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Towards Theorising Information Systems from a Neurobiological Perspective

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Complete Research

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Abstract

In spite of more than 25 years of research, the nature of Information Systems (ISs) remains elusive. To this end, a new conceptualization of ISs from a neurobiological perspective is proposed. ISs are seen as instruments for action, which in turn requires coordination. We posit that the phylogenetic evolution has endowed humans with a neurobiological substrate enabling coordination. The construct of activity modalities – objectivation, contextualization, spatialization, temporalization, stabilization, and transition – is introduced as inherent factors in this substrate. These modalities provide an analytical link for integrating the neural and social realms; thus enabling IS conceptualization as a dialectical relationship between coordinative, individual brain structures and the IT artefact. Consequently, the IS is seen as intrinsically related to the individual. We exemplify implications for the IS discipline by discussing how the concept of sociomateriality can be articulated from the neurobiological perspective. As a result, the "individual" is to put on equal theoretical footing as the "social" and "material", thus providing a way to disentangle the problematic conflation of the "social" and the "human" in sociomaterial contributions. In conclusion, we claim that the neurobiological approach opens up for hitherto untrodden paths to advance the IS discipline.

Keywords: IS conceptualization, activity modalities, neurobiology, coordination, integrative realism

1 Introduction

Information Systems (ISs) lies at the intersection of people, organizations, and technology (Silver et al., 1995), which means that IS research needs to consolidate findings from all these areas. This task has, however, turned out to be problematic. One challenge concerns the very foundation of the IS discipline. In his survey "Retrospect and prospect: information systems research in the last and next 25 years", Lee claims that key IS concepts are left undefined: "Virtually all the extant IS literature fails to explicitly specify meaning for the very label that identifies it. This is a vital omission, because without defining what we are talking about, we can hardly know it" (Lee, 2010, p. 338). As a consequence, the nature of the IS in relation to the IT artefact has been extensively debated in the IS community without reaching closure (e.g. Benbasat & Zmud, 2003; Orlikowski & Iacono, 2001).

In organizational science, technology is either "largely absent from the world of organizing" (Orlikowski & Scott, 2008, p. 434), or "reactive with respect to technology in the sense that it takes technology as 'given'" (Hevner et al. 2004, p. 98). Thus, another challenge is how to theorize the relationship between IT and organizational capabilities:

> Although there has been a myriad of research on how IT could help in today's fierce business competition, a theoretical foundation regarding the relationship between IT and organizational capability is still missing (Sheng, 2004, p. 140).

The recent, huge interest for design science in IS research can be seen as an attempt to address this challenge (e.g. Hevner et al., 2004; Gregor and Hevner, 2013). Although important results in this area have been achieved, there is "an inadequate theoretical base upon which to build an engineering discipline of information systems design" (Hevner et al., 2004, p. 99).

Concerning the 'people' aspect, a wealth of IS research does exist that addresses human-related issues (e.g. Davern, et al., 2012). However, the epistemological and ontological basis for the research is still being debated. To take but one example, the widely cited SECI model proposed by Nonaka (1994), in which knowledge is converted between tacit and explicit forms, has been strongly criticised for misusing Polanyi's' original meaning of "tacit" as a dimension rather than a type of knowledge (e.g. Tsoukas & Vladimiro, 2001).

These haphazard examples of the problematic state of play in theorizing the IS is a strong motivation for finding alternative ways of conceptualizing ISs. The purpose of this contribution is to propose such a way, which departs from the intricate intertwining of the neural and social realms:

> The mental is inextricably interwoven with body, world and action: the mind consists of structures that operate on the world via their role in determining action (Love, 2004, p. 527).

1.1 The approach – "integrational realism"

People need to act alone or together in order to achieve something. Acting in turn requires coordination; be that swinging an axe to cut down a tree, avoid bumping into people walking on a pavement, or participating in a system development task. If, for some reason, an individual becomes incapable of coordinating her actions, she cannot endure in the long run: "I do not see any way to avoid the problem of coordination and still understand the physical basis of life" (Pattee, 1976, p. 176). The foundational character of coordination is evident also in the social realm. For example, Grant claims that given the efficiency gains of specialization, "the *fundamental task* of the organization is to coordinate the efforts of many specialists" (Grant, 1996, p. 113; our emphasis).

Consequently, if we regard ISs as instruments for action, it becomes interesting to explore coordination in relation the neural and social realms. From a neural perspective, we may posit that the phylogenetic evolution of humankind has brought about some kind of *neurobiological* substrate for coordinating actions. Such a substrate should be seen as an analytical device, which comprises mental functions necessary for coordination, and which is realized by various cortical zones in the brain. From a social perspective, we may assume that actions are manifested as artefacts involved in coordination. Accordingly, the neural and social constitute and reflect each other; they are integrated: "[The] internal functional space that is made up of neurons must represent the properties of the external world – it must somehow be *homomorphic* with it" (Llinás, 2001, p. 65; our emphasis).

