intentionality in some respects. However, if we look closer into the ingredients that according to Lane and Maxfield are essential to promote generativeness and hence innovation, we can find several types of conditions that could and should also foster collectivity (Lane & Maxfield 2005).

A first suggestion is that the activities of agents should have a common orientation in the agent–artifact space. This may, for instance, mean that different actors are focusing their attention on the same kind of artifact, though possibly from different viewpoints. Lane and Maxfield call this notion *aligned directedness*. A related idea is called *mutual directedness* and refers to agents' abilities to seek each other out and create new relationships through recurring interactions; it is acknowledged that trust could play a key role in this. Third, an environment needs to be created in which there is freedom to communicate, whether among equals or between subordinates and superiors in a hierarchical structure; this is termed *appropriate permissions*. Fourth, there is the idea of *action opportunities*. This refers to the ability to undertake joint actions among agents that may reveal and foster new competences. All of these attributes could be regarded not only as preconditions for generative relations leading to innovation but also as beneficial for establishing and maintaining cooperation in the we-mode at the moment when innovation is taking place and new artifacts are being conceived. There is a fifth precondition in Lane & Maxfield (2005): *heterogeneity*. This refers to the agents concerned displaying different skills and expertise, or having access to different artifacts, and being willing to try to bridge gaps and combine different competences. It is not a necessary condition for we-intentionality but it may be an important ingredient in successful teamwork.

What we can observe from accounts like those of Lane and Maxfield is that there are transition phases where established relations and cooperations are broken and new generative relations are forged. However, the conditions that foster and promote these transitions are also conditions that help to cement new cooperations and new group alignments.

In his account of attitudes at Honda, Jeffrey Rothfeder emphasises that there is a corporate culture praising individualism and nonconformism. It is also made

[34] For example, Lane's approach to innovation dynamics features prominently in the project INSITE (Innovation, Sustainability, Technology) http://www.insiteproject.org/ (European Commission FP7 project 271574) and especially in MD (Emergence by Design, see http://www.emergencebydesign.org) that focused on how to design for innovation and sustainability in social contexts.

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clear that teams working in a *waigaya* are typically heterogeneous, involving professionals from diverse backgrounds. But note that while *waigaya* encourages a plurality of individual ideas at the lower level, and thinking out of the box, etc., the process is designed to ferment the we-mode participation at the higher level: ideas and solutions belong to the group, there is a strong commitment to the shared ethos, an action plan is agreed as a group, and so on. Rothfeder also stresses that Honda's approach is not 'design by committee' and that *waigaya* does not achieve consensus by compromise.

Once again let us repeat that we-intentionality does not mean collectivity at all levels.

> It seems so rational and fundamental that groups of peers working together toward a common goal should be encouraged, as most large and small businesses do. But Honda views collaboration from the vantage point of the individual, not the team . . . . Honda's belief is that the organizational structure must serve to maximize the aptitude and skills of each individual; in turn, the team, the organization, will benefit. (Rothfeder 2014, p. 133)

In my view, the example of Honda shows how 'higher-level' collectivity (group agency and we-mode intentionality) is compatible with individual attitudes at the lower level, where nonconformism is rewarded. Moreover, concepts like I-mode and we-mode attitudes from social ontology help to explain how collectivity and individualism can co-exist and support innovation in design and production.[35]

7.2. Meaning and use

Let us return to our earlier question about conflicts in design teams. What kinds of conflicts need to be resolved and which ones are likely to be unproblematic? I think the general answer lies in the Houkes and Vermaas model together with those concepts from social ontology that we have introduced. The model describes the stable part of the design and make processes and anchors the nature of artifacts and hence the meaning of artifactual kinds in terms of *use*. There are plans for end use but also plans for intermediate steps in production. When conflicts are so strong that they break the we-mode attitude of individuals, the collective may no longer function as a group agent. So there will not be a group commitment to adhere to agreed plans, goals etc. Thus, if we are thinking of the Houkes and Vermaas model, then what is at stake is the integrity of the design, use and make plans. Note, however, that we would not say in practice that very small changes in a design or use plan always constitute a change of artifact. And in practical terms there may be different manufacturing processes that lead to essentially the same artifact. Moreover, as has been pointed out, the kind is underdetermined by its use plan, since new uses may be found and even encouraged in practice. So this means that very similar artifacts might be associated with (moderately) different plans. And some of these, especially use plans, but possibly others, may evolve and change over time.

