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On technological objects and the adoption of technological product innovations: rules, routines and the transition from analogue photography to digital imaging

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We extend the transformational model of social activity proposed in recent realist social theory by importing into it a theory of technological objects and technological change. The paper begins with an account of the transformational model, focusing particularly on the relationship between routines and social rules. We then outline a theory of what we call the 'technical identity' of technological objects, drawing on the notion of collective assignments of agentive functions proposed by the philosopher John Searle. Finally, we link this theory to the transformational model and derive three broad categories of technological change. The framework as a whole is illustrated with empirical material drawn from a recent study of the shift from analogue photography to digital imaging in consumer photography.

Key words: Social rules, Routines, Technological objects, Technological change, Analogue photography, Digital imaging
JEL classifications: L1, L2, 03K

1. Introduction

The purpose of this paper is to develop a general framework within which to think about technological objects and the adoption of technological product innovations from an interactionist perspective. Our point of departure is the transformational model of social activity (TMSA) proposed in recent realist social theory (Archer, 1995, 1998; Bhaskar, 1979; Lawson, 1997, 2003), and what follows is an attempt to introduce into this model a theory of

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the technical identity of technological objects and how such objects come to be part of the social world.

The paper is structured as follows. We begin in the next section with a brief overview of the TMSA before honing in on the subject of social rules, routinised practices and their interconnection. In the process, we draw some parallels between our approach to routines and the work of Feldman and Pentland (2003, 2005) and show in what respects our approach may be regarded as an extension of theirs. The material on social rules and how they relate to practices provides the link between the TMSA and what we call the 'technical identity' of technological objects. This last idea is developed in Section 3, where we appropriate John Searle's (Searle, 1995, 1999, 2001, 2004) notion of collective assignments of agentive function and show how these contribute to constituting technological objects in the communities in which they have currency. Section 4 provides a conceptualisation of technological change consistent with our theory of technological objects, and Section 5 illustrates the theory with empirical material drawn from an extensive study on the transition from analogue photography to digital imaging in consumer photography. We close with some concluding thoughts in Section 6.

2. Agency, structure and the routinisation of social activity

The TMSA is perhaps best described as an abstract representation of social organisation that steers a path midway between the extremes of pure individualism and pure holism. It does so by focusing on the interaction between human agency and social structure in the emergence, reproduction and transformation of social phenomena, rather than on attempting to explain social phenomena by focusing predominantly on human agency or social structure alone (Bhaskar, 1979; Lawson, 1997, 2003). We begin with a brief overview of the core features of the TMSA, before moving on to the topic of rules and routines that will concern us later in the paper.

2.1 The transformational model

The TMSA offers a particular view of agency, structure and the relation between the two. We will take these three aspects in turn, beginning with agency. Agency is a slippery term because it is used variously to refer to human actors, to human capacities and dispositions, and to human activities. For the most part, in what follows, we will refer to agency in the last sense, i.e. to what human actors do and, specifically, to their routinised practices. But we will also refer to human capacities and dispositions. By human capacities we mean abilities such as our being able to apply reason to our affairs, to learn a new language or to collaborate with others. By dispositions we mean our propensities or inclinations to act in certain ways, such as to tell the truth, to attempt to avoid pain, or to look after our offspring. Human activities are a manifestation of human capacities and dispositions in operation (amongst other things), and range from deliberate actions guided by conscious reasoning through to routine behaviour issuing from tacit knowledge. People's capacities and dispositions are not always manifest at the level of behaviour. For example, while most of us have the capacity to follow written instructions, or may be generally disposed to telling the truth, we may fail to do either of these things in times of emotional turbulence or when we are under duress.

The second core aspect of the TMSA is its emphasis on social structure, the social rules, relations and positions that structure human activity. Space constraints preclude going into detail on each of these categories here (see Lawson, 2003, pp. 28–62), but take for example

the case of social positions such as CEO, University Professor or mother. Each of these positions involves various routines, roles and duties, the performance of which is generally associated with and expected of the people who occupy them. These routines, roles and duties, in terms of the TMSA, are in turn underpinned and informed by various rules, which, taken together, define and shape the roles concerned (both for incumbents and for those who interact with them).

The third and final aspect of the TMSA that we want to highlight is its emphasis on (i) the recursive organisation of agency and social structure and (ii) the generally unintended nature of structural reproduction. The first element is captured by what Giddens (1984) calls the duality of structure, that social structure is constantly reproduced as an ongoing consequence of human activities, where those same activities presuppose the very structures that are being reproduced. The second element is captured by what Bhaskar (1989, pp. 92–3) calls the duality of praxis, which is that while human activities are generally consciously directed at intended ends, their contribution to structural reproduction is generally unconscious and unintended. Thus, it is by filling the positions of CEO, professor or mother, and performing the various routines associated with them, that individual actors unconsciously and unintendedly contribute to the reproduction of these position and their associated rules and routines over time. Further, since neither rules nor routines are ever followed deterministically, there is the always the possibility of variations and innovations in behaviour that, where they catch on and spread more widely, may lead to their transformation over time.

This completes our brief account of the essentials of the TMSA. We are now in a position to proceed to some of the specific social phenomena that will concern us later in the paper. We begin with one of the most striking features of social life, namely the extent to which human activity takes the form of, and is embedded in, routinised practices or simple 'routines'. The pervasiveness of routines is indicative of the considerable 'pull' that social structure in general, and social rules in particular, seem to have on human activities. But what exactly are routines and how is this 'pull' exercised?

2.2 Rules and routines

To answer these questions, it is necessary first to say more something about social structure and, specifically, about the nature of social rules. By social rules we mean generalised procedures of action that can be expressed by appropriate transformations of the formula 'if x do y in situation c', where 'do y' should be interpreted liberally as a placeholder for injunctions such as 'counts as', 'take to mean', 'refrain from', etc. (the 'if x' and 'in situation c' parts of such injunctions are often suppressed in ordinary language, e.g., in statements such as 'publish or perish' or 'keep left') (Lawson, 2003, pp. 36–9).

Three key characteristics of rules will come to the fore in what follows. The first is that social rules are normative, namely that in situations in which some social rule is accepted, if it is the case that x in situation c, then one ought to do y. This normativity is reinforced by the possibility of sanctions against those who fail to conform to the rule. That is to say, people who are seen to break social rules are often judged to have acted wrongly or inappropriately and can expect some form of disapproval or even punishment.

The second characteristic is that social rules have both constitutive and regulative powers. In their constitutive aspect, social rules make possible certain kinds of activity. For example, and looking forward a little, a rule such as 'an object with a view-finder, lens, liquid crystal display (LCD), some form of image capture device (a charged-coupled device or some

combination of image sensors), etc., has the function of capturing digital images' contributes to constituting what we call digital cameras and, by extension, to the ongoing practices associated with digital photography. In their regulative aspect, social rules regulate antecedently existing activities, such as the activity of photography being regulated by the rule that flashlights are forbidden during the Wimbledon final. The third, final, characteristic is that while social rules sometimes arise through deliberate thought and planning, they often emerge and evolve in ways that are not the product of conscious design.

