The Activity Modalities – Bridging the Neural and Social Realms

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Abstract

Brains have evolved to control the activities of bodies in the world. Thus, profound and new insights into the working of the brain will come about when we understand how the neural and social realms are related to each other. A hindrance for researching this issue is that contributions in each realm are more or less disconnected. This paper suggests bridging the neural and social realms from a coordination perspective, in which the concept of the *activity modalities* objectivation, contextualization, spatialization, temporalization, stabilization, and transition, are proposed as phylogenetically evolved categories enabling coordination. The main contribution of the paper is a model of coordination as a *complex functional system* in which the modalities are necessary, albeit not sufficient factors contributing to realizing coordination. This model provides a boundary object towards which extant results in the neural and social realms can be related. Some theoretical influences corroborating the approach are given. Manifestations of the activity modalities in the social realm are illustrated by the activity of a guitar quartet giving a concert. In conclusion, the suggested approach is a promising attempt to address the important but hitherto elided issue of bridging neuroscientific and social research.

Keywords: coordination, neural and social realms, homomorphism, activity modalities

1 INTRODUCTION

In order to fully understand the human brain, it is necessary to acknowledge that brains have evolved to control the activities of bodies in the world. Thus, profound and new insights into the working of the brain will come about only when we understand how the neural and social realms are interrelated[1]:

> The most important issue in brain research today is that of the internalization or embedding of the universals of the external world into an internal functional space (Llinás, 2001, p. 64).

A hindrance for advancing such research is that contributions in each realm are more or less disconnected. Neuroscience is focused on the internals of the brain, often characterizing the social realm in non-specific terms, such as “world” or “environment”. As a case in point, see Fig 1:

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[1] The terms “neural” and “social” realms are introduced for analytical purposes. These realms should not be conceived as independent; rather they are distinct but inextricably related to each other.

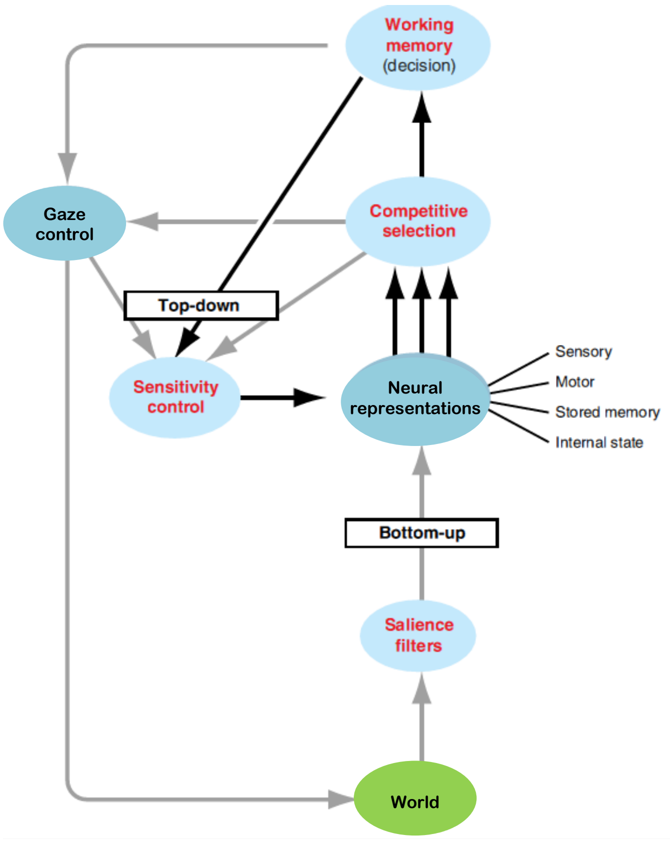

Fig 1 An example of conceptualizing the brain - environment relation (adapted from Knudsen, 2007)

While the brain is modeled in an elaborate way, the environment is amply described as the "world". Thus, it is recognized that the neural organization are influenced by the social realm, but the character of these influences is not problematized. Also, effects in the opposite direction – from the neural to the "world" – are not considered. In short,

> Neuroscience is a highly technical, rigorous, experimental science, which proceeds in the best scientific traditions of experimental exploration, hypothesis-testing, confirmatory replication, and consensus. It is generally not guided by grand or large-scale theory, but rather works forward piece-meal, across large numbers of laboratories worldwide, on myriad modest ad hoc hypotheses of rather small purview [range of operation] in themselves (Macgregor, 2002, p. 23)

As a consequence, neuroscience is strongly in "need of both foundational and large-scale theoretical guidance, which it has not received" (ibid.).

In the social realm, research seldom stretches beyond the cognitive level into the neural realm. The individual is conceptualized as a homogeneous ideal type that can be analyzed and manipulated as any other, non-human element. Thus, biological capabilities and limitations for acting are neglected, which often result in chimerical conceptualizations without contact with the *sine qua non* of human existence. To give just one example, models of organizations are often so complex that they are exceptionally hard to overview, understand and agree upon (see e.g. the TOGAF (2013) framework for developing so called enterprise architectures).

As a consequence, a wealth of research results exist in both the neural and social realms, but the central issue remains unexplained – how the neural and social realms are intertwined. Any approach addressing this issue necessarily needs to assume that evolution has proceeded in such a way that the neural and social realms somehow constitute each other; otherwise our human species would not have survived:

> [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)[2]

An important implication is that action is manifested in both the social and neural realms; as sensorial artefacts in the social realm and as neural structures and processes in the brain. We cannot inspect these imprints inside the brain[3], but we may examine the artefacts in the social realm. The assumption of homomorphism suggests that the nature of these artefacts in some way reflects the neural realm. Thus, by analyzing manifestations in the social realm, we may device ways of inquiring into our neural and biological faculties for action.