[35] At first sight, this quotation might seem to contradict the idea of we-intentionality. But in my view what Rothfeder is criticising here is the kind of teamwork based on blind conformism where there is no scope for individual challenges to current thinking. From his account it is clear that once design and engineering decisions are taken in a *waigaya* the team ethos of cooperation to pursue the agreed objectives holds sway at Honda.

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Many artifactual kinds like chairs and coffee cups are described by ordinary words in the language whose meaning is grasped by any competent speaker of the language. In such cases, there are no alternative and partly conflicting 'technical meanings'. But technical terms, like 'common-rail diesel engine', can be familiar to many language users without their having a complete grasp of their meaning. Automotive engineers who have the requisite knowledge will normally agree on the criteria needed to identify this type of engine and be able to recognise one when presented with a putative example. If not, we should conclude that they understand the term in different ways.

This bears on our discussion of possible differences of opinion about the nature of a new artifactual kind that is being developed. If two agents involved in the process of producing a new artifact have irrevocably different conceptions about the new artifactual kind K, then this difference should manifest itself in meaning and language use. For example, they may not both acquiesce in calling the new item a K and there would not be collective agreement over the use of this term. Alternatively, they may both agree to use the term 'K' while disagreeing on some of its essential characteristics. Since, as Thomasson remarks, the intentionality of the term may leave room for error and ignorance, it may also leave room for different ways in which the concept may be developed and further determined in the future. The characteristics for which the two agents disagree may simply correspond to two different innovations and development paths for K. In this case, we might say that the commonalities they currently share form part of the collective intentionality that determines K at the current moment in time, while the disagreements involve an understanding of K that may manifest itself in future choices about use. If divergences of views are sufficiently strong, and other suitable conditions for innovation are met, we might have an example of an exaptive process leading to a new or highly modified artifact kind.

8. Conclusions

> Underlying these two singular characteristics of human culture – cumulative artifacts and social institutions – are a set of species-unique skills and motivations for cooperation. (Tomasello 2009)

Today, sociality and the forms of human cooperation are highly visible topics of study in many disciplines. Prominent among them are developmental psychology, evolutionary anthropology and neuroscience. Philosophers of engineering and design have proposed action-theoretic models of artifact creation and production where planning and cooperation form pivotal concepts. Models of this kind provide a valuable theoretical framework for the design sciences, especially for the analysis of technology and its development. I have tried to show how one such model in particular, that of Houkes & Vermaas (2009), can benefit from the addition of group notions of agency, belief and collective intentionality that are currently being studied in social ontology. I hope to have shown that this addition goes some way to answer a hidden challenge raised by a prominent defender of the intentionalist view of artifactual kinds in Thomasson (2014), namely to explain adequately how collective artifacts can be understood to depend on collective intentionality.[36]

[36] I realise that this may not be a complete answer to Thomasson, as she would probably wish to see a greater emphasis on the societal recognition of norms (Thomasson 2014).

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We have also seen that the engineering model focuses more on processes that underlie the postconceptualisation phase of artifact creation and less on the disruptive stages that lead up to innovation. The narrative model of Lane & Maxfield (2005) is one approach that addresses the preconceptualisation stage within an organisational setting. Even when focusing on the disruptive stages, this approach emphasises a number of preconditions for successful innovation that should lead to strong forms of cooperation in the future. So we may look upon such conditions as mutual and aligned directedness, permissions and action opportunities as potential fertilisers for collective intentionality.

Reflecting on teamwork in design from the standpoint of group agency and we-intentionality, we can summarise its main features in the following way:

(1) Considered as a group agent the team is a functional social action system with the power to act (Tuomela 2013).
(2) As a group agent the team has derived intentionality.[37]
(3) Viewed in the we-mode sense, the intentional properties of the group or team are emergent with respect to the properties of its members individually.
(4) Viewed in the we-mode, the team shares group agreed plans, goals and intentions.
(5) Personal opinions and beliefs may differ among members; however, group beliefs, goals and plans are communicated among members and transmitted to other actors.

As an explanatory tool for the design sciences, the concepts of group agency and group attitudes may be useful to understand different types of cooperation and group behaviour. As one example, we have seen how, with the help of these concepts, one may grasp how individualism and even nonconformism at a personal level of beliefs can be compatible with a strong, we-mode form of collectivity at a group or team level.