Although their persistence depends in continuing to be implicated in human activities, social rules are a form of social structure rather than a form of human activity. The human-activity counterpart of social rules we will concentrate on here are routinised practices or routines. By routines we mean standard procedures that are regularly enacted, i.e. one or a series of actions that are regularly performed in accordance with one or more rules. There are various things to note here. First, we regard routines as a manifestation of human activity rather than a mere potential, and we thus depart from authors such as Hodgson (2005) who see routines as phenomena that may be latent, i.e., as 'stored behavioural capacities or capabilities'. Second, from our perspective, routines involve not one but two kinds of regularity: (i) the regularity expressed by the rule being followed (the 'if x do y' aspect) and (ii) the regularity that arises in the repeated enaction of that rule. A rule followed only once does not constitute a routine. Third, we use the term 'routine' to cast a wide net that includes what are sometimes called 'recurrent practices' (or simply 'practices') and conventions, as well as standard procedures performed by single individuals in isolation of what others are doing. In this last respect we depart from the organisational literature, which tend to characterise routines as a 'recognizable pattern of interdependent actions, involving multiple actors' (Feldman and Pentland, 2003, p. 96, 2005; see also Becker, 2004, pp. 646–8; Cohen et al., 1996; Cyert and March, 1963; March and Simon, 1958; Nelson and Winter, 1982, p. 73). We retain the possibility of routines that do not involve interdependent actions of multiple actors because the use of technology often involves individuals using technological objects in ways that do not entail the direct involvement of others, and also because initially idiosyncratic 'private' routines may become important sources of innovations in how technological objects are used if they catch on.[1]

Central to our enquiry is the nature of the causal relationship between social rules on the one hand and routines on the other. We accept that there may be cases in which individuals might start behaving in some regular way in the absence of any causal connection with a specific rule, such as when colleagues spontaneously start gathering at the same table for lunch. While social rules are sometimes invoked to describe regularities of this kind, this is legitimate only to the extent that the rule is used to describe the regularity rather than something that contributes causally to its reproduction (at least until the people involved begin to notice and feel that there is something wrong when someone departs from the routine, at which point the rule has begun to acquire normative force in virtue of which it does begin to play a causal role in affecting behaviour). However, the idea that routines (agency) presuppose rules (structure) implies that, in general, a causal connection exists. What then is the nature of this connection?

[1] A good example of this kind of phenomenon is the innovations in the practices of hip-hop 'turntablists' that led to the gramophone turntable becoming regarded as a musical instrument in it is own right rather than merely a means to provide faithful reproductions of pre-recorded performances (Faulkner and Runde, 2008; Souvignier, 2007; Webber, 2003; White, 1996).

There seem to be three ways in which regularities in behaviour may be caused by rules. The first is where people follow a given rule or set of instructions in a conscious and deliberate way, such as when someone is being taught where to distribute their weight by a snowboarding instructor, or is following the steps in a manual to print digital images from a home computer. This kind of rule-following, however, is not particularly relevant for our purposes since routine behaviour implies a certain ingrainedness, automaticity and expertise in the relevant activity. That is to say, it is precisely where an activity is not routine that one goes to an instructor or consults a manual. The second kind of rule following is where people have learned rules in an explicit, discursive way, but where, with practice, these rules have dropped from the forefront of their consciousness (e.g. where they have become expert users of Microsoft Word and can use various functions of the programme without thinking about it). This form of rule following is an expression of tacit knowledge that may be recoverable at the conscious level, at least to the extent that the individual actor can recall the relevant rules.

The third, and perhaps most interesting, case is where people act in accordance with rule structures without following the relevant rules consciously or subconsciously. Searle (1995, pp. 137–47) suggests that, instead of describing people as behaving as they do because they are following the rules of some institution, they might often be more accurately described as behaving as they do because (i) they have a structure that disposes them to behave in that way, and (ii) they have become disposed to behave in that way because that is the way that conforms to the rules of that institution (and it is in being activated and exercised that such dispositions cause the behaviour that turns out to be in accordance with the rules). The dispositions that Searle has in mind form part of what he calls the 'Background' a reservoir of non-intentional 'capacities, abilities, tendencies, habits, dispositions, taken-for-granted presuppositions and ''know-how'' generally' (Searle, 1999, pp. 107–8), and where the relevant rules are generally not recoverable in discursive form and perhaps only recognisable when they are breached.[1] The Background is a precondition for all our activities whether or not they are guided by discursive knowledge, ranging from our use of language, recognising and interacting with the objects that populate our everyday lives, through to the performance of particular tasks and roles.[2] Given that our Background abilities are mostly tacit, all of our activities involve tacit knowledge at some level.

[1] Intentional mental states are mental states that are *directed at* or *about* something. Thus your believing x, appreciating x, or intending x are all intentional states because they are all directed at x. Searle defines the Background as the set of non-intentional or pre-intentional capacities that allow intentional mental states to function. He does not attempt to prove the existence of the Background, preferring to demonstrate it by way of examples. His favourites deal with how the Background enables linguistic interpretation. Consider the following statements:

John hit Paul
John hit his stride
John hit the roof

Each sentence shares the same basic form, 'x hit y', but what we understand by 'hit' clearly differs in each case. Hearing that John hit Paul does not lead us to imagine him becoming comfortable in some activity. Nor do we imagine him losing his temper when we are told that he has hit his stride. Searle's point is that our ability to come to the right interpretation without engaging in any conscious act of interpretation (and that it is very hard to say how we do so) is one manifestation of our Background abilities.

[2] See Fotion (2000), Searle (1995, Ch. 6, 2001, Ch. 2), Nightingale (2003) and Runde (2002) for more on the Background, intentionality and intentional causation.

2.3 The performative and ostensive aspect of routines

Before we move on, it may be useful to compare our account of the relationship between rules and routines with the important distinction between the performative and ostensive aspect of routines proposed by Feldman and Pentland (2003, 2005). The performative aspect, 'the specific actions taken by specific people at specific times when they are engaged in an organizational routine', corresponds to the action that is regularly enacted when people are engaged in routine behaviour in our scheme. The ostensive aspect, that which embodies 'the abstract idea of the routine' (Feldman and Pentland, 2003, p. 95) and 'shapes our perception of what the routine is' (p. 101), plays a role similar to that which the rules mentioned above play in our scheme. While Feldman and Pentland acknowledge the importance of rules, they are wary of identifying the ostensive aspect of routines with rules. One reason for this is that they want to avoid treating behaviour as being determined by rules and, in particular, to maintain a conception of the ostensive aspect of a routine that allows for subjectivity and change in the way that individuals follow it (Feldman and Pentland, 2005, p. 797). This stance opens the possibility of variation, selection and the adaptation of new routines (see also Feldman, 2000, 2003; Feldman and Pentland, 2003; Feldman and Rafaeli, 2002). There is, however, no issue between us here. There is always an infinite number of ways of behaving in accordance with some rule, and many social rules offer scope for minor departures without significantly disturbing the routines in which they are reflected. Further, such departures may be a source of variation that leads to the adaptation and transformation of existing routines. In short, we accept that routines are not strictly determined by rules. Even committed rule-followers such as law-abiding drivers in the UK sometimes depart from the rule—and the associated routines—that they should not cross the solid white line when they have to get past a stationary car on a narrow road.

A further reason that Feldman and Pentland appear to want to avoid treating the ostensive aspect of routines purely as rules has to do with the fact that instances of human behaviour that look to be the same from the viewpoint of an external observer, might nevertheless be an expression of quite different rules, a point driven home by Wittgenstein (1958) a long time ago. We certainly agree with this point, but would argue that Feldman and Pentland's scheme suffers from exactly the same sort of difficulty: different instances of what may appear to be the same routine in their performative aspect may nevertheless issue from quite different ostensive bases. In any event, we will proceed on the basis that it is often possible to identify the rule or rules that inform some routine, given that what we mean by 'the rule' is interpreted so as to allow for some variation across time and space, and in how different people might describe or state it. Of course that leaves the difficult question of how to decide where to draw the line when variations of the same rule become so large as to begin to look like different rules. But again, that is a difficulty that afflicts Feldman and Pentland's scheme as much as it does our own.

