Material Practices of Coordination and Innovation in the Design and Development of Computer Games

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Abstract: Taking as its starting point the growing interest in organizational studies regarding the role of objects and the material (Engestrom and Blackler 2005), this article investigates the role of objects and artefacts in the coordination involved in the development of computer games. The article draws on a comparative study of three leading UK computer games design and development studios the aim of which was to capture an in-depth understanding of the way in which the developers studied create, leverage, and alter shared objects in this work and describe the interactions of the developers both with these objects and with one another in their work. Rather than seeing formal and emergent coordination as antithetical, the article explores the link between formal and emergent types of coordination encountered in the development of computer games to show the important role objects and artefacts play in making this dynamic dialogical relationship work. Furthermore, the article explores, through this link between formal and emergent coordination, how many difficult to represent experiential and aesthetic features of the games are rendered explicit and captured in order to become addressable through the existing formal coordination practices of the studios and how contingencies and previously under-determined elements of the games under development are dealt with.

Introduction

Objects and artefacts are seen in a range of literatures as playing a crucial role in the bringing together of different kinds of human expertise and embodied skills in collaborative work (Gerson and Star 1986; Henderson 1991; Fujimura 1992; Bowker and Star 1999; Carlile 2002; Bechky 2003; Carlile 2004; Bruni 2005; Engestrom and Blackler 2005; Levina 2005; Levina and Vaast 2005; Miettinen and Virkkunen 2005; Suchman 2005; Ewenstein and Whyte 2007; Luck 2007; Nicolini, Mengis et al. 2008; Ewenstein and Whyte 2009). A physical prototype might help a designer communicate an issue to a production engineer and at the same time help the engineer understand the implications for production of that design in order to respond accordingly (Carlile 2002; Bechky 2003). There are also studies that examine the roles design drawings, engineering sketches, methodologies, formal description models, prototypes, and scenarios (Henderson 1991; Bodker 1998; Bechky 1999).

Within organizational studies there is a growing interest in the role of objects and the material, with both the reasons for this interest and the issues it raises summed-up well by Engestrom (Engestrom and Blackler 2005), who points out that objects are not “just given”; but constructed by actors “as they make sense, name, stabilize, represent and enact foci for their actions and activities”. At the same time, this is not arbitrary, because “objects have histories and built-in affordances, they resist and ‘bite back’ ” (Engestrom and Blackler 2005). Because work organizations are key sites where such constructions and resistances play out and are “built and maintained around partially shared, partially fragmented and partially disputed objects”, for Engestrom it is vital that organizational researchers “study the practices by which the objects of work are constructed and to reflect upon associated consequences” (Engestrom and Blackler 2005).

At the same time, the role of objects in organising and organisations is seen as complex, ambiguous, and often problematic. Engeström points out “the ambiguous nature of objects, the difficulty of defining them and, inevitably, problems associated with their study, recur repeatedly” (Engestrom and Blackler 2005). For this reason “a framework is urgently needed to help researchers identify the specific actions through which an object is made to take shape” (Engestrom and Blackler 2005). At the same time “little is to be found about this issue in organization studies” in terms of “how the transformation of objects can be represented and analysed” (Engestrom and Blackler 2005). For this reason, it is important for Engestrom that research attention is directed towards developing a better understanding of how it is that “objects become recognized as objects, enter, then move through the processes of production and consumption” (Engestrom and Blackler 2005).

Focusing on the material practices of computer games development and the interactions among people and between people and things involved in those practices, the article seeks to contribute insights to the issues regarding the role of objects in organising and organisations raised by Engeström, highlighting in particular processes of coordination and cooperation found in this setting, especially the material aspects of those practices and the objects and artefacts implicated in them. It also describes the crucial role objects play in the coordination and organisation of collaboration in

settings in which outcomes are accomplished through the coming together of multiple interdependent, but at the same time diverse, groups of practitioners with often very different types of skills and expertise, as is the case in situations requiring creativity and continuous innovation that involve collaboration, both within and across organizations and without always having recourse to formal organisational arrangements.

The article takes advantage of the research setting studied to address issues of coordination in the context of creativity and innovation and discuss the importance of coordinational arrangements that ebb and flow within organizations as a games development project unfolds. Through this examination the article aims to contribute to the debate regarding the relevance of the literature on cooperation across boundaries through the construction of common knowledge and the use of boundary-spanning mechanisms to organisational settings characterised by "non-hierarchical and shifting contexts, where criteria of worth are contested, and where areas of jurisdiction are blurred" (Kellogg, Orlikowski et al. 2006)[1].

Literature Review

The issue of coordination, the mechanisms and practices through which coordination is pursued, and how interdependent tasks and resources can be ordered so that collective work is accomplished have long been central preoccupations of both organisations and organisation studies (Okhuysen and Bechky 2009).

Objects and artefacts have been at the centre of studies of coordination from studies going back to the use of timetables and standard time in the railways (Stover 1970; Daniels 2000). Schedules, that make possible the positioning of activities in a particular temporal order, have been of particular interest (Yakura 2002; Ballard and Seibold 2003), but much of the literature relating to the importance of objects in collaboration and coordination in or across organisations has drawn on the concept of boundary objects put forward by Star and Griesemer (Star and Griesemer 1989) in relation to artefacts that exhibit a capacity to help different collaborating groups share representations with each other (Gerson and Star 1986; Henderson 1991; Bowker and Star 1999; Carlile 2002; Carlile 2004; Levina 2005; Levina and Vaast 2005).

Star and Griesemer's starting point for developing the concept of boundary objects is that for the success of collaborative work, cooperation and coordination need to be achieved across domains, and shared meanings and understandings established. For this to take place, information needs to "retain its integrity across time, space, and local contingencies" (Star and Griesemer 1989). According to Star and Griesemer boundary objects "both inhabit several intersecting social worlds ... and satisfy the informational requirements of each of them" (Star and Griesemer 1989). They are "both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (Star and Griesemer 1989). In this way, coordination is accomplished through the establishment of shared meanings through the flow of information across different social worlds with different representational systems and practices.

[1] See also Sapsed, J. and A. Salter (2004). "Postcards from the Edge: Local Communities, Global Programs and Boundary Objects." Organization Studies **25**(9): 1515-1534.

Objects and artefacts are also central to coordination and collaboration in studies that come from the field of distributed cognition that seeks to understand the organization of cognitive systems and the cognitive processes involved in memory, decision making, inference, reasoning, and learning by looking at "a broader class of cognitive events" without expecting all such events "to be encompassed by the skin or skull of an individual" (Hutchins 2000). While not specifically about coordination, key studies of distributed cognition, such as that of Hutchins on ship navigation (Hutchins 1995), provide many useful insights regarding how the coordination involved in navigating a ship into port is a joint achievement, not only between people, but also between people and things.

The importance of objects and artefacts as organising devices has been receiving increasing attention in a number of other fields, such as, for example, the social studies of finance that sees the material cultures found in finance and encompassing not just the ideas and the actions of human beings, but also artefacts and technical systems, among its central research foci (Millo, Muniesa et al. 2005; Beunza, Hardie et al. 2006; Caliskan 2007; MacKenzie 2007; Muniesa, Millo et al. 2007). In a key study, Preda has examined the role of documents in banks and shown that this goes beyond traditional concerns with communication, content, and the organising, transmitting, and storing of information (Preda 2002). Preda suggests instead that the documents become actants in their own right, participating in the assembling and holding together of the sociotechnical networks of finance (Preda 2002).