Based on this reasoning, our line of argument proceeds from the social realm towards the neural as follows. As a result of extensive, long-term engagement with coordinating complex system development tasks in the telecom industry, Taxén noted that artefacts employed in coordination could be grouped into certain categories, which seemed to appear over and over again in different coordinative situations (Taxén, 2009). A first observation was that every situation was *about* something; there was always some kind of work object involved towards which actions were directed. Other artefacts, such as information models, signified a distinct spatial dimension; much like a map used for orientation in a specific situation. Various kinds of process models (business processes, workflows, interaction diagrams, etc.) seemed to indicate a temporal dimension. Documentations of rules, norms, routines, etc., had a stabilizing character, showing "this is how we do things around here", while other artefacts, like contracts, specifications, interfaces between IT systems, etc., had a transitional character; they were used in coordinating the work between various work areas like marketing, development, production, after sales, and the like. A final observation was that the actual expressions of these dimensions were intrinsically linked to the situation. For example, a particular product identified by an article number and revision, was characterized quite differently in the market context and the development context.

Once cognized, manifestations of these dimensions – subsequently called the *activity modalities* – were noticed in a variety of different situations. An insight eventually grew that their origin might be neurobiological, expressing fundamental mental predispositions for coordinating actions as follows (Taxén 2009, 2011, 2012, 2015):

- *Objectivation* – attending to an object towards which actions are directed.
- *Spatialization* – orienting oneself spatially in the situation.
- *Temporalization* – anticipating actions.
- *Stabilization* – learning which actions work in a certain type of situation.
- *Transition* – refocusing attention to another situation.
- *Contextualization* – foregrounding relevant things and ignoring irrelevant ones.

In order to link these modalities, as conceptualized in the social realm, to the alleged neurobiological substrate enabling coordination, the following stepping stones will be used:

- Mental functions are understood as *complex functional systems,* in which widely distributed cortical zones contribute with a certain *factor* to the entire function (Luria 1964; Luria 1973; McIntosh, 2000; Bressler & Kelso, 2001).
- Coordination is seen as mental complex functional system in which the activity modalities are contributing factors.
- The notions of *functional organs* (Luria, 1973) and *equipment* (Heidegger, 1962) provide a way to associate internal, neural structures involved in coordination to external means used in acting.
- The concepts of *joint action* and *common identifiers* (Blumer, 1969) enables the linking of the individual basis of coordinative faculties to coordination in the social realm, where several individuals work together to fulfil some social need.

Ontologically, this means that humans and their environment are considered as distinct, yet inextricably related and co-constructing each other in the integration of activity. As in critical realism, this position acknowledges the “view that entities exist independently of being perceived, or independently of our theories about them” (Leonardi, 2013, p. 68). In line with this, we will provisionally call our conceptualization “integrational realism”.

The paper is structured as follows. We illustrate the line of argument by an example of a guitar quartet giving a concert. The rationales for choosing this example are twofold. First, we need to understand the simple before we can understand the complex. Second, we want to accentuate the fact that our biological faculties has not changed significantly during the last couple of millions of years. Thus, in every situation we encounter, we are bound to use these faculties, regardless of whether we play a guitar or participate in developing an IT-system. Certainly, guitar playing and IT development require different skills, but the ability to coordinate actions at all is ultimately dependent on the same neurobiological faculties. To accentuate this, we provide an example of developing an IT application for requirement management in the telecom industry. Following this, we suggest a novel conceptualization of the IS as a dialectical unity of coordinative functional organs in the brain and the IT artefact. Consequently, the IS is seen as intrinsically related to the individual; there will be as many ISs as there are individuals interacting with the IT artefact. We indicate implications for the IS discipline by discussing how the theoretical stream of *sociomateriality* can be articulated with integrational realism as a foundation. A main result is that the "individual" is put on equal theoretical footing as the "social" and "material", thus providing a way to disentangle the problematic conflation of the "social" and the "human" in sociomaterial contributions. In conclusion, we claim that the neurobiological approach opens up for hitherto untrodden paths to advance the IS discipline.

2 Integrating the neural and social realms

In order to elucidate the integration of the social and neural realms, we will make use of the example of a guitar quartet giving a concert as illustrated in Figure 1:

Figure 1: A guitar concert

2.1 The social realm

A first prerequisite for the concert activity is that the players have well-built guitars to play on. This presumes that certain elements are worked out in the transition between the activities of building and playing, such as the placement of the bars on the neck, the number of strings, the string tensions, and so on. Typically, this is a lengthy process that stabilizes only after much experimentation. However, this process depends ultimately on the neurobiological ability of actors to refocus attention from one activity to another; in this case from the guitar playing to guitar building (the *transition* modality).