So much for the similarities. What about the differences? In our view there are three that are particularly significant. First, unlike Feldman and Pentland, and for the reasons already given above, we allow for the possibility that actors might follow the same or similar routines without interacting with other actors in their acquisition and subsequent performance. This might happen, for example, where otherwise separated individuals develop the same or similar routine simply by following the rules or procedures specified in a manual. Second, our account of routines is meant to apply to the routines people follow in all walks of life, rather than focusing specifically on organisational routines within organisations such as firms universites and so on. And finally, and most significantly, on

our account technological objects are not only implicated in the performance routines—in their possible codifying, prescribing, enabling and constraining roles (Feldman and Pentland, 2005, p. 795; Orlikowski, 1992, 2000)—but are partially constituted by rule/routine structures. Our emphasis on social rules is important here, because, as we will reveal in the next section, it is social rules in the form of collective assignments of function that provide the crucial connector between the myriad physical objects that surround us and their technical identity.

2.4 Summary

We have presented a brief account of the TMSA and spelt out some of the causal connections between rules and routine behaviour (as issuing primarily from tacit knowledge and Background capacities). In the process, we hope to have highlighted the ongoing, processual nature of socio-economic activity and the relative stability of social rules and the practices they govern, while at the same time retaining the possibility of individual agency and the transformation of routines. We now turn to the question of how technological objects fit within this scheme.

3. Locating technological objects in the social world[1]

Technological objects such as cameras, computers and cars are so much part of day-to-day life that they seem as real and concrete as mountains and trees. Yet this ready familiarity masks the fact that what we will call their 'technical identity'—what the objects are in the communities in which these identities have currency—is in fact a social phenomenon of some complexity. The source of this complexity lies in that technical identities depend not only on the physical properties or form of the objects to which they attach, but also on the intended use, 'for-ness' (Kroes and Meijers, 2006), or function of those objects in some community.[2] This dual dependence can be seen from the fact that we tend to think of and describe technological objects not only, or even primarily, in terms of their physical characteristics, but in terms of their function. Thus, we think of razors as implements used for shaving, pens for writing, 35mm cameras for capturing still images, and so on. A key consideration here is that functions are always relative to the purposes, goals and values of those who assign them and therefore never intrinsic to the object to which they are assigned (Searle, 1995, pp. 14–19). Thus, while the physical properties of technological objects generally have to be such as to allow them to perform their function, these properties alone do not determine their function and, accordingly, their technical identity. Further, the functions assigned to objects have a normative quality, insofar that an object that has some function x is supposed to cause or lead to x.

If functions are not determined by the physical properties of the things to which they are assigned, how is it that most of the technological objects that surround us appear to have

[1] The material in this section summarises and expands on arguments that are more fully worked out in Faulkner and Runde (2008), and which shares the Delft 'Dual Natures' research project's aim of developing 'a coherent conceptualization of technical artefacts, taking into account their dual nature as (i) designed physical structures which (ii) realise intentionality-bearing functions' (Kroes and Meijers, 2002, p. 6). Clive Lawson (2007A, 2007B, 2007C) brings technological objects into the TMSA in a way that is similar to ours in many respects, but in which he distances himself from Searle's emphasis on functions.

[2] See Kroes and Meijers (2000B) for detailed discussions of the 'dual nature' of technical artefacts. Note that while we regard the function of a technological object as being a social property, we do not claim that assignments of function exhaust the social in relation to any particular object. Thus the use of technological objects may have psychological, ethical, political, etc. implications that stretch well beyond their function in the sense that we interpret it here.

a stable and generally accepted technical identity? Why is it that while the CD on our desk could just as easily serve as a coaster on which to place our coffee mug, the penknife in our pocket could just as easily serve as a screwdriver, and so on, we know that the CD is 'really' a CD, the penknife 'really' a penknife and not a screwdriver, and so on? The answer to this question seems to lie in some kind of generalised, collective agreement about what the functions of particular kinds of objects are. We will now attempt to spell out some of what is involved here.

Following Searle (1995, p. 20), we will call uses that conscious agents assign to objects in pursuit of their interests as 'agentive functions', the general form of which can be expressed by the formula 'the function of x is to y'.[1] It is possible for agentive functions to be assigned by individuals in a private way, such as where someone uses a CD as a coaster. More interesting, however, is the case of what Searle calls 'collective assignments of function', functions that are assigned to objects collectively by members of a social group. Searle (1995, pp. 31–51) is particularly interested in collective assignments of function without which the object to which the function is assigned could not perform its function (e.g. bits of paper serving as a medium of exchange, as opposed to a screwdriver that can perform its function purely in virtue of its physical characteristics). However, functions are collectively assigned to technological objects too, even where their physical constitution is sufficient for them to perform their function even in the absence of any collective agreement about what this function is. And it is the collective nature of such assignments that reflect a community's agreement about the technical identities of particular classes of objects, and on the basis of which its members are able to distinguish between different kinds of technological object and to distinguish their 'proper' functions from their accidental functions.[2] Collective assignments of function are thus a form of social rule that contribute to constituting the technical identities of the objects concerned, and thereby, in a derived way, to constituting the activities in which those objects are implicated, such as the function collectively assigned to the object we call a camera helping constitute the activity of photography.

The link with the TMSA will be apparent by now. The agentive function of objects and the technical identities these help to support are sustained as part of our taken-for-granted social world in virtue of being unintentionally reproduced in action in the same way as described in the previous section. That is to say, in drawing on, or at least acting in accordance with, social rules of the form 'an item with characteristics x has the function of y in situation c', people contribute to the reproduction of those rule, which are then drawn on in subsequent rounds of activity. Of course we are not claiming that people actually think about the familiar technological objects that surround them in terms of explicit formulations of this sort. They merely see the objects concerned and know immediately what their

[1] Agentive functions, in Searle's scheme, are distinct from nonagentive functions that we sometimes assign to naturally occurring phenomena in the course of giving a theoretical account of those phenomena (e.g. that the function of the heart is to pump blood). While assigning functions to objects is a distinctly human activity, some animals have shown the ability to do so too, e.g. wild Capuchin monkeys that apparently use stones as 'hammers' and 'anvils' to crack nuts (Fragaszy *et al.*, 2004).

[2] Kroes (2003) criticises Searle for appearing to suggest that ('causal') agentive functions assigned to technological objects are determined by their 'sheer physical features' (Searle, 1995, p. 45), in which case there would be no need for collective intentionality in establishing the technical identity of technological objects. Since Searle also stresses the role of collective intentionality when functions are assigned to objects, Kroes concludes that there is an inherent ambiguity in Searle's account. Space precludes our going into detail in this issue, so we will merely note that we take the view that collective assignments of function are indeed partly constitutive of the technical identities of technological objects and, contra Searle, in this respect no different to what Searle calls the status functions that attach to objects that can only perform their function in virtue of the function collectively assigned to them.

technical identities are and entail, i.e. the ability to identify and interact with technological objects in the appropriate way, at least the ones that we are familiar with, appears to be a manifestation of the kind of 'Background' abilities mentioned above. The nature and content of the 'agreement' reflected in collective assignments of function is therefore generally implicit and sustained as an unintended consequence of peoples' ongoing activities through time (although there are exceptions here too, such as where a group of people explicitly agree to use two pairs of garden chairs as substitute goalposts in an informal football match). In short, collective assignments of function and the technical identifies they inform are as much part of social structure as the rules of language, the rules of the road and the rights and responsibilities of CEOs.