In organisational studies, similar arguments have been pursued by Cooren, who shows how texts and documents in organisations, not only "broadcast information", but "participate in the channelling of behaviours, constitute and stabilise organisational pathways" and "by remaining, fabricate relatively fixed spaces and times" (Cooren 2004).

Beyond issues regarding the centrality accorded to objects and artefacts, much literature on coordination in organisations has been concerned with formal and explicit coordination mechanisms based on the use by organisations of schedules, rules, plans, and hierarchies in order to ensure that the right resources are "available in the right place at the right time for … work to be performed" (Okhuysen and Bechky 2009).

Organisations and the organisation of work have changed with the growing economic importance of services (Hargadon, Davis et al. 2003) and of sectors in which "a single optimal solution may not exist" (Okhuysen and Bechky 2009). Because of such changes it is increasingly the case that progress towards the completion of tasks or an output may be difficult to plot and assess (e.g. software and interactive design) (Kraut and Streeter 1995; Kellogg, Orlikowski et al. 2006) and boundaries of organisations and functions have become increasingly blurred (Hargadon, Davis et al. 2003; Scott 2004; Kellogg, Orlikowski et al. 2006), the explanatory power of formal coordination arrangements has been found lacking. As Okhuysen and Bechky point out, in these organisational settings "interdependencies between different pieces of work may be uncertain or challenging to identify, making it difficult to know who should be involved in work and whether there is a correct order in which parties should complete their own specialized work" (Okhuysen and Bechky 2009). Okhuysen and Bechky suggest, therefore, that rather than seeing processes and structures of

coordination only “as formal elements planned by organizations” it may be preferable to consider them as “ongoing work activities that emerge in response to coordination challenges” (Okhuysen and Bechky 2009). This is because “formalized, designed, planned, or engineered solutions often fail to account for the many eventualities that organizations face in the performance of their work” and focusing on these ignores the way “unplanned contingencies and the responses to them represent important influences in organizations” (Okhuysen and Bechky 2009).

For many of the reasons given above, Kellogg, Orlikowski, and Yates have argued that much of the literature on cooperation across boundaries with its emphasis on the construction of common knowledge through the use of boundary-spanning mechanisms such as routines, languages, repositories, and models that are arrived at through negotiations and the forging of agreements among clearly defined occupational groups may be of less relevance in relation to organisations characterised by “non-hierarchical and shifting contexts, where criteria of worth are contested, and where areas of jurisdiction are blurred” (Kellogg, Orlikowski et al. 2006). Instead, “practices of display, representation, and assembly” are put forward as more relevant in relation to co-ordination at fast-moving heterarchical organisations such as the web-based interactive marketing firm studied (Kellogg, Orlikowski et al. 2006). Pointing to exchange interactions rather than the sharing of knowledge observed at the interactive marketing firm, Kellogg, Orlikowski, and Yates – drawing on the work of Galison on physicists (Galison 1999) – refer to the constituting of “trading zones” rather than “common knowledge” (Carlile 2004). In these “trading zones”, distinct occupational communities “align their activities without homogenising the inherent diversity of their community interpretations, identities, and interests … without global agreement” (Kellogg, Orlikowski et al. 2006).

Rather than seeing formal and emergent coordination as antithetical, this article will seek to explore the link between formal and emergent types of coordination encountered in the development of computer games and to show the important role objects and artefacts play in making this dynamic dialogical relationship work. Furthermore, the article explores, through this link between formal and emergent coordination, how many difficult to represent experiential and aesthetic features of the games are rendered explicit and captured in order to become addressable through the existing formal coordination practices of the studios and how contingencies and previously under-determined elements of the games under development are dealt with.

It will be argued that in such a setting characterised by emergence and uncertainty in relation to the innovative, aesthetic, and experiential features of the games under development a key coordination device is what the developers refer to as the ‘vision’ for the game that works by tapping into and mobilising for purposes of coordination difficult to access pools of tacit knowledge of the developers.

Research Approach

As Suchman explains in her work on centres of coordination, it is important to analyse “the dynamic structuring of peoples' interactions with each other and with their material environments” as this contributes to “developing understanding of the social and material organization of skilled practice within complex, technology-intensive

worksites" and allows one to "see how a work group distributed in space is tied together through architectural, technological, and interactional resources, as well as the obstacles that such a group must face" (Suchman 1997).

For Carlile also, objects and the material aspects of collaboration are central to the study of organisational settings in which new products are developed. In order to overcome the difficulties of making tacit knowledge explicit verbally (Polanyi 1967) and of knowing "more than we can tell" relying on surveys and interviews is not enough for Carlile (Carlile 2002). It is important to observe "individuals in practice … focusing on the objects they work with and the ends that they pursue", as this provides "a concrete delineation of what to observe and what to compare in terms of how knowledge is created and structured" (Carlile 2002). These objects are "the collection of artifacts that individuals work with—the numbers, blueprints, faxes, parts, tools, and machines that individuals create, measure, or manipulate" while the ends achieved using these objects are "outcomes that demonstrate success in creating, measuring, or manipulating objects—a signed sales contract, ordering prototype parts, an assembly process certification, or a batch of high-quality parts off the production line" (Carlile 2002).

The article draws on studies of three leading UK computer games design and development studios the aim of which was to capture an in-depth understanding of the way in which the developers studied create, leverage, and alter shared objects in this work and describe the interactions of the developers both with these objects and with one another in their work. The ultimate aim was to develop descriptions of the material practices of this research setting through engaged field experience that capture their distinctiveness, complexity, and materiality (Ewenstein and Whyte 2009).

Research Sites

GamesDevCo

The first study site was GamesDevCo, a pseudonym for a UK-based games development company. Since its foundation in 1990 GamesDevCo has grown into a leading independent multi-platform developer employing around 250 people and comprising of five distinct divisions: family games; mature titles; serious games; downloadable games; and games technology. The company develops games under both its own brands as well as on behalf of external publishers and intellectual property rights holders.

PetName

The second site was PetName, a pseudonym for a leading UK-based games development company that since its formation in 1997 has developed a series of commercially successful, critically-acclaimed, and award-winning strategy, action role-playing, and simulation games. The company develops its own titles, almost exclusively for the Xbox console, with dedicated teams moving from one release of the title to work on the next release in quick succession, aiming to have a higher output of releases than has been the case with games studios so far.

Dredd

The third case study was conducted at Dredd. Dredd is a pseudonym for a UK-based computer games developer that since its establishment in 1992 has, through the acquisition of other UK studios, become one of the largest UK computer games developers; what has started to be referred to in the UK games development sector as a "superstudio". The company produces games both under its own brand and for third-party clients and has enjoyed significant commercial success. It is now a multi-platform and multi-genre developer operating out of four different locations around the UK.