To this end, I suggest the homomorphism between the neural and social realms may be articulated from a *coordination* perspective. Coordination, as a prerequisite for action, is at the very core of human existence:

> "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 purpose of this paper is to propose a large-scale theoretical framework for coordination, based on the notion of *activity modalities* (Taxén, 2009). The intention is to provide a *boundary object* between the neural and social realms. Boundary objects are objects that "both inhabit several communities of practice *and* satisfy the informational requirements of each of them (Bowker and Star, 1999, p. 16). Thus, the activity modalities provide a way to relate extant results in the neural realm to the social realm, and the other way around.

The structure of the paper is as follows. In the next section, coordination is elaborated in more detail. Then, the activity modalities *objectivation, contextualization, spatialization, temporalization, stabilization,* and *transition* are described, as well as the inception of this idea. In order to corroborate the modality concept, some crucial theoretical influences for the approach are outlined. Next, the main contribution of the paper is presented, in which coordination is conceptualized as a *complex functional system* (Luria, 1964), including the activity modalities; and realized by the "combined work of a dynamic structure of cortical zones working together" (ibid.). The manifestations of the activity modalities in the social realm are illustrated by the activity of a guitar quartet giving a concert. In the final section, I discuss implications of the approach, indicate its limitations and suggest areas of future research.

A central insight of the activity modality approach is that there are no "universals of the external world" that can be "embedded in the internal functional space" (Llinás, 2001). Rather, the modalities are indications of inborn "universals of the mind" which we confer onto an unsettled environment in order to act purposefully upon it. In conclusion, I claim that the approach presented in this paper is a promising attempt to address the important but hitherto elided issue of bridging neuroscientific and social research.

2 COORDINATION

As a result of random mutations in human genetic makeup that occurred during ancient epochs of human history (starting from the time of the emergence of early hominids such as Australopithecus afarensis, some 3.5 million years ago), some individu-

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[2] As used in this paper, homomorphism means "correspondence in form or external appearance but not in type of structure or origin" (http://universalium.academic.ru/128101/homomorphism)

[3] However, with the advent of brain imaging tools such as fMRI etc., the possibilities to investigate which cortical zones are involved in a certain mental function, have increased substantially (see e.g. Dimoka et al, 2012).

als developed better coordination abilities than others. Because better coordination performance increases chances for survival, those genetic mutations supporting coordination were then passed on to offspring, until the mutations became established as species-wide traits.

What follows is that application of Darwin's theory of evolution (Darwin 1859) suggests that modern humans are endowed with *a neurobiological substrate* enabling coordination of everyday actions, including coordinative abilities related to the individual level (e.g., walking, grasping, using tools) and the social level (e.g., communication with other humans, understanding other people's intentions). Thus, we employ the very same abilities regardless of whether we coordinate actions individually or socially. While the neurobiological substrate includes components of the entire human nervous system (i.e., central and peripheral), its major part is the brain, and hence the focus in this contribution.

Depending on whatever situation an individual encounters, the development of coordinative capabilities will take different forms. Thus, while human coordinative capabilities have a genetic basis, variance in those capabilities is always the result of the complex interplay between both biological and environmental factors (e.g., Cacioppo et al. 2000) like tools, communication, symbols, etc. This means that the functional organization of our brains necessarily must have evolved in interaction with the environment to cater for the survival of our species. Thus, what is "internal" and what is "external" are inextricably related to each other, which imply that we need to investigate coordination in two interrelated reams – the neural and social:

> "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).

The importance of coordination has instigated extensive research efforts. In the neural realm, "a fundamental issue is how to approach a comprehensive understanding of [the brains'] large-scale functions" (Bressler &.Kelso, 2001, p. 26). A major stumbling block to achieve this concerns the coordination problem, that is, "how, for any given cognitive function, the (non-linear) coupling among component parts gives rise to a wide variety of complex, coordinated behaviors (Bressler &.Kelso, 2001, p. 26). A thorough review of results concerning coordination in the neural realm is provided by, for example, Jantzen & Kelso (2007).

In the social realm, coordination has been recurrent theme in organization theory (e.g. Grant, 1996; Malone, & Crowston, 1994; Faraj, & Xiao, 2006), but also in other disciplines such as software development, project management, information system development, and system engineering. A prime research task is to understand how IT-artefacts, information systems, organizations, and coordination are interrelated. In spite of extensive efforts, however, this has been notoriously difficult to achieve. For example, Grant claims that "organization theory lacks a rigorous integrated, well developed and widely agreed theory of coordination" (Grant, 1996, p. 113). Moreover, there is a lack of knowledge about how coordination is actually carried out in practice:

> [We] still know markedly little about the practice of coordination and, above all, the coordination of practices and knowings (Nicolini, 2011, p. 617).

As can be seen from this short account for coordination, much remains to be investigated in both realms. Above all, extant research in one realm seldom is related to findings in the other realm. In the next section, I describe one possible approach to this endeavor.

3 THE ACTIVITY MODALITIES

The "activity modality" concept emanates from the social realm in my long-term engagement with coordinating system development tasks in the telecom industry. In general, such tasks are extremely complex and hard to make sense of. However, over time it became evident that certain dimensions in the ubiquitous flow of phenomena seemed to have a universal character; they appeared over and over again in different coordinative situations. For example, information models, showing what kind of information is relevant in a certain area, signified a spatial dimension; much like a map. Other models signified quite other dimensions, such as process models which had a distinct temporal flavor. Altogether, six such dimensions were identified: *objectivation, contextualization, spatialization, temporalization, stabilization, and transition*, and given the name *activity modalities* (Taxén 2009, 2011, 2012).