To say that technical identities are part of social structure is, however, not to say that they could not have been different or that they cannot change. Further, and as we will go on to discuss below, the emergence of, and changes in, technical identities may emanate purely from how people conceive and use technological objects. This idea is closely related to, and in many respects overlapping with, the concept of the 'interpretive flexibility' of technological artefacts associated with the Social Construction of Technology (SCOT) approach in technology studies (Bijker et al., 1987). Appropriated from the relativist programme in the sociology of scientific knowledge (Barnes, 1974; Bloor, 1976), interpretive flexibility refers to the idea that 'technological artefacts are culturally constructed and interpreted ... not only that there is flexibility in how people think of or interpret artifacts but also that there is flexibility in how artifacts are designed' (Pinch and Bijker, 1987, p. 40; see also Pinch, 1996). The concept has been central to an important series of studies of the evolution of technologies ranging from bicycles, bakelites and bulbs (Bijker, 1995) to ultracentrifuges (Elzen, 1986) and ultrasound scanners (Yoxen, 1987).

Space precludes our detailing the affinities between the idea of interpretive flexibility and the theory we have been proposing (but see Fanlkner and Runde, 2008). It is nevertheless worth noting that our theory might provide the resources to counter some of the criticism that SCOT has received for being overly agent-centred, and for underestimating the influence of social structure (Russell, 1986) and especially the conditioning effect of social rules (Klein and Kleinman, 2002). The reason for this is that, in our approach, the technical identity of technological objects is something that flows from collective assignments of function to those objects, which, as social rules, form part of social structure. So, while there is a sense in which technological objects are what they are partly in virtue of what people in a community think about them, this does not mean that they can be whatever any individual thinks them to be. Experience shows that many social rules are highly stable and resistant to change, and this is also true of the social rules underpinning the technical identities of most of the technological objects that surround us. Technological change is always something that occurs within a context of deeply embedded rule structures, and therefore something that often requires deliberate and concerted intervention, the exercise of power, favourable circumstances, etc., and that deliberate attempts to initiate it or set it on a particular path do not always succeed. Proponents of the SCOT approach are, of course, fully aware of these factors, but without always making explicit the social-structural aspects of assignments of function and the technical identities supported by them.

We finish with five quick points before moving on. First, if functions are always relative to the interest of those who assign them, it then follows that the technical identity of technological objects is always relative to the community in which those functions are collectively imposed or assigned. In many cases this community is a large one, as reflected by the almost universal agreement about the function of commonplace items such as knives,

watches and chairs. But in other cases the community and the relevant function, may be smaller and more localised, such as the hip-hop DJ/turntablist community in which the gramophone turntable functions as a musical instrument. Second, there are items that have a specific function locally but where the function in question—and hence the technical identities of the objects concerned—is not known outside that locality, e.g. dedicated tools used in specialist activities, or artefacts residing in museums that were clearly technological objects at some stage, but the function of which—and the associated technical identity—-have been lost in time. Third, it is quite possible for the same object to have more than one collectively-assigned function within the same community, such as PCs, personal digital assistants (PDAs), and digital cameras that are able to capture both still and moving images. Fourth, it is sometimes useful to think of objects in terms of hierarchies of functions, or nested functions, e.g. the category of the camera (the function of which is to capture still images) being the superset of the category of digital cameras (the function of which is to capture still images digitally), which is itself the superset of digital cameras good for taking underwater pictures (the function of which is to capture still images in a submarine environment), and so on. Finally, collectively assigned functions may be the product of deliberate design (e.g. a memory stick as a convenient facility to transfer data from a camera to a PC) or something that emerges independently of what designers intended (e.g. the turntable being used as a musical instrument or, closer to home in the current paper, using a digital camera as an alternative to a fax or conventional scanner to create images of documents transportable via email).

4. Technological change

Thus far our discussion of the TMSA has focused on the reproductional aspect of social activity and the associated routinisation of, and continuities in, people's practices over time. However, the TMSA can also accommodate change and we now turn to the transformative processes involved in the adoption of technological product innovations. In order to proceed on this front, we need a conception of technological change that is consistent with the categories we have developed so far. The form–function dichotomy proposed in the preceding section suggests that, at least as far as technological objects are concerned, technological change must involve either (i) a change in the physical characteristics of the members of the class of objects to which the same function is collectively assigned; (ii) a change in the function collectively assigned to a class of object of a similar form; or (iii) some combination of (i) and (ii). In the interests of brevity in what follows, we refer to (i) as 'same-function-different-form' and (ii) as 'same-form-different-function' varieties of technical change. To these might be added a fourth category, (iv) radical innovations of the 'new-function-new-form variety', which covers the emergence of technological objects that had no prior existence whatsoever, such as first appearance of the camera, the aeroplane and so on. However, we will not have much to say about this fourth category below.

Note that we are not claiming that every change in form, function, or both, will necessarily lead to a change in the technical identity of the object concerned, or that there is always a clear dividing line between technological changes that are sufficient to yield a change in technical identity and those that do not. Thus, while it seems natural to say that the change in the form of the camera involved in the shift from analogue photography to digital imaging was significant enough to alter its technical identity, the subsequent miniaturisation of digital cameras, also a significant technological advance, probably was not. In other words, there is a sense in which the shift from analogue photography to digital

imaging involved a shift in the technical identity of the devices involved, which is not matched in the case of digital cameras that differ only in their size. Further, although it is possible to think of some close to pure examples of (i) or (ii) (Faulkner and Runde, 2008), many actual episodes of technological change are likely to fall into category (iii). For example, the changes in form involved in connecting the PC to what has become the internet have led to significant changes to its function, the emphasis shifting from its use as a local information storage device, word-processing tool and so on, to serving as the gateway to a global communication and information retrieval network.

Existing and emerging collective assignments of function play a decisive role in the adoption of technological product innovations, irrespective of whether the change in question actually amounts to a change in the technical identity of the objects concerned. The reason for this is that they provide the point of departure for, and a large part of the social context in which, technological change to take place. Take the same-function-different-form variety of technological change, which is probably the most common of the four categories listed above. A good example here is the transition from vinyl records to CDs, and from CDs to MP3 files in the reproduction of music, each step, in this case, involving a change in the technical identity of the players involved. Here designers and manufacturers began with an existing function and came up with new devices to satisfy that function. Similarly, when functions change the associated practices may give impetus to changes in form, such as laptops now coming supplied with a webcam for Skypeing as a standard item, or the various forms of digital players that have appeared designed to facilitate the 'scratching' techniques associated with classical turntablism in hip-hop music (Faulkner and Runde, 2008).

Of course, the activities of users during periods of technological change depend not only on (changes in) the pre-existing collectively assigned functions and technical identities of the objects concerned, but also on all manner of related, understandings, scripts (Akrich, 1992), routines, skills and so on. To organise our discussion of the interplay of some of these factors, we will use the following simple framework for looking at social change drawn from Margaret Archer's (1998) work on morphogenesis. The essentials of Archer's scheme are captured in Figure 1.

Although Archer (1998, pp. 376–7) makes a number of careful distinctions between her own approach and the TMSA, the schema represented in Figure 1 is, in many ways, a fairly straightforward temporal elaboration of the TMSA introduced in Section 2. As before, the guiding idea is that episodes of social interaction are conditioned by pre-existing social structure. Some of these interactions lead to the reproduction of structures, others to their transformation, and in both cases as the unintended consequence of prior rounds of social activity. These structures, both those that are reproduced and those have been transformed, then go on to condition subsequent rounds of social interaction. Thus, in Figure 1, the period of social interaction beginning at T^2 is predated by existing social structure at T^1, the unintended product of prior rounds of social activity. The social interaction that occurs between T^2 and T^3 leads both to the reproduction of some aspects of social structure (morphostasis) and to the transformation of others (morphogenesis). Structure at T^4 then provides the underpinning of subsequent rounds of social activity.