Data Collection

As discussed in the introduction, the research sought to put into practice an approach informed by the concerns of Suchman and Carlile (Suchman 1997; Carlile 2002). This was done by deploying a combination of in-depth interviews and observations at the three sites, accessing key objects involved in the development of the computer games developed there, identifying key boundaries that need to be negotiated during the development of the games, and accounting for how the collaboration across these boundaries was performed by the humans and objects involved. Data collection also sought to pay attention to activities, schedules, hierarchies, routines and variations, significant events, participants' meanings, and social rules (Altheide and Johnson 1994).

Formal interviews that were more wide-ranging and lasted longer (between 1h 40min to 3h) were recorded and transcribed. While a set of headline themes relating to how a game moves from conceptualisation to realisation and what key shared objects were involved in the process informed the questioning, no specific list of questions was used during the interviewing.

Informal interviews were used for much more specific questions relating to key aspects of the development process that emerged during the observations. These typically lasted between 10 and 20 minutes and were usually recorded in hand-written notes rather than through voice recordings in order to capture 'on the spot' and at that moment an explanation from those involved in the activity at that time of a key aspect of the collaboration that was deemed of interest during the observational work.

The observational material was recorded primarily in note form continuously during the time at the studios, usually contemporaneously (or very soon after a certain event or encounter of interest). Field notes were supplemented by: sketches drawn by the developers as they explained something, either to the researcher or to each other; print-outs of key documents used in the development process; screen grabs of computer applications and displays; some photographs taken at one of the studios during observations; and sketches done by the researcher.

Analysis

The descriptions assembled out of the empirical material collected and presented in the paper set-out to show how, in Suchman's words, "a work group distributed in space is tied together through architectural, technological, and interactional resources" (Suchman 1997). They present key shared objects involved in the coordination of computer games development encountered *across the three sites* and describe their

intended purpose, how the developers studied create, leverage, and alter them, and the interactions of the developers with these objects as a game moves from concept to actualisation.

Findings

For a computer game to be realised, a whole set of objects – referred to as "assets" by the developers – need to be brought together and relations among these objects established in a particular way. These "assets", include digital artwork for the entities – both animate and inanimate – found in the game, 3D models, digital artwork relating to the setting within which the game takes place, maps of levels and locations, animation sequences, artificial intelligence (AI) algorithms for entities not controlled by the player, visual textures, special effects, sounds, text and spoken dialogues, music, and many more depending on the game, its genre, and its complexity.

The sequence of processes that "takes assets from their source form (usually the direct output of whatever package the artist created them in) to the final data that can be burned on to a disc or cartridge to form part of the finished game", is what is referred to among the developers as the 'asset pipeline' (Carter 2004)[2]. It was a central common preoccupation of the teams encountered, especially among members in more senior roles, to ensure this "pipeline" is well coordinated and assets are at the right place at the right time and in the right form, both in relation to each other, but also in relationship to the progression of the development process, and the demands of the computer code at the centre of the game known as the 'game engine'.

This temporal and relational ordering work starts from the very first stages of a games project and accompanies games development projects through their various phases to completion. In the process, a number of objects that are shared among the developers play a central but also emergent role in this ordering.

Concept Book

One important material nexus for this early-stage work was what was referred to as the "concept book" or "concept document" by the developers studied. These documents included text that described the game and its features, the thinking behind it as well as visual representations of the main characters of the game accompanied by what can be described as imaginary biographies for them outlining their roles in the game and what they could do. The documents often – though not always – also included outline budgets and cost projections for the proposed game.

Describing what is included in a typical PetName concept document, a development manager explained:

> "It has pictures and varied descriptions of the story and plots and who the main characters are, biographies of who these people are, what they look

[2] See also Arnaud, R. (2010). The game asset pipeline. Game engine gems. E. Lengyel. Sudbury, Mass., Jones and Bartlett Publishers**:** 11-39.

> like; it covers all aspects of the game. It is usually a 70 to 80-page document which encapsulates what the game is going to be – what we intend it to be, anyway – and tries to cover all the risks, all the areas we are going to have to look at, the story, the core technologies, … even a budget section at the end, the staff plan, with the end date, the start date and the phases and all the markers in between. It tries, at a high level, [to] encapsulate the whole game, how long it's going to take, and what it's going to be."

The concept document plays an important role in the game development process because it provides a first, high-level, narrative outline of the main entities in the game that will eventually be realised as 'assets' and of their relational ordering and associates in a rudimentary way that ordering to time and resources. At the same time, however, the concept document is involved in other practices that go beyond ordering and have more to do with the collaborative envisioning the future product. The document makes it possible for members of the development team from a number of areas of expertise to bring together, in a common space, their interpretations of the vision, concept, and ideas of the proposed game These interpretations are then expressed in text, textures, materials, drawings, photographs, tables, and spreadsheets that have been made combinable and accessible to all those involved in the games development process and from different areas of expertise with different representational techniques. This applies as much to members of the team of developers working on a game within a particular studio as to external partners, such as games publishers who commission development projects.

Once all the sign-offs and green lighting procedures – whether internal or external – have been completed in relation to the concept document, the transition from the conceptualisation to the production phase of the game involves the compilation of a key object referred to by the developers as the Game Design Document (GDD).

Game Design Document

The GDD is composed of many sub-documents and is stored on – and available from – the shared servers of the development teams. It is also frequently materialised in the form of physical print-outs – usually of only certain of its constituent sub-documents at a time – for use in meetings. The GDDs specify many of the features of the game under development such as the number of levels the game will have; what these levels will be like; the storyline of the game and how that relates the different levels to each other; who the characters are; what their role in the game is; where they can appear; how they can encounter each other; what the mechanics of their interactions are going to be; how they are going to move; what 'things' they can interact with or manipulate; and so on. The GDD is usually accompanied by an "art design document" and a "technical design document". In the former, art-related assets are specified in much more detail, style sheets are developed for even the most mundane and trivial entities, and so on. In the latter, detailed technical specifications for all the elements specified in the GDD (levels, tasks, characters, environments etc) are defined. Talking with the head of programming at PetName about this, he explained how, after conceptualising the game, the technical team would assemble the "technical design document" that, among other information would also specify budgets for memory use and CPU use for

a range of different kinds of scenes, specifying the number of polygons that can be used; the number of characters that can be displayed at any one time; what these characters can do; and so on. He explained how, for example, in lush outside settings with much environmental content there was much less memory and CPU budget for other things compared to a scene inside a cave where there was much less computing power taken-up by such features. He then went on to explain how the way this tended to play out in practice was that the technical team would set out these kind of limits in the technical design document, then the other disciplines would tend to see how far they could stretch those limits, and then at some point the technical team would have to "rein them in", while still trying to find ways, even as the game was being developed, to optimise the performance of the technical elements in order to "squeeze out as much extra capacity and functionality as possible".

Whether an individual participating in the development process is a coder, an animator, a 3D artist, or a special effects or artificial intelligence specialist, during the trajectory of the game from concept to actualisation, the GDD and its components will continuously cross backwards and forward between individuals and groups of individuals with a particular expertise and way of working and interacting. The following quote from the GameDevCo study provides a good illustration of this role of the GDD:

> "The aim at the beginning of each project … is to create a 'game design document' an 'art design document' and a 'technical design document'. The game design document will contain everything that is in the game. It will classify all the characters, all their moves, all the mechanics, all the animations needed, all the pickups, all the weapons, all the locations, all the mechanics. That will grow to at least a couple of hundred pages for just that. … [The game design document] is also crucial to the relationship with the client [as well as in terms of] visibility for the collaboration. The same with the art and technology design documents and what they deal with. Everything is documented in terms of meeting notes. Everything visual is designed and we obviously design everything digitally or scan it in or drawn digitally. So we keep a record of that."