Next, each player must be proficient in playing his voice in the music. This is accomplished only after long and arduous practicing, which involves the player, the instrument and most likely a musical score like the one in Figure 2:

Figure 2: A score for a bass guitar

In order to play this piece of music, the left and right hand movements must be coordinated. To begin with, the temporal dimension must be grasped. This is signified in the score by the sequence of notes read from left to right. A sense for the duration of each note, as signified by the stems and dots, must be obtained (the *temporalization* modality). Next, the spatial positions of notes in relation to the staff (above, below, distance between notes, etc.) need to be associated with a corresponding spatial position on the guitar neck where the proper string shall be pressed (the *spatialization* modality). Also, various signs must be acknowledged, such as the *mf* indicating mezzo forte, the 𝄢 signifying the F-clef, and the # showing that the key is e-minor. These signs indicate habituated norms of playing, thus lending a certain stability to the activity (the *stabilization* modality). Eventually, musician and his instrument may form a dialectical unity so tightly intertwined that playing becomes virtually effortless:

> There no longer exist relations between us. Some time ago I lost my sense of the border between us…. I experience no difficulty in playing sounds…. The cello is my tool no more (the cellist Mstislav Rostropovich, quoted in Zinchenko, 1996, p. 295).

However, this exquisite example of coordination between a fluent player and his instrument does not mean that they somehow lose their identities. Rostropovich and his cello remain different entities, no matter how tightly integrated they might be.

When in performance, each player must be able to focus on the object of the activity – the concert (the *objectivation* modality). This in turn necessitates an ability of each player to focus on relevant things and ignore irrelevant ones (the *contextualization* modality). The concert hall, the other players, the audience, scores, instruments, and more, are undoubtedly relevant for the concert, while the books in the bookshelf behind the quartet can be safely ignored.

The separate voices in the quartet are coordinated by fitting together individual ways of playing; something which is called "joint action" by Blumer (1969). This requires some kind of external "common identifiers" (ibid.) such as the score in Figure 3.

Figure 3: The score as a common identifier

As can be seen, the score has the same basic layout as individual voices; except that these are now aligned both diachronically (vertically as spatial distances between notes) and synchronically (horizontally in time). Thus, the same modalities are actuated both in individual and joint playing. It can also be noted that the label "common" is applicable to external elements only, not the internals of brains, which are always unique. Moreover, individual voices are meaningful only in the activity as a whole. If each voice is played in solitude, the music becomes void of meaning. This indicates that the relationship between parts and whole is dialectical in nature:

> [The] ancient debate on emergence, whether indeed wholes may have properties not intrinsic to the parts, is beside the point. The fact is that the parts have properties that are characteristic of them only as they are parts of wholes; the properties come into existence in the interaction that makes the whole (Levins & Lewontin, 1985, p. 273).

2.2 In-between the neural and social realms

The integration of the neural and social realms can be seen as a conjunction between phylogenetically evolved morphological features of the brain and the ontogenetic development of the individual. This issue was extensively investigated by scholars like Vygotsky, Leontiev, and Luria. A common tenet in their thinking is that the socio-historical environment encountered by an individual plays a decisive role in the *formation of higher mental functions*. The brain is formed "under the influence of people's concrete activity in the process of their communication with each other" (Luria 1964, p. 6), which means that "areas of the brain which previously were independent become the components of a single functional system" (Luria, 1973, p. 31).

Thus, historically formed artefacts "tie new knots in the activity of man's brain, and it is the presence of these functional knots, or, as some people call them 'new *functional organs'* […] that is one of the most important features distinguishing the functional organization of the human brain from an animal's brain" (Luria, 1973, p. 31). A striking example is that brain-imaging studies of musicians have revealed structural changes in the brain as a result of musical training: "musicians have greater grey-matter concentration in motor cortices […] showing that expert string players had a larger cortical representation of the digits of the left hand (Zatorre et al. 2007, p. 554).

The emergence of functional organs can be seen as an *equipment* formation process, where an artefact passes from a state of being *present-at-hand* to *ready-at-hand* (Heidegger, 1962; cf. also Riemer and Johnston, 2013). Equipment is encountered in terms of its use in practices rather than in terms of its properties: "our concern subordinates itself to the 'in-order-to' which is constitutive for the equipment we are employing at the time" (Heidegger, 1962, p. 98). In this process, the artefact itself may or may not be modified, but for the actor, the tool recedes, as it were, from "thingness" into equipment, when the in-order-to aspect – what the tool can be used for – takes precedence. Thus, the interaction with an artefact like a guitar, cello or an IT system reconfigures – "tie new knots in" – the brain of the individual.

2.3 The neural realm

Given that "extracortical" means are involved in the formation of individual brains (Vygotsky, 1960), the problem is how to fathom the formation of functional organs in relation to the activity modalities. A way forward is provided by Luria's recognition of higher mental functions as *complex functional systems*, in which widely distributed cortical zones contribute with a certain *factor* to the entire function (Luria 1964; Luria 1973). These factors are realized by "large-scale processing by sets of distributed, interconnected, areas and local processing within areas" (Bressler &.Kelso, 2001, p. 26). A destruction of any such cortical zone by, for example, a lesion, leads to the disintegration of the whole functional system (Luria, 1964, p. 12).