We need to make one simple modification to the model in Figure 1 before we proceed: while we agree that much, if not most, of social structure is an unintended consequence of human interaction, we need to retain a place for changes to social structure that are deliberately engineered, or are at least the partial product of deliberate efforts to shape them. Remember that collective assignments of function are an important element of social

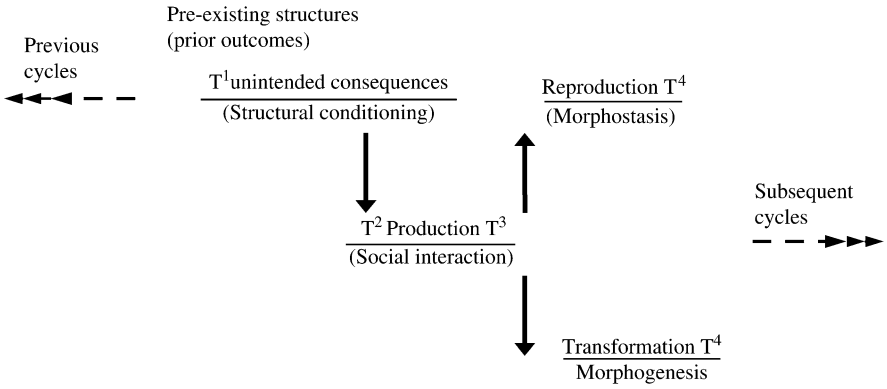

Fig. 1. *Transformational model of change (Archer, 1998, p. 376).*

structure in the present context, and that many (variations of) collective assignments of function are the product of deliberate social agency. That is to say, designers and manufacturers attempting to influence and create markets for technological product innovations are often in the business of attempting to influence assignments of function, be it by encouraging new ones, attempting to support existing ones that may be under threat from technological change but which they nevertheless have an interest in sustaining, or by combining existing functions in new technological objects.

So far we have sketched an abstract picture of a structured social world in which routines reflect more or less stable rule structures, including the collective assignments of function that define the technical identity of the myriad technological objects that we routinely interact with. If the social world is indeed organised on the lines that we have been describing, then it seems unlikely that the adoption of technological product innovations will ever take the form of a seamless switch from the old for the new. Instead, it is more likely to be a gradual, uneven and unpredictable process of adjustment that is dependent upon and conditioned by the (pre-existing) rules and routinised practices associated with forerunner technologies. Social rules and routines take time to change, and indeed there is no guarantee that they always adjust in ways that allow newer, even manifestly superior, technologies to supplant what is already on offer (David, 1985). Further, even where large-scale transitions to a new technology eventually occur, the rate of transition is likely to vary across different localities, depending on factors such as acquisition and switching costs, availability of complementary technologies, geographical location, social context and the positions of the people involved. Indeed, pre-existing technologies may endure alongside newer technologies for significant periods, all the more so when incumbents are able to exploit these factors effectively in their efforts to protect traditional sources of revenue (Munir, 2005).

5. An illustrative case: from analogue to digital in consumer photography

To illustrate the ideas that we have been developing, we will now look at some aspects of the transition from analogue photography to digital imaging in consumer photography. It is well known, that this has been an enormously disruptive episode for incumbent firms (Munir, 2005), and has led to significant changes in the structure of the industry with the

entry of consumer electronics firms not formerly associated with popular photography.[1] Sales of digital still cameras now exceed those of analogue cameras in major markets and sales of film have declined dramatically. Just over two decades after the introduction of the first commercially-available digital camera was introduced by Canon in 1986, analogue photography is close to being eclipsed by its digital competitor.[2]

As shown in Figure 2, the pivotal year for US consumer digital photography was 2003, when digital still camera sales overtook analogue camera sales for the first time.[3] The speed and magnitude of the shift was dramatic. For example, between 2002 and 2003 alone, sales of analogue still cameras declined from US$14.2million to US$11.2million (–21%), while sales of digital still cameras increased from US$9.4million to US$13million (+38%) (Photo Marketing Association International, 2005).

The more pressing concern for the companies that dominated the market prior to the 1990s, however, was less the impact of digital imaging on analogue camera sales and more its impact on the consumption of film and light-sensitive paper. Whereas the stock of analogue cameras still in use ensures that there is still a market for traditional film, film sales have been in significant decline since their peak in 2000 when they accounted for $8billion in the US alone. According to Photo Marketing Association International, US film sales declined from 786 million units in 2000 to 204 million units in 2006 and US film processing sales from 781 million rolls in 2000 to 356 million in 2006. Long-established incumbents, even industry icons like Kodak and Fuji, have gone through protracted and painful downsizings as a result.

We will now consider some salient aspects of this episode in terms of the categories developed in the preceding sections, supported by data collected over the course of a larger research project on the development and commercialisation of digital technologies.[4] For ease of exposition, we have divided our account into two parts under the headings of morphostasis and morphogenesis (but while recognising that the two types of process often play out in interconnected ways). We will concentrate on showing (i) that while the shift to digital represented a significant discontinuity at many levels, it also involved and in many respects depended upon significant continuities in practices and attributions associated with analogue photography; and (ii) how the shift reflects technological change of both the 'same-function-different-form' variety, and, to varying degrees, the 'same-form-different-function' variety.

5.1 Morphostatis

Since morphostatic social processes are, by definition, reproduced over time, it is tempting to associate them with inertia in social affairs and to view them as inhibiting the adoption of

[1] New entrants include electronics firms such as Epson, Hewlett-Packard, Hitachi, Intel, Sharp, Sony and Toshiba, software firms such as Microsoft and Adobe, and Internet service providers such as AOL.

[2] At the time of writing an early draft of this paper (8 August 2005), Dixons, a major UK electronic goods retailer, announced that it would no longer stock analogue cameras. Kodak announced that it would stop producing its traditional 35mm camera for the USA, Canada and Western Europe at the beginning of 2004 (*Guardian Unlimited*, 14 January 2004).

[3] The crossover occurred somewhat earlier in Europe in 2001.

[4] Primary data was gathered via interviews with several senior executives of manufacturing firms and photo-finishing companies between 2003 and 2005, both in Europe and the USA; an analysis of 1,006 UK and USA consumer press advertisements published between 1980 and 2003; a web-based user survey; and interviews with users. Secondary sources included company documents such as annual reports, industry reports, trade journals, business magazines and newspapers, electronic sources such as Standard and Poor's online database, Dow Jones online and Insite; and articles and industry trends reports published by the Photo Marketing Association International.

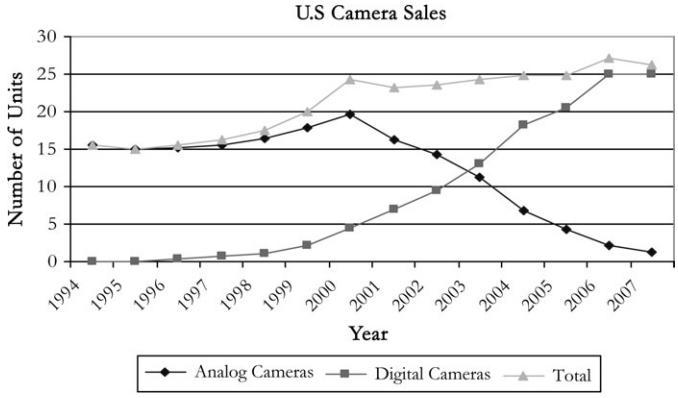

Fig. 2. *US camera sales (millions).*
Source: Photo Marketing Association International, 2007.

technological product innovations. As we will see below, there are indeed various ways in which morphostatic social processes may act as a brake on technological change. However, they also play an important role in facilitating the adoption of new products. One key reason for this is that manufacturers seeking to introduce and promote new products almost always start from pre-existing forms and functions, even in the case of quite significant innovations. In the present case, and despite the marked change in form (and accompanying change in technical identity) involved in the shift from analogue to digital imaging, the basic assignment of function that marks off digital and analogue cameras from non-cameras is the same in both cases: both are for capturing still images. Further, many of the rules and routines associated with this function have carried over from analogue to digital photography in essentially unchanged form. For example, many digital camera users continue to regard their cameras as a means to preserve memories,[1] continue to photograph their pets, and continue to conform to many of the same rules associated with camera use (e.g. that flashlights should not be used during play at Wimbledon).