These documents have a multiplicity of functions that go beyond the relational organisation of the entities that comprise the game. One important such function is to act as a collective memory for the development team. As was explained during the study of GamesDevCo, when – for example – the character artists come into the team, they can see straight away what characters are needed from the concept art already done in 2D and included in the GDD. Or a programmer can "look at the game design document, look at the pages which relate to character movement or even read the whole document with regard to how all that is going to feed into the mechanics and other stuff and then be able to think, 'OK I have got it'."

The importance of these objects to the collaborative practices of the developers became even more explicit during the participant observation phase of the research at PetName where the sections of the GDD relating to a particular quest or level in the

game would form the centrepiece of the interactions between, for example, the design team and the art team in terms of the assets the design team wanted the art team to develop for them; why they wanted them like that; how they should look; where they would have to be placed in the level; and so on. It is worth noting that as a particular level took shape, initial ideas might be modified or dropped, new ones introduced, and unforeseen problems encountered. This would result in different versions of that section of the GDD being spawned, all of which would be retained, however, within the overall GDD.

Milestone Schedule

The GDD is associated to the temporal co-ordination of a game development project through the way it is linked to the crucial for every project, team, and individual team member "milestone schedule". The milestones themselves, however, are more that just temporal ordering devices. It is also through them that the performance of individuals, teams, and ultimately the company itself are judged, evaluated and rewarded, with payments from clients or internal commissioning entities tied to the attainment of the milestones. The following quote from PetName illustrates the point:

> "We just have the usual milestones. At the end of the milestones you bill; at the beginning of the milestones you hand out schedules to everyone. That's pretty standard stuff. I mentioned target teams, beat structure where we have a story, and at the beginning, middle and end, we structured some of the milestones around that. We said for the beginning milestone we are doing this chapter of this story, and sometimes that worked, sometimes that didn't."

It is also in the milestone schedule that individuals or groups of individuals are detailed publically with developing a certain feature, bringing to it particular expertises, interests, or personalities. "You've got to define people who are responsible for things", emphasised a senior producer at Dredd. Furthermore, as many such features are composite and require the bringing together of a wide array of skills and past expertise from across functions, getting the membership of such groups right is as important as allocating the appropriate feature to the right individual or group.

Task Allocation

At PetName the linkages between the GDD and the scheduling were established through what was referred to as the "Work Breakdown Structure", which had been implemented using Microsoft Excel spreadsheet functionality and seen as crucial to facilitating the scheduling of the games projects.

"We have to decide who is going to build [the game] and when it's going to be done", explained a PetName development manager. "We have a staff plan; we know who's available from when to where", he continued. "We work out the costs; we know the dates; we work out when we want it to be in the street, and we work backwards from that", he continued. "We fiddle with the numbers and make sure we have the right number of people and have a plan for when we can recruit them and what kind they are going to be, and then we have to cost the project", he explained, continuing:

> "We say we have this concept document that says it's going to have this many levels and this story and [be] this long and will have this many events and [this] script, and we have to work out if we can afford that, given the time and people we have. … We work with something called the work breakdown structure. … That is vital to the project, [which in this representation is] encapsulated in big … high level chunks … very big chunks and tasks. … [It] is all fully automated. So what we do is we dial in the resources of people, who they are working for and where they are on the project, and on a separate sheet, we put in all those things we know about [the] big chunks of tasks, assign people to them, determine how long it's going to take and how much we want it and how all this will be done and press a big red button—and it is a big read button now—and it just goes 'thunk' and goes up here in about five minutes. This allows us to wave this under the noses of the artists or the programmers, [and] because it's in Excel we can all use it."

Again, however, as with the milestone schedule, the purpose of the work breakdown structure is not only temporal ordering, but also, in the words of the company's executive producer, "a way of very clearly communicating with [the] creatives how their ideas [might not be] feasible in the time we [have]". "That is something that creates a big tension here", she explained, "because we all try to build the best possible game in the time we've got, but we do have a budget and have to run a business, so using a tool like this is vital in showing how *big* those ideas are".

While not referring explicitly to a specific object such as the work breakdown structure, the practices involved in moving form the planning of the project to the development work itself at the two other sites were similar to those encountered at PetName.

Dealing with emergence

Across all the three sites studied a great deal of effort and attention was being directed towards coordination in the form of the organisation and management of the games production process, both in terms of time (meeting of deadlines), but also in terms of reducing the likelihood of the failure of a project and ensuring as unproblematic as possible delivery of the final product. At the same time, again across all three sites, there was unanimous agreement among informers – even from some of the most hard-nosed and completion-driven executives – that there was little point in developing a game that was on-budget and on-time, but no one wanted to play. While the planning and scheduling of the known aspects of the games being developed were seen as crucial across all three sites and a great deal of effort and resources were directed towards managing these activities, there was also a realisation that getting that right was not enough, in itself, for the success of a game. A senior producer at Dredd, talking about this in the context of the processes involved in assembling a project plan, commented characteristically:

> "I've got all this paper interaction going on. I've got strike teams there. I've

> got people getting deadlines. I've got people defining their deadlines to me. I've got a waterfall schedule. I've got an idea of how many people it's going to take to make the game. I've got an idea of how risky and how complex it's going to be. … [But], it's not just all about planning. These guys make tangible assets, [but also], they create an experience on a screen; and that's what it's all about. I provide a beautiful plan, but that's not going to mean anything to Joe Schmoe, who goes out and buys a game on the shelves."

As a result, across all three sites there was a great deal of importance attached to aspects of coordination that did not relate to what is traditionally within the remit of project management, but involved developing collectively certain difficult to represent sensory and aesthetic aspects of the games, something often referred to by the developers as the "vision" for a game. How to capture and share, both internally and externally, this "vision" of a game was a central preoccupation. In all three cases, in order to deal with these difficult to articulate and represent aspects of the game that as a consequence could not be specified easily, what was referred to as the "vision" for a game and how this was understood in a collective way was a central concern of the developers studied.

Co-ordination through envisioning

"The notion of the vision is a difficult one", explained the development director at GamesDevCo when asked during the interview to explain the frequent occurrence of the word in both the interviews but also more generally in the conversations and interactions at the studio. "[It will depend] on the pre-dev stage; that is where the stuff is really born out", he added. "So, although the vision will probably change massively during that time", he explained, "as long as at the end of that point you have a pretty much coherent vision nailed, whether it is the same one you started with doesn't really matter; as long as it is something that everyone has agreed with and everyone is happy to do and follow through during production". It could be "art-led", he continued, in which case "the art style then dictates a lot of the design, a lot of the technical requirements". Ultimately, however, it was about saying, "this is the kind of game we are creating; this is the kind of mood we want to create for the player; this is the kind of visual feeling we want to create and the visual feedback we want to create; these are the kind of technical limitation we want to break; we really want to take it forward with regard to these, or whatever it is going to be, a combination of all that sometimes".