In line with this, Taxén has suggested that coordination should be regarded as a higher mental function, which can be modelled as *dependencies between contributing factors*; some of which are the activity modalities (Taxén, 2015). In Figure 5, such a tentative model shown:

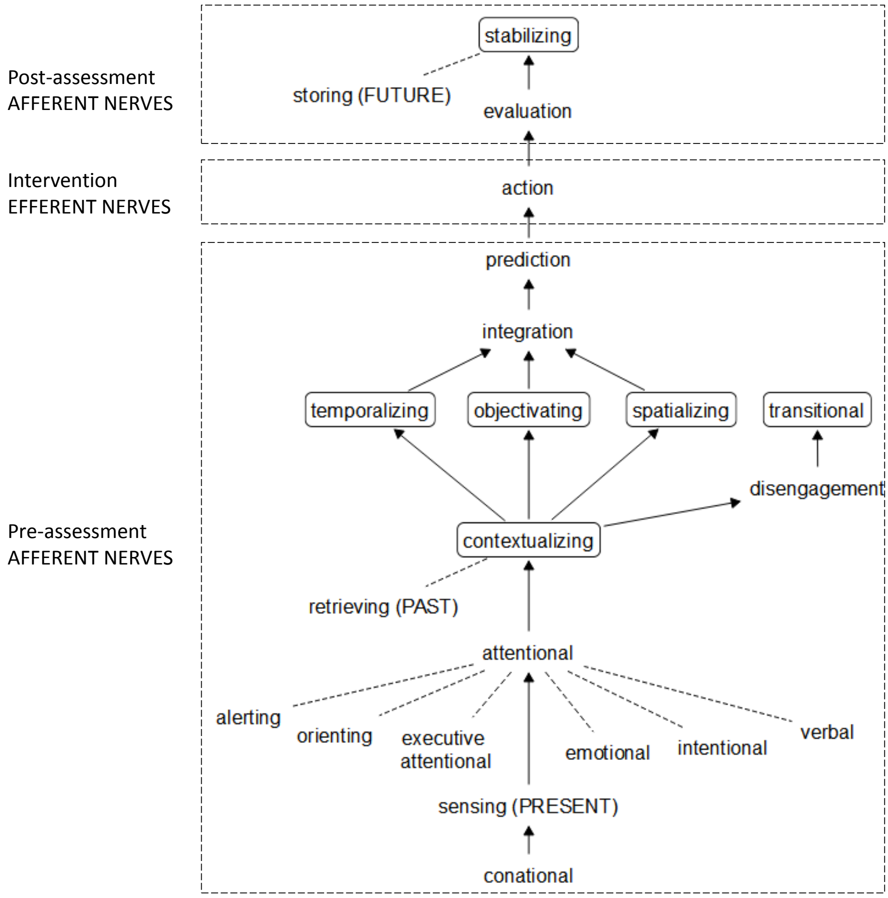

Figure 4. Factors contributing to the mental function coordination.

Figure 5 should be read from bottom up, starting with the basic factor of conation and progressing upwards to the stabilizing factor[1]. The model clearly shows how a loss of a certain factor impacts the entire function. So, for example, if the intentional factor is inhibited, attention cannot be actuated and, consequently, all other factors depending on attention. The model is purely static – it shows only dependencies between factors. How these are dynamically engaged, is a different matter (see e.g. Bressler & Kelso, 2001). It can be noted though, that two kinds of nerves impulses are involved: *afferent* one's going from the periphery of the body to the brain, and *efferent* ones carrying nerve impulses away from the brain to effectors such as muscles or glands. Moreover, in order to simplify the complex functional system to its very essence – how factors depend on each other – the realization of each factor is not shown Figure 4. Identification of the neural correlates of the six activity modalities is a matter for cognitive neuroscience research, and positively outside the scope of this paper. To give but an example of such research, it has recently been found that grid cells in the entorhinal cortex play a crucial role in spatial representation and navigation (Witter & Moser, 2006). Together with place cells in the hippocampus area (O'Keefe & Nadel, 1978) they contribute to the realization of the spatialization factor.

[1] Conation refers to "striving: the directedness of the individual organism toward, away, or against other givens, toward future states, and away from one's present state" (Ridderinkhof, 2014, p. 7).