The importance of the bridging role of morphostatic processes during periods of technological transition is reflected in the lengths that digital camera manufacturers went to present the new technology inside a physical package that, from the outside at least, would be as familiar as possible to users accustomed to traditional cameras. That they did so is noteworthy in view of the fact that digital imaging offers far more degrees of freedom in how camera components are arranged spatially, than does analogue photography. For example, there is no technical barrier to placing the lens, the LCD, and the camera body and power pack in separate locations. Nevertheless, despite this freedom and the various affordances that it might have provided, most digital camera manufacturers stuck to

[1] Digital camera users frequently described using a digital camera as a means to preserve memories. For example:

Because I don't want to ever forget the sweet faces of my boys. They change so much that I don't want to miss anything. I want to have some memories to share with my boys when they are older.
Memory, I suppose. For the history.
We take photographs for memories, to keep track of the kids growing up. We have also never lived in the same place as the rest of the family, so we can share the kids growing up visually with the family by sending a batch of photos out every month.
I take photographs to have a remembrance of an event. I see photos as visual record keepers.

traditional conceptions of what a camera should look like. Even now, most digital cameras continue to sport a viewfinder, possibly a skeumorph (Hargadon and Douglas, 2001) in view of how many digital camera users quickly switch to using the LCD to aim the camera, and come supplied with a synthetic click that mimics the sound of the mechanical shutter found on analogue cameras. This emphasis on maintaining continuities wherever possible with traditional photography was also reflected in the way that manufacturers tended to promote the new technology in terms of familiar functions, practices (e.g. continuing to have prints made by professional developers) and understandings (e.g. using the term 'digital film' to describe electronic storage media).[1]

Morphostatic processes also play an important additional role in technological transitions that require integration with pre-existing technologies that become complementary to the new technology. In the case we are considering here, the already widespread and rising use of PCs, home printers, email and the internet during the last half of the 1990s, provided potential adopters of digital cameras with various skills and capabilities (not to mention a significant stock of complementary devices that could often be drawn on without incurring additional expenditures) that were, or would turn out to become, relevant to their digital picture-taking activities. As observed by an industry executive:

> Obviously, the growth in computer power has been a major enabler. Ten or 15 years ago, having a 1 megabyte file was incomprehensible [to] almost any normal person with a computer and the cost [of] any kind of camera that would do anything was well beyond the reach of all but most well-capitalised professional photographers. Part of what drove it was the power of computers [and] a part of what drove it was software that began to move beyond simply using text but using images as well. People began to look for ways of getting images in the computers, which of course drove the scanner industry. For quite a while, scanning was the best way to reproduce a photograph very well ... There were a lot of things in computers [so] that people did not have to worry about printing. The world wide web began to come in to play and people began to become dependent on that for finding information and looking for images. And, e-mail started to have compressed files because you could not send a very big picture and they were great for looking at screens and the software [was] becoming very image [oriented] where having Microsoft Word and PowerPoint enabled you to drag and drop a picture under those programs and the art was that you could make a newsletter with a picture in it ... So, then, the resolution of cameras began to get better and I think that the early adopters started to pick them up just because they were interested in the technology.

While morphostatic processes may provide impetus to the adoption of new technologies at some levels, they may act in the opposite direction at other levels. Many of the themes that arise here are familiar from the literature on routines, which are often portrayed as sources of inertia (Hannan and Freeman, 1983) or inflexibility (Gersick and Hackman, 1990; Weiss and Ilgen, 1985) in the behaviour of actors across time and space. In terms of our model, it is the normative aspect of rules that tempers variation in the routines they govern. Therefore, so long as the variations displayed by existing routines are sufficiently small, the social rules that underpin them will largely continue to be reproduced by informing the same routines in subsequent rounds of activity. From this viewpoint, there is an inbuilt tendency towards

[1] The adverts of traditional companies moving into digital clearly reflect a desire to maintain continuities with analogue and their reputations: 'Digital flexibility meets traditional quality' (Kodak, 2000); 'Loaded with everything you expect in a Nikon (except film)' (Nikon, 2000); 'Remember the first camera you fell in love with? Here's the filmless version' (Olympus, 1999). Of course, established practices associated with the 'old' technology may also serve as a backdrop against which new entrants are able to differentiate the new, the attractive, the convenient, and so on, associated with the new technology. And to the extent that they provide such a backdrop, of course, existing rules and routines may play a role in processes of change that may lead to their own eventual demise (Becker, 2004, p. 649).

morphostasis that imbues routines (and the associated rules) with a self-perpetuating and stabilising quality. This stability is reinforced by people's apparent psychological need for what Giddens (1979, 1984, 1991) calls 'ontological security', namely for a sense of sameness and continuity over time in their self-identity, and material and social environment. In short, there is a sense in which routines tend to represent zones of comfort that people are reluctant to leave, reflecting tacit knowledge that may have been costly to acquire and commitments to self-image and views of the world that they may be reluctant to relinquish.

In its most extreme form, the desire for ontological security represents a generalised psychological aversion to change, wherever that change may be. It was evident from our study that many of the incumbent companies played on this aversion in an attempt to ward off the competitive threat of digital. For example, Kodak pursued a policy of 'active ignorance' towards digital photography at the onset of the digital era (Munir, 2005), a policy not unlike Microsoft's strategy towards Sun's Java (Garud et al., 2002), and devoted substantial resources to prolonging the life of film by emphasising traditional views on the role and significance of home photography (e.g. the 'Kodak Moment' and associated ideas about capturing and preserving memories).[1] Although there are invariably some early adopters who are specifically attracted by new technologies precisely because they are new, these typically make for only a small segment of the market. There were many reasons why digital camera manufacturers at first struggled to persuade consumers to abandon the 'old' technology and some of the routinised practices associated with it. We will comment briefly on three of these reasons to demonstrate how morphostatic processes may hinder the adoption of a new technology.

The first reason is related to the form of the devices implicated in digital imaging, especially early perceptions of the difficulties of mastering the digital camera and its interface with computers, and doubts about achievable image and print quality. Some of these concerns have yet to be resolved completely even now, and remain an issue particularly with former analogue camera users whose expectations reflect the standards of the 'old' technology. For example, and while significant advances on this front have been made in the interim, the interval between pressing the button and the image actually being captured was considerably longer on early digital cameras than on their analogue forerunners. First-time users of digital cameras accustomed to analogue cameras were often disconcerted when they found that the delay caused them to fail to capture fleeting events. Further, and while there have been significant improvements in the interface with computers and the quality of imaging software, home printers and print materials, many users still find it difficult to generate prints of equivalent quality to traditional prints. Allied to all this, at the early stages of digital photography, was the familiar hesitation associated with investing in the new technology in an environment of rapidly improving quality and falling price.[2] People waiting for the next best thing, or substantially reduced prices, before purchasing a digital camera slowed adoption, particularly at the early stages when incumbent manufacturers were trying

[1] The efforts of both incumbents and new entrants effectively centred on winning the battle over popular conceptions of what photography is and what it should be (Munir and Phillips, 2005). In contrast to Kodak's original attempts to preserve traditional conceptions of photography, newcomers such as Sony went to great lengths to transform what people formerly understood as photography into 'imaging' (and thereby highlighting the new affordances associated with digital, such as immediate review, disposal, sharing, printing and the electronic transmission of digital images). As the 1990s progressed, however, Kodak's strategy increasingly turned towards digital technologies as a way of increasing the range of things people could do with film, and thereby increasing the demand for film (Christensen and Overdorf, 2000).