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[37] 'Derived' because we do not need to suppose that the group has mental states. For a discussion of group agents and group minds, see Tuomela (2013).

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References

Bacharach, M. 2006 *Beyond Individual Choice: Teams and Frames in Game Theory* **(ed. N. Gold & R. Sugden)**. Princeton University Press.

Bijker, W. E., **Hughes, T. P.** & **Pinch, T. J.** (Eds) 1987 *The Social Construction of Technological Systems*. MIT Press.

Bratman, M. 1999 *Faces of Intention: Selected Essays on Intention and Agency*. Cambridge University Press.

Bratman, M. 2014 *Shared Agency. A Planning Theory of Acting Together*. Oxford University Press.

Brentano, F. 1874 *Psychologie vom empirischen Standpunkt*. Duncker & Humblot.

Collins, H. & **Kusch, M.** 1998 *The Shape of Actions*. MIT Press.

Colman, A., **Pulford, B.** & **Lawrence, C.** 2014 Explaining strategic coordination: cognitive hierarchy theory, strong Stackelberg reasoning, and team reasoning. *Decision* **1** (1), 35–58.

Franssen, M., **Kroes, P.**, **Reydon, T. A. C.** & **Vermaas, P. E.** (Eds) 2014 *Artefact Kinds. Ontology and the Human-Made World*, Synthese Library, vol. 365. Springer.

Gaudou, B., **Herzig, A.**, **Longin, D.** & **Lorini, E.** 2015 On modal logics of group belief. *The Cognitive Foundations of Group Attitudes and Social Interaction* **(ed. Herzig & Lorini)**, Springer.

von Gierke, O. 1950 Natural Law and the Theory of Society 1500–1800, Engl. trans. by Ernest Barker, CUP.

Gilbert, M. 1989 *On Social Facts*. Princeton University Press.

Gilbert, M. 2013 *Joint Commitment*. Oxford University Press.

Gold, N. & **Sugden, R.** 2007 Collective Intentions and Team Agency. *Journal of Philosophy* **104**, 109–137.

Hansson, S. O. 2006 Defining technical function. *Studies in History and Philosophy of Science* **37**, 19–22.

Hilpinen, R. 1993 Authors and Artifacts. *Proc. Aristotelian Soc. New Series* **93**, 155–178.

Hilpinen, R. 2011 'Artifact', The Stanford Encyclopedia of Philosophy (Winter 2011 Edition) (**ed. E. N. Zalta**), URL: http://plato.stanford.edu/archives/win2011/entries/artifact/.

von Hippel, E. 2005 *Democtratizing Innovation*. MIT Press.

von Hippel, E., **Ogawa, S.** & **de Jong, J.** 2011 The age of the consumer-innovator. *MIT Sloan Management Review* **53** (1), 27–35.

Houkes, W. & **Vermaas, P.** 2004 Actions versus functions: a Plea for an alternative metaphysics of artefacts. *The Monist* **87**, 52–71.

Houkes, W. & **Vermaas, P.** 2009 Contemporary engineering and the metaphysics of artefacts: beyond the artisan model. *The Monist* **92**, 403–419.

Houkes, W., **Vermaas, P.**, **Dorst, K.** & **de Vries, M.** 2002 Design and use as plans: an action-theoretical account. *Design Studies* **23** (3), 303–320.

Ingarden, R. 1961 *Untersuchungen zur Ontologie der Kunst*. Max Niemeyer Verlag.

https://doi.org/10.1017/dsj.2016.3 Published online by Cambridge University Press

International Organization for Standardization, 2010 ISO 9241-210: Ergonomics of human-centred System Interaction - part 210: human-centred Design for interactive Systems, International Organization for Standardization.

Kroes, P. 2010*a* Theories of technical functions: function ascriptions versus function assignments, Part 1. *Design Issues* **26** (3), 85–93.

Kroes, P. 2010*b* Theories of technical functions: function ascriptions versus function assignments, Part 2. *Design Issues* **26** (4), 62–69.

Lane, D. 2010 Complexity and Innovation Dynamics, INSITE Project Papers, http://www.insiteproject.org/paper/complexity-and-innovation-dynamics/.

Lane, D. & **Maxfield, R.** 2005 Ontological uncertainty and innovation. *Journal of Evolutionary Economics* **15**, 3–50.