3 An illustrative case from industrial practice

In order to discuss how the neurobiological perspective can be applied in the IS domain, we will use an example from Ericsson™, a major provider of telecommunication systems worldwide. In the late 1990s, Ericsson was developing the 3rd generation of mobile systems. The challenges posed by this endeavour were unprecedented in terms of people, organization, and technology. As its peak, around 140 projects and subprojects worked on different parts of the system. One particular project involved about 1000 persons distributed on 22 subprojects and 18 design units world-wide (Taxén, 2003). In order to convey a sense for the complexity of this project, a so called integration plan for the project is shown in Figure 5:

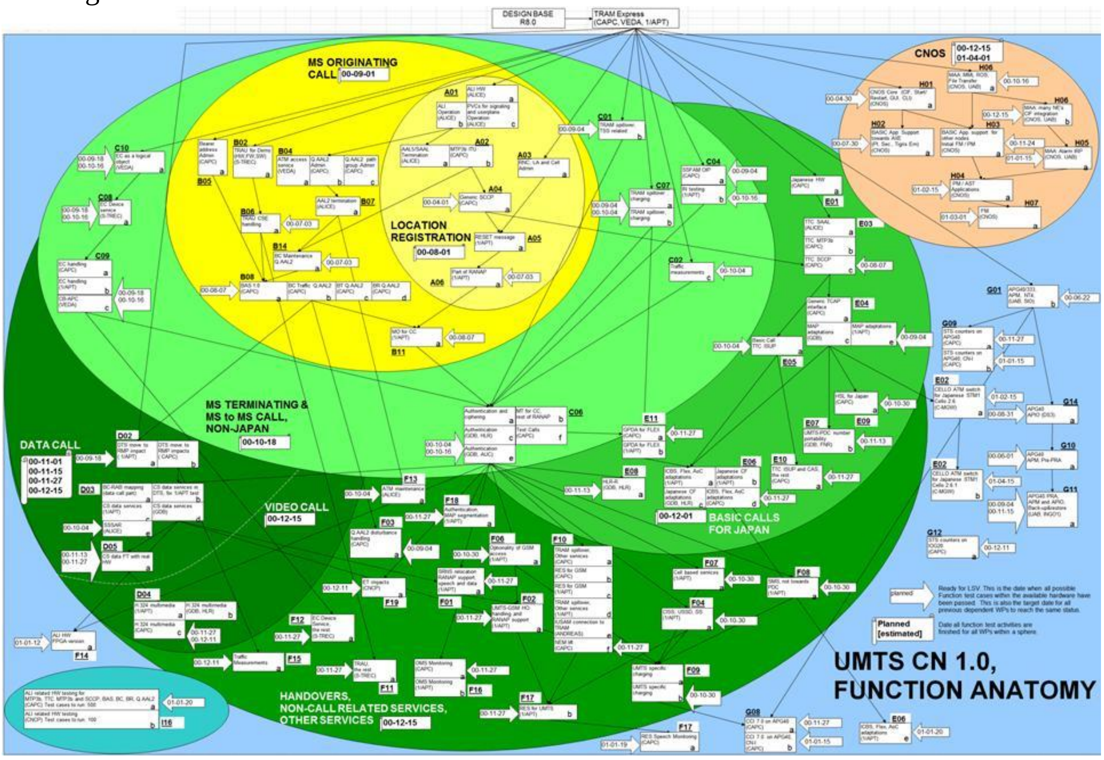

Figure 5. Integration plan for the project (courtesy of Ericsson™)

Each white square indicates a work package developing some functionality in the overall system. The lines show dependencies; from basic functionalities at the top and progressing downwards towards the full functionality at the bottom of the figure. Arrows signify dates for delivery of a particular functionality to be integrated with the rest of system.

It was soon realized that coordination of all deliveries required extensive IS support. With the introduction of modern, object-relational databases in the mid-1990s, quite new information management capabilities became available. In one sub-project, a decision was taken in 1997 to try this new technology out. A particular IT platform called Matrix was acquired for this purpose. An important feature of Matrix was the ease by which organizational-specific IT applications developed on this platform could be modified.

One challenge in the project was to achieve traceability from requirements to system parts implementing these requirements. A small team consisting of the project manager, a requirement manager, a consultant from the vendor of Matrix, and this author was set up to work with this task. By ceaselessly modifying an information model for the requirement context and its implementation in Matrix, a "good enough" way of managing requirements was achieved after numerous iterations. An example of the information model is shown in Figure 6.