[2] The average price fell dramatically from an average of $119 per megapixel in 2003 to $82 per megapixel in 2004 (Photo Marketing Association International, 2005).

to shield their traditional market with actions that would have also encouraged and reinforced doubts of potential early adopters.

A second inhibiting factor was the prospective loss of pre-existing investments in skills and the costs of acquiring new ones. The transition to digital imaging inevitably led to the decay of practical knowledge, as particular skills associated with traditional photography increasingly became obsolete. Not unexpectedly, we found this to have been more of a problem for serious hobby photographers who had made significant specific investments in skills and equipment, than it was for more casual users. More relevant for the last group was that the adoption of digital imaging involved investing in new skills, the acquisition cost of which may have appeared high enough to discourage adoption (particularly to those unaccustomed to dealing with computers). It is clear that manufacturers of digital cameras took this problem seriously, as indicated by their initial and ongoing efforts to make digital cameras look and feel as familiar as possible, and to emphasise ease of use and compatibility with complementary equipment in their advertising.[1]

The third factor that we found to have had an inhibiting effect on the adoption of digital imaging is related to the demographics of different social groups. In Section 2, we proposed that society is structured by social positions amongst other things, and that particular social positions are associated with particular rule/routine ensembles. The issue that arises here is that social groups differ in terms of how eager or resistant they are to making the changes that a new technology might involve. They may also differ in the extent to which they can afford the new technology and whether they have easy access to complementary digital devices (there is also a generational effect here as, with the passage of time, more and more first-time buyers of digital cameras will be familiar with computers and so be less inclined to regard them as a barrier to be overcome). It follows that the relative size of these groups may then be a decisive influence on adoption rates of the new technology. A key aspect of the transition to digital imaging is that early adopters tended to be men, whereas the most active photographer in the US household is typically what the industry refers to as the 'soccer mom' in her family archivist role.[2] As an industry executive observed:

> From a marketing point of view the really big difference is we are really going from male to female. The people who buy [the] majority of cameras in this country are women and the majority of people who take photographs and keep them, catalogue them, and look after the memories for the family are basically women. The people that go out and buy techie, nice silver objects like this [points to digital camera] are men. So ... we foresee that there will be a changeover in that in the next couple of years.

The female, 'soccer mom' social group was crucially important to incumbent companies that had strong interests in the preservation of the usage of film, and who accordingly adopted complex strategies aimed at reinforcing existing routines in home photography and/or at encouraging new ones that would favour the traditional technology. However, now that most major camera manufacturers have shifted their emphasis towards digital, finding ways to overcome the factors that inhibit or slow down adoption of digital photography amongst this group have taken centre stage.

[1] For example: 'That's the hard bit over. Kodak: take pictures further.' (Kodak, 1999); 'Easy to shoot. Easy to share. Share moments. Share life.' (Kodak, 2001); 'Digital pictures. No experience required.' (Nikon, 2002).

[2] 'Currently, [making prints] is not the main reason for using a digital camera, but as the percentage of female users increases, it will become more important. Women may take fewer pictures with digital cameras than do men, but they save and print more than male users' (2004 Industry Report of the *Photo Marketing Association International*).

5.2 Morphogenesis

The transition from analogue to digital photography was driven by various forms of social agency, including the activities of inventors and designers, manufacturers and the interventions of marketing people and users. These activities and interventions in turn precipitated morphogenetic processes of various kinds. We will restrict ourselves to some observations about morphogenesis in respect of three important areas: (i) the ways in which users interact with new forms of camera equipment; (ii) the ways in which the broader activity of picture taking is conducted and conceived; and (iii) the way in which digital imaging has precipitated new kinds of products.

One of the most dramatic effects of the rise of digital imaging has been the increase in the range of tasks that the non-professional camera user can perform, where, often, those tasks were formerly the almost exclusive preserve of professional developers and photofinishers. Each stage of the process involved in producing photographs, from image capture, editing, to the actual making of prints, can now be performed using more or less standard computer equipment and without investment in specialist equipment or skills. This expansion of the layperson's repertoire was facilitated by the extent to which digital imaging reduces what were formerly specialist and often manual skills to simple tasks and or procedures that require little more than the ability to negotiate menus and pre-specified sequences on LCD or computer screens. Compare the complexities of loading film into older traditional cameras with transferring a memory stick between a camera and a PC, for example, or, more significantly, of producing traditional prints in a darkroom with printing digital images on the home printer.[1] This kind of simplification and reduction to menu-following was facilitated in turn by digital cameras being designed to be operated in ways that were already familiar from other digital devices, and to be compatible with existing and largely familiar home computer equipment. According to one of the industry executives we interviewed:

> Well, I think they [digital camera manufacturers] are probably trying to make it more of an IT experience and they are trying to control it on an IT world. The idea of having one button, this button here which controls the menu. So you push the button in and you could move along. This is an incredible easy way to control the camera. Most cameras you have will have buttons like this. You have to make it simply to push lots of different things at different times. This is great because it is very, very simple to use.

The emergence of these new ways of interacting with and operating digital cameras are clear instances of morphogenesis. However, the emergent rules and routines, where they became established and coalesce, soon become morphostatic in nature. This is particularly so with respect to the more immediate and rudimentary operation of digital imaging equipment and software, where many of the menu-driven procedures involved in the use of digital cameras and associated equipment are non-optional and bear little in the way of even minor deviations on pain of the device simply not performing the desired function.[2] While

[1] 'I think of my digital camera as a mobile dark room', as one of the respondents in our user survey put it. Indeed digital imaging has come closer to achieving the early Kodak slogan 'You push the button, we do the rest' (Overdorf and Christensen, 2000, p. 1) than the company might have imagined or subsequently wished. It is significant here that the technical challenge of giving users the means to go from image capture to print had already been met by Polaroid. Indeed the achievement of Polaroid was in one way more impressive than what had been achieved with digital photography insofar as the prints are themselves produced within the camera rather than requiring external printers.

[2] We are here concerned with the basic operation of the tools associated with digital photography, with what is required for the ordinary user to arrive at acceptable results. This is not to deny the availability of a good deal of digital imaging equipment and software that offers highly sophisticated functionality, the mastery of which may require significant investment in time and energy.

this channelling of how users interact with digital cameras is an important, and perhaps even necessary, condition for the increased range of tasks that digital imaging provides, it does so in a way that may inhibit variation over the relevant domain of activities and, with it, the possible emergence and selection of new routines within these domains.