List, C. & **Pettit, P.** 2011 *Group Agency. The Possibility, Design and Status of Corporate Agents*. Oxford University Press.

Margolis, E. & **Laurence, S.** (Eds) 2007 *Creations of the Mind. Theories of Artifacts and their Representation*. Oxford University Press.

McLaughlin, P. 2001 *What Functions Explain: Functional Explanation and Self-Reproducing Systems*. Cambridge University Press.

Millikan, R. 1999 Wings, spoons, pills and quills: a pluralist theory of function. *The Journal of Philosophy* **96** (4), 191–206.

Miłkowski, M. (Ed.) 2013 Relevance of wide cognition for social intelligence. Key trends. Whitepaper available at http://www.sintelnet.eu.

Kroes, P. & **Meijers, A.** 2002 The Dual Nature of Technical Artifacts - presentation of a new research programme, *Techné: Research in Philosophy and Technology* 6, http://scholar.lib.vt.edu/ejournals/SPT/v6n2/kroes.html.

Pinch, T. J. & **Bijker, W. E.** 1987 The social construction of facts and artifacts: or how the sociology of science and the sociology of technology might benefit each other (**ed. Bijker *et al.***), pp. 17–50.

Rothfeder, J. 2014 *Driving Honda. Inside the World's Most Innovative Car Company*. Portfolio Penguin.

Sanders, E. B.-N. & **Stappers, P. J.** 2008 Co-creation and the new landscapes of design. *CoDesign* **4**, 5–18.

Schyfter, C. P. 2009 The bootstrapped artifact. A collectivist account of technological ontology, functions and normativity. *Studies in History and Philosophy of Science Part A* **40**, 102–111.

Searle, J. 1995 *The Construction of Social Reality*. Allen Lane, The Penguin Press.

Searle, J. 2010 *Making the Social World. The Structure of Human Civilization*. Oxford University Press.

Sellars, W. 1968 *Science and Metaphysics*. Routledge and Kegan Paul.

Smith, T. H. 2015 Shared agency on Gilbert and deep continuity. *Journal of Social Ontology* **1**, 49–57.

Sugden, R. 2015 Team reasoning and intentional cooperation for mutual benefit. *Journal of Social Ontology* **1**, 143–166.

Thomasson, A. 2003 Realism and human kinds. *Philosophy and Phenomenological Research* **67**, 580–609.

Thomasson, A. 2007 Artifacts and human concepts. In *Creations of the Mind. Theories of Artifacts and their Representation* **(ed. E. Margolis & S. Laurence)**, pp. 52–73. Oxford University Press.

https://doi.org/10.1017/dsj.2016.3 Published online by Cambridge University Press

Thomasson, A. 2014 Public artifacts, intentions, and norms. In *Artefact Kinds: Ontology and the Human-Made World* **(ed. M. Franssen, P. Kroes, T. A. C. Reydon & P. E. Vermaas)**, Synthese Library, vol. 365, pp. 45–62. Springer.

Tomasello, M. 2009 *Why We Cooperate*. MIT Press.

Tuomela, R. A. 1984 *A Theory of Social Action*, Synthese Library, vol. 171. Springer.

Tuomela, R. 1992 Group beliefs. *Synthese* **91**, 285–318.

Tuomela, R. 2007 *The Philosophy of Sociality*. Oxford University Press.

Tuomela, R. 2013 *Social Ontology. Collective Intentionality and Group Agents*. Oxford University Press.

Tuomela, R. & **Miller, K.** 1985 We-intentions and social action. *Analyse & Kritik* **7**, 26–43.

Ullman, D. G. 2010 *The Mechanical Design Process*, 4th edn. McGraw–Hill.

Vega-Encabo, J. & **Lawler, D.** 2014 Creating artifactual kinds. In *Artefact Kinds: Ontology and the Human-Made World* **(ed. M. Franssen, P. Kroes, T. A. C. Reydon & P. E. Vermaas)**, Synthese Library, vol. 365, pp. 105–124. Springer.

Vermaas, P. & **Houkes, W.** 2006 Technical functions: a drawbridge between the intentional and structural natures of technical artefacts. *Studies in History and Philosophy of Science* **37**, 5–18.

https://doi.org/10.1017/dsj.2016.3 Published online by Cambridge University Press