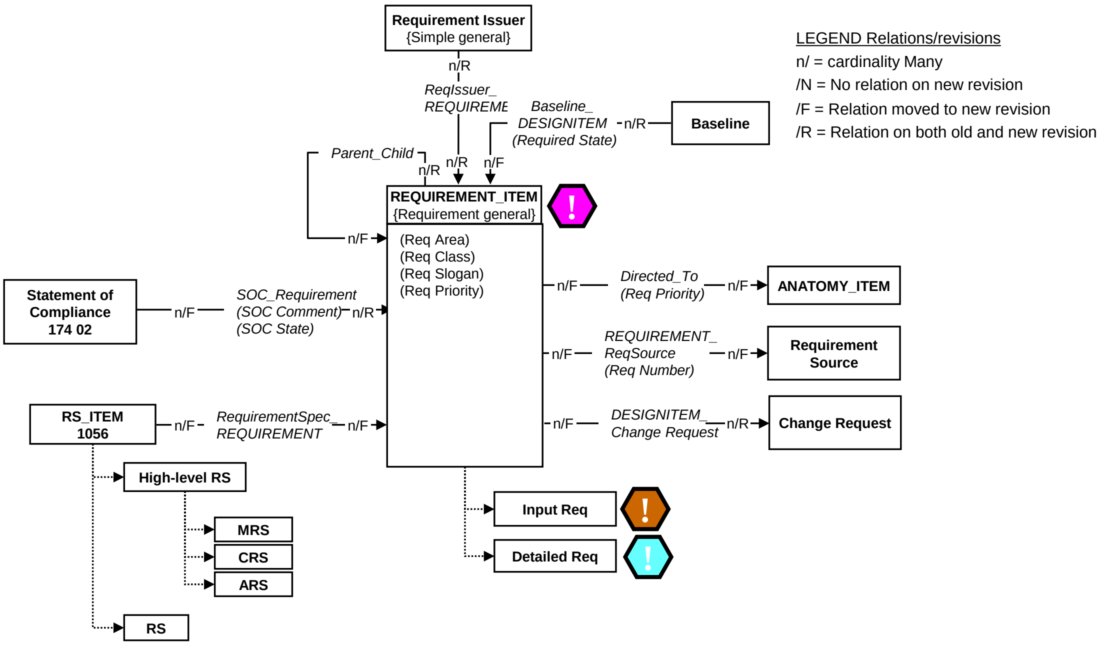

Figure 6. An information model for requirement management (courtesy of Ericsson™)

As can be seen, quite many details had to be worked out. The implementation of the model in Matrix is illustrated in Figure 7, where individual requirements can be traced all the way from the organization issuing the requirement ("PN") down to system modules contributing to the realization of the requirement ("CNT", "CAA") and the software code ("Source Program Information"):

Object	Rev	Class	State	Relation
Req Issuer PN			New	
Input Req MR-1 C	C	Required	AGREED	ReqIssuer_REQUIREMENT
Detailed Req I-10		Mandatory	AGREED	Parent_Child
Detailed Req I-10-01		Mandatory	UNDEFINED	Parent_Child
Integration Increment 1 -	-		Identified	REQUIREMENT_INCREMENT
Function 01 Start / Restart -	-		READY	Impacts
CNT 213 1054 R2	R2		PREL	Impacts
Application Information 155 18 2/155 18-CNT 213 1054 C	C		PREL	DescribedBy
Application Information 155 18 2/155 18-CNT 213 1054 C1	C1		PREL	DescribedBy
CAA 107 5256 R2A	R2A		PREL	ConsistsOf
Data Change Information 109 26 4/109 26-CAA 107 5256 /	A		PREL	DescribedBy
Document Survey 1095 1095-CAA 107 5256 R2A	R2A		PREL	DescribedBy
Signal Survey 155 14 155 14-CAA 107 5256 D	D		PREL	DescribedBy
Source Parameter List 190 73 190 73-CAA 107 5256 C	C		PREL	DescribedBy
Source Program Information 190 55 190 55-CAA 107 5256	E		PREL	DescribedBy
Test Document Survey 152 01 2/152 01-CAA 107 5256 R2/	R2A		PREL	DescribedBy
Test Instruction 1521 1/1521-CAA 107 5256 PA1	PA1		PREL	DescribedBy
Test Report 152 83 1/152 83-CAA 107 5256 PA1	PA1		PREL	DescribedBy
Description 1551 1/1551-CNT 213 1054 C	C		PREL	DescribedBy

Figure 7. Project data loaded in the Matrix (courtesy of Ericsson™)

1.1 Analysis

The convergence of the requirement management process was indeed long and arduous. The form and content of the model were constantly discussed until a workable solution had been achieved. Usually, such a process is interpreted as follows. The sub-project needed to improve requirement management in some way. The new IT technology would greatly enhance traceability, since it enabled the management of individual requirements rather than collections of requirements in documents. The implementation this technology required that an Ericsson-specific application was developed on top of the Matrix platform, that users "unlearned" the traditional management process, and that they adopted new way of working with the new technology.

Such a description focusses on tangible elements like the information model, the IT application, IT platform capacities, user manuals, help-desk support, and so on. What is going on inside the heads of participants is not attended. From the neurobiological perspective, however, an alternative interpretation is possible. The tangible elements may be seen as common identifiers, which gradually emerged to be relevant for the requirement management activity. In the brain of each participant, intangible, idiosyncratic functional organs were developed in interaction with the common identifiers. Although every actor interpreted the common identifiers differently, these individual interpretations became sufficiently fitted together over time to achieve a new way of managing requirements. In this alternative description of the process, the focus is on the integration of the neural and social realms, which means that issues like meaning construction, interpretations, comprehensiveness of model notations, etc. are brought to the fore.