Across all three sites the "vision" for the game played an important role as a non-formal device for coordination. A senior production executive at Dredd phrased it the following way:

> "Generally, the more you fragment [the vision], the more difficult it is to keep your entire team understanding what it is you're trying to create. As soon as you've got that fragmentation … you'll get cracks; you'll get mistakes; you'll get misunderstanding; and you'll get delays and frustration."

At PetName the importance of arriving at a common understanding of the vision for the game in terms of co-ordinating the development of previously under-determined or difficult to represent features was also stressed, despite the involvement of a number of senior people at the company in outlining a particular vision for a game. The executive producer of PetName commented on this issue: "there comes a point where you don't want a hundred different voices", but have to arrive at "one vision and [and try] to execute on that one vision". "You won't please all the of the people all of the time", she explained, "so you almost have to say 'we are holding to our line and trying to get the best of our vision', rather than try to answer everybody else's". "It helps to have a common vision", concurred a development manager at the same studio, "because with many voices, you end up with designing a camel".

Drawings, models, and external references

Again a number of objects were involved, ranging from drawings and other visual representations and references to all sorts of sizes and types of models. External references such as movies, a book, or in some cases, another game were also crucial in this respect. Things such as movies were found to be particularly important in terms of building among the teams studied a shared understanding of what was intended regarding the "emotion" or visual style of the game. This shared understanding would – in turn – coordinate the realisation of these difficult to represent aspects of the game by different individuals and groups as they built into the assets they contributed their interpretation of this understanding.

Drawings, either on their own or within the context of other objects such as concept books and the games design documents, but also more generally in the games development process as a whole, were found to have a crucial role in making accessible to the members of the development teams many of the aspects of the games that are not tangible and difficult to represent verbally.

A central role in such a process was played by what the developers referred to as "concept art", as the following comment from an executive producer at PetName illustrates:

> "The more ways that we can do that – communicate exactly what you want [and] for everyone to get and understand it – [the better]. It is like the Holy Grail; because everyone understands differently. If you go visual that helps immensely. … We have fulltime concept artists. We use a [concept artist] right now who is drawing-up all our levels that will educate far more than any 20-page document about how that level is going to be."

Drawing and concept art was seen in a similar light at the other two studios also. The following comment captures vividly the use of concept art and drawing at GamesDevCo:

> "We try and draw a huge amount of stuff during the project because the cheapest way of getting any visualisations is by drawing. The [art specialists] are trained to draw extremely fast as well, so we spend a lot of time drawing out the environments, drawing out some of the character

> moves in regards to the animations cycles, drawing out all the characters' weapons, individually style anything else we need, sometimes just drawing with regards to diagrammatic things, saying: 'I want this character to move like this'; or, 'here is one of the character moves and I want it to look dynamic in this kind of way'; or whatever. Some quite functional things like that. So, when we hit production we've got a huge amount of material there."

Although vitally important in terms of capturing and making available, not only across the development team but also to external collaborators and backers, the intended "vision" and "feel" of the game, concept art was also important in terms of the practical work of translating those intangibles into the concrete assets for the game, as the following from the development manager at PetName regarding the importance of the concept artist shows:

> "We use concept [art] in huge amounts. We have one guy whose only job in the world is to sit there with a drawing pad and knock out lots and lots of concept artwork of creatures, characters and costumes. … Sometimes [it is for] the internal team, sometimes the outsourcing teams. When someone says: 'I've got this task on my schedule to go and build the bucket', there's concept [art] along with it to make sure that the style is consistent; that he is not thinking of a silver bucket, rather than a wooden bucket; that everyone understands what he is to build. Alongside that you [might] have in the databases and the artbase a prototype bucket, or what is set-up. [The concept artist might have also] made a model as practice. This is a bucket; here's the description, and here's how many [there] are supposed to be. Here's what your [technical] budget is. So there's no room for error there; they can't get it wrong."

But it is not just drawings that were important in terms of the capturing and circulation throughout the development team of the "vision" for a game. Within the studios there was wide-spread use of all sorts of sizes and types of models in the development process ranging from miniature mock-ups of landscapes made from the kind of modelling materials used by model railways enthusiasts, to small sculpted figures or portraits of characters. Throughout the studios, props and objects could be seen on the desks of individuals and in areas occupied by different teams, but also all around the office space, giving a visually intense feel to the sites.

External visual resources and references were also widely utilised in order to convey to the individuals involved the elusive "vision" or a particular "feel", "mood", or "atmosphere" for a level, quest, or scene, as illustrated in the passage below, again from GamesDevCo, but which was also confirmed from viewing the pages from the game design document of one of the games at PetName in which copious visual and other external references were provided:

> "With everything we have created, even if it is 'true to original' there is always a movie, or a book in some cases, or another game possibly, that have done something similar or have done something diametrically

> opposite that we can say: ‘this is really what we don’t want, we really don’t want this vision’. Or, ‘what I am trying to get to is this’, or ‘here is a movie’. Everyone watches the movie and they then hopefully understand what you mean about the emotion of the game or the visual style of the game or whatever it might be. … Using those … references, to say, 'right we really want this', then … people come up with ideas and come up with visual styles [and] that's how [the vision] works; it kind of trickles down.”

At PetName, there was also use internally of video to make material that would have been made available via the documentation more compelling and easily absorbable across the development team. The executive producer described this as follows:

> “In [the previous game we] spent a lot of time having a design document and detail. … The team didn’t really read it; a document is a very dry thing. [Our lead designer] ended up, at one point, doing videos of the script, so that people could sit down and listen to him talking.”

It was also explained that the use of the videos was then also supplemented with “two meetings on Mondays” to do “a show and tell every week” in order to get “other portions of the team to share what they are working on, so the whole team begins to get what [others are] working on”.

There was an interest in the wider use of video for coordination at PetName, not only in terms of sharing a ‘vision’ for the game across the team, but also as part of the process of rendering explicit features either not fully specified or specifiable or even not encountered previously. One example that was shown during the research at the site was of the video of a wrestler from which the prototype for a confined combat animation sequence was developed. Another concerned developing scenes and animations for the sword fighting in the game. The video itself was of lessons that the animators attended with a professional swordsman in which, in addition to the direct feel and understanding for the movements and techniques that the development team acquired from the session, it also enabled the animators to take the video “and pause it right down” in order to analyse and translate the moves into 3D computer animations.

“This is where we took some guys off-site and [sent] them [to a] real-life sword master … who sword fights and works in the film industry”, explained the development manager of the team. The sword master helped both animate the scenes through performing the moves and also contributing to the design of the sward fighting scenes in the game. In addition, he also showed the developers “how to fight with a sword so they knew ahead of time that when they came to animate and design that”, what the “real-life experience of sword fighting” was like.

Despite the central importance of visual and other non word-based references in terms of making knowable across the team many of the non-explicit or difficult to represent features, it was stressed that it was not instead of, but through a combination with more formal word-based approaches that these worked best. “If

we can use pictures … we will, but that doesn't mean there can be no words", emphasised the executive producer at PetName. "There still need to be technical design documents, which are very careful thinking about the structure and masks and architecture of those features and programming points; there still need to be design documents, stories and dialogue written out for these kinds of notes."