Gradually, an incipient idea began to take shape; that the basis for the modalities are to be found in our neurobiological endowments for coordinating actions. They enable the following mental functions:

- Objectivation - focusing on the target towards which actions are directed.
- Contextualization – inducing a horizon of relevance around the target, having bearing on achieving the goal of actions.
- Spatialization - spatial orientation in relation to relevant things.
- Temporalization – conceiving a temporal ordering of events to achieve the goal.
- Stabilization – learning what is relevant and advantageous in a particular situation; a habituation which lends a sense of familiarity to the activity.
- Transition – refocusing attention from the current situation to another target.

These modalities mutually constitute each other; if one fails due to some brain lesion, coordination is inhibited or severely hindered.

4 THEORETICAL INFLUENCES

In this section I outline some theoretical influences bordering between the neural and social realm. The reason is that they, in various ways, corroborate the conjecture of this paper – that the activity modalities may provide a bridge between these realms.

A priori intuitions

Kant argued that perception depends on what he called *a priori* ideas or categories of space and time. These categories cannot be "seen" or sensed externally. Rather, time and space are *modes* of perceiving objects; innate in the thinking subject (Kant, 1924). According to Dehaene & Brannon,

> [The concepts of space, time and number] are so basic to any understanding of the external world that it is hard to imagine how any animal species could survive without having mechanisms for spatial navigation, temporal orienting (e.g. time-stamped memories) and elementary numerical computations (Dehaene & Brannon, 2010, p. 517).

The a-priori categories of time and space correspond to the activity modalities temporalization and spatialization. These are necessary but not sufficient for successful action; the other modalities are also needed. Concerning objectivation, Mead claims that objects are human constructs and not self-existing entities with intrinsic natures (Blumer, 1969, p. 68). Their meaning is "not intrinsic to the object but arises from how the person is initially prepared to act toward it" (Blumer, 1969, pp. 68-69). Thus, objectivation may be interpreted as an a-priori category in the Kantian sense. The same goes for contextualization, stabilization and transition, which are all categories that cannot be "sensed" as externally existing, physical objects. However, action will result in physical manifestations of the a-priori categories, such as maps (spatialization), clocks (temporalization), and so on.

The social genesis of the individual

A core issue is how to conceptualize the relation between phylogenetically evolved morphological features of the brain, and the ontogenetic development of the individual. This problem was a prime concern for the Soviet psychologist Lev Vygotsky and his colleague, the neuropsychologist Alexander Luria. A common tenet in their thinking is that the socio-historical environment an individual encounters during ontogeny plays a decisive role in the formation of higher mental functions. All throughout his professional life, Vygotsky was concerned with "the cultural development of people, about how each human mind becomes a social mind, about 'society' participating in the construction of mind" (Miller, 2011, p. 228). What makes Vygotsky's contribution so distinctive and innovative is not "that he breaks down the barriers between the individual inside and the social outside, or extends the mind beyond the skin, but that *he incorporates the social as part of the constitution of his concept of a human person*" (Miller, 2011, p. 26; italics in original).

The functional organization of the brain

A main interest for Luria was the nature of mental functions, which he defined as a "complex adaptive activity (biological at some stages of development and social-historical at others), satisfying a particular demand and playing a particular role in the vital activity of the animal" (Luria, 1963, p. 36, referred to in Vocate, 1987, p. 10). Although certain elementary "physiological 'functions' (such as cutaneous sensation, vision, hearing, movement) are represented in clearly defined areas of the cortex" (Luria, 1973, p. 25), *complex functional systems* (CFS) "cannot be localized in narrow zones of the cortex or in isolated cell groups, but must be organized in systems of concertedly working zones, each of which performs its role in complex functional system, and which may be located in completely different and often far distant areas of the brain" (ibid, p. 31). This finding is now since long recognized (see e.g. McIntosh, 2000; Bressler & Kelso 2001).

A cortical area involved in a CFS provides an essential *factor* to the entire function, and the "removal of this factor makes the normal performance of this functional system impossible" (ibid, p. 39). The same factor may contribute to several complex functional systems, and a disturbance of that factor may appear as seemingly unrelated symptoms. For example, damage to the occipito-parietal sections of the brain impacts spatial orientation and the ability to preserve simultaneous spatial schemes. As a result of this primary disturbance, "spatial orientation of movement suffers, spatial schemes of writing are disturbed, [and] defects of counting and of the logical-grammatical schemes (which include this very same spatial factor) occur" (Luria,1964, p. 14).

Functional organs

A key tenet in the thinking of Vygotsky and Luria is that CFSs are formed "under the influence of people's concrete activity in the process of their communication with each other" (Luria 1964, p. 6). External, historically formed artefacts such as tools, symbols, or objects, among others "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" (ibid.). This means that "areas of the brain which previously were independent become the components of a single functional system" (Luria, 1973, p. 31).

Striking examples of functional organs can be found in professional musicians, which have structural changes in the brain as a result of their 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).

Equipment

The emergence of a functional organ can be seen as an *equipment* constructing process, where an artefact for the individual 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 recedes, as it were, from “thingness” into equipment, when the in-order-to aspect – what the artefact can be used for – takes precedence. A particularly nice example of this originates from the cellist Mstislav Rostropovich:

> 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 (cited in Zinchenko, 1996, p. 295).

The evolution of artefacts from being *present-at-hand* to *ready-at-hand* takes place entirely in the brain of the individual. In this process, the artefact may or may not change, depending on the material properties of the artefact. Learning how to use a hammer will probably not change the hammer significantly. On the other hand, learning to use a software tool such as Word may bring about adaptations of tool, like individual parameter settings and personalized templates. All in one, the concept of “equipment” provides a way to discuss the nature of the dialectical unity of an individual interacting with an artefact; thus contributing to elucidating the relation between the neural and the social.