During the construction of the requirement management context, all activity modalities were involved. The object in focus was "requirement", which means that "new knots" were established between external expressions of "requirement" (for example, the hexagonal-shaped icons in Figure 6) and cortical areas realizing the objectivation modality. If a participant had been hit by a stroke affecting her perirhinal cortex during this process, she would have been unable to continue, since this part of the cortex is involved in object recognition (Bright et al., 2005).

The same is valid for the other modalities. The information model in Figure 6 has a distinct spatial character (things related to each other and characterized by relevant attributes, relations, cardinalities, and so on.). Thus, this model and its implementation in Matrix became associated with cortical areas realizing the spatialization modality. Other external expressions were associated with other modalities. Stabilization was manifested by the Ericsson-specific way of naming elements, for example, "CAA 231 1054 R2" for signifying a particular revision of a software module. Traces of temporalization were signifies by different states of elements such as "AGREED", "PREL", etc. Thus, we can see that the activity modalities are indeed influential in this example from the IS domain as well as in the guitar playing activity.

4 IS conceptualization

In order to analytically explain how the concepts of activity modalities, functional organs, equipment, common identifiers and joint action entail a novel conceptualization of ISs, we will use a cyclic model of human action proposed by Goldkuhl (2009). This model consists of three phases: pre-assessment, intervention, and post-assessment, which can be associated with afferent and efferent nerve impulses as illustrated in Figure 5.

We assume that the IT artefact is involved in all these phases. As soon as an actor starts interacting with the artefact, the formation of equipment begins. In the pre-assessment phase, afferent nerve impulses are active, influencing factors from 'conation' to 'prediction'. These factors are actuated in order to prepare the individual for subsequent intervention in the external world. Against this background, we may say that the artefact is in an *afferent* mode in pre-assessment since effects are manifested in the inner, neural realm, impacting, among other factors, the modalities contextualization, objectivation, spatialization, and temporalization. The result of pre-assessment is an integration of afferent nerve impulses, which enables the prediction of effects from choosing different action alternatives.

In the intervention phase, the intention is to make a change in the external, social realm. This is effectuated by efferent nerve impulses, which means that the IT artefact can be seen as being in an *efferent* mode in intervention. Actions may produce a range of different effects. A straight-forward one is to search for more information. Other effects may be communicative such as informing someone or requesting something. Still other effects may be predominantly physical, like intervening in the process flow in a nuclear power plant.

In the post-assessment phase, the effects of the intervention are assimilated. Once again, the artefact is in an *afferent* mode since afferent nerve impulses are active. The effects are manifested neurally in long-term memory and socially in the IT artefact for retrieval in subsequent actions; hence contributing to the stabilization factor. Afferent nerve impulses may also result in attention being refocused to another situation, in which case the transitional modality is actuated.

In reality, these phases are of course intertwined. For example, perception is guided by anticipation of action as well (Lewis, 2002). However, the same mental processes are involved regardless of whether the IT artefact is used by a single individual or by several individuals in joint action. The equipment formation process, in which “new knots” are tied in brain, remains idiosyncratic. This suggests that the relationship between the individual and the IT artefact has a *dialectical* or *internal* (Faulkner & Runde, 2013) character. The individual and the IT artefact co-construct each other while remaining ontologically distinct; there is no conflation between them. The individual remains an individual and the artefact remains an artefact, even if both are changed during equipment formation.

So far, the analysis above is valid for any artefact or means employed in action, not just IT artefacts. For example, you need to master all modalities in order to coordinate the swinging of an axe for some purpose. However, this coordinative capability remains manifested internally in the brain only, not in the axe. With the IT artefact at hand, coordinative capabilities conceptualized as activity modalities can be manifested also externally, thus contributing to the integration of the neural and social realms. This capability is particularly important in joint action, when the IT artefact function as a common identifier, fitting together the actions of many individuals; like the Matrix IT application in Figure 7.

The most sensibly conceptualisation of an Information System from this perspective is *as the coordinative equipment made up from IT artefact and the functional organ in brain*. Thus, we include the individual user, the IT artefact and their dialectical relationship in the definition of the IS. An inevitable consequence is that there will be as many ISs as there are actors engaging with the artefact.

5 Implications for the IS discipline

A first implication of the proposed IS conceptualization is that the IT artefact and the IS are seen as quite different things. In order to elucidate this aspect, we may depart from practical relevance; a challenge that keeps haunting the IS discipline:

> IS academics have not caught up with the dynamic environment of the IS practitioners’ world… Instead of leading practice, or at least co-existing with it, IS research chases after practice and publishes articles only after the technology has been used by practitioners (Hirschheim & Klein, 2012, p. 219)

In order to see how current IS conceptualizations addresses this challenge, we may consider *socio-materiality*; the perhaps most influential IS research stream in the IS community today (see Cecez-Kecmanovic et al., 2014, for a comprehensive overview). Sociomateriality posits that…

> …entities (whether humans or technologies) have no inherent properties, but acquire form, attributes, and capabilities through their interpenetration. This is a relational ontology that presumes the social and the material are inherently inseparable (Orlikowski & Scott, 2008, pp. 455-456).