Interestingly, while undoubtedly a clear shared vision for the game was something that was seen as important by developers, during the observational work it was possible to see at first hand how although at any particular stage in the development process a 'vision' did inform the work of the developers, while temporarily stable, this was not a closed but rather an under-determined notion that evolved and became more explicit and stable as the game development process unfolded and the vision started to find increasing concrete expression in the assets and early stages of the game. Nonetheless, it still served a clear coordinative purpose, despite its own emergence and under-determinacy.

Review and iteration

It was found that iterations and revisions were central to how such emergence was dealt with by the developers in practice and how emergent – or previously under-determined – features were captured and shared among the development teams.

With "[subjective] features its going to go a bit crazy", explained a producer at Dredd. "For features you want stakeholders, you need reviews, you need sign offs", he continued highlighting some of the key stages of such review and iteration processes that were encountered at all of the three sites studied.

Within a particular project these iteration and review processes could be either formalised, as in the case of regular and highly structured milestone review meetings, or more ad hoc, relating to collaboration among certain sub-teams on much more specific and discrete elements of the game.

There was general agreement among all the participants across the sites in this research that there was no substitute for seeing how assets being developed would behave within the ambit of the actual game itself, even if that was a very minimal and underdeveloped version of the expected final polished outcome. In addition, during the observational work undertaken, it was clear that a great deal of time during the working day was spent in meetings of varying degrees of formality and scale of participation – ranging from three or four people around a computer terminal to entire teams in a meeting room – examining in some detail the impact of alterations to assets on the game and whether the desired result was achieved by their incorporation into the game. Furthermore, it was through such review and iteration type of interactions that a great deal of co-ordination across functions and specialisations took place.

At GamesDevCo, the importance of the review and iteration process was described in the following way:

> "When work starts getting developed, like character scenarios or storylines or character designs or weapons, we can look at those – the leads look at those – and go: 'this really doesn't fit …can we revise it', or 'do we have to

> junk it, or what?' By going through that process and learning, and by saying: 'yes, I get it, current design doesn't fit because it's got the wrong kind of proportions', or, 'the wrong colour skin', or whatever it might be, and then learn from that and [go], 'OK, sorry about that I didn't realise, I'll revise and redo'. Then next time [it] will be closer and closer until at some point they will hit it; and that is how we go forward. It is important, that kind of iteration and going through the work around and around, approving stuff and going forwards."

Milestone review meetings were the most extensive and formally organised and structured of these review and iteration arrangements. Their format owed as much to the way they related to many of the shared objects described previously – such as the game and technical design documents and work breakdown and other schedules – as to the tacit and explicit rules and roles involved in their performance and the embodied previous experiences and understandings of the individuals participating in them.

By being the venue in which the human and material entities involved in the development of the game were brought together and confronted with what has been done so far and what was still needed to complete the game, these meetings were a crucial mechanism through which the boundary between what is know, explicit, and formally represented and what is missing or needs to be further determined and rendered explicit in a way that allows the representational practices of the developers to deal with it, is dynamically defined, meeting-by-meeting.

A great deal of insight regarding the way milestone review meetings were performed, the practices involved, and the central role the meetings played in managing the emergence involved in the development process was gained from being able to observe an entire meeting lasting the whole working day at PetName.

Review meetings at PetName took place every six weeks and in addition to checking the delivery by the teams of the outputs agreed for that period, they also provided a forum for a detailed "show and tell" in which the teams would also talk more generally about what they had been working on in the past six weeks and what they were planning to work on over the subsequent six weeks to the next meeting.

The teams participating in the meting would use their own game console – sometimes more than one – with those presenting plugging in their console to the audio visual system of the meeting room and demonstrating the objects of the task being assessed and reviewed as they were in the game.

Central to the performance of the meeting were the printouts of the milestone schedule that participants collected as they came into the room. In the table the 1st column describes the High Level Goals of the project which are divided into key work areas such as "Engine", "Gameplay", "Characters & Creatures", "Regions" and so on and which are then subdivided into smaller tasks and outputs. These had then been allocated to individuals and teams, identified in two separate subsequent columns, with the concrete deliverables expected described in the column after. A column after that then allowed for comments regarding the work and the outcomes

to be added by the teams or individuals involved. This is also where problems being encountered could be inserted and described. Finally there are columns that relate to signing-off with fields for the final 'owner' of the deliverable and comments and notes on that particular sign-off.

In addition to checking progress and managing interdependencies, a key purpose of the review meeting was for everyone on the development team to become familiarised with the layout and features of existing and new locations and levels in the game and for participants to understand what kind of inputs might me required from them for the latter. This was not a one-way explanation, however. During the "walk through" of existing and still being worked on levels and quests, quite a lot of interaction between the level designers and all the others in the room took place, with intervening, commenting, and the asking questions taking place on a continuous basis. This way, it was possible, not only for the thinking of the designers to be rendered more explicit and shared with the others, but also for the response of those outside the design team to be elicited, articulated, and also recorded in the notes being taken by the senior members of the production team and if necessary added from there to the project documentation and schedule.

From small issues of unforeseen dependencies to large questions concerning how a particular feature relates to the 'vision' for a game or a particular aimed-for playing experiences for the end-user, the milestone review provides the forum for team-wide debate, discussion, argument, clarification, agreement, and the collective entering into commitments. Combined with the fixedness of the milestone schedule and accompanying temporal regularity of the review process, milestone reviews were found to be crucial in terms of rendering explicit issues that may have not been resolved or even considered previously. It is also in the milestone review meetings that the value and worth to the game of particular features is debated collectively and decisions regarding whether to persist or not with them through further investments of resources and time are agreed upon or whether they are jettisoned.

From the perspective of the coordinative importance of these meetings, it was significant to note that it was not only within the four walls of the room within which the actual milestone review meetings took place that these meetings had an effect on the teams and their working, but also during the build-up and preparation for these meetings, showing how the tacit and embodied understandings and anticipations of those involved would find a concrete expression in their preparations.

Across all three sites, dealing with the emergent nature of the work of the games developers went beyond rendering elusive aspects of the game – such as the vision – explicit. At all three studios there was great importance attached to having – or being in a position to develop quickly – responses and coordinative mechanisms through which previously unforeseen – or even unforeseeable – problems with the game could be surfaced and dealt with.

A powerful illustration of this and how such a contingency was dealt with in practice was provided in the game being developed by Dredd based on the popular TV cartoon series The Simpsons.

The problem came-up as it was found – after the development of the game had started – that because of the particular way the cartoon characters were drawn in 2D for the TV series, to translate them into the 3D models used in computer games would actually require them to be distorted quite radically.

"If you look at Bart [in the TV series] from different angles, he'll have different numbers of spikes on his head and, also, his eyes will be in different positions", explained the developer in charge of the project. "We needed a really versatile script that allowed us to basically deform these characters incredibly, to make sure that the eyes were moving, so that when Bart moved from one side to the other, it's not just eyes going like this", he said while imitating the movement, "his eyes had to stay in view; … the mouth has to change", he continued. It is "moving up and down on the side – like this", he explained, mimicking the movement, "but it's wide open when it's in the front [and] that forced his entire chin to deform in a really bizarre way". This was not only an issue with the Bart character, but also the other ones: the amount of bumps Marge has in her hair depending on which view one is looking at; Lisa's necklace and the spikes on her hair; even Homer's three strands of hair which change from two to three at different angles.