Tacit knowledge

The notion of “tacit” knowledge is a topic often discussed in the social realm, especially in connection with the so called “knowledge-based view” of the firm (e.g. Grant, 1996). Often, tacit knowledge is seen as a particular type of knowledge that can be converted into other forms such as “explicit” knowledge (e.g. Nonaka and Takeuchi, 1995).

However, Polanyi spoke about the tacit “dimension” of knowledge rather that tacit “knowledge”; thus indicating that knowledge cannot be divided into separate types. The structure of knowledge derives from the fact that “all knowing is action—that it is our urge to understand and control our experience which causes us to rely on some parts of it subsidiarily in order to attend to our main objective focally” (Polanyi, 1975, p. 2). Moreover, tools, signs and symbols

> can be conceived as such only in the eyes of a person who relies on them to achieve or signify something. *This reliance is a personal commitment which is involved in all acts of intelligence by which we integrate some things subsidiarily to the centre of our focal attention* (Polanyi, 1962, p. 61, emphasis in original)

Thus, Polanyi considered knowledge as strictly personal: “*All* knowing is personal knowing” (Polanyi, 1975, p. 44; emphasis in the original). The tacit dimension of knowledge can be associated with the activity modality construct as follows. Polanyi’s “center of focal attention” is clearly related to objectivation, while “things subsidiarily” to the centre” on which action relies, can be associated with contextualization. Also, the emphasis on the individual as the sole knower complies well with the notion of functional organs and equipment; knowing ensues when something used for action is transformed from being *present-at-hand* to *ready-at-hand.* There is no question about knowledge as being “externalized” into the artefact.

Joint action

When several individuals coordinate their actions in order to achieve a common goal, they are engaged in “joint action” according to Blumer (1969). This term refers to the “larger collective form of action that is constituted by the fitting together of the lines of behavior of the separate participants” (ibid., p. 70). Since each actor occupies a different position in space and “acts from that position in a separate and distinctive act” (ibid., p. 70), joint action cannot be interpreted as participants forming identical functional organs and equipments. Rather, individual equipments need to be fitted together by common, external artefacts that provide guidance in directing individual acts so as “to fit into the acts of the others” (ibid., p. 71). Such artefacts are called “common identifiers” by Blumer. Joint action is, according to Blumer, a fundamental aspect of a society:

> To be understood, a society must be seen ... in terms of the joint action into which the separate lines of action fit and merge (Blumer, 1969, p. 71).

As can be seen, the concept of joint action provides a way to conceptualize the coordination of social action[4] without abandoning the idea of the individual as the genesis of all knowledge.

Integrationism

Since communication is such an inherent aspect of human actions, it is essential to analyze how communication can be associated with the activity modalities. To this end, the *integrationist* approach to language and communication may be utilized. One axiom on which integrationism is based is the following: “What constitutes a sign is not given independently of the situation in which it occurs or of its material manifestations in that situation” (Harris, 2009, p. 73). This means that “[e]very act of communication, no matter how banal, is seen as an act of semiological creation” (ibid., p. 80). Contextualization is fundamental for sign making and use:

> Integrational semiology .... starts from the ... thesis that no act of communication is contextless and every act of communication is uniquely contextualized. (Harris, 1998, p. 119)

In addition, integrationism views all communication as time-bound. “Its basic temporal function is to integrate present experience both with our past experience and with anticipated future experience” (Harris, 2015).

The rationale of the term *integrated* in the integrationist approach towards communication is “that we conceive of our mental activities as part and parcel of being a creature with a body as well as a mind, functioning biomechanically, macrosocially and circumstantially in the context of a range of local environments” (Harris, 2004, p. 738). The first relates to the physical and mental capacities of the individual participants; the second to practices established in the community or some group within the community; and the third to the specific conditions obtaining in a particular communication situation. Thus, integrationism provides a general and coherent foundation for communication that complies well with the other theoretical influences discussed above.

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[4] The term ”social action” as used by Mead is equal to “joint action” (Blumer, 1969)

5 A COMPLEX FUNCTIONAL SYSTEM FOR COORDINATION

I propose that a complex functional system (CFS) for coordination may be modelled as *dependencies between factors* contributing to the CFS. In **Fel! Hittar inte referenskälla.**, such a tentative model shown:

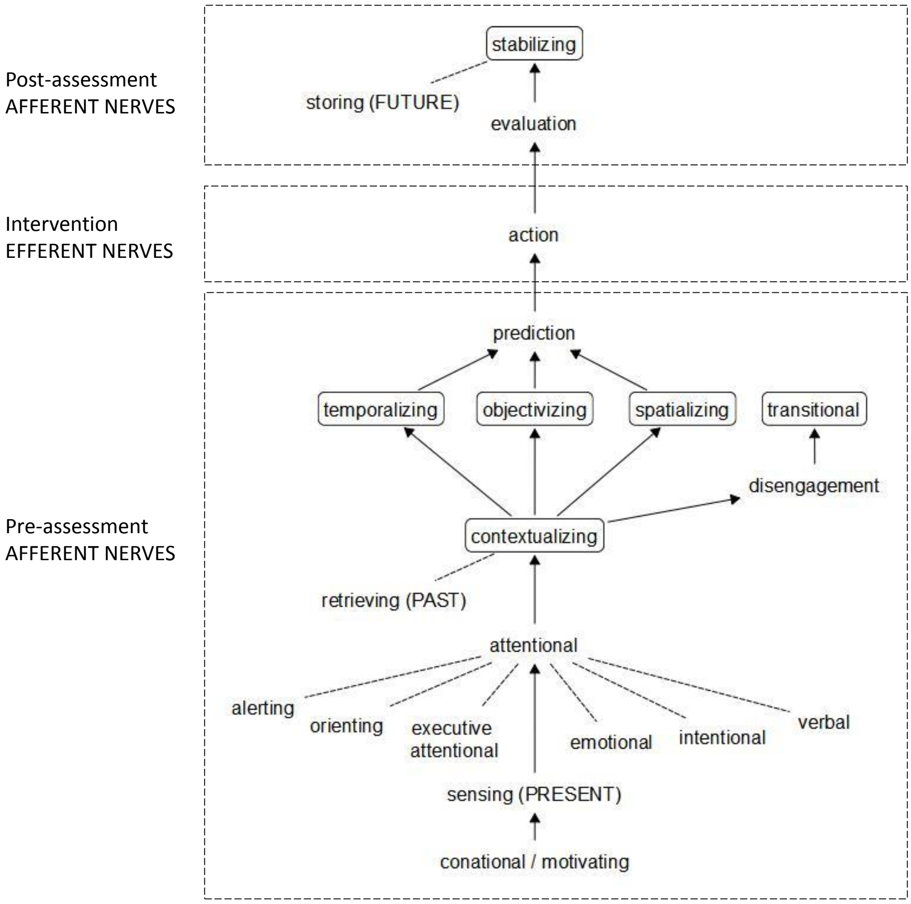

Fig 2 Illustration of the CFS for coordination (the six activity modalities are emphasized)

Fig 2 should be interpreted as follows. Each entry is a factor in the CFS. These factors should be seen as labels for elements in the neurobiological substrate brought about by the phylogenetic evolution of our species. In order to avoid category mistakes, it is important to clarify that the individual actuate these factors, not the brain[5]. The brain and body provide the necessary enablers for “me” to do the sensing, attending, contextualizing, and so on.

Some factors may be realized by locally confined areas in the brain, while others require “large-scale processing by sets of distributed, interconnected, areas and local processing within areas” (Bressler &.Kelso, 2001, p. 26). The contributing cortical areas are not shown; the reason of which is to simplify a complex system to its very essence – how factors depend on each other. Thus, the model clearly shows how a loss of a certain factor impacts the entire CFS. In addition, the model is purely static – it shows only dependencies between factors. How these are dynamically engaged, is an entirely different matter (see e.g. Bressler & Kelso, 2001).

The factors can be conveniently groped into three modes: pre-assessment, intervention, and post-assessment (Goldkuhl, 2009), depending on the nature of nerve impulses: afferent one’s going from the periphery of the body to the brain, and effer-

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[5] A category mistake is a semantic or ontological error in which things belonging to a particular category are presented as if they belong to a different category (Ryle, 1949).

ent ones carrying nerve impulses away from the brain to effectors such as muscles or glands. In the pre-assessment mode, a very foundational factor is the conational / motivating one. 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). Next, the sensing factor is realized by the different sensory systems in the brain (visual, auditory, somatosensory, gustatory, and olfactory ones). Sensing in turn is a prerequisite for attention, which depend on a number of other factors as indicated in Fig 2 Fel! Hittar inte referenskälla. (see e.g. Posner and Rothbart, 2007; Lewis, 2002; Changeux & Dehaene, 1989; Clancey, 1993).

Drawing on previous experiences retrieved from long-term memory, the ensuing *contextualizing* factor provides an integrated pre-motor and actionable stable-state, in which the object in focus (*objectivizing*), relevant background phenomena (*spatializing*), and different action alternatives (*temporalization*) are included. This enables the predictions of proper action alternatives by evaluating the current situation with respect to previous consequences of acting in similar situations.

In the intervention mode, the motor system executes the chosen action when an action alternative has been decided. Before action impulses are transmitted, motor circuits have to become active in the brain, including the premotor cortex, posterior parietal cortex, supplementary motor area, basal ganglia, cerebellum, and the speech production areas located in left inferior frontal lobe (Dehaene et al. 1998). After the action has been performed, its consequences are evaluated and stored in long-term memory; thus contributing to the *stabilizing* factor in the post-assessment mode. Subsequently, the *transitional* factor enables attention to be redirected to another task, which requires disengagement of the current focus and orientation towards the new one (Posner and Petersen, 1990, pp. 28-29).

5.1 Neural correlates contributing to activity modalities

Identification of the neural correlates of the six activity modalities is primarily a challenge for cognitive neuroscience research, and there is a wealth of existing results that may advantageously be used to this end. However, such a task is far beyond the scope of this paper. Here, I merely indicate some results that may be associated with the activity modalities.

Contextualization

The function of contextualization is to refine an initial, vague, and unsettled impression into specific, actionable motor plans that can be executed by the organism (Lewis, 2002). The brain is continuously generating associative predictions based on memories of past experiences: "[Analogies] are derived from elementary information that is extracted rapidly from the input, to link that input with the representations that exist in memory" (Bar, 2009, p. 1235), see Fig 3:

Fig 3 Predictions generated from initial object-related, salient sensory signals (adapted after Bar & Neta, 2008, p. 321)

Such associative predictions bring with them a set of related items, which Bar & Neta calls "context frames". In the figure above, the weapon may be associated with violence, robbery, war, and the like, while the hair-dryer and the cordless screwdriver are associated with quite different things. Context frames consistently activate three interconnected cortical foci: the parahippocampal cortex and the hippocampus in the medial temporal lobe (MTL), the retrosplenial complex in the medial parietal cortex (MPC), and the medial prefrontal cortex (MPFC) (Bar & Neta, 2008. p. 328).