Sociomateriality thus understood is "extremely theoretical" (Leonardi, 2013, p. 60). Since the analysis of and intervention in practice presumes some kind of separation of the social and material, sociomateriality is difficult to operationalize (Leonardi, 2013). If, for example, applied to the guitar activity, sociomateriality asserts that players and their guitars do not exist as separate entities. Only in playing, they come into existence as undifferentiated sociomateriality. This stance would indeed be arduous to explain to the musicians. No less hard would it be to convince employees at Ericsson that they cannot distinguish themselves from the IT applications they use in daily work.

The key issue seems to be that the original conceptualization of sociomateriality is based on the foundation of *agential realism*, which denies "any separation between technologies and technology use, the 'social' and the 'material', and more profoundly, the realms of structure and action" (Leonardi, 2013, p. 65).

To overcome the problems with agential realism, Leonardi (2013) and Mutch (2013) propose *critical realism* as an alternative foundation for sociomateriality. According to Leonardi (ibid), this has the following advantages:

- Conflation of action and structure is avoided by treating materiality as existing in the realm of structure and social action as existing in the realm of action.
- Empirical studies to demonstrate sociomateriality is enabled by the ontological separation of "social" from "material" according to actors' categorization with and experience of phenomena.
- Change and development of activity is considered by the inclusion of an explicit theory of temporality, which is missing in agential realism.
- Critical realism examines how "social" and the "material" become constitutively entangled to produce the "sociomaterial", rather than assuming the conflation of these from the outset.

A cursory analysis of integrational realism indicates that it complies well with these points. In addition, integrational realism may elucidate the problematic conflation of "human" and "social" in sociomaterial accounts, as evident from the following examples: "… human beings and things—the social and the material…" (Cecez-Kecmanovic et al., 2014, p. 809), "… the material/technical and the human/social…" (ibid., p. 810), "…the technical/material as well as the social/human…" (ibid., p. 814).

By acknowledging our neurobiological foundation for acting in the world, integrational realism puts the "individual" on equal footing as the "social" and "material" in theorizing sociomateriality. The individual and social are related by the notions of equipment, common identifiers and joint action, thus eschewing the conflation between the "social" and the "human". Also, since human biology does not change in contrast the "social" and "material", the neurobiological perspective brings with it a stable point of grounding for inquiries into development and change.

Concerning practical relevance, integrational realism was derived from "real" problems in an industrial setting, which warrants its relevance in the social realm. If the notion of activity modalities can be corroborated in future research, the assumed homomorphism between the neural and social realms enables the operationalization of integrational realism in practical settings. For example, in IS design, methods and tools for co-construction of IT artefacts and functional organs must be developed. The IT artefact should be designed in such a way that manifestations of all modalities can be managed. As can be seen from the screen dump in Figure 7, this particular IT application fulfils this requirement to some extent. However, the one modality missing in most (if not all) commercially existing IT platforms today is contextualization. There is no straightforward way to manage the same entity differently, depending on in which activity it is relevant.

Finally, the term "integrational" in integrational realism is inspired by the "integrational linguistic" approach to language and communication as elaborated by the English linguist Roy Harris (e.g. 1981; 1996; 2004; 2009). This approach complies well with integrational realism, as this example shows:

> The integration on which communication is based is contextualized integration. We have to learn how to integrate various forms of proficiency in order to achieve our aims in a given situation or type of situation (Harris, 1996, p. 30).

Thus, integrational linguistics adds a communicative resource to integrational realism.

6 Concluding remarks

In this contribution, we have suggested a neurobiological approach for theorizing ISs called integrational realism. It must be underscored that this approach is currently in an incipient stage, which best can be characterized as "prescience": "An orientation toward prescience holds some promise for advancing our craft of theory development, as well as enhancing the receptivity of the audiences" (Corley and Gioia, 2011, p. 13). A main limitation of the neurobiological perspective is its focus on coordination. Other aspects associated with ISs, such as power, emotions, trust, fairness, system usability, cognitive overload, and more, are not considered. However, if we regard ISs as instruments for technology mediated actions, it is imperative that we understand coordination as a prerequisite for other aspects.

Since the activity modality is a novel concept, it needs to be further researched in both neuroscience and social sciences. Some questions to be investigated are: is the set of activity modalities valid? Should we add to or withdraw elements from this set? Can we find convincing neural correlates for the modalities? How should the modalities best be operationalized for coordination efficiency?

Future research should also inquire into consequences for established IS theoretical concepts like representation, distributed cognition, shared understanding, and the like. Also, the epistemological and ontological grounds need to be investigated. In conclusion, however, we claim that a neurobiological approach to ISs has potential to open up interesting and productive new lines of research in the IS discipline, simply because such an approach connects with the *sine qua non* for our existence as a biological creatures. If this connection is lost, IS theorizing, however ingeniously conceptualized, may nevertheless be void of practical relevance.

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