Suddenly, when this issue surfaced, what had been considered by the development team as "a fairly simple 'do it by the numbers' " kind of job, became: "'all right …. we've got a problem; something big that we hadn't planned for [and] how the hell are we going to do it?'" "If [we] couldn't do it with a [software] script, [we] would probably need a small army of animators to do it all by hand, and it would be murderous", explained the developer in charge, "it would have really bloated my team out, so I was really doubtful". "Initially, the [technical] guys said it would probably be quite easy", he continued, "then three months down the line we realized this has gone very badly wrong, and the only recourse I had at that point was to, from my end date, go back through time to plan that arduous 'by-hand' route out, and then just basically see where my cut-off point was," he continued. "I had to turn around to the team and say, 'listen lads, if we haven't got it in two weeks time, then we cut, and we ditch, and move for this plan B, because otherwise we won't get it done'". In the end, the scripting approach was made to work – just in time – and the project was completed successfully, and despite the uncomfortable situation, the developer in charge also acknowledged that in addition to learning the hard way the importance to "always have a plan B, [and] … an escape route", those involved had also become conscious of how, through dealing with such unexpected and unplanned for features it was possible to "throw much creativity into a game".

Co-ordination and collaborative tools

Finally, it is important to note the coordination provided by a number of software tools and development methodologies that have roles, skills, expertise, and ways of viewing and knowing the processes involved in games development built into them.

Of particular interest in relation to this point was the reluctance in two of the three sites (GamesDevCo and PetName) to use established commercial project management software due to what was seen as the inflexibility of the software in

terms of accommodating frequent changes resulting from the need to deal with the emergence observed in the games development process and the rendering explicit and knowable of under-specified or unknown aspects of the game during development. At both these sites there were comments along the lines of Microsoft Project being too rigid in terms of dealing with complex and often-changing dependencies for use in the context of computer games development where so much of the project could change as it unfolds. Furthermore, in the case of PetName, specialised project management software was seen as overcomplicated and difficult to interact with and master for many on the development team, so solutions using Microsoft Excel spreadsheet functionalities with which all members were conversant and at ease with were usually put together. At GamesDevCo, rather than improvise a solution in-house, it was decided to abandon Microsoft Project in favour of a programme called Hansoft, which has been developed by a number of games developers who built a specialist project management software application specifically for games development.

Even at Dredd, where Microsoft Project was used, this use was restricted to the assets and elements of the game under development that were considered well-defined – or "cookie cutting" as one developer described it – and for which it was seen as appropriate to use a traditional waterfall project management approach. For other aspects of the game and development process that were seen as less well-defined and characterised by emergence, again there was recourse to improvised in-house solutions using spreadsheet functionalities and macros.

Another striking feature at all three sites was the increasing use of wikis, blogs, and online forums, all of which are designed to capture the dynamic and collaborative production of new knowledge and often with individual developers or groups of developers taking the initiative in terms of initiating their setting-up and use. These tools were not only for internal use and collaboration, but – with the necessary security and privacy arrangements delineating clearly the boundary between internal and external areas – also provided a conduit for interactions of the developers with the external world, especially communities of end-user enthusiasts with a passion for the games produced by the studios.

Discussion

The empirical findings present a detailed account of some of the key objects and artefacts involved in the coordination of work encountered in the design and development of computer games. As has been shown, these objects give shape, form, stability, repeatability, and visibility to the work of the developers. At the same time, it has also been shown how many of these are not static entities that are in place and just faithfully mediate the activities of the developers. They are open-ended, evolving, dynamic, and participating in reflexive iterative processes that change the developers as much as the game being produced.

Many of the functions of the objects identified and analysed in this article chime with the coordinative mechanisms and arrangements identified in the literature relating to the both formal and emergent aspects of coordination (Okhuysen and Bechky 2009). The concept books, for example, can be seen as early representations of the new object being developed. The way that the milestone

schedules are associated with billing and the allocation of resources and personal as well as the linking of time and tasks makes these objects important in terms of coordination because they provide a collective and public running view of the responsibilities and contributions of individuals and teams to the project, which has important implications in terms of co-ordination in the albescence of formal rules a hierarchies. These schedules are therefore important in terms of what Okhuysen and Bechky refer to as "scaffolding" that provides "a reminder of which tasks still need to be done, and who needs to do them, in order to complete the work" (Okhuysen and Bechky 2009). In addition, as has been shown in relation to the processes of reviewing and iteration such as the milestone review meetings highlighted in the findings, the milestone schedule is also important in terms of a more general function of "mobilising discussion and action" (Okhuysen and Bechky 2009). As has also been shown, however, all the objects studied were found to be engaged in a multiplicity of roles, highlighting "the ambiguous nature of objects, the difficulty of defining them and, inevitably, problems associated with their study" (Engestrom and Blackler 2005). In order to deal with this multiplicity and ambiguity, it is important to analyse the objects encountered in relation to the "material and discursive assemblages" that they are part of and that link people with other people, people with things, and things with other things (Muniesa, Millo et al. 2007). Seen in this light, objects are not simply a representation, but are performative, contributing to and shaping the development processes studied in many different ways (Callon 1998; Muniesa, Millo et al. 2007)

The research settings in which these objects and their relation to coordination were studied share many of the characteristics of the kind of post-bureaucratic or heterarchical organisation studied by Kellogg, Orlikowski, and Yates (Kellogg, Orlikowski et al. 2006). The computer games studios studied were relatively un-hierarchical, with work taking place in temporally varying and often cross-specialisation teams and generally de-centralised decision making. While in terms of staff plans, personnel on all three sites were classified as belonging to functions such as design, art, programming, or production, there were also examples of cross-cutting teams such as animation that illustrated some of the problem encountered at the sites in terms of the identification and definition of boundaries in the actual work of developing computer games. Instead of the clear specialisations found in the staff plans, boundaries in terms of the work team members undertook were found to be fuzzy, permeable, and shifting during projects. Furthermore, as has been shown in the findings, a significant degree of emergence in terms of the specification of the new product being developed was also encountered, with many features and innovations emerging – or taking more explicit shape – in the development process rather than being specified in detail during some clearly demarcated design stage. In addition, many of these features were of a subjective, intangible, and difficult to represent nature concerning aesthetic and experiential aspects of the game.

Many of the kind of "practices of display, representation, and assembly" put forward in relation to co-ordination at a web-based interactive marketing firm my Kellogg, Orlikowski, and Yates can also be discerned in the setting of computer games development (Kellogg, Orlikowski et al. 2006). Furthermore, there were occurrences of the kinds of exchange interactions Kellogg, Orlikowski, and Yates refer to as constituting "trading zones". At the same time, it is also clear from the

findings presented that many of the approaches to co-ordination across boundaries seen as not applicable "in dynamic conditions, to nonmanufacturing firms, or within loosely coupled and heterogeneous communities" (Kellogg, Orlikowski et al. 2006), were not only present, but also central to co-ordination in this setting.