Contextualization might also be seen as an integration process proceeding from unconscious processing of sensuous input into consciously "attended to" foci, which requires conscious but "unattended from" subsidiaries. These subsidiaries lasts "only so long as a person, the knower, sustains this integration" (Polanyi, 1975, p. 38). (see Fig 4):

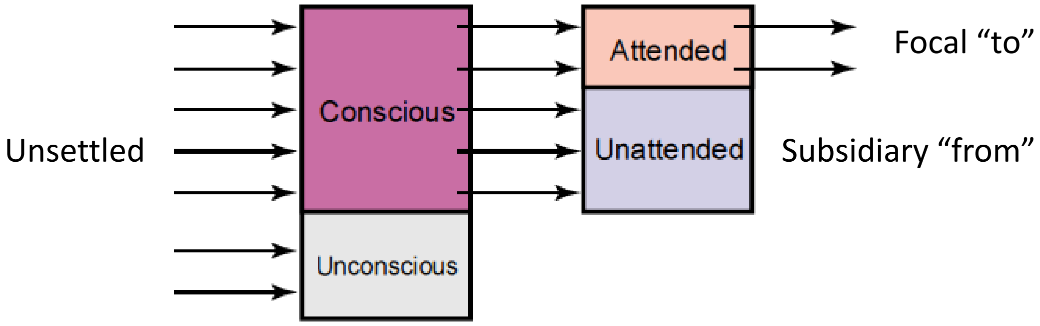

Fig 4 Attention and awareness (adapted after Lamme, 2003, Fig. 2, p. 13)

Contextualization implies that everything needed to evaluate action alternatives is stored in long-term memory:

> If the organism carries a "small-scale model" of external reality and of its own possible actions within its head, it is able to try out various alternatives, conclude which is the best of them, react to future situations before they arise, utilize the knowledge of past events in dealing with the present and future, and in every way to reach in a much fuller, safer, and more competent manner to the emergencies which face it. (Craik, 1943, p. 61).

Objectivation

The selection of one out of a set of appropriate actions starts when the individual becomes aware of something. Awareness "always has an object" (Edelman, 1992, p. 5); it is *about* something that needs to be recognized and acted upon. Object perception is "one of the most remarkable capacities of the primate brain" (Kourtzi & Connor, 2011,

p. 45). The relevance and apprehension of the object arises from how an organism is initially prepared to act toward it:

> [The] character or meaning [of the object] is conferred on it by the individual. The object is a product of the individual's disposition to act instead of being an antecedent stimulus which evokes the act. (Blumer, 1969, p. 80)

The neural correlates of objectivation remain controversial (Kourtzi & Connor, 2011). However, recent results suggest that two interacting processes are involved (Goodale & Humphrey, 1998). A dorsal "action-oriented" stream connected to the forebrain, superior colliculus, and various pontine nuclei, is involved in motor actions (ibid.). This stream may mediate the visual control of actions by modulating the activity of more phylogenetically ancient visuomotor networks (ibid.). The other stream involved in objectification is a ventral one, projecting to the inferotemporal cortex, which in turn is connected to medial temporal lobe and prefrontal cortex involved in long-term memory (ibid.). This stream is involved in long-range planning, communication and other cognitive activities.

Temporalization and Spatialization

A fundamental capability for any organism to survive is navigation, which requires interrelated spatial and temporal information. According to Luria (1966), the brain performs two basic activities: simultaneous and successive synthesis:

> The first of these forms is the integration of the individual stimuli arriving in the brain into simultaneous, and primarily spatial, groups, and the second is the integration of individual stimuli arriving consecutively in the brain into temporally organized successive series (Luria, 1966, p. 74, related in Vocate, 1987, p. 138).

How the brain keeps track of time is still not understood (Jin et al., 2009). According to Edelman (1992), the cerebellum, the basic ganglia, and the hippocampus are concerned with timing, succession in movement, and the establishment of memory. These structures - the "cortical appendages - the organs of succession" - are closely connected with the cerebral cortex (ibid., p. 105). The cerebellum is needed to ensure smoothly coordinated and rapid motion, while the basal ganglia enable the orchestration of planned movement. The hippocampus makes it possible to link "categorization in a time range between the immediate and those forever stored" (ibid., p. 107). Recent research indicates that the brain uses "differential timing mechanisms and networks —specifically, that the cerebellum subserves the perception of the absolute duration of time intervals, whereas the basal ganglia mediate perception of time intervals relative to a regular beat" (Teki et al., 2011, p. 3805).

A crucial neural correlate for spatialization is the posterior hippocampus, which stores a "cognitive map" that an organism can use in spatially guided behaviors such as navigation (O'Keefe & Nadel, 1978; Jeffery et al., 2004). This result has been corroborated by research on London Taxi drivers (Maguire et al., 2000). Since the need to navigate is common to most species, spatialization probably appeared early in the evolution; something which is consistent with the fact that the hippocampus is a phylogenetically old part of the brain. More recently, it has been found that grid cells in the entorhinal cortex play a crucial role in spatial representation and navigation (Witter & Moser, 2006)[6].

Stabilization

The essence of stabilization is to routinize actions. In every recurrent activity there is a need to take some things for granted; things that do not have to be questioned when

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[6] The 2014 Nobel Prize in medicine was awarded May-Britt Mosel, Edward Mosel, and John O'Keefe for these discoveries.

a familiar situation is encountered. By evaluating action effects, an organism learns what works and what doesn’t, which lends a stabilizing or habituating character to the activity:

> All human activity is subject to habitualization. Any action that is repeated frequently becomes cast into a pattern, which can then be reproduced with an economy of effort and which, *ipso facto*, is apprehended by its performer as that pattern. Habitualization further implies that the action in question may be performed again in the future in the same manner and with the same economical effort (Berger & Luckmann, 1966, p. 70-71).