As we noted in the preceding section, various practices and rules associated with the broader activity of photography have carried over from the analogue to the digital domain. However, our data also shows considerable evidence of morphogenesis in the wake of digital imaging with respect to particular behaviours such as the dramatic increase of images captured by the individual camera user, the immediate review and sharing of images, the greater variety of images captured and the editing of images. To the extent that these changes emerged over time only as users became familiar with their digital cameras, moreover, they may be seen as instances of innovation in use in the 'same-form-different-function' sense. Consider the following observations excerpted from our user interviews:

I definitely use the digital camera differently to how I use analogue cameras. And I suspected that I would. Let me give you some examples. I am just back from a big family reunion, with some 30-odd people, and I took along my camera, laptop and printer. And I took lots of family photos that weekend and within ten minutes of taking them, I had printed out copies and was handing them to the family members to take home with them. It made the photography a much more social phenomenon because you could immediately share the results with others.

Initially, I had seen digital photography as very similar to film photography, and I was interested to see if the digital camera could match the quality of my analogue camera. But now the digital camera is taking me well beyond what the analogue camera could allow me to do. For example, I would never think of using an analogue camera as a Xerox machine. ... And I have come to appreciate the value of capturing images and documenting events, even if these pictures are never printed.

The digital camera has definitely changed the way we take photographs. ... What has changed is that now we take photos of a much bigger range of things, things that we would not have wasted film on before. [For example,] we go to plant shows and take lots of the pictures of plants we like. Then when we get home we can review them at our leisure and think about what we like and what we might get for our garden. ... [Before] we would never have burned film on hosta leaves at the Lily show.

[Digital photography] is quite different [than analogue photography]. It's instant and most people use it as a communication tool. More a public thing than a private thing. If you take a digital photo you are able to share it more with your friends.

The digital camera has changed my photography habits. I am less worried about whether I am taking the perfect picture. It has become a no-risk process. I don't have to wait and see if I took a good photo or not. I review every photo—either at the time of taking the shot or after I have downloaded it—and I can just throw it away if it is not good.

I have modified some of the digital pictures on the computer, but I don't do anything sophisticated, just things like sharpening the image, changing size, rotating, etc. [My husband] does a lot more: crops, changes colours, etc.

Many of these comments reflect the emergence of new functions specific to digital cameras, some of which were user- rather than producer-driven innovations in use (e.g. using a digital camera as a Xerox machine or, more significantly, to provide images intended primarily for immediate sharing rather than for printing and archiving). The changing practices associated with these new functions provide interesting examples of how new routines have emerged as digital cameras have become more ubiquitous, and continue to become even more successfully embedded in hybrid electronic devices such as mobile phones and PDAs. We have already mentioned the role of complementary technologies and that much of digital imaging technology was, and continues to be, designed to fit in with the evolving 'digital

culture' (Gere, 2002). Indeed, the way in which users engage with their Sony digital camera may in many ways have more in common with how they engage with their Sony laptop and mobile phone using the same proprietary memory stick device, than with how they engaged with their former 35mm camera. Here morphogenesis may lie in routines from one context being transposed to others, such as cut and paste functions in imaging software being operated in much the way as is in word-processing, spreadsheet and digital audio recording software. What is new in the context of hobby photography may simply be the replication of a similar routine from another context.[1]

5.3 Summary

The examples and empirical material provided in the preceding two subsections are, of course, partial and impressionistic, intended to serve as illustrations of aspects of the transition rather than an account of the transition as a whole. Nevertheless, we hope that they will have provided some insight into the nature of change involved in episodes of the kind that we considered. The general picture that emerges is neither of a sudden and total rupture, nor of a gradual and seamless morphing of the 'old' technological regime into the 'new'. What we see instead is a mixture of continuity and change, with morphostatic and morphogenetic processes proceeding simultaneously, interconnected with and often nested within, larger processes of one or the other type. In the present case, the collective assignments of function associated with the analogue camera, and the various routines and related user-conceptions have provided the necessary background (including in the more restricted Searlean sense of the term) for the introduction of digital imaging. And, in turn, the developments that we have been considering—the shifts in function in particular—will themselves contribute to forming the necessary background that will inform, facilitate and shape future rounds of innovation. Indeed they already have, as evidenced by the emergence of camera-phones, iPods and other hand-held digital devices used to capture, view and share digital images.

6. Conclusion

We set out at the beginning of this paper to provide a general framework within which to think about technological objects and the adoption of technological product innovations, focusing on the relationship between social structure and human agency, and in particular on the interconnection between social rules and routines. To this end we offered a theory of the causal relationship between rules and user routines within the context of the TMSA; embedded within the TMSA is a theory of the technical identity of technological objects that can accommodate both their material (form) and social (function) aspects; and proposed a conception of technological change consistent with our theory of the technical identity of technological objects. We also considered how technological transitions may be shaped by social structure, and especially by the social rules that contribute to constituting technological objects and regulating the activities in which those objects are implicated.

[1] Routines often emerge as the product of repetitions of slightly different attempts to perform some task in similar conditions, and in many cases the routine ultimately 'selected' may be an efficient adaptation to the typical environment in which they are enacted (Feldman and Pentland, 2005; Kesting, 2004). It is therefore misleading to talk about the effectiveness or efficiency of any one routine in the abstract. Routines that are perfectly effective ways of doing things in some contexts may be considerably less so in others.

In this connection we demonstrated various ways in which the adoption of technological product innovations is conditioned by predecessor technologies, and how the successful introduction of technological product innovations is likely to require deliberate intervention into existing rule/routine structures, many of which may be resistant to transformation and, when they do change, often do so in unforeseen ways.

In our illustrative case, we looked at some of the morphostatic and morphogenetic processes that appear to have played a role in the transition from analogue to digital imaging in consumer photography. Few would deny that the transition represents major dislocation within the sector, both technologically to the extent that the new electronic means of capturing, storing and reproducing images differ from its chemically-based forerunner, and in its effects on incumbent manufacturers, retailers and consumers, and the demands it has placed on them to respond. The face of the industry has changed significantly over the last 20 years. Incumbent firms, even household names like Kodak and Polaroid, have struggled to adapt and stay in business, while many of the new major players are consumer electronics companies that had no visible presence in the home photography market even less than a few decades ago. User practices have changed significantly in many respects, as we have demonstrated.

Nevertheless, the transition was, and continues to be, characterised by significant continuities in the social rules and routines associated with consumer photography. We have attempted to show how new entrants have attempted to exploit existing collective assignments of function as their point of departure in introducing digital cameras and, on many fronts, have sought to make them look, feel and be used as much as possible like their analogue forerunners. Paradoxically, then, the very agents of the technological disruption were, at the same time, devoting significant resources to promoting the view that the new kind of camera and its use were little different from what analogue camera users were already familiar with. These efforts represented a balancing act comparable to the one facing incumbent firms attempting to move over to digital while at the same time generating messages aimed at prolonging the life of their traditional product lines. That is to say, digital camera manufacturers had to manage the difficult trick of promoting their products in a way that revealed the new affordances of digital imaging in a manner accessible to its target audience, but without at the same time fanning consumer fears about the extent to which they would have to change their practices and learn and adapt to unfamiliar technology. What is clear is that the transition, and the morphogenetic processes it triggered once it started gathering pace, required both kinds of message.

Of course, as any adherent of the TMSA would immediately point out, the story does not end here. At the same time as the new technological objects and interfaces associated with digital imaging were becoming established, they were already leading to the emergence of new functions and routines, many of them emanating from users. And, just as the functions and many of the routines associated with analogue photography paved the way for digital photography, so the new functions and routines associated with digital photography have paved the way for the subsequent development of new kinds of technological object (e.g. hybrid devices such as phone cameras), new kinds of business (e.g. online printing and image-archiving services), and new forms of consuming and sharing digital images (e.g. via portable media players and social-networking websites). That is to say, the kind of reproductional and transformational processes we have described in this paper are ongoing ones, and the form and often the functions of many of the technological objects that surround us are in a constant, if often subliminal, state of transition.

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