The narrative of the concept book, for example, at its most rudimentary provides a sketch map of the interrelations among entities in the game that need to be first brought into existence and then associated with one another. At another level, however, the contributions made from across functions and types of expertise in order to bring a concept book into being also provide an initial platform of shared understanding of what the game to be developed will be like. It not only has syntactic and semantic functions (Carlile 2002), but also provides the space within which the inputs and contributions of different functions to the future game are compared, negotiated, evaluated, and ultimately collectively judged when decisions regarding what to be put in and what left out are made. These pragmatic considerations and the interdependencies and entanglements that are surfaced – but also put into place – by objects such as the concept books, are part of the kind of pragmatic knowledge boundary-spanning that Carlile refers to in relation to the forging of a new "common knowledge" when novelty is encountered in new product development (Carlile 2004).

The informational and syntactic dimensions (Carlile 2002) of the development of computer games can also not be ignored in favour of the looser arrangements described by Kellogg, Orlikowski, and Yates (Kellogg, Orlikowski et al. 2006). This can be seen from the prominent role of the game design document and accompanying art design document and technical design document. It is clear that they are not just plans. These artefacts are crucial in the translation of the narrative of the concept book presented using a combination of pictures, words, numbers, timelines, and tables into the objects – "common lexicon" (Carlile 2004) – that make up a computer game (characters, levels, quests, functionalities, objects, environments etc), naming them, listing them, outlining their technical parameters, setting out their limitations, providing the syntaxes for the articulation of these with the existing computer code of the game engine, and making yet more interdependencies explicit.

Furthermore, these documents also had important pragmatic roles in terms of framing the interaction and negotiations among the different specialisations involved in developing the games. Print-outs of the relevant sub-documents from the game design document would usually accompany all but the most ad hoc interactions among different specialists, providing a common reference regarding what assets were needed for a particular level, why they were needed, why they needed to be in a particular way, where they would be placed, what dimensional and other specifications and limitations had to be met and so on. It is important to note that these are not only technical and procedurally important issues but ones that were found to be important loci of innovation as it was around these characteristics that negotiations regarding the more subjective aspects of the games would take place as shown in relation to the review meetings described. It would be out of these tensions and their resolution and trying to push the limits as far as possible that valuable and often unexpected new features would be generated.

Finally, the persistence over time and durability of the artefacts studied means that they also have important functions in terms of capturing key facets of emergent common knowledge that results out of negotiations relating to the reconfiguration between common and local domain-specific knowledge that is needed when dealing with novelty (Carlile 2004). The importance of this collective memory function of the documents encountered cannot be overstated, especially as games become increasingly complex and with many thousands of assets, and increasing pressures of time and resources on the development process. It is very important for a developer from any specialisation in the team to be able to look-up things that may have been decided and even produced many months previously and remember how and why they were done like that and how they need to fit in with other elements of the game already developed or in the process of being developed at a different temporal location.

While much of the literature about objects and coordination draws on the concept of boundary objects (Gerson and Star 1986; Henderson 1991; Bowker and Star 1999; Carlile 2002; Carlile 2004; Levina 2005; Levina and Vaast 2005), the empirical findings show this view of objects in relation to collaboration and coordination as too restricted to concerns with sense-making and the establishment of shared meaning. The objects studied here were found to have a multiplicity that goes beyond issues of common meaning. Kellogg, Orlikowski, and Yates also raise an important point regarding the notion of boundary objects in relation to organisations operating in fast-paced and dynamic settings, pointing out that a certain closure in relation to interpretations, values, and interests is presumed so that "differences and dependencies can be acknowledged and accepted" and built into objects (Kellogg, Orlikowski et al. 2006). They argue that in organisations in which change is ongoing, "attempts to construct shared mechanisms such as boundary objects are difficult because ideas and knowledge are changing too rapidly to be effectively inscribed within objects" (Kellogg, Orlikowski et al. 2006). It has been shown here, however, that through their open-endedness a number of shared objects can perform these roles in the management of coordination in an organisational setting characterised by a need for continuous innovation, emergence, a product with difficult to represent experiential and aesthetic features, and lack of formal rules and hierarchies. For example, in the combination of game design documents and milestone schedules the emergence involved in the development of the computer games is recorded, making visible how high-level known but underdetermined features become broken down and increasingly defined through the development process, or how and why features seen initially as promising are abandoned.

What was found in this research was that emergence requires emergent coordination. To deal with emergence of tasks and work and the unavoidable under-determinacy of developing computer games, coordination and many of the mechanisms of coordination encountered had to be emergent. As Kellogg, Orlikowski, and Yates point out, co-ordination in such settings is an on-going achievement rather than a fixed structure (Kellogg, Orlikowski et al. 2006). The empirical account provided, however, shows that this does not preclude the kind of work involved in bridging syntactic, semantic, and pragmatic boundaries proposed by Carlile and seen of less relevance to heterarchic or post-bureaucratic organisations involved in "high-pressure, project-based" work with unpredictable

demands and volatile conditions (Carlile 2004; Sapsed and Salter 2004). What was found instead was that in order to deal with the emergence encountered in this setting, the game development teams studied worked hard and invested significant resources into finding ways of accessing the intuitive, embodied, tacit skills, knowledge, and experience of the developers and finding ways of surfacing and capturing these and translating them into the existing coordination mechanisms employed. And as has been shown, objects played a vital role in the accessing, capture, and presenting back to the developers in this way many emergent features of the new games being developed.

At the same time, there was a constant vigilance and concern among the teams studied regarding the adequacy of existing coordination mechanisms, the objects and tools involved, and how to improve them. This resulted in a significant degree of experimentation with ways of developing a shared understanding of emergent and difficult to represent features of the games being developed and ways of better coordinating the production process through often improvised solutions based on spreadsheets, wikis, blogs, and online discussion forums that, if successful were then gradually formalised and polished technically.

For the games developers studied, formal and emergent, tight and loose, flexible and rigid aspects of coordination were not mutually exclusive. What was seen as important across all three sites was achieving the right balance. It is suggested, therefore, that what is important instead is to see how these are related and reconciled. And because objects and artefacts were found to play crucial role in terms of translating between the two and framing interactions among the developers in a way that gives some stability and durability without reliance on formal institutions and hierarchies, they provide an important empirical focal point to the study of coordination in settings characterised by emergence, lack of hierarchy, and clear disciplinary or occupational boundaries.

Conclusion

Drawing from the setting studied that is characterised by technological intensity, creativity, continuous new product development and collaboration between individuals from backgrounds as diverse as art, design, and computer programming and with widely differing ranges of embodied skills and expertise, the article has sought to demonstrate the central importance of objects and artefacts in the coordination needed for the progressive realisation of new computer games title. This was found to be especially the case in these settings because they involve much ad hoc collaboration without always having recourse to formal organisational arrangements and hierarchies.

Furthermore, with sensory user experience and aesthetic considerations shown to be of primary importance, insights into coordination processes that seek to bring together non-explicit and aesthetic as well as technical forms of expertise were also provided, contributing to the development of theorisations aiming to link coordination with creativity and innovation (Bodker 1998; Carlile 2002; Hargadon and Bechky 2006; Ewenstein and Whyte 2009).

By providing an empirical account of the material work of coordinating and

cooperating in a setting of technological intense creativity and innovation, the article provides empirically-based insights of relevance to the relationship between the process of coordinating and the emergence of innovation, whether coordination itself can be considered as a form of creativity, and how coordination changes over time.

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