Stabilization presumes some kind of storing capability. As stated, the hypothesis in this paper is that the entire situation is stored, as characterized by its motive, object, spatial and temporal features, as well as emotional and intentional aspects.

> [An] ‘*action schema*’ ... tends to be the basic principle of sensorimotor learning: perceived situation-> activity->beneficial or expected result. Or to state it in another way: there is recognition of a certain situation, a specific activity associated with that situation, and the expectation that the activity produces a certain previously experienced result (Glasersfeld 1995: 65). What matters therefore are not merely the actions themselves but their results (Reybrouck, 2001, p. 612).

A distinguishing feature of stabilization is balancing/equilibration between chaos and petrification. If a situation cannot be remembered, for example, due to a lesion in the hippocampal area, actions cannot be habituated. Activities are disintegrated into chaotic and unconnected fragments. At the other extreme, habituation has overtaken improvisation and exploration, which results in petrification. At both extremes, purposeful action is inhibited:

> Every movement has to be subordinated to a stable program or a stable intention. They are provided in the prefrontal lobes of the brain (included in the third block). If the frontal lobes are injured, the sensory base, spatial organization and plasticity of the movement remain but goal-linked actions are replaced by meaningless repetitions of already fulfilled movements or impulsive answers to outside stimuli. The whole purposive conduct of the patient is disturbed (Luria, 1970).

Recently, *metastability* has been proposed as a neural correlate of equilibration, where “the individual parts of the brain exhibit tendencies to function autonomously at the same time as they exhibit tendencies for coordinated activity” (Fingelkurts & Fingelkurts, 2004, p. 851). This leads to a “looser, more secure, more flexible form of function that can promote the creation of new information…Too much autonomy of the component parts means no chance of coordinating them together. On the other hand, too much interdependence and the system gets stuck, global flexibility is lost” (Kelso & Tognoli, 2007, p. 43).

Transition

Transition is the capability to refocusing attention from one context to another. This requires disengagement:

> The parietal lobe first disengages attention from its present focus, then the midbrain area acts to move the index of attention to the area of the target, and the pulvinar is involved in reading out data from the indexed locations (Posner & Petersen, 1990, p.28-29).

A shift in attention may be caused by caused by "alarm" signals that are passed “down to the midbrain value systems that connect back to the cortex and the basal ganglia” (Edelman, 1992, p. 143). These in turn may send back signals interrupting ongoing motor plans in the cortex and blocking these in order to engage a different motor plan (ibid.). In particular, the superior colliculus in the midbrain seems to play an important role in transition:

> Patients with a progressive deterioration in the superior colliculus and/or surrounding areas also show a deficit in the ability to shift attention (Posner & Petersen, 1990, p. 28).

The placement of transition in the CFS in Fig 2 is motivated by the fact that contextualization is required in order attend from something in focus to something else.

5.2 Integration

The activity modalities need to be seen as dialectically interrelated. By this I mean that the modalities are distinct but mutually constitute each other. This requires some kind of integrative faculty in which all modalities are included. The function of integration is to synchronize distinct brain regions for perception, decision, and action (Feldman, 2013). Depending on contextual influences from the environment, the role of highly connected local regions is determined by how they interact with other, loosely connected regions – what McIntosh (2000) calls *neural contexts*. Thus, the contribution of locally connected regions to a particular factor varies depending on the context. Consequently, the contextualization modality is a prerequisite for integration of the other modalities:

> Regional specialization is, in part, determined by the connectivity of the area. But the functional relevance of that area cannot be realized unless operates in conjunction with other parts of the brain. (McIntosh, 2000, p. 868)

Several mechanisms have been proposed for the realization of integration, for example, the global neuronal workspace (Changeux & Dehaene, 1989; Dehaene et al., 1998; Dehaene & Changeux, 2011), the theory of neuronal group selection (TNGS; Edelman, 1992), and the formation of “global neurocognitive state” which “plays a critical role in adaptive behavior by allowing the organism to perceive and act in a manner consistent with the context of the changing situation in which it exists” (Bressler, 2007, p. 61).

6 THE ACTIVTY MODALITIES IN THE SOCIAL REALM

As long as our phylogenetically evolved constitution remains unchanged, the underlying structure of any activity will be the same. I have proposed the term *activity domain* for activities structured from the activity modality perspective (Taxén, 2009). This concept should be interpreted as follows. When individuals come together in pursuit of a common goal, they are engaged in joint action. The coordination of individual lines of behavior requires “extracortical” manifestations – common identifiers – that in some way are homomorphic with the activity modalities. Such manifestations may be anything that is relevant in the integration of the activity towards fulfilling the goal – artefacts, tools, instruments, speech, gestures, and so on. Stated differently, in each activity domain there will be contextualized manifestations of objectivation, spatialization, temporalization, and stabilization. In addition, there will be manifestations of transition, enabling the cooperation with other activities.

Such manifestations are the tangible elements of the domain. Equally important elements, however intangible, are the functional organs being developed in the brains of participants as the activity unfolds. Thus, what we can observe as signs of activity, such as plans, models, drawings, rules, etc., are only half of the story. The rest is manifested in the brains of participants in the activity.

An example

As a paradigmatic example of an activity domain, we may use the guitar concert illustrated in Fig 5. What does it take for this activity to succeed?

Fig 5 A guitar concert

To begin with, the players need to have well-built guitars to play on, which means that the concert activity depends on other activity domains such as the ones in which the guitars are built. This presumes that certain elements are agreed upon in the transition between the activities, such as the placement of the bars on the neck, the number of strings, the string tensions, and so on. These manifestations are examples of a "solidified" common identifier for transition, which is relevant in every enactment of similar kind such as other concerts, other quartets, solo playing, and so on.

Ultimately, the ability to cooperate between domains rests on the factor *transition* in the brains of participants engaged in making this happen. Such cooperation would not be possible if, hypothetically, all participants had a lesion in the superior colliculus area of their brains. If so, disengagement would suffer and, consequently, they would not be able to shift attention from one focus to another.

Another prerequisite is that each player can play his voice in the music; something which comes about only after a long and arduous practice. This process involves the player, the instrument and most likely a musical score like the one in Fig 6:

Fig 6 A score for a bass guitar

In order to play this piece of music, the player needs to master the coordination of the left and right hand movements as follows. First, the temporal dimension, signified by the sequence of notes read from left to right must be controlled. A sense for the duration of each note, as indicated by the stems and dots, must be obtained (the factor *temporalization*). Next, the spatial positions of notes in relation to the staff (above, below, distance between notes, etc.) must be associated with a corresponding spatial position on the guitar neck, where the proper string shall be pressed (the factor *spatialization*). Finally, various signs, such as the *mf* indicating mezzo forte, the 𝄢 signifying the F-clef, and the # showing that the key is e-minor, need to be acknowledged. Together with the rest of the score, these signs indicate habituated norms of playing, lending a certain stability to the playing activity (the factor *stabilization*). All these modalities need to be integrated into a coherent playing activity.

In the concert hall, each player must be able to focus on that which the activity is all about – the concert (the factor *objectivation*). This in turn necessitates an ability to concentrate on relevant things in this particular situation and disregard irrelevant ones (the factor *contextualization*).

The separate voices are coordinated through the common identifier in Fig 7:

Fig 7 The score as a common identifier

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, we can see that the same factors – the activity modalities – are present both in individual and joint playing. The only "common" or "shared" elements in this situation are outside individual brains, such as the score. Moreover, it is only in the activity as a whole that the individual voices make sense in terms of rhythms, harmonics, etc. If each voice is played in solitude, the music becomes void of meaning.

The pattern illustrated by the guitar concert activity is found in any joint activity. Over time, common identifiers homomorphic with the activity modalities may result in macrosocial "solidifications" as it were; identifiers that are conveniently utilized in similar activity domains where they make sense. A prime example is of course language, but also standards, tools, and knowledge in the form of equipments, i.e., individuals skilled in using a particular artefact. Importantly though, every act is an act of construction simply because acts change functional organs:

> Every act of communication, no matter how banal, is seen as an act of semiological creation (Harris, 2009, p. 80)

7 DISCUSSION AND CONCLUDING REMARKS

In this paper, I have attempted to articulate the homomorphism between the neural and social realms from a coordination perspective. The ability to coordinate actions is regarded as evolutionary engendered, neural faculties, which I conceptualize as "activity modalities". The elucidation of this conceptualization started in the social realm from observations of coordination activities in the telecom industry, and proceeded towards the neural realm as a search for neuroscientific contributions that somehow corroborated the activity modality concept. The main knowledge contribution of this search is a complex functional system for coordination, modeled as dependencies between factors involved in coordination (see Fig 2). This model, which includes the activity modality factors, may serve as a boundary object between the neural and social realms.

I make no claim of this model to be the "final answer" to the homomorphism between these realms. Rather, it should be seen as a first attempt that hopefully can be articulated in future research through a joint effort between neural and social researchers. The benefits of such an enterprise may be huge. In the social realm, coordination endeavors may be informed by the internal organization of the brain. Incipient initiatives in this direction do indeed exist, as for example, in organizational cognitive neuroscience (Senior et al., 2011), and in the NeuroIS initiative, which promotes the design and evaluation of information systems from a neuroscientific basis (Dimoka et al, 2012).

Conversely, important indications for investigating coordination in the neural realm may be found from investigating manifestations in the social realm. For example, Dehaene and Brannon (2010) have recently suggested a general 'Kantian' research program, aiming at understanding how basic intuitions arise and how they can be related to their neural mechanisms. In such a research program, the concept of activity modalities may add a distinct "action" character to this program.

Another potential benefit might be to problemize the thorny issue of "representations". Cognitive science has for a long time "been dominated by approaches based on assumptions of information processing and mental representations of the world" (Linell, 2007, p. 606). An example of this is the previously cited passage from Llinás (2001): "[The] internal functional space that is made up of neurons must *represent* the properties of the external world" (ibid., p. 65, my italics). However, in the conceptualization presented in this paper, there are no "universal of the external world" that can be "embedded in the internal functional space" (Llinás, 2001, p. 64). Rather, the activity modalities are indications of inborn "universals of the mind" – Kantian a-priori intuitions – which we confer onto an unsettled environment in order to act purposefully upon it. This is in line with, for example, Edelman:

> [We] are tempted to say the brain represents. The flaws with such an assertion, however, are obvious: there is no precoded message in the signal, no structures capable of high-precision storage of a code, no judge in nature to provide decisions on alternative patterns, and no homunculus in the head to read a message. (Edelman, 1999, p. 77)

Obviously, the activity modality approach brings with it a number of limitations and potentially weak points. As far as I can tell, this approach is entirely new, and as such merely tentative in nature. Moreover, since this author is only superficially acquainted with neuroscience, I may well have misinterpreted contributions from the neural realm. Hopefully, future research will straighten out such flaws. Nevertheless, the activity modalities are grounded in long-time observations and research in the social realm (see e.g. Taxén, 2009), which warrant their relevance for conceptualizing coordination. Substantial research efforts are undoubtedly needed to illuminate activity modality approach further. However, in conclusion, I claim that this approach is a promising attempt to address the important but hitherto elided issue of bridging neuroscientific and social research.

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